# Analysis and design of web-geographic information system for tropical diseases-prone areas A case study of East Java Province indonesia

*by* Anik Vega

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# Analysis and Design of Web-Geographic Information System for Tropical Diseases-Prone Areas: A Case Study of East Java Province, Indonesia

Anik Vega Vitianingsih, Dwi Cahyono, Achmad Choiron
Informatics Department Universitas Dr. Soetomo Surabaya-Indonesia
vega@unitomo.ac.id, dwikk@unitomo.ac.id, choiron@unitomo.ac.id

***Abstract*— Analysis and design system in this paper is used to model Web-Geographical Information System (Web-GIS). The results can be used to create Web-GIS applications that are able to identify prone-areas to tropical diseases in East Java of Indonesia, using Multi-Attribute Utility Theory (MAUT). This Web-GIS information system includes the distribution of the affected areas, endemic areas, epidemiological inquiry and tropical diseases-free areas. Web-GIS analysis process consists of: describing requirements system, outlining the need of spatial data (layers) and attribute data tables, create a process model with tiered diagram and data flow diagram that describe the process flow of a Web-GIS system. System design process by making Conceptual Data Model (CDM) serves to describe the needs of spatial data and attribute data in a database system. CDM is generated and produces Physical Data Model (PDM). PDM contains the metadata structures of the spatial data and attribute data that will be processed and stored in the Web-GIS application program. Geoprocessing Layers are implementation of the analysis process and design system, processing layer by buffering, union, and intersection layer techniques. The layer is generated from geoprocessing and processed by entering parameters in MAUT method to result the identification of tropical diseases prone areas.**

**Keywords—*Web-GIS, System Analysis, System Design, Tropical Disease, MAUT Method*.**

## I. INTRODUCTION

East Java Province is a tropical region with average temperature between 21 - 34ºC and average annual rainfall of 1,900 mm [1]. With these climatic conditions, East Java Province is prone to tropical diseases such as *Tuberculosis, Diphtheria, Pertussis, Tetanus neonatorum, Leprosy, Dengue Haemorrhagic Fever (DHF), Measles, HIV-AIDS, Malaria, Filariasis* [2]. The society nowadays are still difficult to get information about the number of incidents of tropical diseases, because the information generated is still limited to annual data recorded in the form of data tables and analog maps. The data includes the number of cases of people with tropical diseases, death rates, cure rates, percentage of patients and extra-ordinary events [1]. In order to support health sector development through Dinas Kesehatan, there is a need of accurate data and information with digital mapping system to be used in the decision-making process and program planning to reduce the spread of the diseases.

In East Java, which is one of Indonesia's tropical regions, many emerging tropical climatic diseases arrive during transitional season. Tropical disease refers to infectious diseases caused by bacteria, viruses, and parasites that thrive in the tropics. Tropical disease is almost uncontrollable which is characterized by the number of extraordinary events in recent years. The disease caused by several factors of transmission such as parasitic factors (agent) and host factors. The long dry season and heavy precipitation events greatly influence the formation of breeding grounds for disease agents [1].

Regional susceptibility to tropical diseases in East Java is determined based on outbreak data on certain types of the diseases in 3 (three) consecutive years. Category of the Endemic area applied to a region if there are tropical disease events in 3 (three) consecutive years, category of a sporadic area in case of non-consecutive events in three years (annual data scale), and potential area for certain disease types if there is no occurrence in the last 3 years [1]. The classification ofendemic levels is not associated with the number of cases.

In recent times, the map of regional distribution based on the level of susceptibility to the tropical diseases already exists. However, the map is only based on the diseases occurrence in the last year, mapping by combining data intensity and diseases frequency has not been done. Information about the area distribution based on the level of susceptibility is necessary to determine priority areas for the implementation of anticipatory and prevention programs by the Public Health Services[3,4].

Accurate data and information are required for the process of decision making and program planning in order to support the development of health's field practices. In addition, the Law of the Republic of Indonesia Number 36 Year 2009 concerning Health Article 17 Paragraph (1) states that the government shall be responsible for the availability of access to information, education, and health service facilities in order to improve and maintain maximum health degree. Article 168 also states that to organize an effective and efficient health effort is required health information that shall be conducted through the

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information system and cross-sector. Article 169 mentions that the government shall provide convenience to the public to gain access to health information in order to improve public health status [1].

Based on the research that the authors did, the use of Geographical Information System (GIS) and Web-GIS technology can perform spatial analysis and temporal analysis. It has the capability to produce an integrated analysis covering all aspects [3]. Map showing the regional distribution of the diseases is useful for the empirical study of the relationship between climate, weather and other diseases or other health problems that are useful to implement the intervention plan [5].

The purpose of this research is to develop the Geographic Information System Web-GIS which can map information about the distribution of tropical diseases affected areas in East Java. The result shows that tropical diseases-prone area can be identified based on the data intensity of tropical diseases such as the type of residential area, population density, puddle type, air temperature, average rainfall, air humidity, the number of health facilities and the diseases frequency[6,7]. Web-GIS modeling system uses Multi Attribute Utility Theory (MAUT) to display the mapping analysis by determining the weight value and priority value for each parameter [8].

Web-GIS GIS system is expected to help people to be aware and live a healthy lifestyle to avoid the danger of tropical diseases and also for East Java Provincial Health Office as the decision-maker to do the planning, prevention, and eradication of tropical diseases to some areas with extraordinary events.

## II. RESEARCH METHODOLOGY

### A. System Requirement Analysis

The analysis of system requirements explore the needs of spatial data (layer) and data attributes (database) that will be used as the basis of analysis and system design. Analysis of system requirements includes a real system, evaluation and the study of data feasibility by describing the form of Web-GIS to be created [9]. Analyzing the need for spatial data and attribute data that will be used to process the system and determine the data flow for database design by depicting it into a tiered Diagram and Data Flow Diagrams (DFD).

In this research, the output model of Web-GIS requirement analysis is data availability of tropical disease in East Java Province, multiplying the supporting parameters that will be used as a reference to determine tropical diseases-prone areas and perform the process of analysis and design of application system to a database system. As the results shows in Table 1 below,

Table I. Output Model of System Requirement Analysis

| Type | Output |
|---|---|
| Literature Studies | - Concept of Web-GIS<br>- GIS technology |
| Field Studies | - User requirement<br>- Organizational initialization<br>- Observe the scope of the research |
| Information Requirements | - Spatial data requirements (layer)<br>- Attribute data requirements (database table) |
| System Analysis | - Description of GIS<br>- System process flow<br>- Analysis of spatial data and attribute data<br>- Parameter analysis of spatial data layer and attribute data by making a tiered Diagram of the DFD system process<br>- User Interface Design |
| Database System Design | - Spatial data and attribute data with CDM (Conceptual Data Modelling), PDM (Physical Data Modelling) and Star Schema<br>- Geoprocessing Layer (Buffer, Union, and Intersect Layer)<br>- Layer design with MAUT method<br>- Database design is completed |

Database system design is performed by designing Conceptual Data Model (CDM), Physical Data Model (PDM), Geoprocessing Layer (Buffer, Union, and Intersect Layer), Layer Design with MAUT method and User Interface Design. As shown in Figure 1 and Table 1 below,

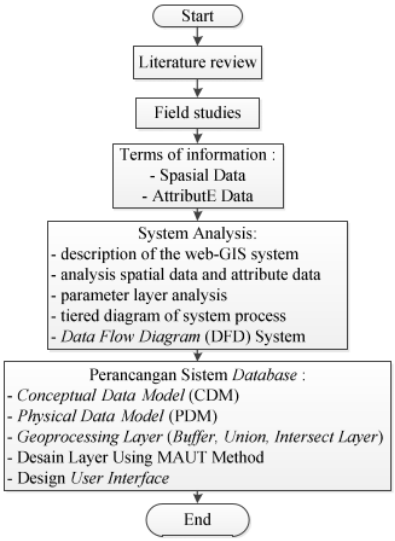


Fig.1. Analysis of System Requirements

### B. Geoprocessing Layer With MAUT Method

Type of decision making in GIS involves several viable alternatives and interrelated evaluation criteria called multi-criteria decision making (MCDM). GIS-based multi-criteria decision analysis is a process to combine and transform spatial data into a result decision, in which the ability of GIS are data acquisition, storage, search, manipulation and spatial analysis. The use of MCDM is to combine geographic data and preferences for the decision-maker to determine alternative values [10].

The technique and procedure of GIS in multi-criteria decision analysis is to automate, manage, and analyze spatial data and attribute data in a spatial decision. MCDM procedure

determines the relationship between input map and output map [11].

Multi-attribute utility theory (MAUT) method used to calculate the overall value of the choice alternative on a sub-criterion. The form of the representation theorem for some attribute value function is determined by the set of conditions for the decision-maker, with the formula as follows [8]:

$$v(x1, x2, \dots x_N) = \sum_{i=1}^{N} k_i v_i (x_i) \qquad (1)$$

In which $vi\ (x_i)$ is function value for attribute $i$, $k_i$ is the attribute parameter and $i$ based on the uncertainty relation between the attributes.

Geoprocessing layer processed by digitizing an analog map to insert all attribute data, parameters, and criteria stored in the form of a Shapefile (*.*shp*) which will become a layer. Then the buffer process will be performed to the layer to create polygons from the layer area, after the buffer layer is formed then the main layer data and the region layer will be merged. The layer generated from the merging process will produce some outer layer coverage beyond the actual layer range, remove it using intersect process to create overlay layer result. The process of geoprocessing layer is as shown in Figure 2 and Table II below,

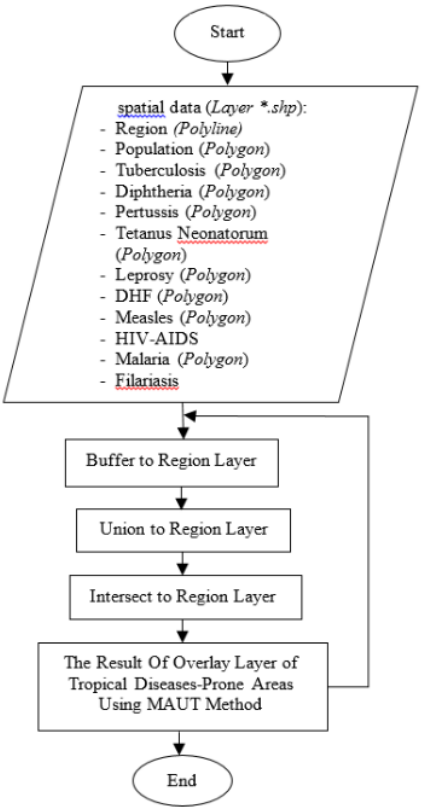


Fig. 2. Geoprocessing Layer

Table II. Output Model of Geoprocessing Layer

| Type | Output |
|---|---|
| System Implementation | - Database connection application program (Microsoft SQL Server Management Studio)<br>- System framework implementation (Arc GIS API 3.2 for Silverlight dan Arc GIS Viewer for Silverlight)<br>- Implementation of GIS (ArcGIS Desktop 10.2 dan *ArcGIS* Server 10.2)<br>- Coding programming<br>- Menu design of application program<br>- Coding application program with PHP |
| Evaluation System | Prototype improvements to check the program that has been made based on the expected solution |
| Documentation System | - System reports<br>- Data reports<br>- Program file report |

### C. *Building Prototype of GIS System*

Prototype of Web-GIS system is formed from the results of geoprocessing layer, the layer then connected to the SQL Server database to form the attribute data table as a link between the spatial data and attribute data. In this research, GIS prototype is built in the form of Web-based GIS or referred to as Web-GIS system. Web servers are used to connect spatial database and attribute database in Web-GIS system using ArcGIS Desktop 10.2 and ArcGIS Server 10.2. The implementation of system prototype is using ArcGIS API 3.2 for Silverlight and ArcGIS Viewer for Silverlight with PHP/Hypertext Preprocessor programming.

System evaluation performed through trial and error process, and the final stage is performed by making the documentation system. The flowchart of GIS system prototyping shown in Figure 3 below,

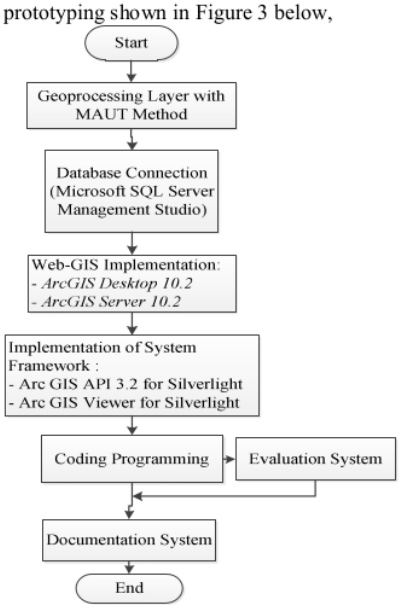


Fig. 3. Flow Prototype System Web-GIS

The output model to build GIS prototype is the availability of spatial data analysis' result and attribute data with MAUT method in the form of overlay layer produced from digitization process, buffer, union, and intersect layer. The results are shown in TableIII below,

Table III. The Output Model to Build GIS Prototype

| Type | Output |
|---|---|
| Implementation of Spatial Data (*Layer*) | - Digitization of all spatial data layers<br>- All layers have been digitized (**.shp*) |
| Implementation of Layer Analysis | - Process of buffer layer, union layer, and intersect layer |
| Result of analysis using MAUT method | - The results of overlay layer of areas prone to tropical diseases<br>- The overlay layer is ready to use in Web map application |

## III. RESULT AND DISCUSSION

The design of this web-GIS application required analysis of spatial data and attribute data to be used in every process in the system. The correct analysis and process will result in a decision support system that capable of explaining logic and transforming from input data to output data.

### *A. Proses Model*

Process model aims to clarify and demonstrate a process in the business flow on this web-GIS system, the system are expected to run in accordance with the procedures and processes described in the tiered diagram in Figure 4 below,

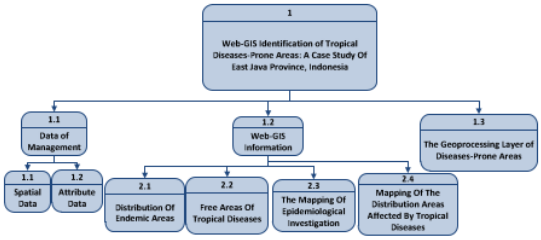


Fig. 4. The process model of Tropical Disease Web-GIS System

This research produce system analysis and system design for the process of designing prototype using data availability (1) Each district in East Java Province (2) Population per district (3) Affected areas, distribution and endemic areas on a case-by-year basis, case by age group and case by sex, (4) Epidemiological investigation of total patients with tropical diseases and (5) Parameters of areas prone to tropical disease; the intensity of the tropical disease, type of residential area, population density, puddle type, air temperature, average rainfall, air humidity, the number of health facilities and the frequency of tropical diseases in the area.

### *B. Data Flow Diagram (DFD)*

DFD is used for the development of structured systems where the data flow and the data will be stored. It can describe the flow of data in the system with a structured. Besides, DFD is a good documentation system. The analyst process to describe the flow of DFD is using the device from the power designer that allows users to present the process in the context diagram information system as shown in Figure 5 below,

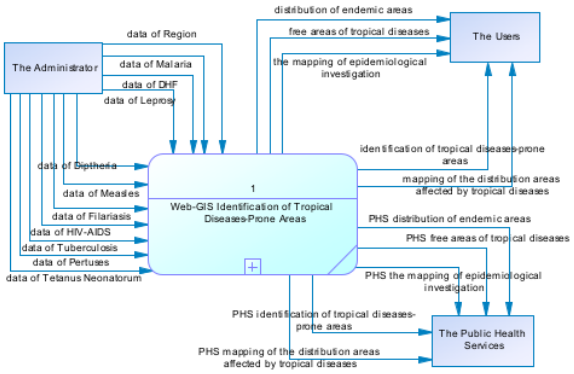


Fig. 5. Context Diagram of Tropical Diseases Web-GIS system

The system process in Figure 4 is where the spatial data of the **.shp* layer and spatial data table of Region, Population, Tuberculosis, Diphtheria, Pertussis, Tetanus neonatorum, Leprosy, Dengue Haemorrhagic Fever (DHF), Measles, HIV-AIDS, Malaria, and Filariasis are entered by admin to web-GIS system. The system then will be processed to produce information distribution of areas affected by tropical diseases, the process of distribution of areas free of tropical diseases, process of endemic areas of tropical diseases, epidemiological investigation process and information on tropical diseases prone areas for external entities users and health department as policymakers. The next process is to decompose the process to explain the next process of DFD level as shown in Figure 6 below,

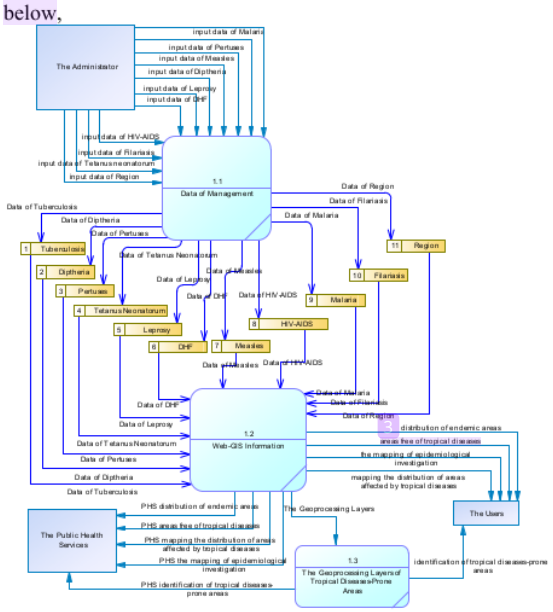


Fig. 6. DFD Level of Tropical Diseases Web-GIS System

DFD Level in Figure 6 explains:

a. Process 1.1 data management is used to process spatial data of **.shp* and attribute data table *.mdb, the data obtained from the East Java Provincial Health Office will be entered into the system web-GIS by admin, including the attributes that will be used in the system;
b. Process 1.2 web-GIS information. There are four information processes that will be delivered by the system to the public, and also to the policy makers of East Java Provincial Health Office. The system obtained from the process of data management 1.1, including the process of distribution of areas affected by tropical diseases, the process of distribution of areas free of tropical diseases, the process of endemic areas of tropical diseases and the process of epidemiological inquiry.
c. Process 1.3 geoprocessing layer processes to identify tropical disease prone areas based on the data of tropical disease intensity such as the type of residential area, population density, type of inundation, air temperature, average rainfall, air humidity, number of health facilities and the frequency of incidence of tropical disease using MAUT method.

### *C. Conceptual Data Model (CDM)*

Each of these internal entities on web-GIS comes with attributes that presents all the facts of the built database. The entity on this CDM is the data processed in Figure 5.4. The entire spatial data and attribute data is automatically generated when creating a geodatabase in *Arcmap* software which then integrates with *Microsoft SQL Server 2008 R2* as shown in Figure 7 below,

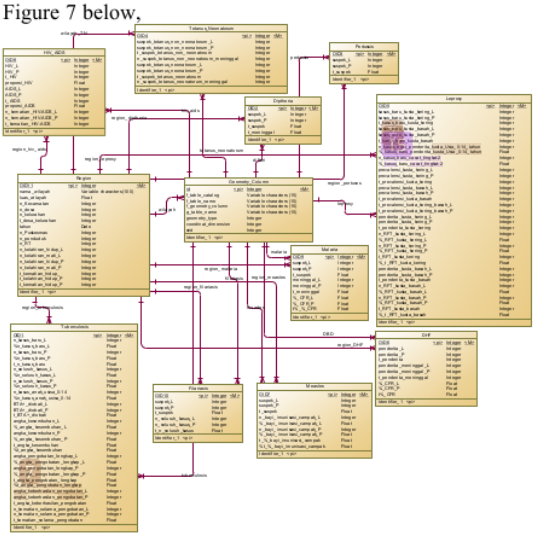

Fig.7. Conceptual Data Model of Tropical Diseases Web-GIS System

Figure 7 is a design of a CDM system that maps the needs of tables and attributes which will be used in database creation on the creation of spatial layer data. The data attributes of Web-GIS system tables are identify areas prone to tropical diseases, including:

1. Region, which includes the name of the region, region size, the number of the sub-districts, the number of the villages, total number of villages and urban community, year, number of puskesmas (community health center), number of the population, households, live births of men, stillbirths of men, number of women births, number of women stillbirths, total births of men, total deaths of men, total female births and total deaths of women.
2. Tuberculosis, which includes the number of new male cases, the percentage of new male cases, the number of new female cases, the percentage of new female cases, total number of new cases, total number of male cases, percentage of total men cases, total number of women cases, percentage of total women cases, number of cases on children aged 0-14, percentage of cases on children aged 0-14, BTA+ treated in men, BTA+ treated in women, total BTA+ treated, male healing rate, the percentage of male healing rate, female healing rate, the percentage of female healing rate, total number of healing rate, total percentage of healing rate, full medication rates in male, percentage of full medication rates in male, full medication rates in female, percentage of full medication rates in female, total of full medication rates, total percentage of full medication, number of medication success in male, number of medication success in female, total number of medication success, number of deaths during medication in male, number of deaths during medication in female and total deaths during medication.
3. Diphteria, which includes male suspects, female suspects, total suspects and total deaths
4. Pertussis, which includes male suspects, female suspects and total suspects
5. Tetanus Neonatorum, which includes tetanus non neonatorum male suspects, tetanus non neonatorum female suspects, total suspects of tetanus non neonatorum, total deaths of tetanus non neonatorum, tetanus neonatorum male suspects, tetanus neonatorum female suspects, total number of tetanus neonatorum suspects and total deaths of tetanus neonatorum
6. Leprosy, which includes new cases of pausi basiler of men, new cases of pausi basiler of women, total new cases of pausi basiler, new cases of multi basiler of men, new cases of multi basiler of women, total new cases of multi basiler, total number of new cases of pausi basiler and multi basiler of men, total number of new cases of pausi basiler and multi basiler of women, total new cases of pausi basiler and multi basiler, total cases of leprosy on children aged 0-14 years, the percentage of new cases of lepers aged 0-14 years, the number of new cases of second-level disability, the percentage of new cases of second-level disability, the prevalence of pausi basiler on men, the prevalence of pausi basiler on women, the total prevalence of pausi basiler, the prevalence of multi basiler on men, the prevalence of multi basiler on women, total prevalence of multi basiler, total prevalence of pausi basiler and multi basiler on men, total prevalence of pausi basiler and multi basiler on women, total prevalence of pausi basiler and multi basiler, male patients of pausi basiler, female patients of pausi basiler, total number of pausi basiler patients, RFT number of pausi basiler on

men, RFT percentage of pausi basiler on men, RFT number of pausi basiler on women, RFT percentage of pausi basiler on women, total RFT of pausi basiler, total RFT percentage of pausi basiler, male patients of multi basiler, female patients of multi basiler, total patients of multi basiler, RFT number of multi basiler on men, RFT percentage of multi basiler on men, total RFT of mulit basiler, RFT percentage of multi basiler on women, total RFT of multi basiler and total RFT percentage of multi basiler.

7. DHF, which includes cases of male DHF, female DHF cases, total cases of DHF, DHF cases of male deaths, DFH cases of female death, total death of DHF cases, percentage of CHF DHF on men, percentage of CFR DHF on women, and total percentage of CFR DHF.
8. Measles, which includes male suspected patients, female suspected patients, total suspected patients, number of measles immunization on male, percentage of infant immunization against measles on male, number of measles immunization on female, percentage of infant immunization against measles on female, total of baby measles immunization, total percentage of baby measles immunization.
9. HIV-AIDS, which includes HIV-positive male, HIV-positive female, total HIV, HIV proportion, AIDS on male, AIDS on female, total AIDS, AIDS proportion, number of HIV-AIDS deaths on male, number of HIV-AIDS deaths on female, total HIV-AIDS deaths.
10. Malaria which includes male suspects, females suspects, total malaria suspects, male deaths, female deaths, total deaths, percentage of male CFR, percentage of female CFR and total CFR percentage.

### *D. Physical Data Model (PDM)*

PDM is a generated ERD from CDM that aims to analyze the tables needed on tropical disease web-GIS. All the layers are connected to the geometry entity column so that the OID appears to be the foreign key of each entity as shown in Figure 8 below,

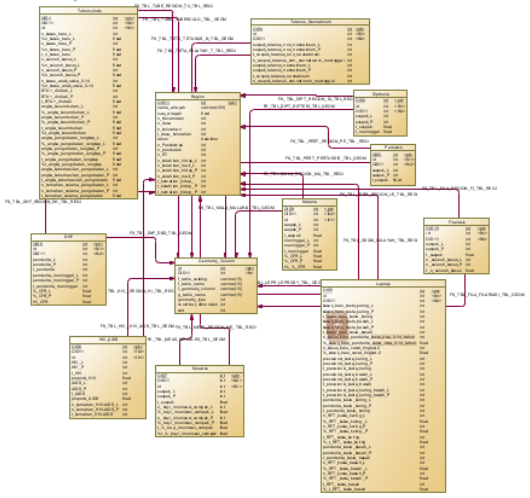

Fig.8. Generate Data from CDM to PDM

## IV. CONCLUSION

The result of database design formed from spatial data and attribute data that identified by doing the process of: (1) Geoprocessing layer, (2) Digitization of the layer which is then processed into buffer, union, and intersect process to generate overlay layer and (3) Overlay layer using MAUT method has formed with connection to database. After the layer of geoprocessing results has formed, the programming is given to the layer to generate a prototype of Web-GIS which is ready for use. The final stage is to make sure that Web-GIS system is perfect by evaluating the system through trial and error process.


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