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ASYNCHRONOUS MULTI-SITE METHOD DESIGN DISASTER RECOVERY CENTER ON THE BUSINESS PROCESS AUTOMOTIVE MANUFACTURING (CASE STUDY: PT XYZ)

[1]EDY YULIANSYAH, [2]BENFANO SOEWITO
[1,2] Computer Science Department, BINUS Graduate Program – Master of Computer Science,
Bina Nusantara University
Jakarta, Indonesia
Email : [1]edy.yuliansyah@binus.ac.id, [2]bsoewito@binus.edu

ABSTRACT

In a series of business processes of a company, there are of course various obstacles that cause disasters so that business processes are disrupted even to a standstill, which ultimately results in significant financial losses, where the IT factor is one of them. These problems are found in the business process of PT XYZ which has a line stop annual recapitulation caused by IT factors for 451 minutes, with the biggest cause at the level of availability of the production process information system server. In maintaining the continuity of its business processes, PT XYZ requires a risk control measure for the main problem, namely improving the quality of the availability of the production process information system server, by building an on-premise replication method suitable for various disaster threats. This study aims to find out the specific steps in determining what replication methods are appropriate to be implemented in a manufacturing environment with the conditions of business needs such as PT XYZ, whose investment feasibility is then evaluated through a systematic approach in the form of a Cost-Benefit Analysis (CBA) method. From the overall results of the analysis process of PT XYZ's business needs, and by utilizing a combination of existing technologies, the appropriate replication method is obtained for the manufacturing environment, then integrating the needs of the Disaster Recovery Center (DRC) system with the infrastructure it has today can produce DRC designs that are more efficient and effective from a technical and cost perspective.

Keywords: *Disaster Recovery Center, Replication, Manufacturing, Risk Management, Cost-Benefit Analysis*

1. INTRODUCTION

In the development of the industrial world, technology and information systems are increasingly relied on in carrying out important tasks on all lines in it that are already very dependent on systems built in ensuring business processes run normally. However, in its activities, there are unplanned conditions that result in disrupted business operations. Webster's Dictionary defines a disaster as a sudden catastrophic event that brings great, sudden or severe damage, loss or destruction, misfortune or failure. In the context of contemporary IT, disasters are events that kill the computing environment for more than a few minutes, often for several hours, days or even years (1). The disaster recovery process is needed to maintain the continuity of the business process, saving important functions that are available as quickly as possible during a disaster. Therefore a Business Continuity Plan (BCP) is needed to ensure business processes can continue in an emergency, one of the procedures in it is Disaster Recovery Planning (DRP). DRP is a blueprint for recovery from all events and is intended to increase the chances of survival of a business process and reduce the risk of loss (2). Many factors cause disrupted business processes (line stop), one of them is from the IT factor. The causes of disruption of business processes from IT factors are incidents of data loss which can be in the form of hardware and software, the most common causes of data loss are hardware failure of 40%, human error by 30%, software corruption by 13%, computer viruses by 6%, theft data at 9%, and disaster at 3% (3).

In small scale needs, the provision of backup servers can be an easy solution in overcoming potential disasters such as software corruption, viruses, human errors. However, on a large scale, the method will be constrained by availability. To meet availability expectations, the concept of High Availability (HA) can be the right choice in preventing potential disasters in the form of hardware failure, because HA is a fault-tolerant system by minimizing a single point of failure (4). Meanwhile, what about the catastrophe that occurs is larger and unpredictable, such as natural disasters that cause massive hardware failure, of course, will cause unmeasured downtime, even business processes will be stopped for a long time. To meet the needs of all potential disasters, replication can be the right solution in all types of potential disasters. Replication is the process of copying data from one system to another. The result is two data sets that are consistent and can be applied in several physical locations (1).

2. LITERATURE REVIEW

2.1 Similar Research

Zhiyuan Shao and Hai Jin in 2006 made a study to accelerate the coordination of replication on the assumption that the operation would be successful. The proposed scheme has the advantages of flexibility and portability. This method has a more effective process than the peer to peer (P2P) method, but replication requires checking the log request messages regularly because it only relies on the assumption of success in the replication process (5). Then, in 2011 Adnan Omar, David Alijani, Roosevelt Mason researched multiple site work business processes, with a DC located at the head office and a DR located at one site. Data replication uses the concept of active/active P2P between DC and DR and low RPO level requirements (1).

Subsequently in 2012, Rekha Singha proposed a DR replication method by providing sub-DR devices installed at each site. During normal operation, DC operational data is replicated to all sub-DRs through any DR device and can be replicated internally at one or more locations. In the event of service failure on DC, one sub-DR will redirect the user request to the available sub-DR (6). Hong Wang in 2017 designed a system that can make data backup smaller and can recover with the latest data by building a Warm-CDP system as a separator between DC and DR. Full replication of the DR can be fully replicated with DC data periodically, in the next turn the data replication on the DC is forwarded to the CDP system which only consists of data that is changed or updated, then CDP continues the data update on the DR. When a system failure occurs, the CDP server located at one site can send DC the latest data replication (7).

Furthermore, research conducted by Wibowo, Diana, Subekti, & Hendro in 2018 discusses a replication method carried out to all sub-DRs throughout and each site can act as a backup when needed when disasters and can service transaction requests accompanied by snapshots of a server that replicates a minimum of two data backups, one stored in DC for disaster recovery purposes, and one for data integrity stored in the DR. When data integrity is interrupted, snapshot backups can be transferred from other machines and returned to the main server (8). The last one, in the same year Narendra Dhanujati and Abba Suganda Girsang conducted a study that discussed a replication concept to meet the needs of High Availability services. The replication model runs at the database level, which means that replication is suitable if it is applied to business processes that prioritize high levels of data availability, simple management, and cost requirements that are not too large (4).

Table 1: Similar Research Reference

Based on the results of previous replication research methods, it was found that all of these studies have the same goal, namely to improve the quality of the availability of IT services by using different replication and evaluation methods that have been adapted to the needs and areas of each research. This study also has the same goal and has a different method, namely by applying a combination of virtual and storage replication methods supported by other technologies to obtain flexible replication methods against various disaster threats with specific research areas in the automotive manufacturing environment. The evaluation method used is based on one of the research, namely the evaluation of cost analysis, in addition to technically comparing the ability of each method.

2.2 Manufacture

Economically, manufacturing is the transformation of materials into items of greater

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value through one or more processing and/or assembly operations. The key point is that manufacturing adds value to the material by changing its shape or properties, or by combining it with other materials that have been similarly altered (9).

2.3 Data Center (DC)

Data Center (DC) is a set of facilities providing complex services, accessing the internet, it includes not only computer systems, storage devices, and communications equipment, it also contains redundant data communications connections, environmental control equipment, monitoring equipment, and various security devices. (2).

2.4 Disaster

Disaster is a course of events that causes serious physical damage to IT facilities located in primary location and used by the organization daily, such that it renders them useless (10). Meanwhile, according to Martin, disaster is any event that can cause a significant disruption in operational and/or computer processing capabilities for a period, which affects the operations of the business. (11). From an operational perspective, a Data Center (DC) can be defined as a place that processes business transactions, host websites, process, and stores intellectual property, maintains financial records and routes e-mails. In other words, a data center can be considered as the brain of the company (12).

2.5 Backup/Recovery Strategy

Backup and recovery methods and strategies are a series of work processes to recover system operations as quickly and effectively as possible after a disruption in service according to the downtime that has been identified in Business Impact Analysis (BIA). Technologies such as redundant arrays of independent disks (RAID), automatic failover, UPS, server clustering, and mirrored systems should be considered when developing a system recovery strategy (13).

2.6 Business Impact Analysis (BIA)

Business Impact Analysis is an identification of the impacts that can result from disrupted normal operations in the organization, where impacts can be both qualitative or operational and quantitative or financial. (14). NIST defines BIA as an important key to running a contingency plan that is used to correlate the system with business processes or critical points and services provided, to then characterize the consequences of disruptions and set priorities and needs for recovery plans (13).

2.7 Disaster Recovery Plan (DRP)

The design of the Disaster Recovery Plan is the result of a BIA that is prepared by involving the entire business process of the organization so that the results of the planning truly reflect the company's needs and priorities in the event of a disaster. In general, there are important parameters to measure the effectiveness of a DR, the Recovery Time Object (RTO) or the recovery time of a physical system environment after a disaster. Recovery Point Object (RPO), or the time when the latest backup is available right before the disaster, which means the amount of data loss (2).

2.8 Disaster Recovery

Snedaker explained that disaster recovery is part of business continuity, and deals with the immediate impact of an event, disaster recovery involves stopping the effects of the disaster as quickly as possible and addressing the immediate aftermath (15). According to Uddin, disaster recovery is a huge area that covers end-to-end solutions to cater for contingency situations (16).

2.9 Classification Of Disaster Recovery

The backup model can be divided into four types, such as cold standby, warm standby, hot standby (active/standby) and hot standby (active/active). The four types of backup methods are identified in six aspects, namely model attributes, recovery time, costs, data replication, RPO and RTO compared, each has advantages and disadvantages, requires a reasonable choice according to actual needs (2).

2.10 Replication

Replication is a technique for copying and distributing data and objects, a database to another database and synchronizing between databases so that data consistency can be guaranteed. Using this replication technique, data can be distributed to different locations through local and internet network connections. Replication also makes it possible to support application performance, physical data dissemination according to its (17).

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2.11 Technology Of Disaster Recovery

There are several disaster recovery technologies in replicating data that can be divided into several types, including data replication based on application, databases, data hosts, data storage virtualization, and remote data storage. Each type of method has different implementation schemes, determining the technology to be used refers to business needs with all the factors that influence it (2).

2.12 VMware Site Recovery Manager

VMware Site Recovery Manager is an extension to VMware vCenter Server that delivers business continuity and disaster recovery solution that helps you plan, test, and run the recovery of vCenter Server virtual machines. Site Recovery Manager can discover and manage replicated datastores, and automate the migration of inventory from one vCenter Server instance to another (18). When using array-based replication, one or more storage arrays on a protected site replicates data to an array partner at the recovery location. With a Storage Replication Adapter (SRA), it is possible to integrate Site Recovery Manager with various arrays (18).

VMware vSphere Replication is an extension to VMware vCenter Server that provides a hypervisor-based virtual machine replication and recovery (19). There are two OS terms in a virtual machine, namely Host OS and Guest OS. Host OS is a device operating system where a virtual machine runs in it, while Guest OS is an operating system that is installed on a virtual machine.

2.13 Cost-Benefit Analysis (CBA)

Cost-Benefit Analysis is an extension of cost revenue analysis where the costs of the technology are compared to the benefits that can be directly and indirectly attributed to the system (20). According to Whitten in his book entitled System Analysis & Design For The Global Enterprise, there are three stages in analyzing the efficiency of a project through CBA, namely the stages of cost identification, benefit identification, and comparative analysis of costs and benefits related to the project being planned with three criteria, between others Payback Period, Return on Investment, and Net Present Value (21).

2.14 Payback Period (PP)

Payback Period is an excellent measurement of risk because it is a measure of the required time to bring back the cost of investment (22). Payback Period is also defined as the expected number of years required to recover the original investment. If all factors being held constant, a project with a shorter payback period is considering a better project because an investor can recover the capital invested in a shorter period (23).

2.15 Return On Investment (ROI)

ROI is an indicator that shows to which extent a specific business produce gain from the use of capital. ROI is calculated as the ratio between operating profit obtained after the action of investment and the total amount invested (Valahian 24). The ROI as a profitability performance measure is used by bankers, investors, and business analysts to assess a company management's efficiency in using available resources and financial strength or to compare the efficiency of several different investments (25).

2.16 Net Present Value (NPV)

NPV is the net present value which is the sum of all the future cash flows to determine the present value. Cash flows include both inflows and outflows that are discounted at a rate (26). The Net Present Value (NPV) method as an investment appraisal or capital budgeting technique shows how an investment project affects the company shareholder's wealth in present value terms (27).

2.17 Research Methodology

The research was carried out with action research methods to a problem of IT is happening with a case study in corporate environments. Action research is a type of research used in an organization to gain a deep understanding of the issues facing the organization by enabling internal research and opportunities for members of the organization to openly discuss possible options and alternatives to produce long-term change in a permanent organization (28).

Data collection techniques using the study of literature, observation, and interviews. The literature study was carried out theoretically, previous research, PT XYZ organizational documents, and the internet. Observations were made at the Corporate Information Technology

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(CIT) division to obtain primary data about the current state of IT and business processes at PT XYZ.

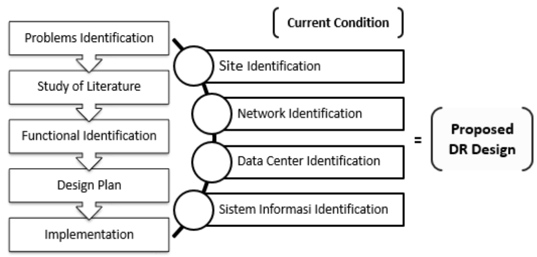


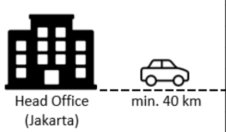
Figure 1: Research Framework & Stages

The interview technique used was a semi-structured interview, just like structured interviews, this type of interview also an outline of topics and questions prepared by the researcher. However, unlike structured, semi-structured interviews have no rigid adherence. Their implementation is dependent on how the interviewee responds to the question or topics laid across by the researcher (29).

3. IDENTIFICATION CURRENT CONDITION

3.1 Site

PT XYZ has eight work units in running its business processes which are currently scattered in Jakarta, Cibitung and Karawang. Following regulations in Indonesia that refer to ISO 27001, the initial consideration in building a DRC is related to the distance of the DRC which is at a minimum distance of 30 km from DC.



No.	Site	Location	Distance(km)
1	Plant 1	Jakarta	0.7
2	Plant 4	Jakarta	0.95
3	**Plant 2**	**Karawang**	**66.3**
4	**Plant 3**	**Karawang**	**65.7**
5	**Plant 5**	**Karawang**	**79.6**
6	VLC	Jakarta	1.5
7	**Part Center**	**Cibitung**	**45.7**

Figure 2: Distance of HO to Others Sites

Based on the 2013 Indonesian Disaster Risk Index (IRBI) published by the National Disaster Management Agency (BNPN) states that none of the Regencies/Cities in Indonesia are free from the threat of disasters, including Karawang and Cibitung Regencies which are the locations of the four sites. However, Karawang and Cibitung districts are still in the safe category because they are not included in the national priority disaster risk in the Java region (30).

3.2 Network

PT XYZ's Wide Area Network (WAN) uses a combination of ring and mesh topology, each site is connected to the closest site with the concept of forming a circle with several alternative connections as fault tolerance.

Figure 3: WAN Topology PT XYZ

3.3 Data Center

PT XYZ's DC is located in HO, with a Tier 2 classification system that has an uptime rate of 99.74% or within a year the maximum fault tolerance limit is 22 hours. Also, have facilities include such as UPS modules, chillers or pumps, and engine generators to increase the margin of safety against IT process disruptions resulting from site infrastructure equipment failures (12).

3.4 Information System

PT XYZ's information system runs entirely on-premise virtual servers totaling 200 servers as of March 2019, which can be grouped based on service functions, namely application servers, databases, and the web. Referring to the limitations of the research problem, the information system displayed is the production information system. In its main business activities, PT XYZ's production process is supported by 31 interconnected information systems.

Table 2: Production Information System

Production Information System			
No.	High	No.	Moderate
1	FGW	17	Andon System
2	FTH Pooling Production	18	Part Traceability
3	Sending FTH	19	QIS #2
4	ADPPS	20	ISCS
5	PIS Line 1 & History	21	ADTPS
6	PIS Line 2 & History	22	FTH Pooling Dev
7	Exto DMC VPH	23	PIS Web
8	ADLES	24	OTD
9	PIS 1 Calculation	25	Hourly Delivery Achivement Line 1
10	PIS 2 Calculation	26	Hourly Delivery Achivement Line 2
11	PBS Printing #1	27	Andon Domestic Whosales
12	PBS Printing #2	28	RMS #1
13	Insys Nameplate #1	29	RMS #2
14	Insys Nameplate #2	30	Prod Sequence
15	OSM Line 1	31	Passrate Web
16	OSM Line 2		

4. ANALYSIS METHOD

4.1 Data

The data analysis method used in this study is the hermeneutics method. Hermeneutics is a method that emphasizes the contextual description of a case of a phenomenon, in contrast to the

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positivist method that seeks to identify the generically free context (31).

Figure 4: Data Analysis Method

4.2 Risk Analysis

The risk of financial loss to the company due to disruption of the production process is calculated in rupiah per minute which is calculated in each production process so that if all processes stop due to disaster, the total loss is the loss of the entire process times the number of minutes the production process is interrupted.

Table 3: Cost of Loss Due To Line Stop

Production Process	Money Loss (IDR/minute)
Welding #1	1.336.681
Welding #2	435.302
Welding #3	626.880
Painting #1	859.495
Painting #2	854.533
Painting #3	886.502
Assembly #1	723.414
Assembly #2	619.427
Assembly #3	485.350
Inspection #1	125.477
Inspection #2	102.136
Inspection #3	59.139
Total	**7.114.336**

4.3 RTO, RPO & IT Service Priority

The level of RTO and RPO of the production information system has not been determined with certainty, but we can reflect on the needs of the company's core business processes, where the core manufacturing business lies in the continuity of its production process to produce a finished product. Therefore, the production process is a top priority for IT services in maintaining the availability of data or information needed by PT XYZ.

4.4 Alternate-Site

Previous site identification obtained by Karawang and Cibitung Regencies can be used as alternate-site. However, only the Karawang Regency location is following the Telecommunication Industry Association (TIA) standard. TIA states that the selection of DRC site selection can consider the following conditions (32):

1) Not located at a flood site, near an earthquake fault, and on a hill
2) There is no nearby building that can make debris fall during an earthquake
3) Not 0.4 km from airports, research laboratories, chemical plants, rivers, coastlines or dams.
4) Not closer than 0.8 km from the railroad track, and military base
5) Not located 1.6 km away from nuclear, ammunition or defense plants.
6) Not located close to foreign embassies and high crime areas

The three sites are located within an industrial area that has easy access that can be reached directly from the Jakarta-Cikampek toll road (only 1.3 km from the toll gate). Its strategic location is between Jakarta, Bandung and the province of Central Java, supported by good water treatment technology and wastewater treatment plants to create an environment free from flooding, and the level of security facilities 24/7 so that it is far from potential external threats.

Other internal factors also need to be considered such as the availability of manpower, space, server and network infrastructure, as well as the extent of the site's function to the company's business processes, so as not to cause major changes to the running infrastructure, which causes additional costs in implementing DRC.

Table 4: Resource Availability

No.	Site	Availability				Function
		Space (Room)	Man Power (Shift)	Infrastructure		
				Server	Network	
1	Plant 2	O	X	O	O	Production engine
2	Plant 3	O	X	O	O	Production block engine
3	**Plant 5**	**O**	**O**	**O**	**O**	**Production - assembly**
4	Part Center	O	X	X	O	Component supply

Considering the minimum, geographical distance, ease of access, low level of disaster risk, environmental security, and all internal factors in building DRC, the site Plant 5 (P5) can be chosen as the main choice in determining alternate-site.

4.5 Network

The network interconnection between HO and P5 currently passes through two other sites, namely through P3 and P2 (HO → **P3** → **P2** → P5). The current interconnection scheme is less effective if used for DRC purposes. DC interconnection with DRC should be a point to point and used specifically for data replication purposes, as well as being used as backup interconnection links between P2 and P5.

Figure 5: Proposed WAN Topology

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4.6 Information System

The work processes of all information systems are interrelated, for example, the core system of PT XYZ, the Production Instruction System (PIS) which serves as a reference for the production process, the PIS system cannot be used without the support of data from other information systems, for example, which has the function of ensuring the availability of logistics of raw materials, regulating daily production plan, and production achievement information. Therefore, for operational DRC requires priority order recovery of information systems when a disaster occurs massively.

Figure 6: Recovery Sequence

4.7 Storage & Server

Each production information system consists of two dedicated servers, the first server specifically runs applications, and the second server provides a database resource. So, overall the production information system requires 62 servers consisting of 31 application servers and 31 database servers. Production information system requires ± 13 TB or about 22% of the total DC storage server allocation, the need is obtained from the current total production information system storage allocation, additional assumption of 10% data growth, then 20% obtained from the PT XYZ threshold storage difference 80% of the total storage capacity.

Table 5: Production IS Requirements

Storage Server Alocation

No.	Datastore	Size (GB)
1	DS1	10.000
2	DS2	10.000
3	DS3	15.000
4	DS4	15.000
5	DS5	10.000
	Total (GB)	60.000

Storage Server Production

Type	Size (GB)	Grow data (+10%)	Threshold (+20%)
Application	7.040	7.744	9.293
Database	2.850	3.135	3.762
			13.055

Storage requirement for DRC about 22% of storage DC

4.8 Design Method

The design of the DRC prototype that will be built consists of two variants with different levels of RPO and RTO, and is designed with replication server capabilities on the DR-site that can be used in general or partially without disrupting the performance of other information systems.

4.9 Evaluation Method

The evaluation process is carried out by comparing the advantages and disadvantages based on several parameters, then proceed with an analysis of the cost requirements of each replication method design. Furthermore, a Cost-Benefit Analysis (CBA) will be carried out to determine the value of the efficiency of the company's investment value.

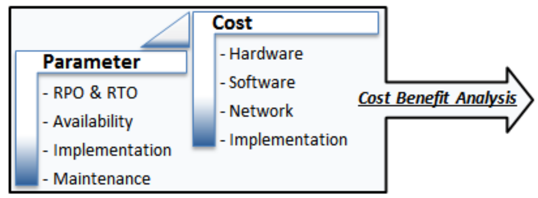

Figure 7: Evaluation Method

The analysis consisted of three criteria, including Payback Period, Return on Investment, and Net Present Value. Then, at the final stage, further evaluation will be carried out by PT XYZ as a validation of the results of the final replication method design.

5. DISASTER RECOVERY PROCEDURE

The use of DRC must have clarity of recovery objectives, and the stages to be carried out must be well understood by each member of the recovery team when a disaster occurs. Disaster recovery procedures can be divided into three stages of the process.

Figure 8: Disaster Recovery Steps

However, in its use, not all disasters or disruptions require the activation of the DRC, depending on the level of risk of failure, whether the failure can be minor or major in the course of business processes.

Minor system failures:

1) The main components of the Data Center system (server, storage, network, electrical) can still operate
2) Data Center support facilities are not physically damaged
3) The main systems related to business processes in the Data Center can still be used, although some are done manually
4) Disasters do not require employee evacuation or major repairs to the company's data center facilities

Major system failures:

1) The main components of the Data Center system (server, storage, network, electrical) cannot operate

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2) Data Center support facilities are physically damaged
3) The main system related to business processes in the Data Center cannot be used
4) Disasters that require employee evacuation or major repairs to the company's Data Center facilities.

5.1 Activation & Notification

The activation phase of the system on the DR-site is carried out after a disaster or when an IT service is interrupted which may exceed a predetermined RTO. When the DRC is activated, the recovery team provides management with information about potential disruptions to IT services and an assessment of the impact of disruptions on the system as a whole. The results of the assessment will be used as a reference in carrying out recovery procedures which are then informed to the recovery team and all users.

Figure 9: Activation & Notification Scheme

5.2 Recovery

This stage focuses on activities related to recovery procedures for systems affected by disasters.

Figure 10: Recovery DRC Scheme

5.3 Reconstitution

Reconstitution stage is a process of testing and validation of the ability of the system and functions of the system when returning the main service to the Data Center, then made the documentation of the recovery effort process.

Figure 11: Reconstitution DRC to DC Scheme

6. DETERMINATION OF RPO & RTO

The initial parameters that must be known are the allocation and time series of the production process to determine the possibilities of time to carry out the replication process.

Figure 12: Time Allocation Production Process

The next parameter is the accumulation of data growth from the entire server supporting the production process.

Table 6: Growth of Production Server Data

No.	Server	Average (KB) /minutes	Size (KB) /day
1	Application	4,491	3.818
2	Database	16,522	14.044
	Total		17.862

} 18 MB

Then the next parameter related to server device specifications. The server equipment used by PT XYZ is the HPE ProLiant BL460c Gen9 Server Blade with VMWare ESXi 5.5.0 as its Operating System (OS).

Figure 13: PT XYZ Server Device Specifications

Also have been determined the minimum standard specification VM server, then performed a brief simulation on several servers to determine the range of time required in a VM server recovery effort, and obtained an average recovery time of about 90 seconds (1 minute 30 seconds).

7. RESULT AND DISCUSSION

There are two proposed replication method designs, the first design replication method is designed based on the analysis of business process needs, while the second replication method design acts as an alternative design which is an improvisation of the main design.

7.1 RPO & RTO #1

When the production process of PT XYZ is disrupted, it will also have an impact on the external value chain, this condition is inseparable from the status of the existence of PT XYZ as the *Agen Tunggal Pemegang Merek* (ATPM), therefore PT XYZ is expected to be able to reduce the fault tolerance minimal line stop. Each production information system has a different level of RPO, the smallest RPO is owned by the Production Instruction System (PIS) with a 2-minute RPO obtained from a total of 20 checkpoints multiplied by takt time per checkpoint for 6 seconds. Each scanning data is directly connected to the PIS, the data scanning results on the application server will be sent to the database server in intervals of 120 seconds (2 minutes).

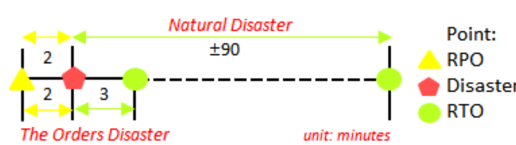

Figure 14: Parameter RPO & RTO #1

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The RTO determination is divided into two, the first RTO specifically for natural disasters, the determination is based on the recovery time per server multiplied by the total production server, as a result, the RTO is obtained for 90 minutes, then the second RTO is taken from the tolerance of the daily production process line stop for 3 minutes.

7.2 RPO & RTO #2

RPO & RTO #2 was built based on the improvisation of RPO & RTO #1, which was further analyzed by pressing several parameters that could influence it. Seeing the intensity of data development on production application servers, the development of data on database servers is more dynamic compared to application servers. RPO database server can refer to monthly line stop tolerance per production line for 30 minutes. Whereas the application server, RPO can refer to the third monthly line stop tolerance of the production line for 90 minutes.

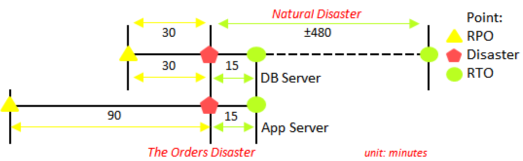

Figure 15: Parameter RPO & RTO #2

The first RTO is intended for natural disaster conditions, where it is most likely at that time not only the IT factors that require recovery, for example, the damage to the location, production machines or other factors that have not been known for a long time recovery. Under these conditions a low RTO will not be effective, to simplify the calculation the RTO can refer to one normal production shift time, which is 480 minutes. Then the second RTO can refer to the line stop tolerance of the weekly production process, which is 15 minutes.

7.3 Design Of Replication Methods

It is known that the Karawang Assembly Plant (Plant 5) is a location that meets the requirements for building a DRC, as well as the two sets of RPOs and RTOs needed, an appropriate backup model is a hot standby (active/passive) with an asynchronous data replication model, where the DRC is only are in one location, and there is still a line stop tolerance in the business process. Replication is built according to the running server infrastructure by utilizing VMware vCenter Site Recovery Manager (SRM).

7.4 Replication Method #1

Based on the initial requirements where the RPO and RTO levels are low, the replication technology that will be utilized is a combination of Storage Replication (Array-Based Replication) and Virtualization Replication (VMware vSphere Replication).

Figure 16: Replication Method #1

The Array-Based Replication method is used to meet the needs of universal server replication while applying the vSphere Replication method that runs at Guest OS level replication is used to be able to do partial replication

7.5 Replication Method #2

With higher levels of RPO and RTO, the replication technology used is enough with Virtualization Replication (vSphere Replication) at the Guest OS level. With the characteristics of a more dynamic replication allows users to implement different RPOs on each server, but the RTO achieved is higher because it requires several manual operations to run it.

Figure 17: Replication Method #2

Then to improve the efficiency of data replication, the level of RPO of the application server and database server can be distinguished, based on the previous analysis, the level of data change on the application server is smaller than the database server.

8. EVALUATION

8.1 Comparison Parameters

Several parameters are used as a consideration in choosing the design of a replication method that suits the business needs of PT XYZ. The first parameter is the level of effort in the implementation and maintenance of each DRC replication method design that will later influence the level of project success and the level of potential problems that will be encountered in future operations to keep the DRC running. Then compare the operating models of each DRC design when a disaster occurs, which affects the steps that the recovery team must take when a disaster occurs. These technical parameters are important to know and serve as a reference for the IT department, especially the IT infrastructure section.

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Table 7: Parameter Comparison

The next comparison parameter is cost, the cost is the main concern that needs to be known by PT XYZ Management in each project, such as how much the cost is needed and the extent to which the investment has a positive impact on the company.

8.2 Estimated Costs

Cost estimates can be divided into three types of expenditure needs, the first is the need that does not require costs (non-costs), which consists of the utilization of assets currently owned and located in the location to be built by the DRC, namely in P5 (Karawang Assembly Plant). Then the non-recurring costs are also the initial investment costs in the DRC implementation process. Finally, operational costs are needed after the implementation process is carried out and has recurring costs in a certain period.

Table 8: Estimated Costs

8.3 Cost-Benefit Analysis

NPV analysis results show that financially investing in DRC method #2 is more profitable than method #1. However, both of them show numbers> 0, meaning that both investments are feasible and can provide benefits for the company in the future.

Then, the results of the ROI analysis found that the ratio of potential investment returns on method #2 is greater than method #1, given the basic concept of DRC investment that is guaranteed to the continuity of the business process in anticipating a greater impact or loss due to disasters, the objective and both morals are considered appropriate.

Table 9: Cost-Benefit Analysis

Parameter	Method #1	Method #2
NPV	Rp 153.072.321	Rp 812.007.737
ROI	4.5%	23%
PP	4.8 years	3.6 years

Finally, from the payback period analysis, it is known that method #2 requires a shorter time to reach the return point of capital compared to method #1, but both methods are still fairly feasible to implement because it is still within the standard criteria of the depreciation period of PT XYZ.

8.4 Final Evaluation

The final evaluation in this study was carried out by the Division Head of Corporate IT as a representative of PT XYZ to determine the DRC replication method that best suits the business needs of PT XYZ. He stated that investment in DRC replication method #2 had more promising profit potential, technically the implementation was simpler, but there was a big risk involved. The main orientation of PT XYZ is to provide the highest quality service to all customers spread across Indonesia and in 75 other countries. So, don't get the wrong orientation, don't because looking for a certain nominal disturbs the sustainability of the existing value chain process.
DRC replication method #1 is considered to be more in line with PT XYZ's business needs, although investment costs are high, with little profit potential, the risk offered is lower, achieving a minimum downtime, and more reliable in dealing with various types of potential disasters.

9. PROBLEM IDENTIFICATION

In one year at PT XYZ, there was a line stop of 451 minutes of IT factors, all aspects of the problem were analyzed using a fishbone framework, where the problem domain of the fishbone framework was taken based on a variant of the Toyota's Problem Solving Network Framework (33).

Figure 18: Problem Identification

Obtained main problems on the Production Instruction System (PIS) server with the accumulation of line stop causes for 114 minutes. The potential loss of PT XYZ due to disruption of the production process is calculated in rupiah per minute. Losses are calculated at each production process so that if all processes stop due to disaster, the total loss is the loss of the entire process multiplied by the number of minutes of stopping production.

10. CONCLUSION

From the results of the PT XYZ case study, it was found that the DRC system that was built was not only able to eliminate the main IT problems that caused the line stop, but also could be a solution to various other disaster threats. The integration of needs with the availability of assets and the current IT infrastructure has resulted in DRC designs that are more efficient and technically and cost effective.

From the results of the two proposed DRC systems, method # 1 is more in line with PT XYZ's business process needs that require a low level of risk, is flexible to more potential causes, has expectations of a technically difficult level of implementation, is investment-worthy and meets the PT depreciation period XYZ is related to the age of use of the device.

For future research, the DRC system can use several other types of replication methods, other evaluation approaches, and utilize the latest technology today, for example various types of cloud computing services, such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS) , or Disaster Recovery as Service (DRaaS).

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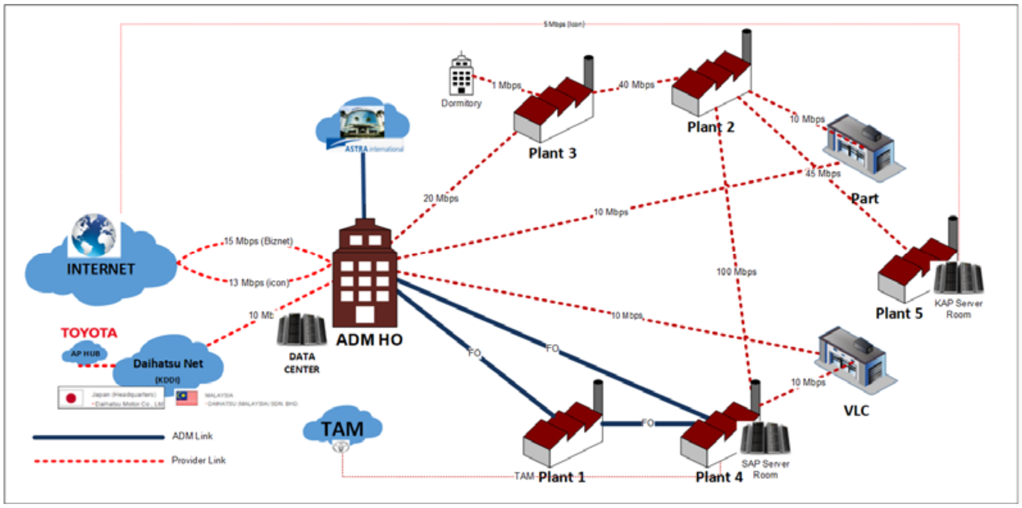

Figure 3: WAN Topology PT XYZ

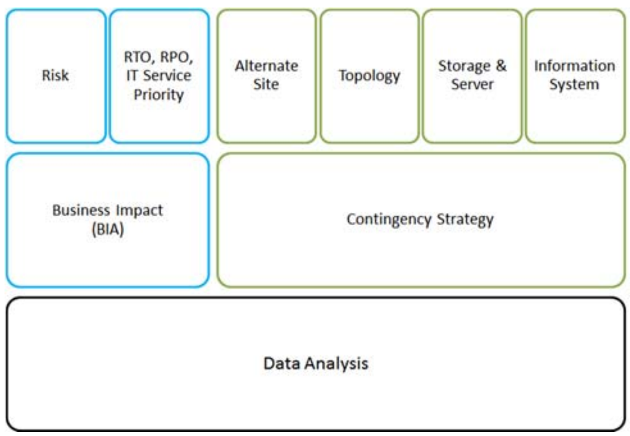

Figure 4: Data Analysis Method

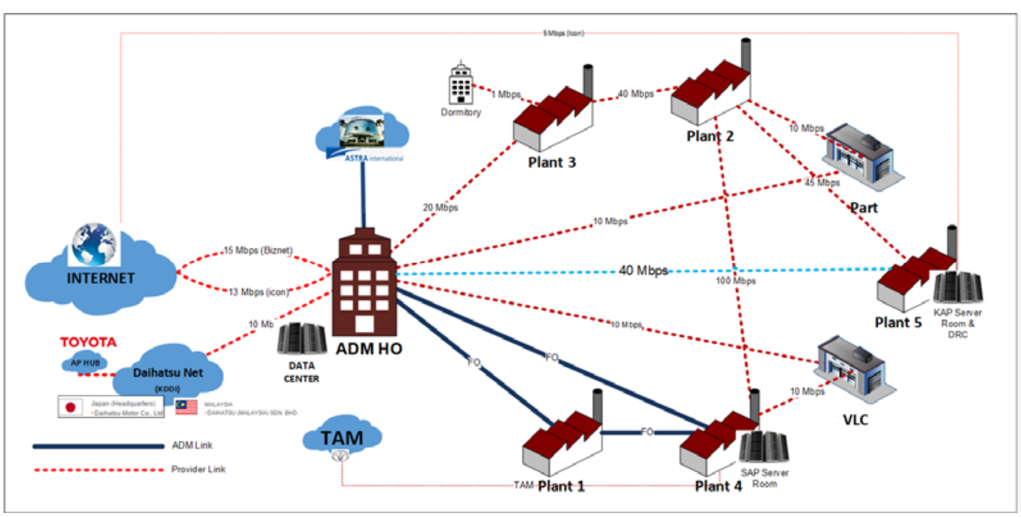

Figure 5: Proposed WAN Topology

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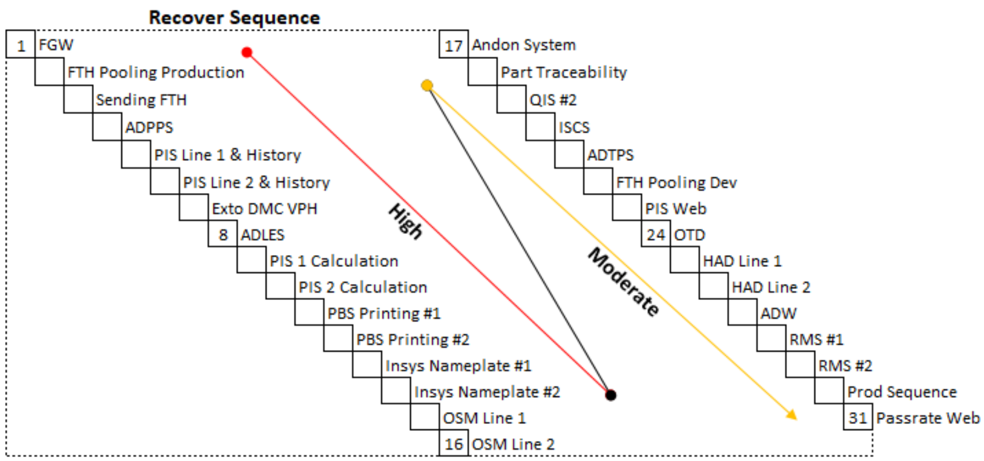

Figure 6: Recovery Sequence

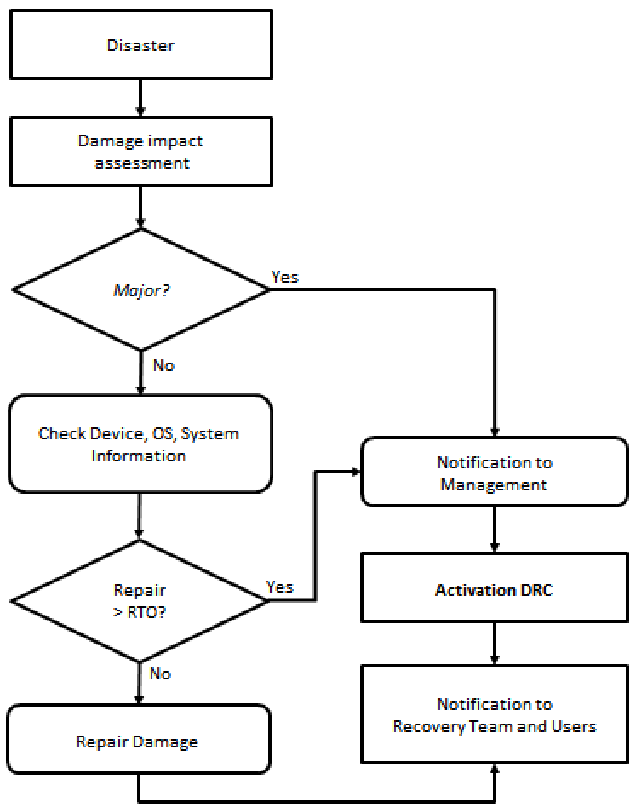

Figure 9: Activation & Notification Scheme

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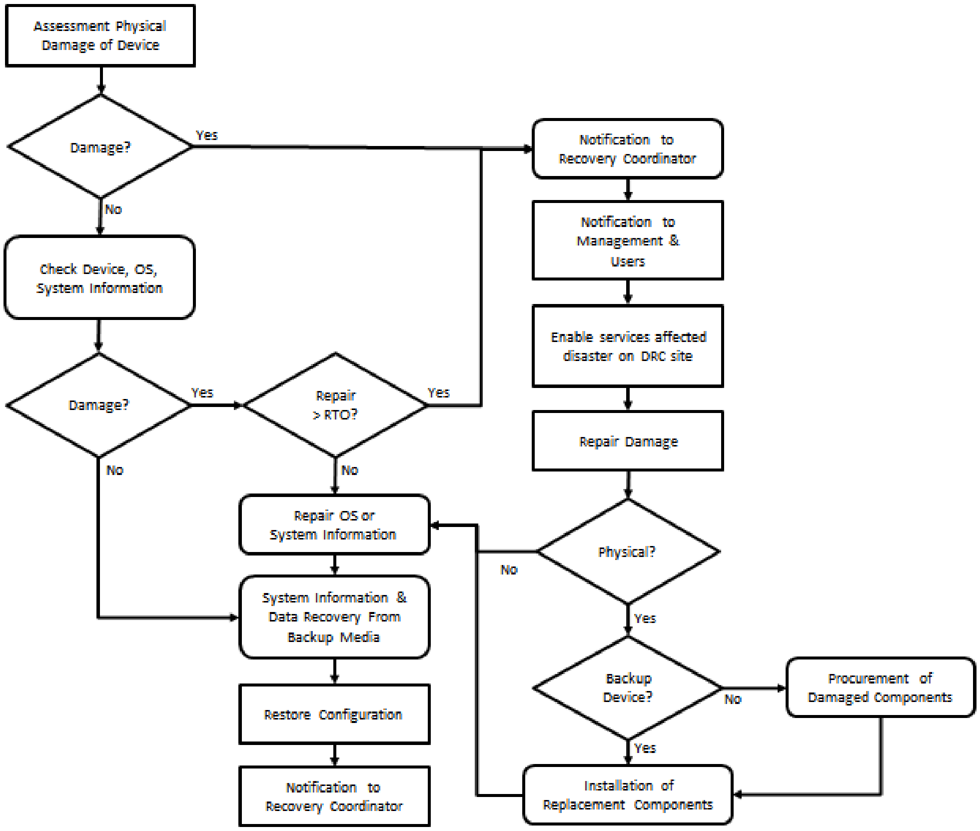


Figure 10: Recovery DRC Scheme

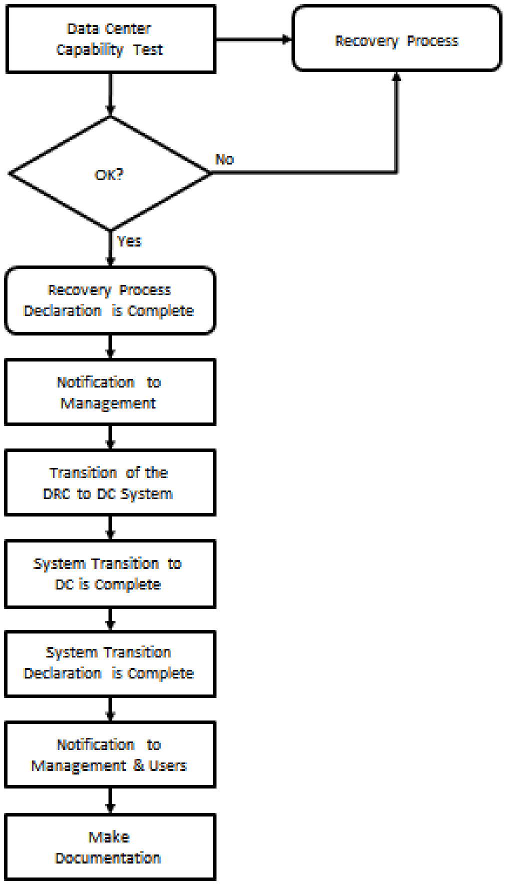


Figure 11: Reconstitution DRC to DC Scheme

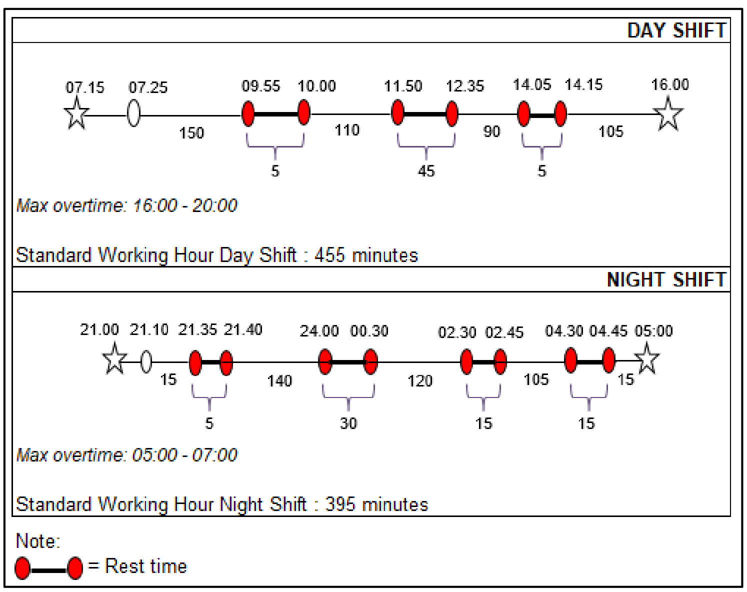


Figure 12: Time Allocation Production Process

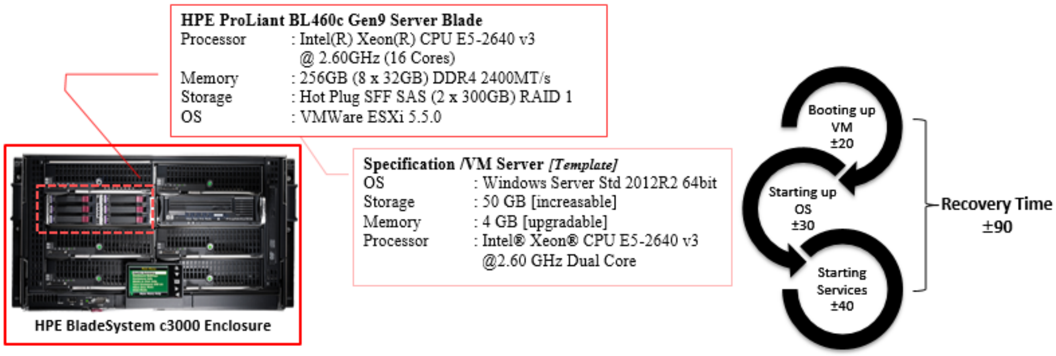
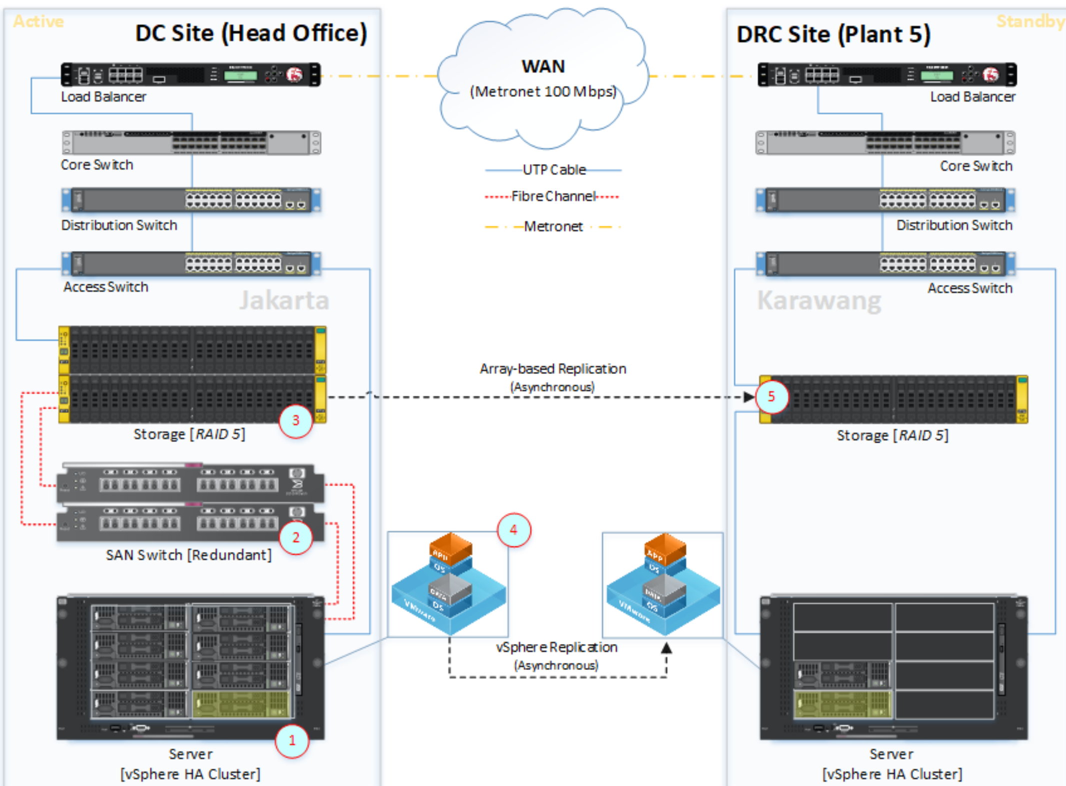


Figure 13: PT XYZ Server Device Specifications



Point	Threat	Handle With..
1	Host OS crash, server broken	vSphere HA cluster
2	Connection server-storage error	SAN Redundant
3	Logical or physical storage disk broken	RAID
4	Guest OS crash	vSphere Replication
5	Natural disaster	Array-based Replication

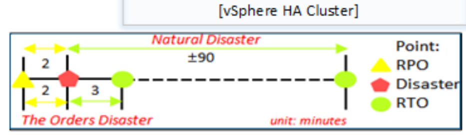


Figure 16: Replication Method #1

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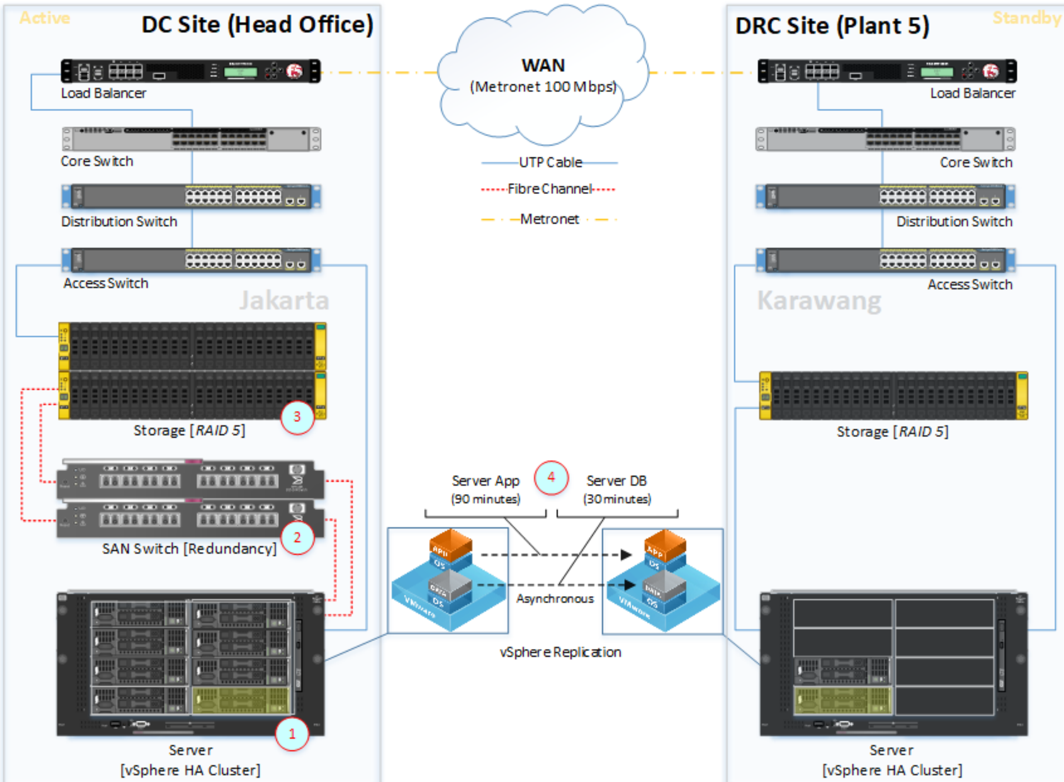

Point	Threat	Handle With..
1	Host OS crash, server broken	vSphere HA cluster
2	Connection server-storage error	SAN Redundant
3	Logical or physical storage disk broken	RAID
4	Guest OS crash, natural disaster	vSphere Replication

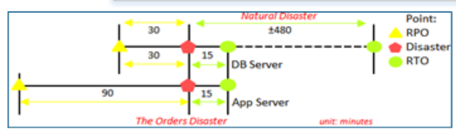

Figure 17: Replication Method #2

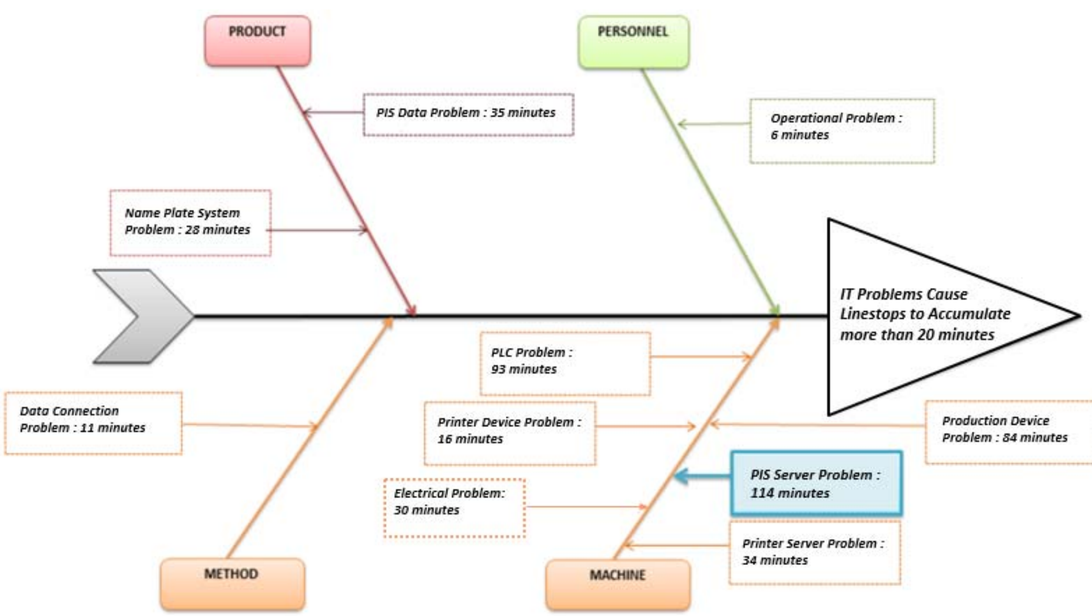

Figure 18: Problem Identification

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Table 1: Similar Research Reference

No.	Authors	Issue	Method	Outcome	Environment
1	Zhiyuan Shao, Hai Jin [2006]	The sync process with the same results is repeated	Utilizing the response of a request message	High level of effectiveness in the replication process	Not specific
2	Adnan Omar, David Alijani, Roosevelt Mason [2011]	Complex operations with high availability requirements	Replicate P2P data between DC-DR	Simple replication concept with a high level of data availability	Community college
3	Rekha Singha [2012]	Constraints related to the distance of the DC connection in reaching DR	Replicate data from DC to all sub-DR	Achieve high level data availability services	e-Governance services
4	Hong Wang [2017]	High level of downtime in DR during natural disasters	Data replication between DC to DR via an intermediate (Warm-CDP)	Higher levels of data stability and flexibility	Not specific
5	Wibowo, Diana, Subekti, Hendro [2018]	High traffic / bandwidth needed for DC replication to DR	Separation between master replication to DR, and updates to sub-DR	The replication process is more efficient, because master replication does not need to be distributed to all sub-DRs	Not specific
6	Narendra Dhanujati, Abba Suganda Girsang [2018]	High data availability requirements in all conditions of disaster threat	Replicate data from DC to all sub-DR	High scalability with simple management of replication	Electricity company

Table 7: Parameter Comparison

Parameter	Method #1		Method #2			
	Minor	Major	Minor		Major	
			App	DB	App	DB
RPO	2		90	30	30	
RTO	3	90	15		480	
Cost	High initial investment and maintenance costs		Lower initial investment and maintenance costs			
Implementation	The time required is longer, with a high difficulty level		The time required is shorter, with a lower difficulty level			
Maintenance	Requires more intense and complex maintenance		Requires less frequent and simpler maintenance			
Potential Problem	High potential technical and operational problems		Potential lower technical and operational problems			
Recovery Type	Enables automatic or manual recovery		There is still a manual recovery operation			
Recovery Level	Full or partial recovery		Partial recovery			

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Table 8: Estimated Costs

NON COSTS

No.	Cost	Method #1			Method #2		
		Qty	Cost		Qty	Cost	
1.1	Building	1	N/A		1	N/A	
1.2	Room	1			1		
1.3	Rack	1			1		
1.4	PAC	2			2		
1.5	Fire suppresion	1			1		
1.6	UPS/Gen-set	2			2		
NON-RECURRING COSTS (Initial Investment)							
2.1	Hardware Server (Host)	2 unit	Rp	1.040.000.000	2 unit	Rp	765.000.000
2.2	VMware Vsphere, Vcenter License	4 unit	Rp	332.000.000	4 unit	Rp	257.400.000
2.3	Windows Server DC Edition (Guest OS)	4 unit	Rp	308.000.000	4 unit	Rp	257.400.000
2.4	VMware SRM License	2 unit	Rp	174.000.000	2 unit	Rp	174.000.000
2.5	Storage (Datastore)	40 TB	Rp	624.060.000	32 TB	Rp	443.776.000
2.6	SAN Switch	2 unit	Rp	700.000.000	2 unit	Rp	700.000.000
2.7	Labour (implementation, support)	1 lot	Rp	104.000.000	1 lot	Rp	76.500.000
			Rp	**3.282.060.000**		**Rp**	**2.674.076.000**
RECURRING COSTS							
3.1	Main Power	12	Rp	10.320.000	12	Rp	10.320.000
3.2	Metronet HO-P5	12	Rp	384.000.000	12	Rp	384.000.000
3.3	Preventive Maintenance	1	Rp	82.051.500	1	Rp	66.851.900
			Rp	**476.371.500**		**Rp**	**461.171.900**