



CHAPTER IV

RESEARCH METHODOLOGY

This chapter contains the research methodology and procedures. First, research framework will be described. Secondly, Inspection Data Collection System (IDCS) and development of an ArcPad application to support field data collection will be explained. Thirdly, the detail of workflow of handheld mobile inspection and attribute data of roadway inventory system will be discussed. The inspection process transformation will be explained in the last part of this chapter.

4.1 Research Methodology

The basic framework of road inventory system is represented by centerline of street and road network, which consists of road attributes data attached to the segment, nodes and links. The roadway attribute data consists of three categories: static, predictive and dynamic. Figure 4.1 presents the research framework of the present study.

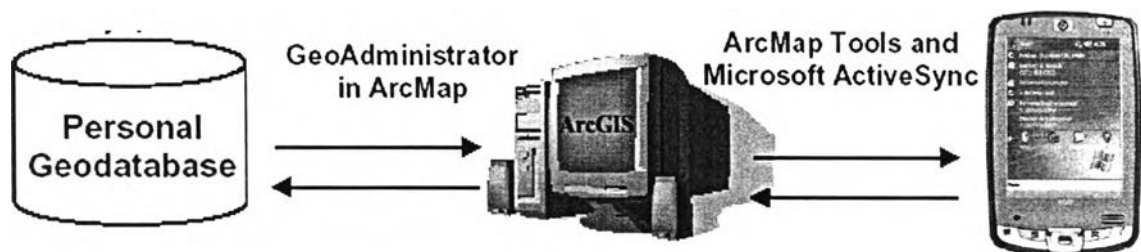


Figure 4.1 Research Framework

As reflected from the research framework above, the system is generally made up of two sub-systems, Personal Digital Assistance (PDA) and Desktop PC. The PDA used in the study employs the ESRI's ArcPad Geographical Information System (GIS) software and Global Position System (GPS) receiver. Road inventory and condition data will be recorded and evaluated by using "editing form" that was created in the ArcPad Application Builder software. All road inventory and condition

data will be attached in road segments, nodes and links, forming into several shape files. The shape files will be transformed back to the desktop via Microsoft ActiveSync. ArcGIS and ArcPad Toolbar are then used to verify street and bridge inventory as well as the condition data into the Geo-database. The condition rating data entry and severity pavement defects will be recorded and evaluated by using editing form created in the ArcPad Application Builder (Arcpad Studio). All of these data entry will be attached in the segments, nodes and links of road network shape files. The mobile inspection system is easy to adapt to the remote field location and allows all of the inspection data collected in the remote field location to be exported to a Microsoft Access Database.

4.2 Data Collection Method

As mentioned in the previous chapter, this study applies handheld mobile inspection (iPAQ PDA) and Arcpad application with GPS receiver to collect and record the inventory attributes data in the remote field location. This section describes linear location referencing system data collection method that will be used for supporting essential of handheld mobile inspection for data collection in the remote field.

4.2.1 Linear Location Referencing System

The fundamental objective of linear location referencing method is to identify a location on the road, provide a means for designating and recording the geographic position of specific location on a roadway and for using designation as a key to stored roadway inventory and condition on the specific segment locations. The location referencing method is used in the field to ensure that proper address is used to describe a location and that the location can be found using its address. The reference needs to be well documented and designed to accommodate all situations. In general, all location referencing methods have the following components:

- Identification of a known point (e.g. kilometer post);
- Direction (e.g. increasing or decreasing); and
- Distance measurement (i.e. a displacement or offset)

There are two common location referencing methods. The first method gives an address consisting of a distance and direction from a known point, while the second method provides an address consisting of a set of coordinates, commonly by Global Positioning System (GPS) data. It needs to be recognized that one location can have many addresses, as illustrated in Figure 4.2.

Link and node are a special implementation of a generic referencing system. The nodes refer to specific locations on the roads, and the links are unique segments connecting the nodes. Nearly any referencing method can be applied with a link node system.

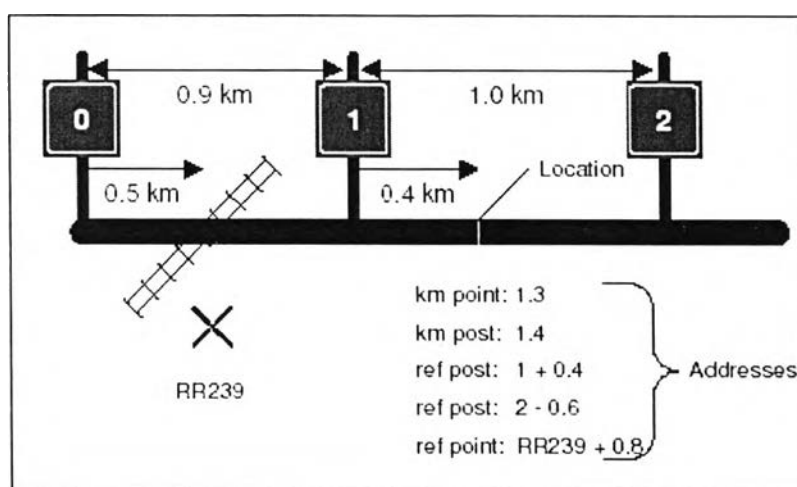


Figure 4.2 Illustration of Various Addresses Applying to the Same Location

Source: Deighton Associates Ltd., April, 2005.

4.2.2 Transportation Linear Feature

Most of data collection technologies use linear referencing for recording data. The data are recorded between a start point and an end point. The addresses are usually expressed relation to the start point and ideally, intermediate points. This

techniques is commonly known as Linear Referencing Method (LRM), which is defined as a “way to identify specific location with respect to a known point.” (National Cooperative Highway Research Program, NCHRP, Report 506). A Location Referencing System (LRS) is “a set of office and field procedures that include a roadway location referencing methods” (Christopher R. B. and Chamorro A. 2005). Roadway can be conveniently modeled as linear features, allowing the application of linear location referencing.

There are three basic approaches to segmentations that will be used in this study:

- Fixed Length Segments: do not change over time.
- Dynamic Segments: represent a road network attributes and analysis segments are created based on pavement defect, shoulder defect, side drain defect, culvert defect, and right of way defects. All of these attributes change from year to year. In this research, dynamic segments will be used to represent roadway condition attributes and record roadway condition defect on the road network.
- Static Segments: are created for representing road network attributes on the segments principles but are treated as static for several years. Since attributes such as surface type, surface width, number of lane, lane width, length, guardrail, etc. in this study will be used static segmentation representation static attributes and also used for record road inventory data on the road network (Bennett, 2004).

This LRM use an offset distance along a roadway from a known beginning point to define the position or segment of interest. Such items include attribute of the road segment and features that exist as part of the road characteristic. Both attributes and features may be of the point or linear type. A point data item is located using a single offset distance, common features include intersection, bridges, signs, and

guardrail. While a linear data item is located using a pair of offset distance (beginning and ending). The basic of collecting road inventory data in street and road network are which the attributes information attached on the segments, node and links. The typical attributes include road functional class, pavement types, shoulder, pavement width, number of lanes, and lane width.

According to the Location Referencing Manual, the road is defined by nodes, links and LRPs (segments). A road runs from one location to another. Each road can be broken into a number of links, starting and ending with a node (villages, intersection etc.). A link will generally have a uniform traffic flow. The length of the link should generally be kept within 30-40 km. On each link is defined a number of Location Referencing Points (LRP). The distance between two LRPs should generally be kept within 4 -5 km. The road section between two LRPs is called segments. Condition data, such as road element and pavement surface condition is collected on survey sections, typically 100 or 200 meter intervals. Survey sections will be given with an offset in reference to a LRP. The RMS will calculate the corresponding chainage (RAMBOLL, October, 2003).

This study applies mobile inspection (PDA) combined with Arcpad application and GPS receiver to collect static and dynamic data on the segment. Streets on the GIS base map will be divided by fixed length segmentation algorithm as a part of the quality assurance process. Segments are created from the data that RMS needs to collect on the road network. All attributes of static and dynamic data types will be attached in segment. The inspection process will help identify any ambiguities in the segmentation methods used in the data collection process.

The attributes of road network consist of three categories: static, predictive, and dynamic. The attributes of road network transportation related data to road geometry, road inventory, road classification and surface condition and maintenance history. Static data will consist of road information that will not change frequently such as road name, road type and classification, number of lanes, lane width, edge of pavement, width, length, etc. Predictive information can be estimated or pre-defined. These information include road construction and maintenance and road closure due to

the special events including seasonal roads surface condition. Dynamic road information changes very rapidly and usually unexpectedly in relatively short period of time and requires constant update such as surface condition, weather condition and accessibility. All of these data come from wide varieties of source.

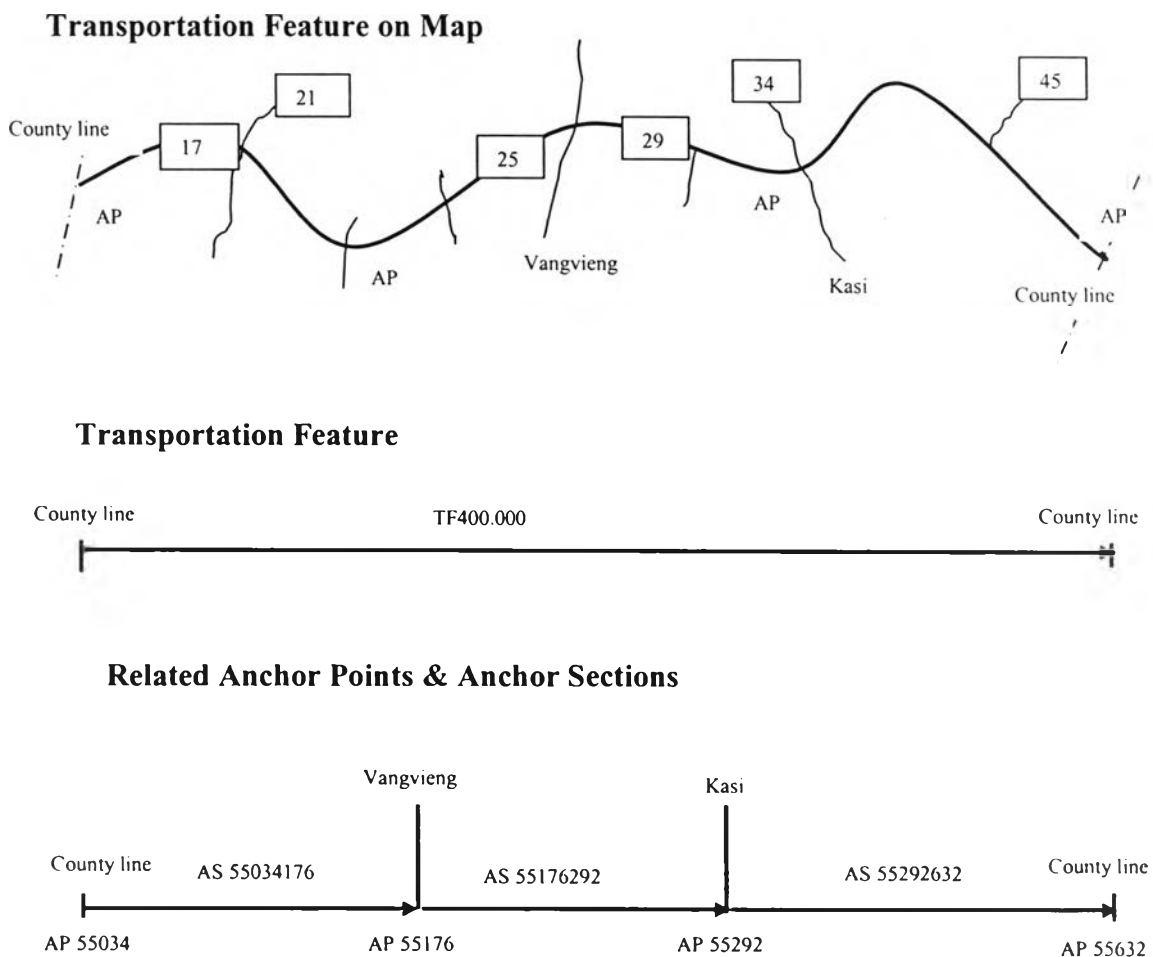


Figure 4.3 Transportation Feature (Roadway) with the Proposed Geographic and Geodetic Objects

4.3 Field Data Capture

Initial work of establishing centerline fixed length segmentation from base map GIS was carried out on desktop computer using ArcView GIS. The vector map was later converted to ArcPad support format by exporting as an ArcView shape file. The line shape file and orthophoto are used as the base maps. Several screen shot images were created and converted to GeoPEG file format. To maximize on the limited memory of the pocket PC, only the images for the roadway to be mapped were copied to the mobile inspection device.

The solution involving ArcPad consists of three main components:

- 1) A mapping component
- 2) An information component
- 3) A storage and exchange component

The mapping component involves all GIS data installed on the handheld and the customized standard mapping functionality of Arcpad for collecting point and linear of road information. As the shape of the roadway inventory fields can be determined in most cases with GIS digital base map and ArcPad application to create form for capture roadway inventory data, the mapping requirements of the application are very simple. The inspector has to be able to put a point feature on the map falling within the street of roadway inventory field. Inventory attributes information can be linked via an entry form, comments, date and time, code of picture taken, etc.

The entry form that pops up if a point is placed on the map is created with Application Builder (ArcPad Studio). All requirements have been fulfilled using the standard functionality and customization possibilities of ArcPad and ArcPad Application Builder.

4.3.1 ArcPad Data Model

Base on the structure of database shown in Figure 4.5, point and linear feature layers were created with attribute fields using ArcPad on the desktop as new map layers on the geo-referenced vector and orthophoto layers. When the new shape file is created, ArcPad automatically generates a new layer definition file with the same name as the shape file but with extension .apl. The .apl is the ArcPad form format. Each of road and bridge inventory .apl files is related to their corresponding shape files. Data collection forms were created for the four layers using Edit form function in the ArcPad Application Builder.

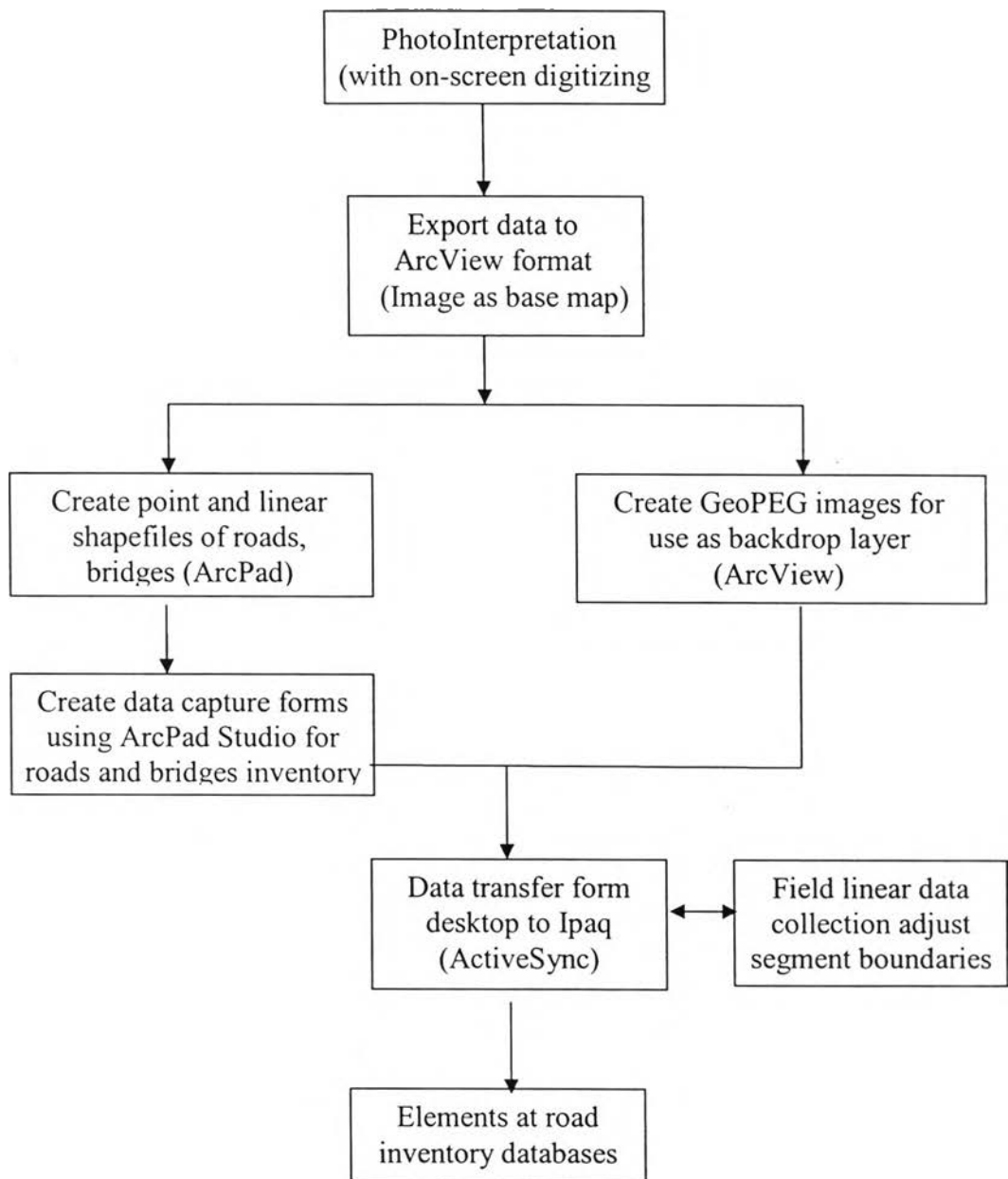


Figure 4.5 Elements at Roadway Inventory Field Digital Mapping Methodology

Source: Jacob Kanwaria Njagih, March, 2003

4.3.2 Edited Digital Linear Maps

Mapping of elements at roadway inventory in the remote field location was done along the streets where the roadway boundaries were checked from across the streets. Boundary vector lines created from interpretations in the office were

confirmed in the field. The roadway linear layer was overlain on the backdrop image and the boundaries check from the ground if they match the map. In order to edit a feature in the field, the layer to be edited was made active by tapping on the layer's edit box. Various techniques applied to line editing using ArcPad mobile GIS, using the identified tool, the fixed length segment of the street centerline to be edited was selected and highlighted by a box round it. Then, selecting the feature properties and the page form of road inventory will appear and data can be directly input or edited.

However, this technique of linear editing was found to be generally taking a lot of time since one has to keep changing the editable layer between the linear and point shape files. Each time a feature is deleted in a layer; ArcPad performs what is called packing shape file that could take a few minutes with the size of the shape file.

4.3.3 Point and Linear Data Capture

Observations made on physical attributes of roadway in the field were stored to the forms created in office using Pocket PC. First the roadway inventory layer is made active for editing by checking the edit box on the layers dialogue box. Then the segment editor is selected in order to open a blank data entry form by tapping at a segment street centerline within the boundaries of each polyline (Figure 4.6). Though the system automatically assigns an identifier for each segment, the street id identifiers have been declared as required fields when the forms were being customized and this make sure that fields were entered first before navigating to the other pages. The roadway identifier has the zone as well as the segment id as prefix, thus defining the location.

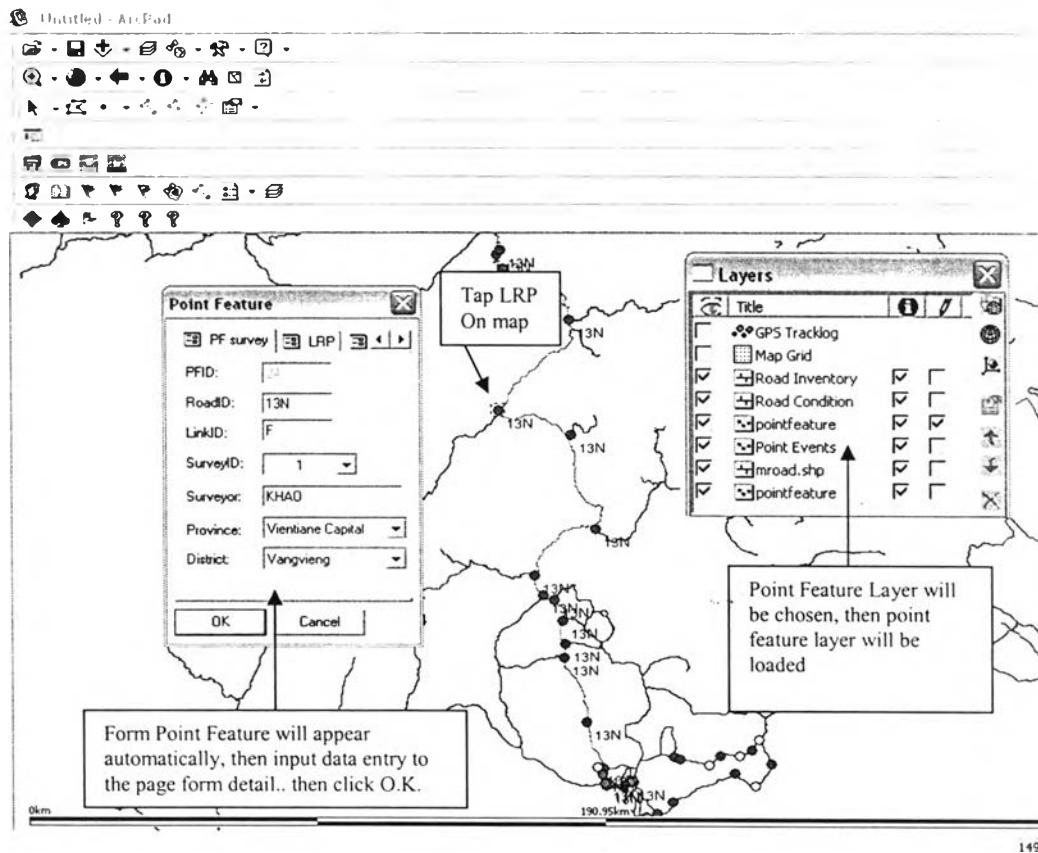


Figure 4.6 Location Referencing Point Setup Techniques

Attributes were then keyed in by typing on soft touch keyboard or by making selection from lookup tables defined in the office. A reconnaissance survey was done on the first day of the fieldwork to assess the general characteristics of the roadway so as to modify the lookup tables at the field camp. The lookup tables reduce data entry time instead of having to type each time and equally helps in observing the usage of description terminology by limiting the inputs of a certain field to the defined classes. Observations were made from the same side of the street and in case where it was not clear, attributes were confirmed across the street.

The road and bridge inventory system in forms regular rectangular patterns with condition defect for each section of road, a point was entered and an identifier was assigned to the custom form and the attributes filled accordingly. The locations of

bridge were identified on the base map and information recorded on bridge inventory and condition layer using the data collection forms displayed in Figure 4.9.

Property	Value
ID	123 0
ROADID	abc 13N
LINKID	abc DA
SURVEYID	123 1
SURVEYOR	abc KHAO
DISTRICT	abc 3
LINK1	abc 0+0000
LINK2	abc 4+843
PFDATE	20040107
PFLRP	123 1

Figure 4.7 Location Referencing Point Inventory Form

Activating point layer for Editing from layer dialogue box and selecting point Editor in order to tap on a new location and open data entry form. Double click select feature and click on the segment that street centerline and the page form for data entry will appear. The Street Name and Road Class and populated with data as this information is developed from the GIS centerline shape file. Use drop down menu to add data. Use the drop down menu to add data for reducing time delay and typical input errors.

Data automatically recorded

- Map coordinates of point feature (x,y)
- GPS of inspection remote field location (x,y,z)
- GPS data quality parameters (number of visible satellites, hdop)
- Date and time of point recording (if the session was started)

Data entry by inspector

- Point feature ID to be identifier
- Name of road to be classified “Roadname”
- Link ID of road to be identifier
- Surveyor ID

- Province and District
- Code and file location of picture taken with digital camera

A critical component of any digital data collection method is reliable data storage. To prevent data lost by lack of battery power or technical malfunction, the application saves the collected data on removable memory card instead of saving it in the internal memory of the handheld. As an extra safety measure the inspector has the option to copy and save the data into the laptop or PC after data collected each time.

4.4 Inputting Data Using ArcPad Application

4.4.1 Configuring ArcPad of Road Inventory Entities Application

A shape file and attributes of the road inventories entities used in this study are consistent with the existing data at the Ministry of Communication Transportation Post and Construction (MCTPC). Road inventory entities include geometric characteristics, pavement condition, road elements condition, bridge condition, and history of roadway.

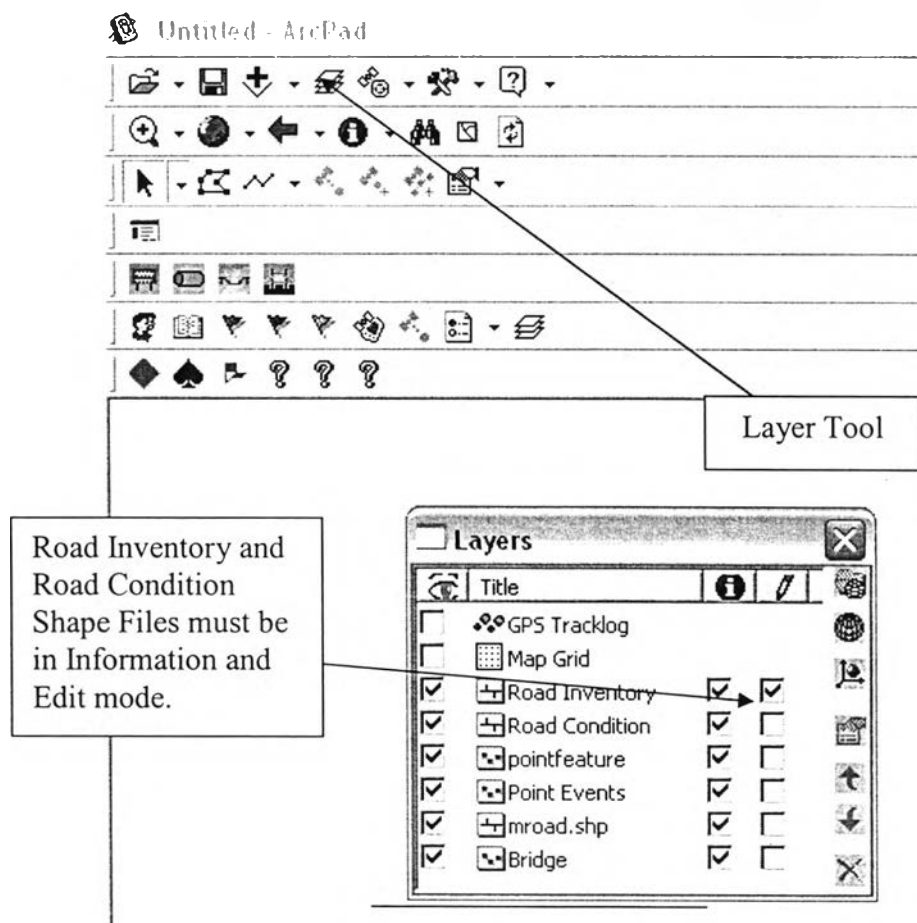


Figure 4.8 Road and Bridge Elements Shape Files

The data specification has further requirement that the standalone .dbf tables be created for location referencing point (road ID, segment ID, LRP ID, etc.), road inventory (surface type, number of lane, shoulder type, sign, etc.), and road condition (pavement defect, shoulder defect, side drain defect, etc.). These dbf tables were created in ArcCatalogue using attributes and formatting as prescribed by the data specification.

4.4.2 Collecting Road Inventory Entities Data

The ArcPad road inventory entities application is automatically activated when the associated shapefile is loaded in ArcPad. Additional data layers can be displayed for reference when using the application. The page form for data entry will

appear when selecting the feature by tapping a segment or location on the screen or activate the GPS polyline button in ArcPad. The application displays the page form for attribute entry. All entities could be stored in the shape files for entities type.

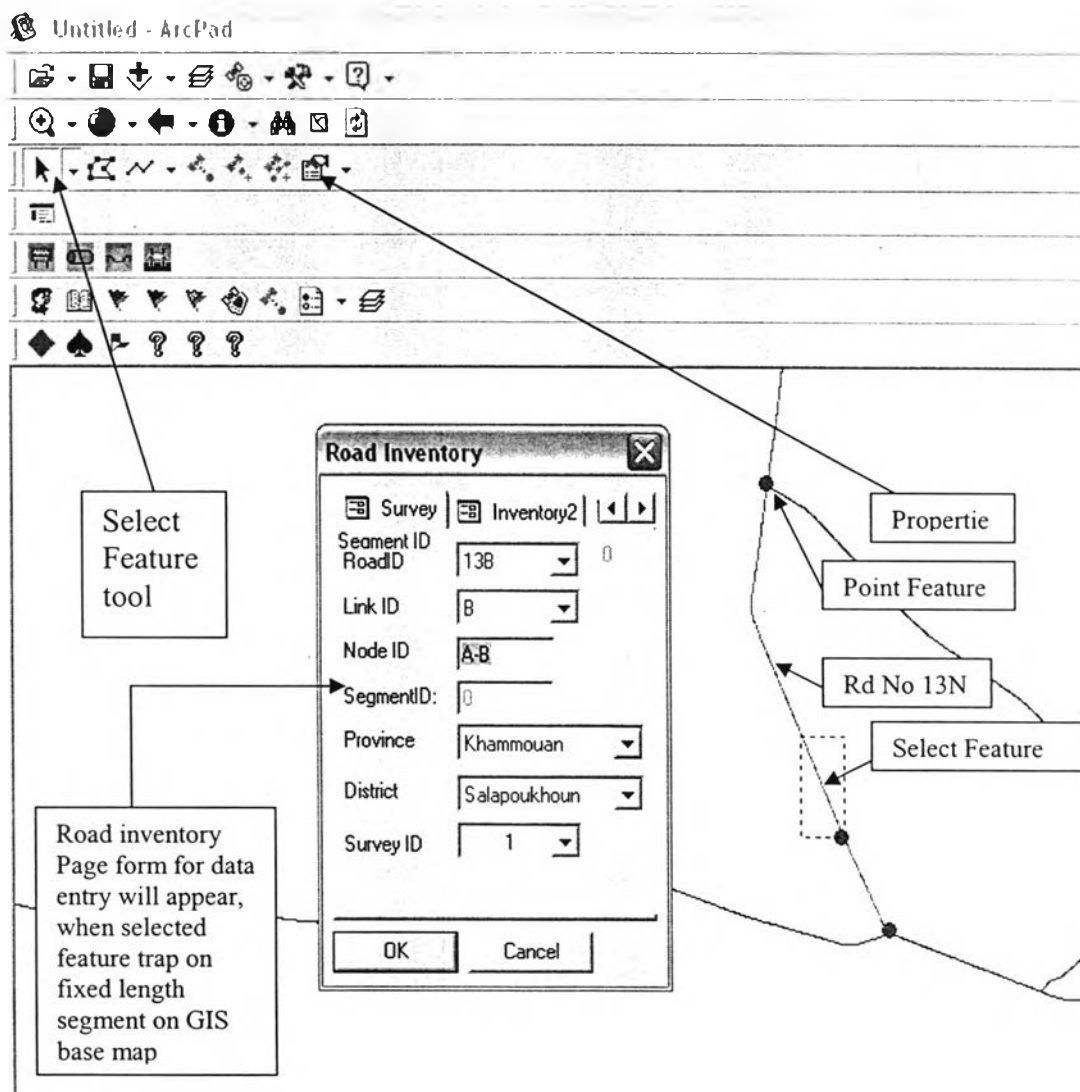


Figure 4.9 Road Inventory Edit Form and Page Details

4.4.3 Creating Custom Forms for Road and Bridge Inventory Mapping

Form for field data collection are customized using the same procedure for elements of road and bridge inventory mapping as discussed in Section 3.4.2. For the entire road and bridge inventory observation table, the first page gives the field for the

identified road information. It also gives fields for locating and identifying road and bridge inventory. In other pages, characteristics of the road and bridge inventory are described. The dropdown menu and checkboxes are designed, outlining the possible causes of field type of road and bridge inventory. For road and bridge condition, causes, damage observed, and any stabilization measures are reported.

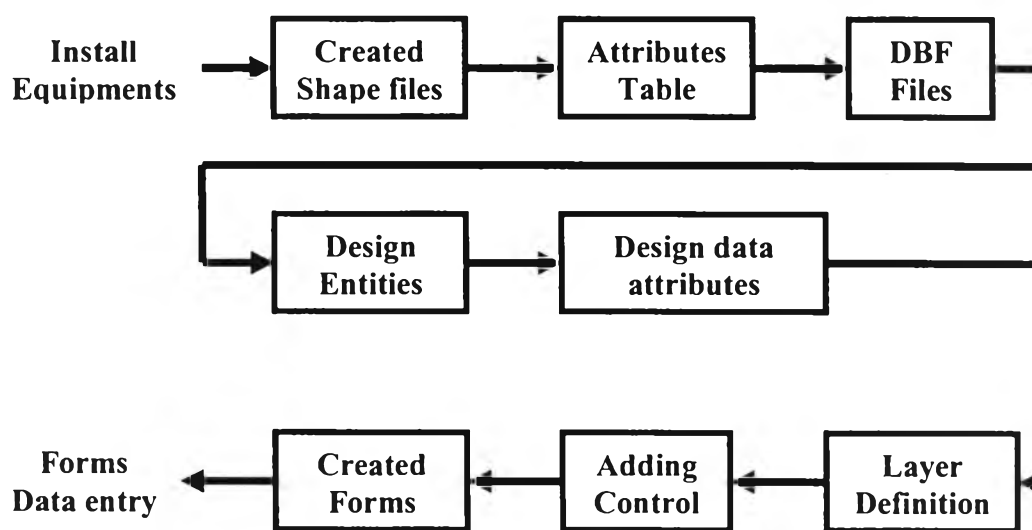


Figure 4.10 Block Diagram for Creating Form Data Entry

4.4.4 Roads and Bridges

Road information was collected as linear and point data, where road sections were mapped with their attributes data recorded. The roadway inventory consists of mapping of roads system, covering details such as geographic location, construction materials, and the class and the length, as well the width of each road segment (Federal Emergency Management Agency, 1999). Location and type of bridges are also important in bridge inventory. Other attributes are width of the bridges, length, and riverbed Figure 4.14 presents the look up table for road and bridge inventory and condition. Figures 4.11 to 4.14 illustrate examples of several forms used in the present study.

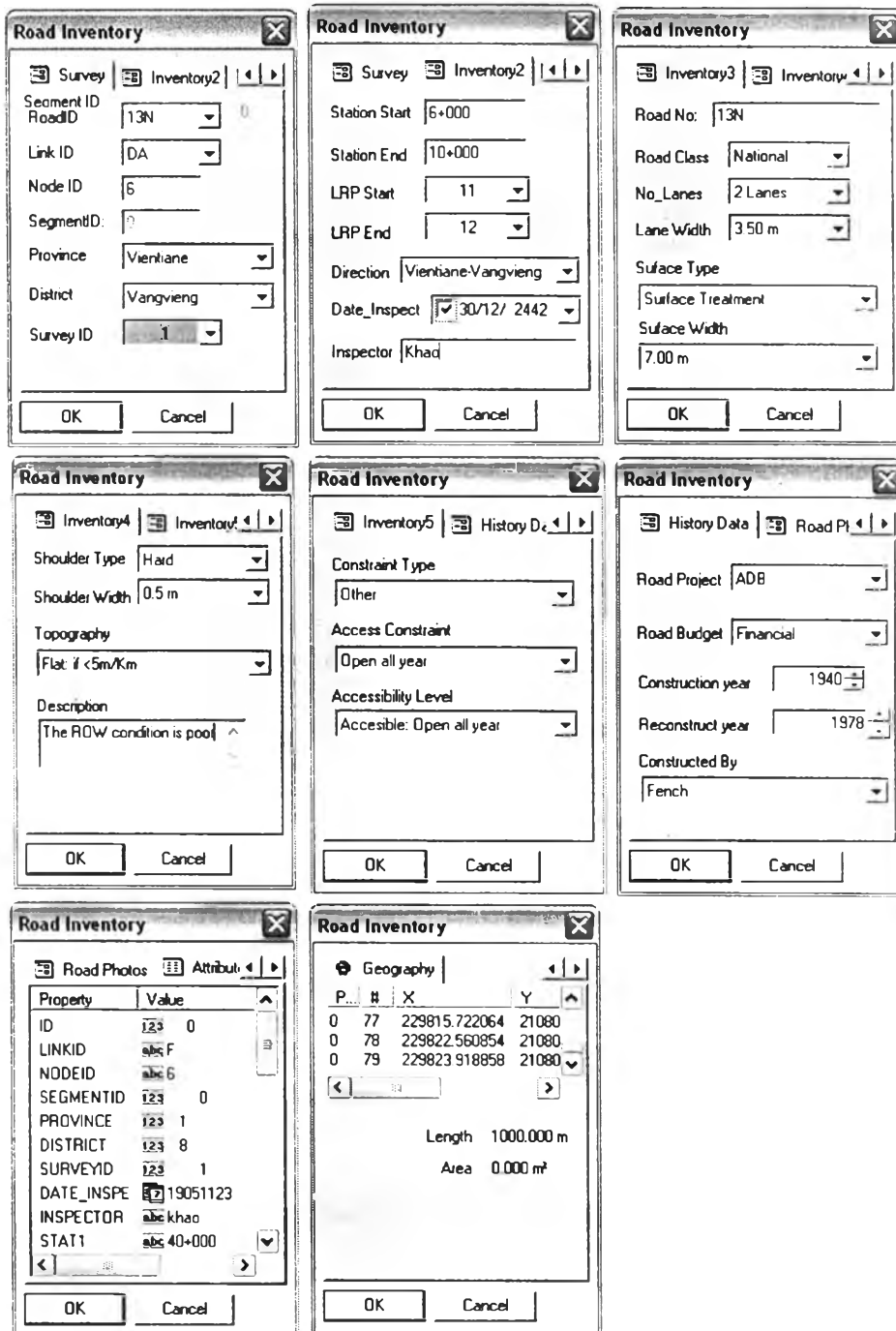


Figure 4.11 Road Inventory Forms

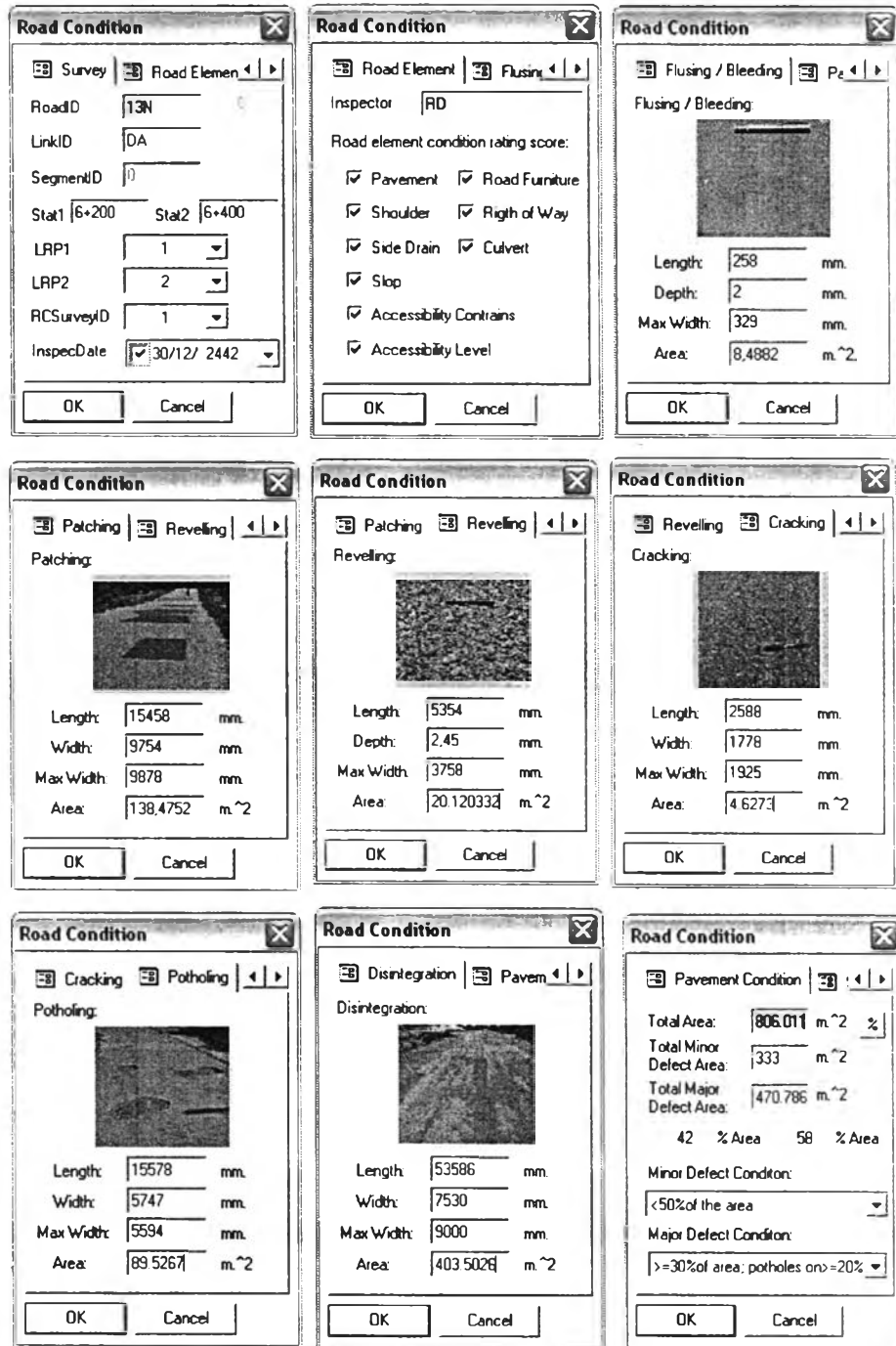


Figure 4.12 Pavement Condition Data Entry Forms

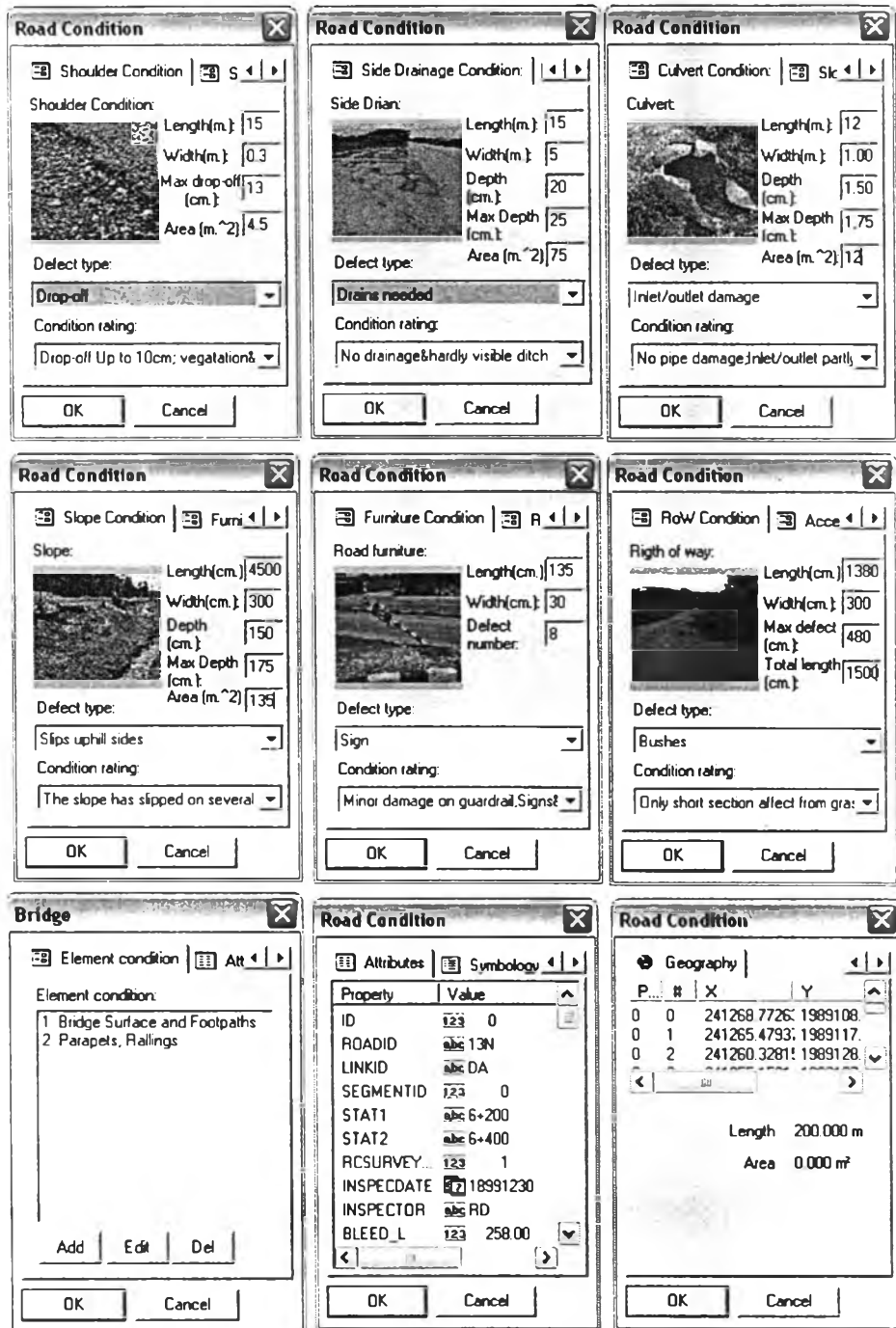


Figure 4.13 Road Element Condition Data Entry Forms

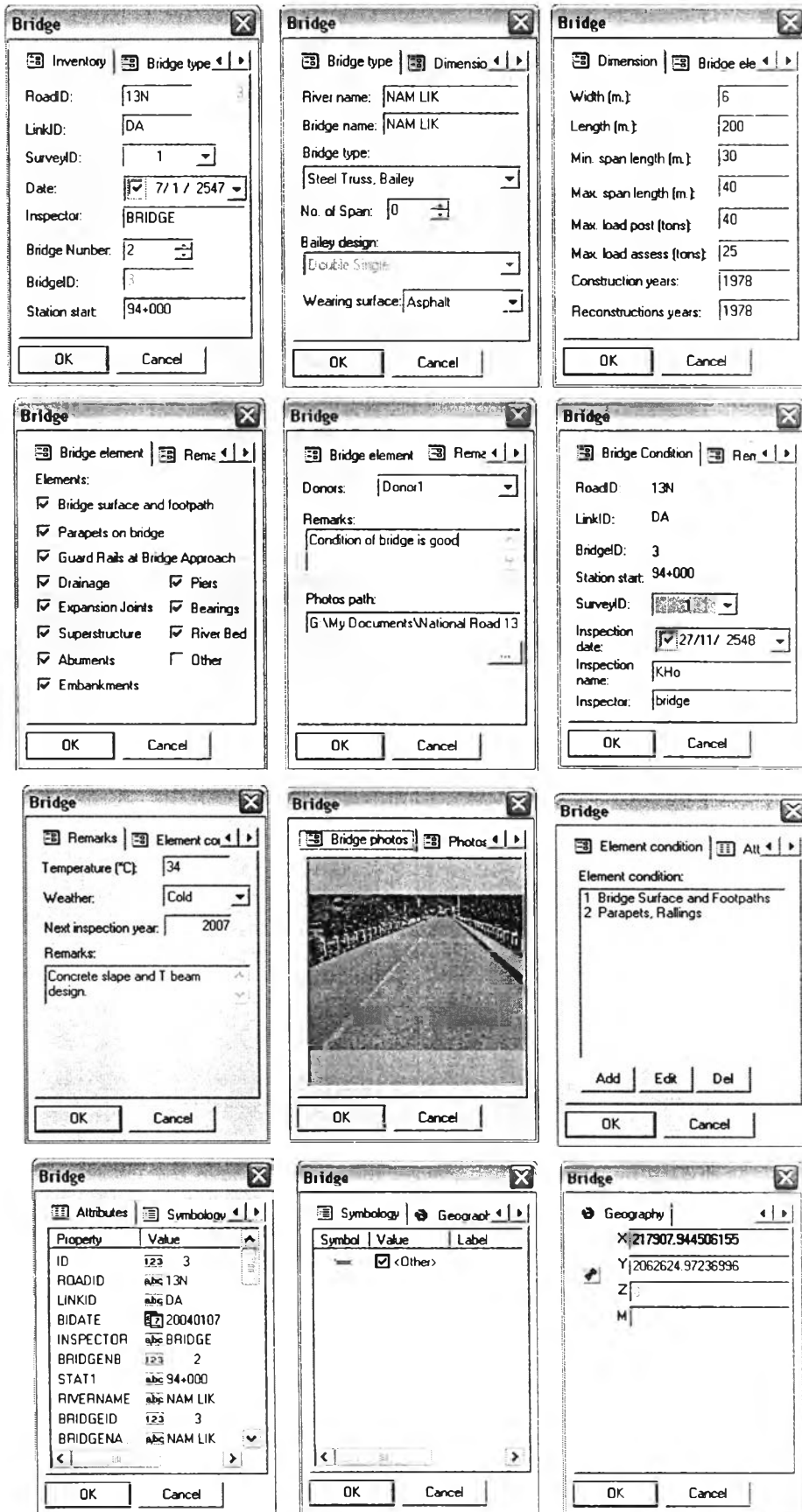


Figure 4.14 Bridge Inventory and Condition Forms

<p>Road inventory</p> <p>RoadID LinkID NodeID SegementID District Province Direction Sta1 Sta2 LRP1 LRP2 SurveyID Surveyor DateInspection RoadClass SurfaceType SurfaceWidth ShoulderType ShoulderWidth NoLane LaneWidth Topology LastInspection InspectionYear</p>	<p>Road Condition</p> <p>RoadID LinkID SegementID Stat1 Stat2 LRP1 LRP2 RCSurvey InspectionDate Inspector RoadElements PavementDefect BleedArea BleedCR PatchArea PatchCR RevelArea RevelCR CrackArea CrackCR PothArea PothCR DisArea DisCR TotalArea MinorArea MajorArea P_MNArea P_MJArea MNCR MJCR SHDefectType SHDefect Area SHDefect CR SDDefectType SDDefect Area SDDefect T_CR CVDefectType CVDefect Area CVDefectCR SLDefectType SLDefectArea SLDefectCR RFDefectType RFDefectArea RFDefectCR ROWdefectType ROWdefectArea ROWDefectCR</p>	<p>Location Referencing Point</p> <p>Point featureID RoadID LinkID SurveyID Surveyor Province District Date Link Start Link End PF offset PF types Photos PF attribute Symbology Geography</p>	<p>Bridge Inventory</p> <p>RoadID LinkID BIDate Stat1 Stat2 RiverName BridgeID BridgeName BridgeType NoSpan Bailey Wearing YRCostruct YRReconstruct Donors Remark</p>
		<p>Bridge Condition</p> <p>BridgeSU Parapet Guardrail Drainage ExpanJoint SuperSTRS Abument Piers Bearing Embankment Riverbed BridgeGen Width Length Maxspan Minspan MaxloadPost Maxload Ass Photo InspectName Temper Weather Inspector BCRemark BISurveyID RCSurvey</p>	<p>Accessibility Level</p> <p>Accessible Good Fair Poor Bad Inadequate</p>

Figure 4.15 Look up Table for Road and Bridge Inventory and Condition

4.5 Collecting Data in Field

When arrived in field, the inspector starts a session by starting ArcPad, GPS receiver, and loading the prepare ArcPad application and activating the appropriate icon from the mobile inspection (PDA) of the inventory project data. After activating GPS in ArcPad and zooming in to the route segment, inspector is ready to start adding points feature to the GIS mapping. The inspector needs first to identify the roadway point feature, using the point feature entry form on the handheld. From the shape file definition layers, the inventory shape file layer will be loaded. The forms for recording inventory data entry will appear and the tap button on the page can be used to drag and fill detail on each page form. During the data input, the inspector should stand preferably on the middle roadway segment.

By placing the point on the map, the entry form is brought up and a point feature needs to be selected from the quick list or by pressing other from the complete point feature list. All other data such as time, date, project code, x,y coordinates, etc. are automatically stored in the attributes table of the collection point.

The whole process of identifier roadway point features, center line segment fixed length and mapping them is repeated until the fieldwork data collecting is finished. Roadway inventory data and pictures from the mobile handheld inspection will be downloaded and transferred to the central database, where the data of different segment will be integrated in a consistent way and linked to the polyline map with roadway inventory boundaries. The resulting map will be used in the future procedure, including classification and validation of the roadway inventory in Lao PDR.

4.6 Processing Data

Microsoft Access Database is used in this research to implement Road Inventory Database, which contains tables used to process the data collected from the remote field location as well as to generate the data to be uploaded into the mobile

handheld inspection (PDA) at the start of the inspection. The benefits associated in developing a roadway inventory database are:

- Up-to-date, accessible data for decision making purposes
- Standard format for exchange of information
- Virtual elimination of duplicate data
- Centralize access to important data
- Centralize modifications and updates capabilities
- Improve data accuracy

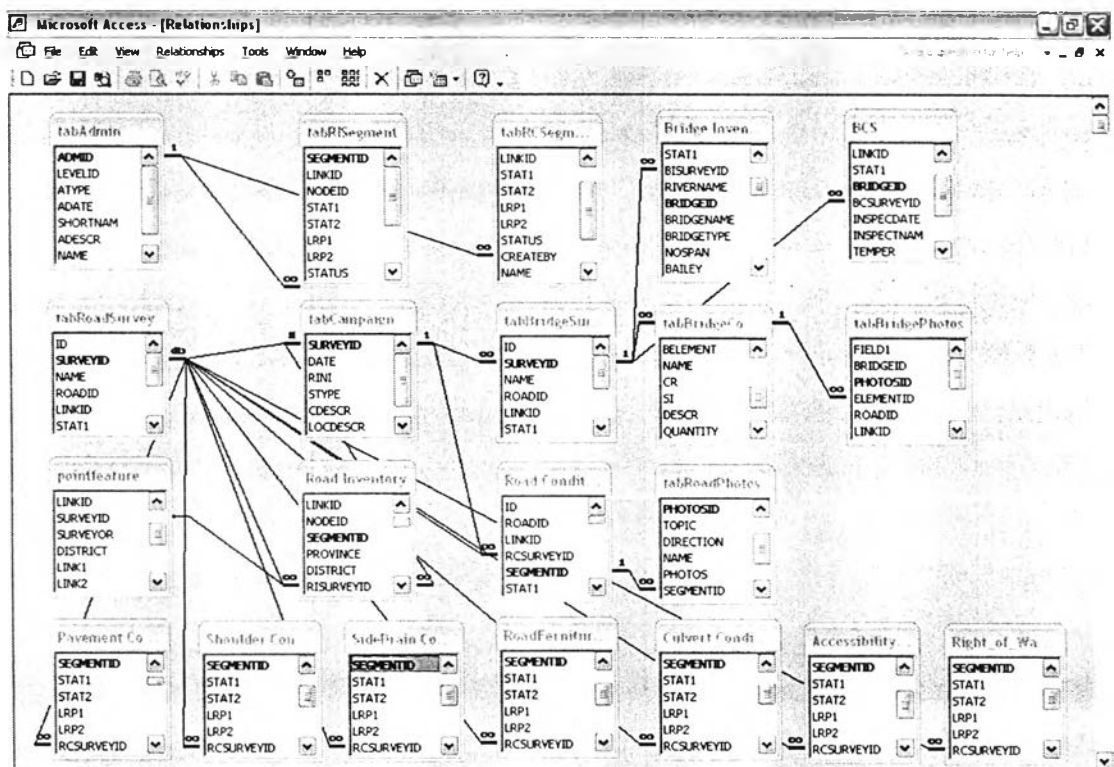


Figure 4.16 Road Inventory Processing Data

The importance of the key identifiers are to link together information derived from individual entities and it should be considered with existing database of MCTPC as a standard identifier for future data updates. The key Identifiers provide user ability to created relationship among multiple tables both within and outside the database.

The key identifier established in the figure above are used the relationship between the point feature class and the line feature class to exist as well. The point feature class contains the GPS coordinates representing the beginning point and end point of the segmentation, hyperlink to digital pictures for the road inventory segment unique identifier. Therefore, if the user clicks on a line feature representing a form for data entry, they can easily identify the unique identifier assigned to that segmentation as well any digital photos associated with the centerline segment. One of the limitations with relating the line features to the point features is where a begin or end point.

4.6.1. Required Data

As mention in the previous chapter, this research study consist of three types data such as: road inventory is represent the static and physical road data (street name, length, surface type, shoulder width, number of lane, width and guardrail) road condition is consist of dynamic and predictive data (The defect of pavement, shoulder, side drain, culvert, slope, and right-of-way) has already been collected by using mobile handheld inspection and GPS receiver. All of data are useful for the RMS priority criteria that particular treatment option for planning and budget tool used to select candidate streets and assign cost base on road condition defect.

4.6.2. Uploading Data

Using the street information table populate in the road inventory inspection table by using an append query. Query the data base on the re-inspection field; data matching the inspection previous years can be appended to the blank road inventory inspection table template in the present year. Once the table is created export it to dbf file and link it to the shape file that will be uploaded to the handheld mobile inspection. This will copy the streets slated for inspection (Re-inspection field) and copy just those streets to a file that can be used by handheld mobile inspection (PDA).

4.6.3. Updating Inspection Data

Once the inspection is completed, download the dbf file containing the inspection data from the handheld mobile inspection (PDA). This process can be used to import the data to the Microsoft Access Database (Road inventory database), and this process also provides to create a query between the download table and road inventory inspection, link on street identified number. In addition, tag linked records in road inventory inspection. This has been updated field as true, append records from downloaded file to road inventory inspection. This will document the previous inspections as being updated, then the new data is added to the table. Instead of deleting the old inspections, the data is tagged as update so history can be developed for the road inventory performance.