NEW TECHNOLOGY IN ROAD MANAGEMENT IN THE PHILIPPINES: THE GPS AND VIDEO IN THE CENTERLINE SURVEY

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Abstract: It has long been recognized that spatial data and Geographic Information System (GIS) have an important role to play in effective road management. However, the challenge for many developing countries like the Philippines lies in obtaining the basic information and data required as the foundation of the GIS. The Locational Referencing System (LRS) under the Road Information and Management Support System (RIMSS) Project of the Department of Public Works and Highways (DPWH) addressed this problem by undertaking a nationwide centerline survey of the entire 28,000 km. national road network using a comprehensive Global Positioning System (GPS) and video survey. In addition, the foundation was laid for future updates to ensure the sustainability of the system. This paper describes the technology developed for the project and how it was used in the surveys. This paper will also attempt to share the DPWHs experience and lessons learned from the initial survey and the methods utilized to ensure its sustainability. We hope this paper will be very useful to other countries which will be doing similar surveys for the first time in the future.

1. INTRODUCTION

1.1 Background

The existing methods of. locational referencing used by the DPWH are not suitable for comprehensive computerization of highway information. Many discrepancies can be noted as to the exact position of the same feature as recorded by the different offices in the DPWH. This is because independent survey activities had been carried out by different offices within the DPWH with little attempt at coordination. This led to extensive collection and duplication of the same data for different purposes. To solve this problem, the Locational Referencing System (LRS) was used as the primary method to relate various types of road data.

Before the actual LRS centerline survey started, a series of workshops was conducted by the DPWH Central Office/RIMSS for the regional/district level engineers on how to properly identify "nodes" at road intersections, administrative boundaries and "section" which is the length of the road measured along the centerline between nodes.

The DPWH under the RIMSS project conducted a nationwide Locational Referencing System centerline survey for the 28,000 km. along national road network from December 1999 to June 2000. It used a comprehensive Global Positioning System (GPS) and video for collection of the data. The centerline survey was undertaken to establish an accurate location for the identified nodes and sections. The data collected will be used from now on to establish the exact length of the national road network. These data will serve as the backbone for development of the DPWH's GIS and related applications.

DPWH has begun the establishment of an enterprise-wide Geographic Information System with the completion of LRS. It will serve as the backbone of the data for this GIS. It will enable implementation of embedded GIS, where the GIS and traditional databases combine to produce truly integrated applications. The same spatial representation of the road network will be used by all applications and will be used to manage various data on roads and bridge infrastructure, including condition, inventory, traffic, right-of-way and locations.

2. PURPOSE OF LOCATIONAL REFERENCING SYSTEM

The Locational Referencing System is defined as anything associated with the road network through the use of *"nodes"* and *"sections"*. Nodes are defined as points in the road network. Typically these are intersections and administrative boundaries. Sections represent the road's centerline between two nodes. A section's limits and location are defined by the nodes that represent the end of the sections.

The primary purpose of the Locational Referencing System (LRS) is to accurately define and identify the National Road Network of the Philippines. This can be accomplished by establishing and implementing a standard link and node system that will be utilized to store in a computer system all linear data related to road centerlines. The linear data to be stored will include spatial data, inventory of roadway feature and roadway characteristics.

2.1 Purpose of Centerline Survey Data Collection

It has been the practice in various offices within DPWH to maintain separate data related to the National Road Network. This presents a problem in that the data stored by each office do not match. Therefore, if the question, "How long is the national road network?" is asked the answer will depend entirely on which office the question is addressed to. That is, the Planning Service and the Bureau of Maintenance will give two different answers. Without a common definition and understanding of the actual network, decisions made based on this information cannot be reliable. The DPWH has long recognized that accurate and reliable information on the national road network is essential in its efforts to improve and strengthen is business processes and decision making.

The GPS centerline survey data collected will address the spatial data referencing needs for DPWH. These will be used as a foundation for referencing all data collected and for displaying road data in the GIS format. This will enhance the Department's ability to display data in an easily understood format and facilitate the interpretation of these data. The GPS centerline survey data will also be used to support and strengthen planning and decision support purposes.

Provide positioning data to define all road sections for the national road network which includes the arterial and secondary national roads. The survey will also establish the position of Locational Referencing Points. These points are generally the existing kilometer posts along the road. The survey can also collect video data of the road network and roughness data of the paved roads.

The video data collected will facilitate the verification of existing data such as surface type and assist in the gathering of future data by the Central Office and regional Office staff for visually seeing the features on or along a roadway. The video data can also provide a historical record and visual features which can be used at a later date if needed.

While the collection of the initial data is very important, it is only the first step. The data must be updated so it is current and accurate. The frequency for the updating of the data is determined based on the type of data and the regularity with which the data may change. For example, the centerline survey data only needs to be updated when new road is added to the network or an existing road alignment is revised. On the other hand, the roughness data for a road needs to be updated on a more regular basis. The actual procedures and frequency for the updating of the data are currently being developed as a component of a project funded by the World Bank loan. As part of this contract, the consultant will develop detailed procedures for the collection and storage of these data.

3. METHOD OF THE CONDUCT OF CENTERLINE SURVEY

Because of the limited time allotted to complete their work, six (6) survey teams were fielded to conduct the survey. Each of the six survey teams was composed of a local driver, a trained and experienced operator and a DPWH regional representative. The DPWH Regional representative also assisted in logging key data. To maintain regular contact with the Manila office each survey vehicle was provided with a mobile telephone.

Additional team was formed to conduct surveys on islands not accessible by the survey vehicle. The team consisted of a single trained and experienced operator. The equipment used by the team consisted of a portable GPS unit, hand held digital video camera and a digital camera. The survey was conducted using other local means of transportation such as motorcycle, tractor or by walking along the road. Since no Bump Integrator was used, the roughness data of the paved road was collected by visual assessment of the road.

a. Logging of Nodes and Sections

The positions of the nodes provided by the RIMSS office (i.e., intersections, borders and junctions) were recorded. In defining the road log during the survey, the node definitions were utilized. When ever necessary each node and section was verified and corrected using this method. The coordinates of all node points were collected and reported on the log-sheets which were later verified at the Central Office.

b. Centerline GPS Survey

In all the 28,000 kilometers of national roads, the centerline co-ordinates were recorded using the Trimble Pro-XRS GPS units which have been set-up to store the surveyed coordinates at second intervals. The systems have been set-up to automatically correct the GPS readings for two offsets:

1. The vehicle offset from the Centerline;
2. The GPS antenna height above the road surface.

The GPS signal was then stored in a laptop computer in the vehicle using the ROMDAS software. The software also recorded the PDOP (data) which is a required deliverable.

The survey team conducted the centerline survey by driving along the roads aboard the vehicles equipped with GPS units, and Inertial Navigation Units. The data were recorded at the following level of accuracy:

95%+/-2m Horizontal
99%+/-5m Vertical

To achieved their level of accuracy the geo-coordinates of the centerline survey were captured at approximately 10 m. frequency with the maximum distance of 50 m. between data points. This data will allow the accurate mapping of the National Road Network. The video survey will provide a method for individuals not familiar with the road to view the road and in some cases obtain data without going to the field. The roughness survey will provide additional data for the road network that can be used for planning purposes.

The horizontal level of accuracy for the GPS centerline survey is sufficient for storing spatial data related to a roadway and for use in planning or feasibility studies. Its vertical level of accuracy is sufficient to determine the relative profile of a roadway but not for use in most detailed studies, such as a feasibility study.

A TRIMBLE Placer 455 Inertia Navigation Unit (INU) inside the vehicle ensures that the vehicle position is recorded when the GPS loses satellite connection. The INU output is also recorded in the ROMDAS file.

During the GPS survey of the centerline, the vehicle follows the middle of the road with a consistent offset. When the vehicle is forced to overtake vehicles or deviate from the centerline, the beginning and end of the "deviated" section is logged in the ROMDAS file for subsequent correction. (Table 1 shows a sample of the centerline data with latitude, longitude, and elevation data for every point).

Table 1. Sample Centerline Survey Data

RECTYPE	LRP NUMBER	CHAINAGE	LAT 1	LONG 1	ALT 1
1	12083	1.0			0.00
2	To taal	0.0			0.00
3	08/12/99	0.0			0.00
31	Swannie en	131304.0	054155.09		0.00
31	THB972	0.0	5.1AB		0.00
31	1	0.0	N14°05.99988	E120°55.5206	574.28
31	1	7.0	N14°05.97904	E120°55.4760	632.28

c. Defining and Logging Location Referencing Points (LRP's)

During Centerline Surveys it is recommended that location-referencing points be defined , logged and recorded at maximum intervals of 3 kilometers. The LRPs should be noticeable, fixed items and preferably distance markers or bridge abutments. The ROMDAS software must be set up to record the LRP definition, which is logged into the electronic base-file.

A digital photograph at each LRP must be taken and the position logged electronically (both coordinates and distance offset from Node Point). The inscriptions on existing kilometer posts must also be recorded. Table 2 shows a sample of the Location Referencing Point (LRP) data collected.

Table 2 Sample Location Referencing Point (LRP) Data

LRP NUMBER	LRP DISPL	LRP DESC	PHOTO NUM	PHOTO NAME	LATITUDE	LONGITUDE
	36	12083				
	0	To taal				
	131304	08/12/99				
RP 12083	1	Swannie en Wyn en Dok Chris		5.1A8		
0	1	THB972		Sony DSC-550		
1	0	Km 61	43	DSC00043.jpg		
2	987	LRP - km62	44	DSC00044.jpg	N14°05.77146	E120°54.9693
3	2006	LRP - km63	45	DSC00045.jpg	N14°05.37552	E120°54.6119

d. Survey Control Points

In each island, at least one National Survey Control Point was surveyed to tie in the GPS survey. On islands with no control point, a benchmark was established, logged and photographed.

e. Video Survey

A S-VHS camera is mounted on the roof of each vehicle. A video record was taken of the roadway over entire sections. The camera collects one frame of picture approximately every 10 meters of the road.

f. Pavement Roughness

A Bump Integrator mounted on the survey vehicle captures the pavement roughness data, and the raw data is processed into the format for the International Roughness Index (IRI) expressed in m/km. The roughness is recorded in maximum of 100 m. intervals. The roughness measured with a Bump Iintegrator is speed dependent that's why the speed at the time of measurement is also recorded. During the post-processing the speed correction factors will be applied to the measured data. The minimum recommended speed of the vehicle at which reliable data can be recorded is 15 km/h. This speed can be adjusted in the software and can be set higher if deemed necessary.

Where it is impractical to transport the vehicles to remote islands, the IRI will be assessed visually. A scale of 1 to 5 will be allocated to the visually assessed riding quality where a value of 1 is good and a value of 5 is poor. The assessor will be calibrated by accompanying a vehicle equipped with the bump integrator while measuring various road roughness. This method of assessing the riding quality has been used extensively in the past and all the assessors are familiar with the process. Table 3 shows a sample of the roughness data.

Table 3. Sample Roughness Data

CHAINAGE	ROUGH_1	ROUGH_2	SPEED	COMMENT
	16050		0	To taal
	0		1	Swannie en Wyn en Dok Chris
	10		100	THB972
08/12/99	131304		0	DMY1YYRP12083 YY
5-1AB	0		0	12083
0	0	0	0	Survey start LRP
100	885	0	32	End of Interval
200	664	0	42	End of Interval
951	287	0	14	Exclude BI count
987	490	0	0	LRP – km 62
13	0	0	16	Include BI count
100	-53	0	18	End of Interval

3.1 Data Collected as part of the Centerline Survey

- Geo-coordinates of road centerline
- Geo-coordinates for all nodes and locational referencing points
- Video log data
- Roughness data on paved roads
- Surface type

3.2 Data Processing

All packages received from the six (6) survey teams were recorded upon arrival at the Central Office. The contents of the packages were opened, reviewed and logged in the system. Any discrepancy in the data was cleared with the field teams by the supervisor. To reduce risk of data loss, survey data were stripped at regular intervals and a backup CD was kept in the survey vehicle.

The processing of all data was done in Central Office. Data were cleaned and prepared in a format shown in Table 4 as specified by the RIMSS Office.

Table 4. Data Processing Activities

Input	Output	Activities Involved
GPS section string	3D GIS data files	Obtain the survey and base station GPS data Post process the GPS data Re-import the corrected GPS data into ROMDAS Include INU data where satellite loss occurred Import data to Arcview "Straighten out" problem areas "Snap" nodes from different links that should meet Export and prepared in DXF format
Video AVI files on CD	Video AVI files on DVD	Copy AVI file Prepare the AVI-Chainage log file Check and Save
ROMDAS node point Coordinates	Node point coordinate	Extract node point coordinates Format and save
LRP ROMDAS log	LRP Chainages	Extract LRP detail from ROMDAS file Format and save
Node sketch forms	Scanned node sketches on CD	Sort sketches Scan changed diagrams Format, save to CD
LRP photographs	LRP photographs	Photograph referenced to scanned diagram Save on CD

4. INTEGRATING THE LRS SURVEY DATA IN GEOGRAPHIC INFORMATION SYSTEM (GIS)

The data set obtained from the above survey is very large. It includes approximately 9,000 road sections, 8,000 nodes, 20,000 digital photographs, and 3,000 video files, as well as numerous database files. GIS provided the best mechanism for integrating all of the above data into a single environment and to enable spatial querying and analysis of that data. The Department used a stand-alone GIS to manage and verify the survey data. This data is to be made available to many applications through a department-wide GIS. Please see Figure 1.

5. LESSON LEARNED FROM THE CONDUCT OF CENTERLINE SURVEY

The centerline survey we conducted encountered a number of problems. One of them is the geographical composition of our country which is composed of many islands. The lack of ferry services in some of the islands to transport vehicles needed in the centerline survey is one of them. Not only was it necessary to collect the data on 42 different islands, but the specifications of the survey were such that accurate data was required on all roads, even in the remotest area. It was also necessary to precisely establish the geo-coordinates of kilometer posts and to take digital

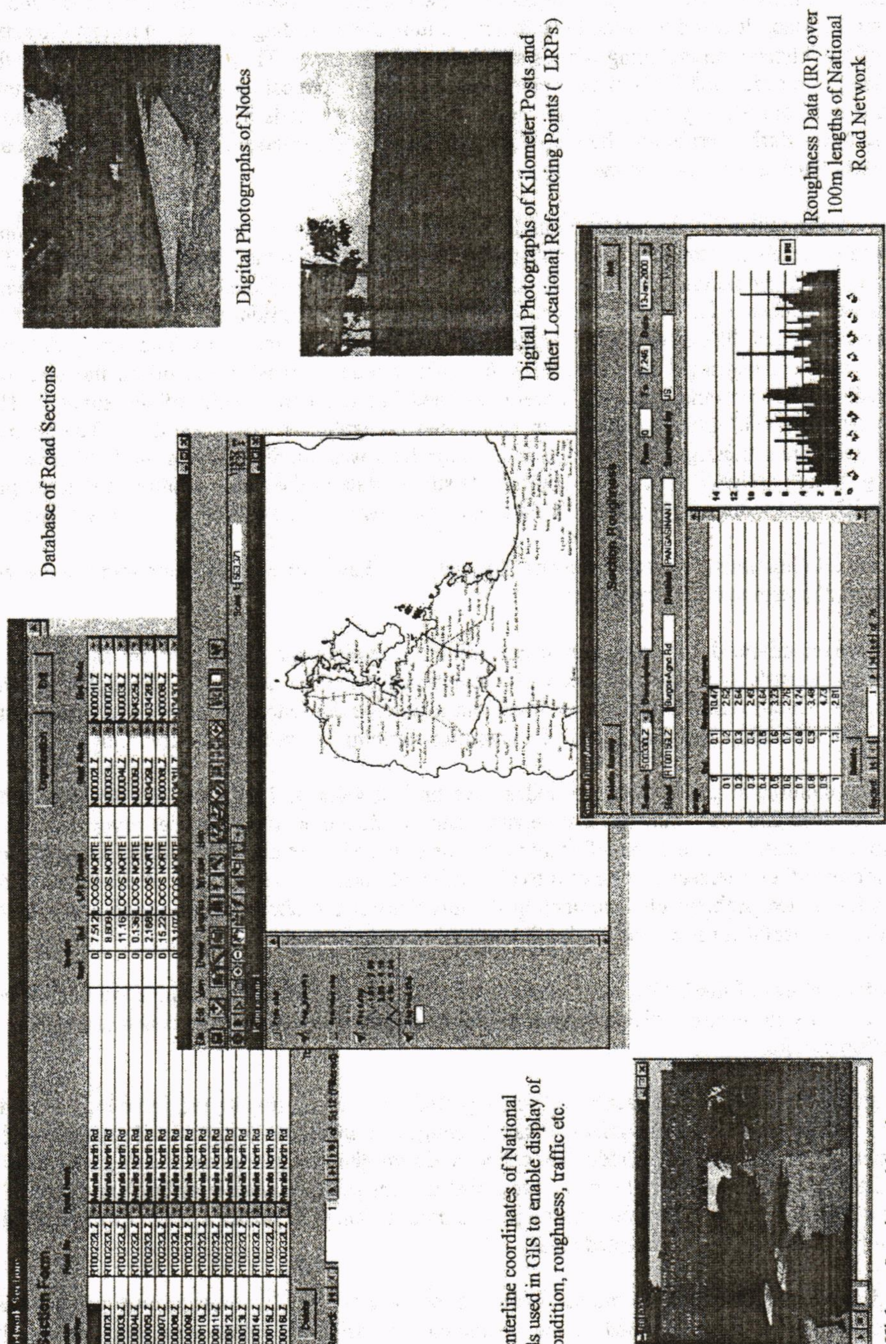


Figure 1. Integrating the LRS Survey Data

photographs of them. Also, due to funding constraint, the survey was calendared for completion in less than 7 months.

The preparation of the node diagrams proved to be time-consuming. Field staff were instructed that these diagram must contain sufficient detail to allow the proper identification of the node and its location on a road. It was determined that at a minimum, the node diagram should reflect the actual layout of the intersection including islands and dedicated turn lanes. They must show the nodes that immediately precedes and follows the node being depicted. In most cases the use of road names alone did not help identify the particular node because some roads have many different names. This was particularly a problem when the node was placed at the intersection of a national road and a local road (such as city, provisional, etc.).

The pre-assignment of node and section ID's created problems in the processing of the data. Considerable time was spent comparing the node and section ID's to the pre-assigned database ID's to ensure the survey data matched the LRS database data. A more efficient method was used when the data was collected for Manila. Because of the tight time constraint for the collection of the field data in Manila, the surveyor did not attempt to use the pre-assigned ID's. The survey data was based on routes determined on the spot by the survey team. Back in the office the data was processed and Section and Node ID's were assigned based on the results of the survey. This process proved much easier for the survey teams and the staff processing the data. The primary problem with the pre-assignment of node and section ID's was the difficulty of the field crews in matching the pre-assigned ID's to the appropriate survey data in the field. Another is that the pre-assigned ID's had to be modified in the field every time new Sections or Nodes were identified.

Where the administrative regions (Regions, District, etc.) have considerable autonomy, there will be disputes concerning boundary points.

As we have experienced, the collection of centerline survey data and digital pictures should not be done simultaneously with the collection of roughness data. The collection of roughness data requires the vehicle Bump Integrator to maintain a relative consistent speed while taking digital pictures and collecting centerline survey data requires stopping the vehicle intermittently.

The digital pictures of the intersection nodes have limited value to LRS data. At best the digital pictures for dead end roads may have some value only for documentation that the survey terminates at a particular location. The same information can be obtained from the video survey data. In most cases pictures of an intersection do not provide sufficient detail as to the layout of the intersection. There is the added problem of documenting the direction of the photo and being able to identify details that are useful for someone not familiar with the intersections.

The digital pictures of the LRP's such as kilometer post, bridges and administrative boundaries can be used to verify locations particularly at nodes for an administrative boundary much better than an intersection picture.

The collection of video survey data in traffic congested areas has some limited value but cannot be collected in conjunction with roughness data. In congested areas, the collection of roughness data is best performed at night. The video data collected during the daylight hours in congested areas is very limited due to the number of other vehicle obstructions such as buses interfering with the view of the roadway or adjacent features. Extreme care must be taken to obtain a video of the road and adjacent features in heavily congested areas.

It would have been beneficial to the surveyor and the department if the data format and database structures had been better defined at the beginning. Considerable time was spent during the equipment and procedure validation process defining these details. This activity continued even after the first submission of data had occurred. Once the data format and database structures were finalized the automated procedures for the processing of data could be developed. Until that occurred each submission had to be manually manipulated.

Receiving the data in either GIS or DXF format was very helpful and reduced the department's processing time. It is important that the staff verifying the data be familiar with the GIS or CADD application being used to verify the data before the data is received. This will significantly reduce the learning curve time required for the processing of the early submissions of data.

6. BENEFITS OF LOCATIONING REFERENCING SYSTEM

- Enable integration of all DPWH information in a common locational referencing system
- Eliminate unnecessary duplication of data collection effort
- Enable efficient access to all DPWH spatially related data by computer application

The centerline survey conducted in the Philippines was executed at a much lower cost compared to similar surveys in other countries because the system was built using off-the-shelf components. Nevertheless, the resulting data were found to be accurate and once put into a GIS can be used for effective road management in the entire DPWH

7. TECHNOLOGY USED IN THE SURVEY

The use of portable GPS and video in the centerline survey was developed for the RIMSS Project. The system used GPS receivers, which were post-processed to provide differential corrections. For areas where satellite lock was lost, an inertia navigation unit was used to provide the missing coordinates. Due to the large number of road network to be surveyed, the video images were sampled every 10 m. and captured in real-time on a computer. The positions of the kilometer posts were established using a hand-held portable laser distance measurement gun.

7.1 Description of the Equipment used in the Survey

The system used in the centerline survey is illustrated in Figure 2. The various components of the system which were mounted in a 4-wheel drive vehicle are described below.

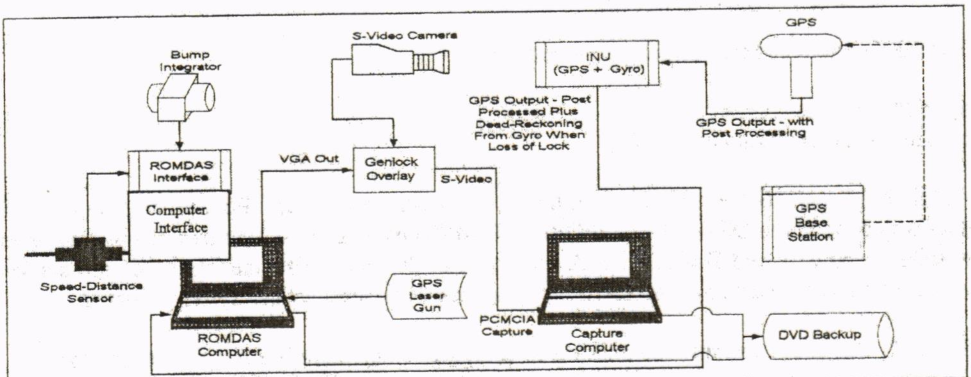


Figure 2. Survey System

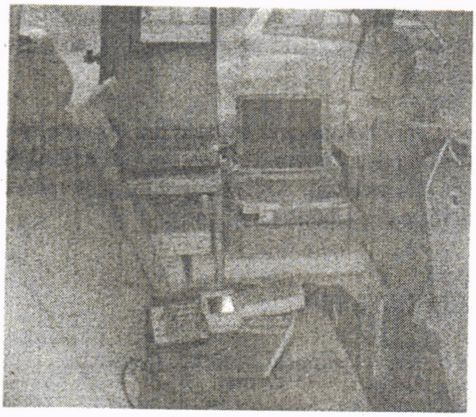


Figure 3. Survey Equipments

Figure 4. 4-Wheel Drive Vehicle

a. Computer system

The Computer System integrated the following functions:

- GPS Data. GPS data was recorded on a second-by-second basis.
- Chainage Recording. The distance traveled from the last recorded Locational Referencing Point (LRP) as the vehicle drives down the road is recorded. The distance recording was performed using a Terratrip connected to the vehicle gearbox.
- Roughness Measurements. The road roughness is recorded using a bump integrator. The data is measured and recorded at maximum of 100 m intervals.
- Video Overlay. A video overlay is created with the location reference, time, chainage, and roughness on the video image produced by a S-Video camcorder.
- Laser GPS Recordings. The data from the laser GPS gun giving the co-ordinates of attributes are also recorded.

b. Global Positioning System (GPS)

The GPS system had two principal components:

a) GPS receiver
b) Inertial Navigation Unit (INU)

A Trimble Pro-XRS GPS machine with post processing was used. Post-processing of GPS data was done at the DPWH Central Office (RIMSS) using base station data from stations in Manila, Cebu City and Davao City. A limitation of 200 km. distance from the base station was applied; the accuracy of the GPS for work done at greater distances was validated.

The INU was used to supply the missing co-ordinates when there is a loss of satellite lock. An algorithm was derived which integrates the GPS and the INU.

Figure 5. Global Positioning System

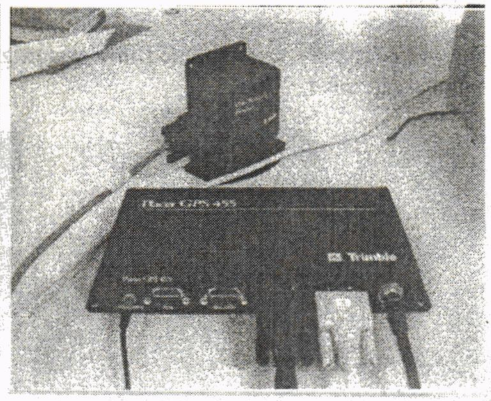


Figure 6. Inertia Navigation Unit

A TRIMBLE Placer 455 unit was used as a dead reckoning device. This unit does not supply height. Consequently height measurements were not available while there was loss of satellite lock during the survey. All height recordings during satellite loss were interpolated between the nearest recorded Pro-XRS positions.

c. Road Roughness

The road roughness was measured using a Bump Integrator (BI). This is a response-type roughness meter, which records the relative displacement of the vehicle floor to the axle. The measured BI roughness can be transformed to IRI. The transfer function for each vehicle was determined on a series of 8 calibration sections during December 1999. On islands where it was not practical to ship the vehicle, the roughness was assessed visually (IQL-4). Surveyors were calibrated on the roughness sections to ensure compatibility with the mechanical measurements.

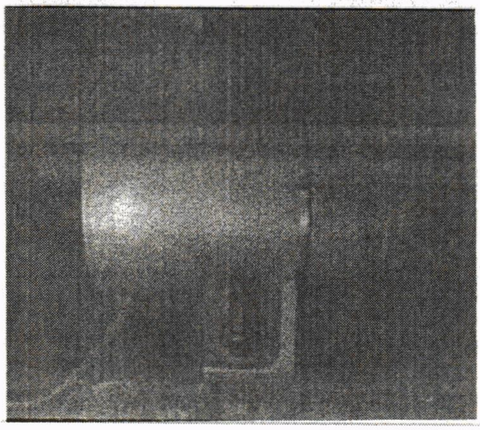
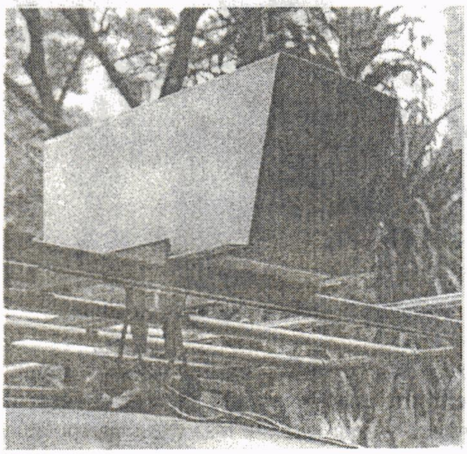


Figure 7. Bump Integrator

d. Video Camera

The video camera was mounted in a watertight housing on the roof of the vehicle and is remote controlled.



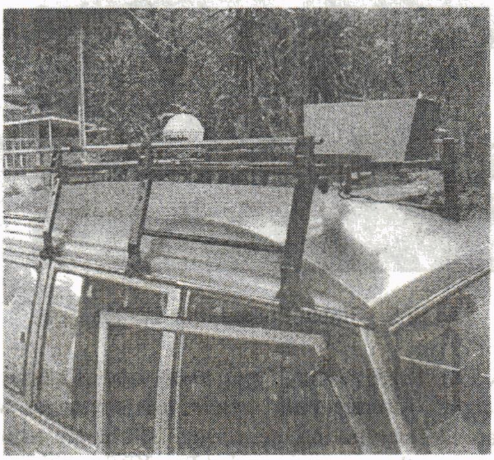
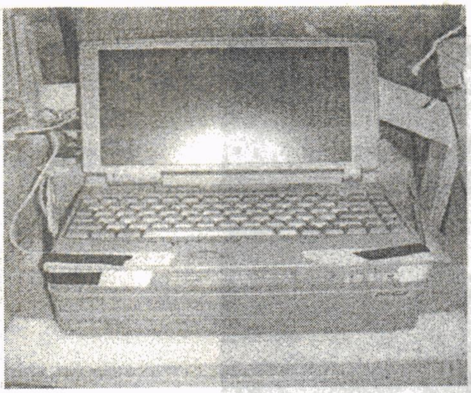


Figure 8. Video Camera

d. Video Capture

The video capture was done using a video capture card mounted in a docking station and managed from a notebook computer. The files are saved as .AVI files at a sampling rate of 1.3 (every 10m at 50km/h) frames/second. In the process the section description and the DMI information is overlaid onto the image.



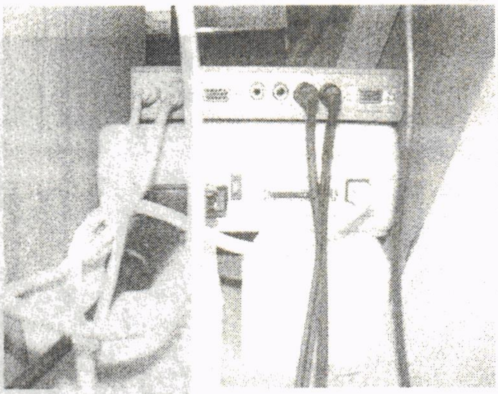


Figure 9. Video Capture Equipment

e. Laser Distance Gun

The positions of Location Referencing Points were established using a Laser Technology Inc. Impulse laser system with the MapStar compass. This system allows the surveyors to take a 'shot' of an LRP or node point while driving. The distance and direction is measured and by including the GPS position of the vehicle the geo co-ordinates of the LRP are determined. This information is then stored in the computer system along with the chainage of the LRP.

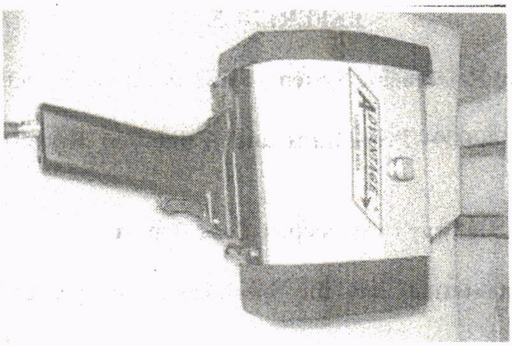


Figure 10. Laser Distance Gun

f. Digital Camera

A digital camera with zooming capabilities is used to capture a photograph of each LRP. The photographs are uniquely numbered and the reference is stored in the Computer System. The photographs are stored in JPEG format.

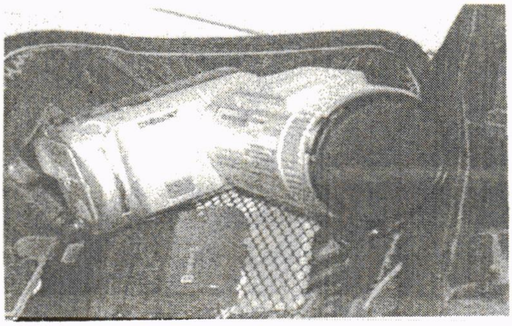


Figure 11. Digital Camera

7. CONCLUSION

The sustainability of all aspects of the new data collection methods are critically dependent upon keeping the centerline survey up to date at all times. If all records are to be maintained on the computer, an accurate centerline survey is the key to the storage of all data.

Nevertheless, survey updates are still very important, and responsibilities and updates procedures must be defined and managed to ensure that the centerline survey is always complete and up to date.

Proper attention must also be applied to the regular backup of all LRS data. Since large volumes of other data will rely on the LRS for accurate positioning, it is essential that the coding and survey information cannot be lost through any form of computer failure.

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