PMGSY ROAD ASSET INVENTORY AND PAVEMENT CONDITION DATA ASSESSMENT USING A PORTABLE LOW-COST VIDEO IMAGING BASED SYSTEM

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ABSTRACT

Road asset inventory and pavement condition data surveying is one of the important tasks in road planning, designing, construction, maintenance and management practices, particularly for developing repair /maintenance, rehabilitation strategies and budgeting purposes. In India, this is largely being done via traditional field inspection techniques or manually using road videos or still images collected by dedicated road survey vehicles. This is very expensive, time consuming and has limited uses in road asset management. In this paper, methodologies for road asset inventory and pavement condition data assessment using a portable low-cost video imaging based system called BETQ PARSS-2016 are presented. Using this system, raw video clips of Indian rural roads are captured without any artificial lighting systems in normal day light conditions and processed using its semi-automated data processing software (SemiAsset and SemiDistress) for development of road asset inventory and condition database. The results indicate that the presented system has a significant capability in development of road asset inventory and condition database semi-automatically, accurately and objectively. And it is found to be a better choice for rural / PMGSY (Pradhan Mantri Gram Sadak Yojana) roads where dedicated road survey vehicles are very expensive and / or impossible to use.

KEYWORDS

PMGSY Roads, Road Survey Systems, Road Asset Inventory & Pavement Condition Data, Video Image Processing, PARSS-2016, India

1. INTRODUCTION

Government of India has launched Pradhan Mantri Gram Sadak Yojana (PMGSY) in year 2000 for the construction of rural roads as a key intervention to provide connectivity which results in ensuring sustainable poverty reduction. Under this flagship programme, rural road networks of more than 5,13,384 km length have been already constructed so far in various states of India (*1*). Since then, Govt. of India has been endeavoring to set high and uniform technical and management standards and facilitating policy development and planning at State level in order to ensure sustainable management of the rural roads network**.** As early as 1988, the World Bank

asserted that one dollar spent in maintenance will save four dollars spent in rehabilitation (*2*). A little improvement in maintaining the physical infrastructure, road transport provision and operation can result in large economical benefits. Today, these losses are increasing / accelerated due to poor maintenance and increasing traffic. This needs to be controlled or minimized by improving their conditions and upgrading the maintenance practices for road networks. To achieve this goal, one of the important tasks is to develop an effective rural road asset management system (RRAMS) so that it can monitor and assess the conditions of rural roads networks continuously, objectively and rapidly. The RRAMS will help and facilitate in the following practices (*3*):-

- In Improving the safety for all road users
- In developing repair and maintenance strategies to ensure a good and an effective road network for the users:
  - (a) Determination of various maintenance levels / Road Condition Index / Pavement Condition Index
  - (b) Prediction of Future Performances
  - (c) Estimation of Cost for Repairing Road Asset
  - (d) Quality Check of the Works done by Contractors
- In Identification of the needs for road widening, pavement strengthening, and up-gradation
- In Establishing a complete inventory of all road networks with all its elements
- In Providing a clear picture of the current condition/performance of the road network
- In Estimating the value of the asset
- In Predicting future demand of traffic and service needs

For developing an effective RRAMS, it is necessary to carry out the road asset inventory and pavement condition survey of the existing rural roads on a regular basis to develop road inventory and pavement condition databases. According to the Indian guidelines/manuals (*4-5*), location & category of rural roads, carriageway width, formation width, road land width, surface type, road type, terrain type, cross-drainage structure type and its dimensions are some parameters of road asset inventory database whose inspection is essential for every 100m chainages while location of defects, potholes, cracks, ruttings /depressions, raveling, edge breaks, patchies, pavement failure and shoulder drop off are some parameters of pavement condition database whose evaluation is essential. The effectiveness of a RRAMS of any PMGSY state implementing agencies will be governed by the accuracy and reliability of these input parameters (database). As such, accurate, objective and speedy assessment of these road inventory and pavement condition parameters is of utmost importance.

In current field practices, road asset inventory and pavement condition data assessment is largely being done using various imaging methods since imaging methods are more reliable, efficient and accurate than the other methods of data collection such as manual or vibration based methods. The imaging based method for road inventory and condition data assessment usually comprises of two steps. The first one is the recording of road visual data (video / images) which is generally called as Data Collection and the other one is the analysis / processing of the recorded visual data for

useful information extraction which is generally called as Data Processing. In India, road networks spreading over 46 lacs kilometers in length are maintained and managed by various competent authorities / agencies. All these agencies survey roads via traditional field inspection techniques or manually using road videos or still images collected by dedicated road survey vehicles. This is very expensive, time consuming and has limited uses in road asset management. Thus, there is need of an improved / new methodology for road asset inventory and pavement condition survey particularly for rural roads where dedicated road survey vehicles are very expensive and / or impossible to use. This will also enables to plan and carry out the required asset management activities in less time and efforts. In this direction, the authors strive to develop rural road asset inventory and pavement condition databases using a portable low-cost automated road survey system.

In this paper, methodologies for developing PMGSY road asset inventory and pavement condition databases using a portable low-cost automated road survey system called BETQ PARSS-2016 are presented. Using PARSS-2016, raw video clips of PMGSY roads are captured without any artificial lighting systems in normal day light conditions and processed using its automated / semi-automated video data processing software for development of road asset inventory and condition databases. The results indicate that the presented system has a significant capability in development of road asset inventory and condition databases automatically, accurately and objectively. And it is found to be a better choice for rural / PMGSY roads where dedicated road survey vehicles are very expensive and / or impossible to use.

2. WHAT IS BTEQ PARSS-2016?

2.1 Overview of PARSS-2016

The Portable Automated Road Survey System (PARSS-2016) is a proprietary integrated road data collection and data processing system developed indigenously by BETQ Data Analytics Pvt. Ltd., India (*6-7*). PARSS has been developed through doctoral level research and it has been designed to be very portable, easily detachable, plug & play / recording type, modular system with its automated / semi-automated data processing software. At present, PARSS-2016 has two video imaging modules. First one is *Asset view Video System* for collecting road asset inventory data while the other is *Pavement View Video System* for collecting pavement condition data and these modules can be mounted on various vehicles (Figure 1).

2.2 Asset View Video System

The Asset View Video System captures right of way (street view) geo-referenced videos (Figure 3). This system is normally used to obtain road asset and inventory information / database. The videos from this system are often processed with software products like SemiAsset where the name, size and number of each visible assets / events are semi-automatically measured and reported in a suitable road inventory inspection / entry form.

2.3 Pavement View Video System

The Pavement View Video System captures geo-referenced pavement surface videos (Figure 3). This system is normally used to obtain road condition information / database. The videos from this system are often processed with BETQ software products such as SemiDistress, AutoDistress, AutoPotholes, AutoCracks and / or AutoPatches where the size, number and extent of each visible pavement distresses are automatically or semi-automatically measured and reported in a suitable pavement condition inspection / rating form.

FIGURE 1 Side View of PARSS-2016 that can be mounted on various vehicles

2.4 Scope of Applications

The current model of PARSS-2016 can be readily used for road asset inventory and pavement condition surveying for various needs in both pre-construction and post-construction stages of a road project, particularly for following professional practices.

- Development of Pavement Condition Database using Pavement View Videos captured by PARSS-2016
- Development of Road Inventory Database using Asset View Videos captured by PARSS-2016
- Video Mapping of Road Survey Sections using Google Street Maps as well as Satellite Imagery
- Determination of PMGSY Pavement Condition Index (PCI) or Road Condition Index (RCI) using Distress Information extracted from Pavement View Videos captured by PARSS-2016
- Quality Assessment / Verification of PCI / RCI / Inventory data collected by Contractors / Consultants.

2.5 Salient Features

The salient features of PARSS-2016 include the following [6]:

- A low-cost, portable and easy to use tool for rural roads / highways practitioners

- A better choice for low-volume / rural / PMGSY roads / highways where dedicated road survey vehicles are very expensive and / or impossible to use
- Compared to manual inspection method, PARSS is more objective, speedy and accurate, gives a powerful and effective data collection and visualization whenever / wherever required
- Compared to dedicated road survey vehicles, PARSS is easy to use and cost-effective, can be used where heavy, complex and expensive survey vehicles are impossible to use
- Surveys a road network with a smart phone and camera
- Does not need distance measuring instruments, specific vehicles, expensive spare parts and expert knowledge
- Records road video in time mode, vehicle needs to ply at a constant speed to minimize overlapping frames / regions.
- Outputs useful data / information such as road land width, formation width, carriageway width, distress area, number of occurrence and extent for every 100m of road sections length.
- Data can be viewed, mapped or integrated on a GIS based platform.

3. DEVELOPMENT OF PMGSY ROAD ASSET INVENTORY DATABASE

The proposed methodology for semi-automated development of road asset inventory database using PARSS-2016 is performed in two stages at the current time. The first one is the recording of road asset view video from the field which is generally called as Asset Data Collection using the asset view video system and the other one is the analysis / processing of the collected video data for useful information extraction and development of road asset inventory database which is generally called as Asset Data Processing. The various steps involved in the development of road asset inventory database are depicted in Figure 2.

3.1 Asset Data Collection

For Asset data collection using PARSS-2016, the asset view video system is mounted on the front side roof top of a vehicle, Bolero in such a way that its face is pointed at 180 degree (horizontal) to the road surface (Figure 1). Then, the video system is calibrated by using the smart phone and calibration stick supplied with the equipment to obtain the desired field of view / coverage area of road section. The smartphone installed with the pavement view camera app is used for remote viewing / control of video footage. After the completion of calibration task, the vehicle engine is started and plied at a constant speed of 30 km/hr. When the vehicle reaches the survey start point, pavement video recording is started by taping the video recording button in the camera app and the asset view videos are recorded continuously in the resolution of 1920x1080 pixels with frame rate of 30 fps along with other sensors information such as gps coordinates, elevation, speed, distance, grade and date time information. Once the vehicle reaches survey end point, the video recording is stopped by again taping the video recording button in the camera app. The asset video data collected during the survey is stored in the memory card (128GB) of the camera along with other sensors files /data.

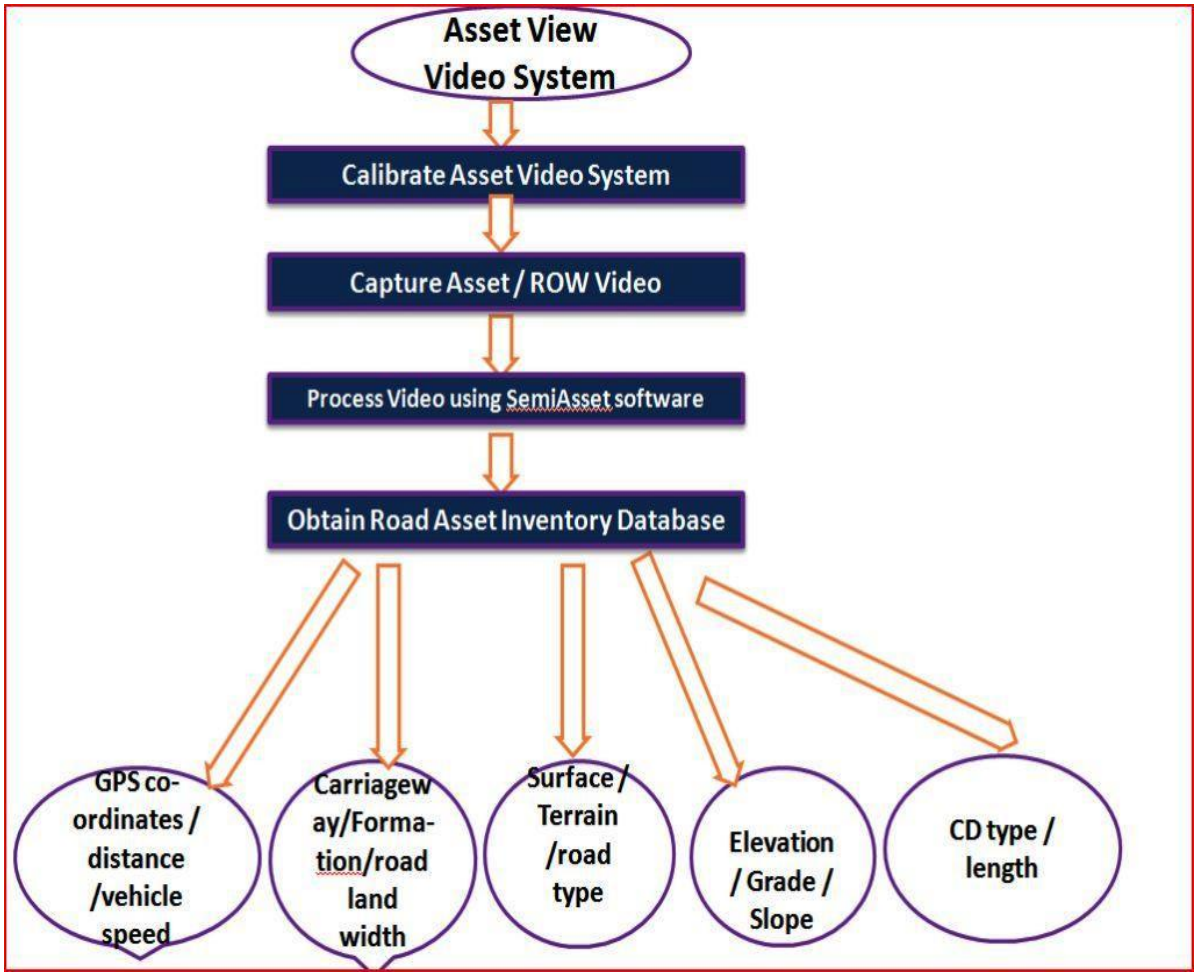

FIGURE 2 Steps involved in development of road asset inventory database

3.2 Asset Data Processing

The raw asset view video data stored in the memory card of the asset camera along with other sensor data need to be processed for development of the road asset inventory database. For this, the raw video data are processed using BETQ SemiAsset Software. The SemiAsset software is a proprietary road video data processing software from BETQ Data Analytics Private Limited. This software, a simple GUI based application is used to identify and assess road asset inventory parameters semi-automatically from raw video files. This software allows the user to access asset view video data, do the analysis and generate useful reports for development of road asset inventory database and it is designed as per the latest road inventory survey format available at PMGSY website (*4-5*).

4. DEVELOPMENT OF PMGSY PAVEMENT CONDITION DATABASE

The proposed methodology for semi-automated development of pavement condition database using PARSS-2016 is performed in two stages at the current time. The first one is the recording of pavement view video from the field which is generally called as Pavement Data Collection using the pavement view video system and the other one is the analysis / processing of the collected video data for useful information extraction and development of pavement condition database

which is generally called as Pavement Data Processing. The various steps involved in the development of pavement condition database are depicted in Figure 3.

4.1 Pavement Data Collection

For Pavement data collection using PARSS-2016, the pavement view video system is mounted on the back side roof top of a vehicle, Bolero in such a way that its face is pointed at 90 degree (perpendicular) to the road surface (Figure 1). Then, the video system is calibrated by using the smart phone and calibration stick supplied with the equipment to obtain the desired field of view / coverage area of road section. The smartphone installed with the pavement view camera app is used for remote viewing / control of video footage. After the completion of calibration task, the vehicle engine is started and plied at a constant speed of 30 km/hr. When the vehicle reaches the survey start point, pavement video recording is started by taping the video recording button in the camera app and the asset view videos are recorded continuously in the resolution of 1920x1080 pixels with frame rate of 30 fps along with other sensors information such as gps coordinates, elevation, speed, distance, grade and date time information. Once the vehicle reaches survey end point, the video recording is stopped by again taping the video recording button in the camera app. The pavement video data collected during the survey is stored in the memory card (128GB) of the camera along with other sensors files /data.

4.2 Pavement Data Processing

The raw pavement view video data stored in the memory card of the pavement camera along with other sensor data need to be processed for development of the pavement condition database. For this, the raw video data are processed using BETQ SemiDistress Software. The SemiDistress software is a proprietary road video data processing software from BETQ Data Analytics Private Limited. This software, a simple GUI based application is used to identify and assess pavement condition parameters semi-automatically from raw video files. This software allows the user to access pavement view video data, do the analysis and generate useful reports for development of pavement condition database and it is designed as per the latest road inventory survey format available at PMGSY websites (*4-5*).

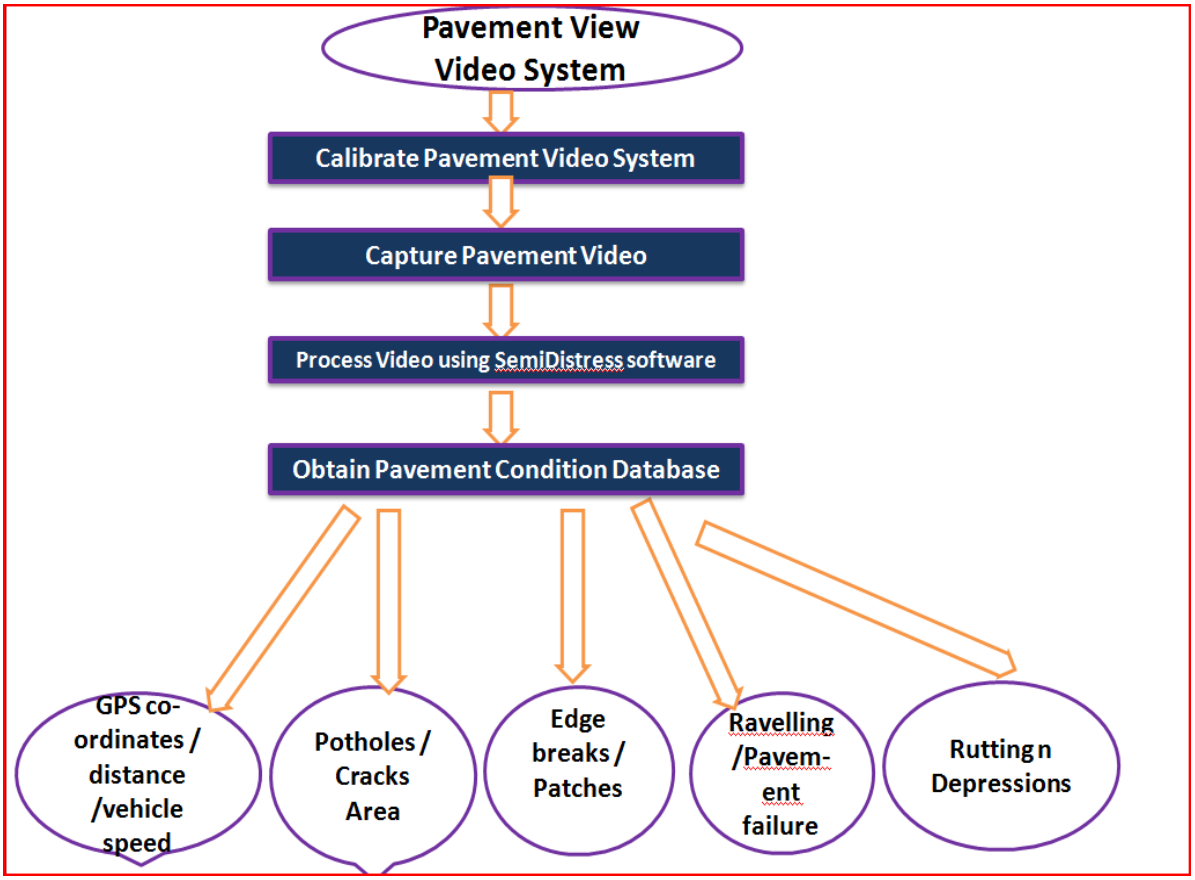

FIGURE 3 Steps involved in development of pavement condition database

5. IMPLEMENTATION RESULTS AND DISCUSSIONS

For testing its performance, the presented methodologies presented in this paper were implemented using a PARSS-2016 for road asset inventory and pavement video data collection while SemiAsset and SemiDistress software were used for semi-automated development of road asset inventory and pavement condition databases from raw video data. Using a PARSS-2016 mounted on Bolero, road inventory and pavement condition surveys were carried out on various PMGSY roads in Arunachal Pradesh and Manipur states and various asset view and pavement view videos were captured / collected at the vehicle speed of 30 km/hr with video resolution of 1080p and frame rate of 30fps. Later, the collected raw videos were processed semi-automatically using SemiAsset and SemiDistress software in a Windows environment (Dell Laptop with i5 Proccessor 2.20 GHz, 4 GB RAM and OS Windows 2010). After the completion of the processing, SemiDistress software generated two types of printable reports automatically in CSV formats which can be further converted into other file formats such as Excel Sheets / PDF etc. The first report is called Video Frame Wise Report and it contains detailed analysis report for each video frames such as chainage, frame number, speed, latitude, longitude, potholes area & number, cracks area & number, patches area & number, edge breaks area, pavement failure area, shoulder drop off area, raveling area and rut / depression area . The other report is called Kilometre or 100m Wise Report (Table1) and it contains summary of the analysis report for each 100m road chainage / section. This 100m wise report was designed for RCI rating estimation as per the format available in the PMGSY website (*1*). Besides, SemiDistress

software was able to separate / save all the frames with defect / distress from the video. Similarily, SemiAsset software also generated two types of printable reports automatically in CSV formats which can be further converted into other file formats such as Excel Sheets / PDF etc. The first report is called Video Frame Wise Report and it contains detailed analysis report for each video frames such as chainage, frame number, speed, latitude, longitude, elevation, grade, carriageway width, formation width, road land width, terrain type, surface type, road type, PCI, CD type and length. The other report is called Kilometre or 100m Wise Report (Table 2) and it contains analysis report for each 100m road chainage / section. Besides, SemiAsset software was able to separate / save all the frames in the video where road asset inventory parameters were identified and measured. Total processing time taken by the SemiDistress software on a pavement video clip having 1351 frames was found to be one hour ten minutes only while the total processing time taken by the SemiAsset software on a video clip having 1358 was found to be forty minutes only. Since these software were semi-automated (i.e. human intervention is required), the accuracy level in the identification and assessment of road asset inventory and pavement condition parameters could be reached upto 99%. Examples of video frames processed by SemiDistress and SemiAsset software are illustrated in Figures 4 and 5.

TABLE 1 100m wise report (RCI rating) generated by SemiDistress software

Report Generated using BETQ SemiDistress V-1.0
Report Generated by :

Start of Report Generation....
Date : 3-6-2017
Time : 8:40:34

Report File Author :

File Path C:\Users\betqdata\Desktop\TRAINING-VIDEOS-RWD\Back-4-3-17-27-data.avi

Defect Type

Date	Chainage(	Latitude	Longitude	Potholes	EdgeBreal	Ruts/Depr	Cracks	Pavement	Shoulderl	Maximum	Rating Scc	MaintenanceRequired
04/03/2017	0.2 to 0.3	N27.0° 8' 5	E93.0° 44'	2	1	3	1	1	1	0	9	Periodic
04/03/2017	0.3 to 0.4	N27.0° 8' 5	E93.0° 44'	2	1	1	1	1	1	0	7	Routine
04/03/2017	0.4 to 0.5	N27.0° 8' 5	E93.0° 44'	6	1	1	1	1	1	0	11	Periodic
04/03/2017	0.5 to 0.6	N27.0° 8' 5	E93.0° 44'	6	1	1	1	1	1	0	11	Periodic
04/03/2017	0.7 to 0.8	N27.0° 8' 5	E93.0° 44'	2	1	1	1	1	1	0	7	Routine
04/03/2017	0.8 to 0.9	N27.0° 8' 5	E93.0° 44'	4	1	1	3	1	1	0	11	Periodic
04/03/2017	1.1 to 1.2	N27.0° 8' 5	E93.0° 44'	2	3	3	1	1	1	0	11	Periodic
04/03/2017	1.2 to 1.3	N27.0° 8' 5	E93.0° 44'	6	3	1	1	1	1	0	13	Periodic
04/03/2017	1.4 to 1.5	N27.0° 8' 5	E93.0° 44'	6	1	1	1	1	1	0	11	Periodic

End of Report Generation....
Date : 3-6-2017
Time : 9:51:34

TABLE 2 100m wise report generated automatically by SemiAsset software

Report Generated using BETQ SemiAsset 1.0V
Report Generated by :

Start of Report Generation....
Date : 3-6-2017
Time : 10:45:37

Report File Author :

File Path C:\Users\betqdata\Desktop\TRAINING-VIDEOS-RWD\Front-4-3-17-4-Data.avi

Frame #	Date	Latitude	Longitude	Speed	Chainage	Elevation	Grade	Terrain T	Road Land	Formatio	Carriagew	Road Surf	Road Typ	PCI	CD Type	CD Total L	Span Wid	Remarks
19	04/03/2017	N27.0° 8' 5	E93.0° 43'	17	0.0 to 0.1	132	-8%	Plain	7.39	6.18	3.4	BT	AWR	0		0	0	
55	04/03/2017	N27.0° 8' 5	E93.0° 43'	21	0.1 to 0.2	131	-2%	Plain	5.61	4.31	2.53	BT	AWR	0		0	0	
147	04/03/2017	N27.0° 8' 5	E93.0° 44'	19	0.2 to 0.3	129	0%	Plain	6.54	5.18	3.28	BT	AWR	0		0	0	
287	04/03/2017	N27.0° 8' 5	E93.0° 44'	23	0.3 to 0.4	126	-1%	Plain	6.09	4.95	2.67	BT	AWR	0		0	0	
350	04/03/2017	N27.0° 8' 5	E93.0° 44'	25	0.4 to 0.5	125	0%	Plain	6.52	5.05	2.89	BT	AWR	0		0	0	
400	04/03/2017	N27.0° 8' 5	E93.0° 44'	24	0.5 to 0.6	124	0%	Plain	4.65	2.91	2.25	BT	AWR	0		0	0	
487	04/03/2017	N27.0° 8' 5	E93.0° 44'	24	0.6 to 0.7	123	0%	Plain	5.04	3.99	2.74	BT	AWR	0		0	0	minus 0
577	04/03/2017	N27.0° 8' 5	E93.0° 44'	21	0.7 to 0.8	122	-1%	Plain	4.44	3.31	2.22	BT	AWR	0		0	0	
656	04/03/2017	N27.0° 8' 5	E93.0° 44'	21	0.8 to 0.9	120	0%	Plain	4.94	3.93	2.93	BT	AWR	0		0	0	
709	04/03/2017	N27.0° 8' 5	E93.0° 44'	22	0.9 to 1.0	119	0%	Plain	5.32	4.25	2.44	BT	AWR	0		0	0	
785	04/03/2017	N27.0° 8' 5	E93.0° 44'	22	1.0 to 1.1	120	0%	Plain	5.34	4.23	3.16	BT	AWR	0		0	0	
870	04/03/2017	N27.0° 8' 5	E93.0° 44'	24	1.1 to 1.2	121	0%	Plain	5.17	4.21	2.52	BT	AWR	0		0	0	
975	04/03/2017	N27.0° 8' 5	E93.0° 44'	18	1.2 to 1.3	121	0%	Plain	4.23	3.39	2.72	BT	AWR	0		0	0	
1099	04/03/2017	N27.0° 8' 5	E93.0° 44'	19	1.3 to 1.4	121	-1%	Plain	3.97	3.39	2.63	BT	AWR	0		0	0	
1184	04/03/2017	N27.0° 8' 5	E93.0° 44'	22	1.4 to 1.5	118	-1%	Plain	4.32	3.49	2.37	BT	AWR	0		0	0	
1322	04/03/2017	N27.0° 8' 5	E93.0° 44'	9	1.5 to 1.6	115	-2%	Plain	3.82	3.13	2.52	BT	AWR	0		0	0	

Overall information:

Total No. Of Frames=1358

End of Report Generation....
Date : 3-6-2017
Time : 11:26:15

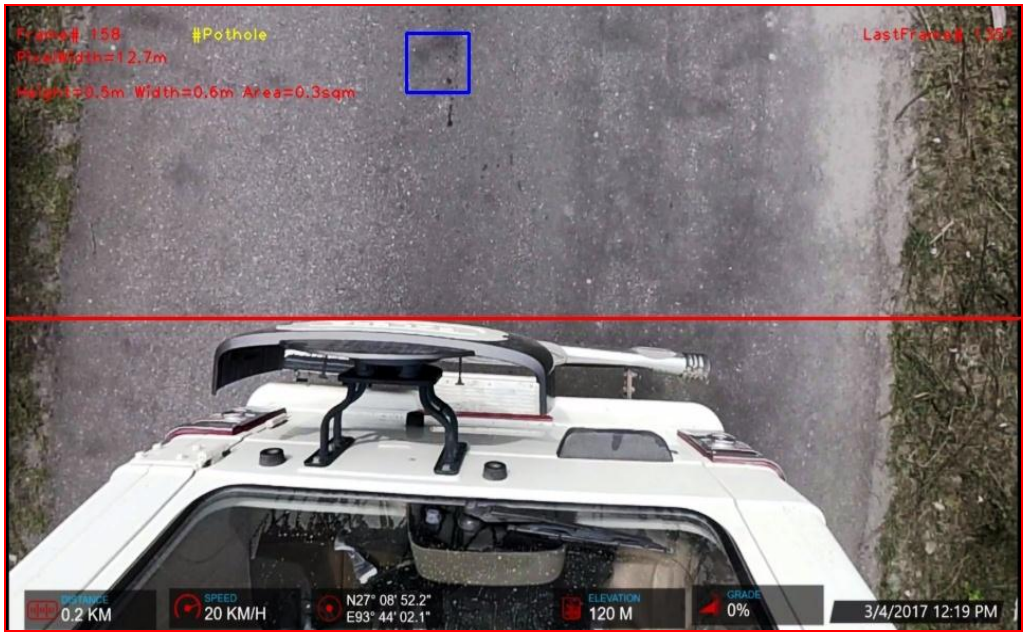

FIGURE 4 Example of video frames processed by SemiDistress software

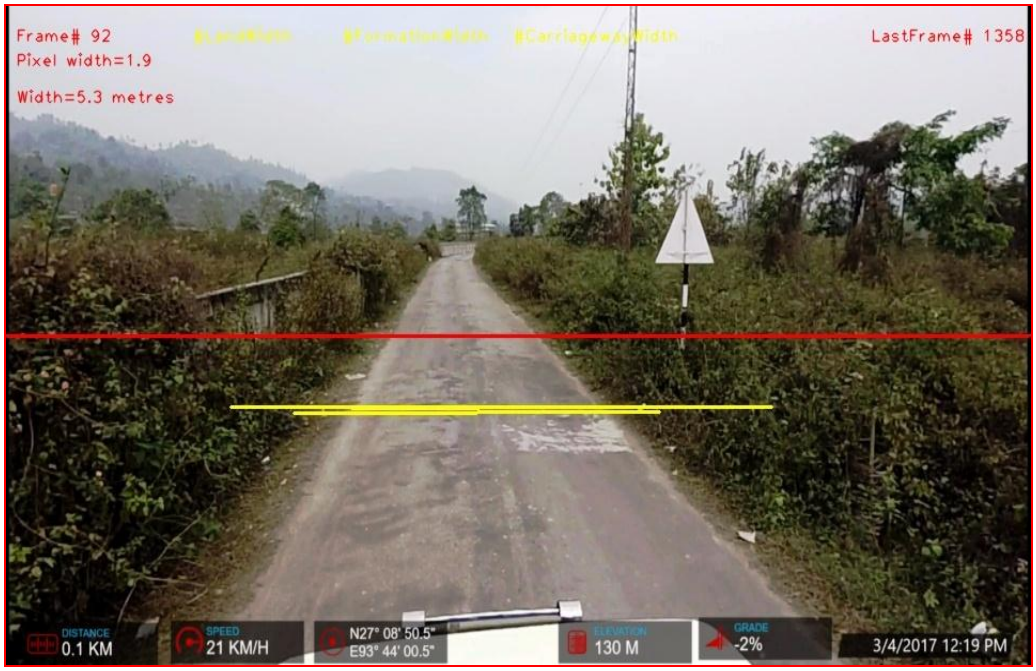

FIGURE 5 Example of video frames processed by SemiAsset software

4. CONCLUSIONS AND FUTURE WORK

In this paper, authors presented methodologies for PMGSY road asset inventory and pavement condition data assessment using a portable low-cost video imaging based system called BETQ PARSS-2016. PARSS-2016 is a proprietary integrated road data collection and data processing system developed indigenously by BETQ Data Analytics Pvt. Ltd., India. It has been designed to be very portable, easily detachable, plug & play / recording type, modular system with its automated / semi-automated data processing software. At present, PARSS-2016 has two video imaging modules. First one is *Asset view Video System* for collecting road asset inventory data while the other is *Pavement View Video System* for collecting pavement condition data and these modules can be mounted on various vehicles. Using this system, raw video clips of PMGSY roads in Manipur and Arunachal Pradesh states were captured without any artificial lighting systems in normal day light conditions and processed using its SemiAsset and SemiDistress software for the development of road asset inventory and pavement condition database. The results indicate that the presented system has a significant capability in development of road asset inventory and pavement condition database automatically, accurately and objectively. And it is found to be a better choice for rural / PMGSY roads where dedicated road survey vehicles are very expensive and / or impossible to use.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support in field data collection by Rural Engineering Department (RED / MSRRDA), Govt. of Manipur particularly Er. Th. Nandakishore Singh, Chief Engineer (RED / MSRRDA) as well as Rural Works Division (RWD), Papum Pare District, Govt. of Arunachal Pradesh particularly Er. Jobae Techi, Executive Engineer (RWD).

The authors also express their gratitude to Director, CSIR-Central Road Research Institute and his team for the support & encouragement they provided for the doctoral research, based on which this paper is presented.

REFERENCES

1. *Online Management, Management, Monitoring and Accounting System (OMMAS)*, http://omms.nic.in/, Accessed July 12, 2017.

2. I.G. Heggie. *Management and financing of roads; an agenda for reform*. World Bank Technical Paper No. 275, 1995, Washington DC: World Bank.

3. *Road Asset Management: An erf position paper for maintaining and improving a sustainable and efficient road network*, http://erf.be/images/Road-Asset-Management-2014-07.pdf, Accessed July 12, 2017.

4. *Road Maintenance Management System*, PMGSY, Ministry of Rural Development, Govt. of India, http://pmgsy.nic.in/mapr.pdf, Accessed March 1, 2017.

5. *Rural Road Maintenance Training Modules for Field Engineers, Module-4, Planning, Inspection, Reporting and Monitoring*, PMGSY, Ministry of Rural Development, Govt. of India, http://pmgsy.nic.in/EngineerModule4.pdf, Accessed March 1, 2017.

6. Namita Akoijam and L.K. Das. An indigenous solution for automation in Indian road inventory and condition survey, *TrafficInfraTech*, April-May 2016, pp.43-56.

7. *Portable Automated Road Survey System (PARSS-2016)*, Betq Data Analytics Private Limited, http://www.betqdata.com/products, Accessed July 12, 2017.