AN APPROACH TOWARDS AUTOMATED ESTIMATION OF PAVEMENT CONDITION INDEX FOR PMGSY ROADS USING PAVEMENT VIDEOS

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ABSTRACT

For Pradhan Mantri Gram Sadak Yojana (PMGSY) roads, pavement condition survey is essential to estimate Pavement Condition Index (PCI) rating value for the road sections as well as for further verification of the estimated value by an auditor. PCI rates the condition of the surface of a road network in terms of a numerical rating and it is used to (a) identify maintenance, rehabilitation and / or up-gradation needs, (b) monitor pavement condition, (c) develop road maintenance budgets, (d) evaluate pavement materials and designs. In current field practice, PCI is determined manually by arithmetic mean value of three different ratings for each km of PMGSY road sections. This is very subjective and time consuming.

In this paper, authors proposed a methodology for automated estimation of PCI for PMGSY roads using pavement videos. Using the proposed methodology, geotagged pavement videos of PMGSY roads are captured without any artificial lighting systems using a pavement view video system. Then, the collected raw videos are processed automatically using a robust video image processing algorithm for accurate estimation of PCI value using pavement distress information extracted out of the pavement videos. The test results indicate that the proposed methodology has a significant capability in estimating PCI value as well as its further verification in less time and effort. And the proposed methodology for automation in PCI rating can be readily applied in professional practice as a reliable and accurate approach.

KEYWORDS

PMGSY Roads, Pavement Condition Survey, Pavement Condition Index, Video Image Processing, India

1. INTRODUCTION

In India, Government of India has launched Pradhan Mantri Gram Sadak Yojana (PMGSY) since year 2000 for the construction of rural roads as a key intervention to provide connectivity which results in ensuring sustainable poverty reduction. After its construction, maintenance management of these rural road assets is also essential so that roads are in good condition and serve the increasing Indian traffic and population more efficiently and effectively till their serviceable life. To achieve this goal, one of the important tasks is to develop an effective rural road maintenance management system so that it can monitor and assess the conditions of rural roads networks continuously, objectively and rapidly. For developing an effective rural road maintenance management system, it is necessary to carry out the pavement condition survey of the existing rural roads on a regular basis to estimate the accurate rating of Pavement Condition Index (PCI).

For PMGSY roads, pavement condition survey is essential to estimate PCI value for the road sections as well as for further verification of the estimated value by an auditor. The PCI provides a five point numerical ratings for the condition of road sections within the road network, where 1 is the very poor condition and 5 is the very good. PCI rates the condition of the surface of a road network in terms of a numerical rating and it is used to (a) identify immediate maintenance, rehabilitation and / or up-gradation needs, (b) monitor pavement condition over time, (c) develop road maintenance budgets, (d) evaluate pavement materials and designs (*1*). In current field practice, PCI is determined manually by arithmetic mean value of three different ratings for each km of PMGSY road networks (*2*). The three different ratings are (a) Rating based on Pavement Surface Condition, (b) Rating based on Riding Comfort and (c) Rating based on Comfortable Driving Speed.

(a) **Rating based on Pavement Surface Condition:** In this rating type, the condition of the road surface is assessed visually through naked eyes by an experienced engineer for each km while observing severity and extent of pavement distresses like pothole, raveling, wide cracking and failed sections. The rating value corresponding to different road surface conditions are listed in Table1.

TABLE 1 Rating based on Pavement Surface Condition

Surface Condition	**Rating**	**Description**
Very Good	5	No signs of distress
Good	4	Noticeable loss of bituminous surface material, occasional shallow potholes in less than 10% length
Fair	3	Disintegrated surface with loss of bituminous surface material, frequent shallow potholes with occasional deep potholes in less than 25% length
Poor	2	Highly disintegrated surface with loose material, frequent deep potholes with resulting in reduction in vehicle speed in less than 50% length
Very Poor	1	Frequent occurrences of base course failure with wide cracking, along with other distresses such as pothole of high severity spread across carriageway

(b) **Rating based on Riding Comfort:** In this rating type, a car is driven at 50 km/hr and the riding comfort is noted for each km based on the “riding comfort” felt by the experienced rater / engineer. The rating value corresponding to different conditions is given in Table 2.

TABLE 2 Rating based on Riding Comfort

Riding Comfort @ 50 km/hr	Rating	Description
Smooth and pleasant ride	5	No pavement distress
Comfortable	4	Occasional loss of material or potholes
Slightly uncomfortable	3	Frequent shallow potholes or disintegrated surface
Rough and bumpy	2	Frequent deep potholes and highly disintegrated surface deep potholes with resulting in reduction in vehicle speed in less than 50% length
Dangerous	1	Potholes / failed sections across carriageway

(c) **Rating based on Comfortable Driving Speed:** In this rating type, the driver is instructed accordingly to drive at the most comfortable and safe speed possible on the road. The rating is then provided for each kilometer assessed on the normal driving speed. The rating value corresponding to different conditions is given in Table 3.

TABLE 3 Rating based on Comfortable Driving Speed

Normal Driving Speed	Rating	Description
Over 40 km/hr	5	No pavement distress
30-40 km/hr	4	Occasional loss of material without affecting speed
20-30 km/hr	3	Frequent shallow potholes affecting speed
10-20 km/hr	2	Frequent deep potholes reducing speed
Less than 10 km/hr	1	Potholes / failed sections across carriageway

Although, the aforementioned methodology of pavement condition survey and estimating PCI value is found to be largely being used by field practitioners in India, it is very subjective, time consuming as the process of estimating PCI value is manually done and the accuracy and reliability of the PCI data is wholly dependent on the experience of the rater at the field site. Thus, there is need of an improved / new methodology for pavement condition survey and estimating PCI value so that PCI rating is done more objectively and rapidly. This will also enables to plan and carry out the required maintenance management activities in less time and efforts. In this direction, the authors strive to develop an automated approach for pavement condition survey and PCI rating estimation using pavement distress information only.

In this paper, authors proposed a methodology for automated estimation of PCI value for PMGSY roads using pavement videos. Using the proposed methodology, geo-tagged pavement videos of PMGSY roads are captured without any artificial lighting systems using a pavement view video system. Then, the collected raw videos are processed automatically using a robust video image processing algorithm for accurate estimation of PCI value using pavement distress information extracted out of the pavement videos. The test results indicate that the proposed methodology has a significant capability in estimating PCI value as well as its further verification in less time and effort. And the proposed methodology for automation in PCI rating can be readily applied in professional practice as a reliable and accurate approach.

2. PROPOSED METHODOLOGY

The overall objective of this study is to test whether a portable low-cost video imaging equipment can estimate the value of PCI automatically and accurately. For this, BETQ PARSS-2016, a portable low-cost video imaging based road survey equipment from BETQ Data Analytics Pvt. Ltd., India is chosen. At present, PARSS-2016 has two different video systems viz. Pavement View Video System and Asset View Video System (*3*). The Pavement View Video System captures geo-referenced pavement surface videos and it is normally used to obtain pavement condition database / information while Asset View Video system captures right of way (street view) geo-referenced videos and it is normally used to obtain road asset inventory information / database.

The proposed methodology for automated pavement condition survey and PCI rating estimation is performed in two stages at the current time. The first one is the collection of distress information from the field which is generally called as PCI Data Collection using a pavement view video system and the other one is the analysis / processing of the collected video data for useful information extraction and PCI rating estimation which is generally called as PCI Data Processing. The various components of the proposed methodology are depicted in Figure 1.

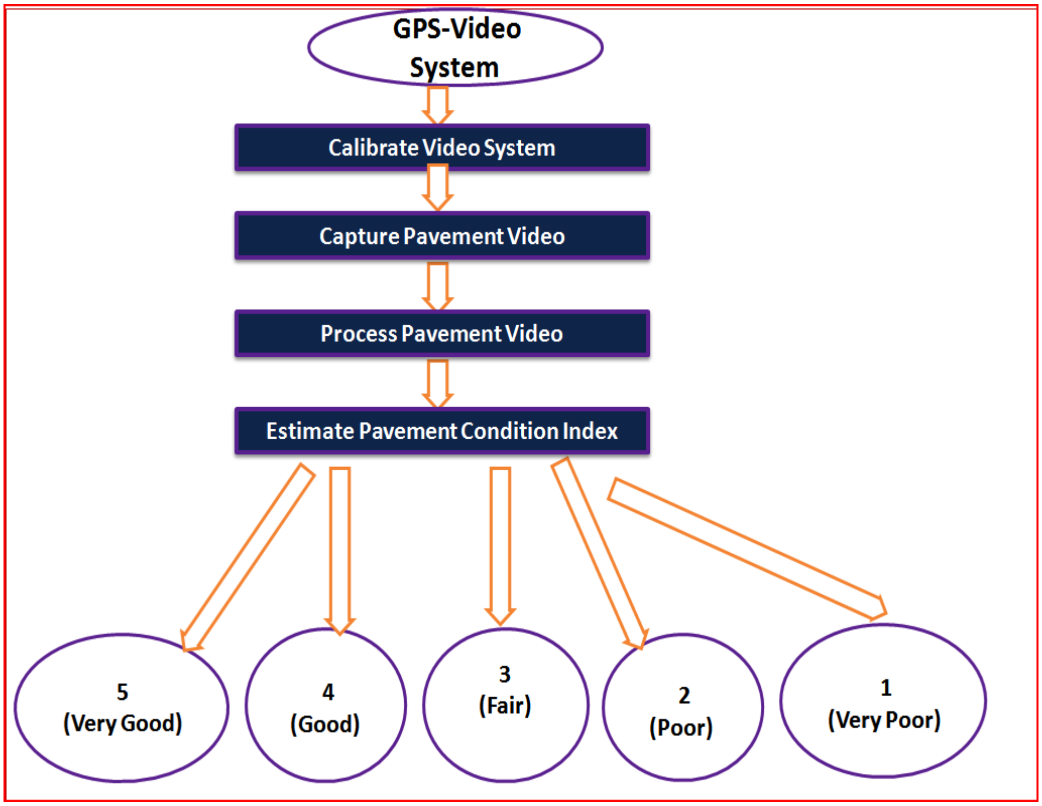


FIGURE 1 Components of the proposed methodology

2.1 PCI Data Collection

For PCI data collection using PARSS-2016, the pavement view video system is mounted on the back side roof top of a mini car, WagonR (Figure 2). 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 pavement 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 stop 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.

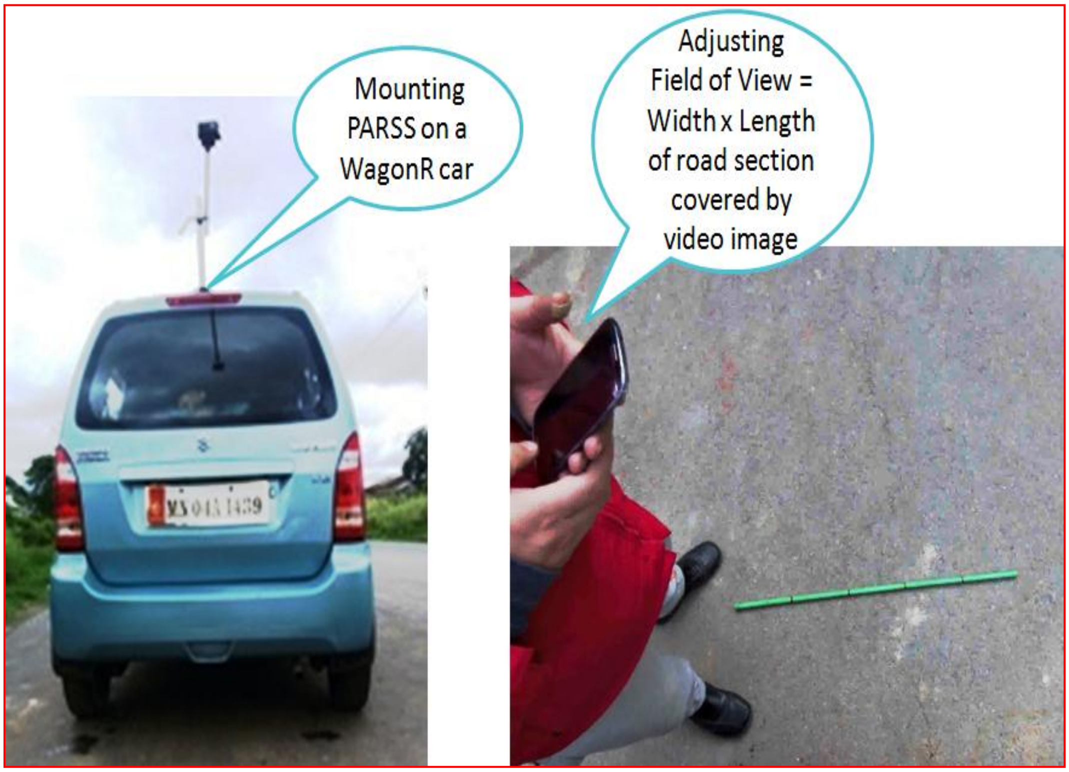


FIGURE 2 Automated PCI data collection using BETQ PARSS-2016

2.2 PCI Data Processing

The raw video data stored in the memory card of the pavement camera along with other sensor data need to be processed for detection of pavement distresses and estimation of PCI rating value based on the detected distresses information (Figure 3). For this, the raw video data are processed using BETQ AutoDistress software. AutoDistress software is a robust video processing software from BETQ Data Analytics Pvt. Ltd., India and it is used to detect and analyze distresses automatically from road surface video clips. It is developed based on a robust video processing algorithm called Distress Frames Selection (DFS) algorithm. DFS algorithm is the one presented by Lokeshwor et al. (2013) for segmentation of frames with/without distress from road surface video clips (*4*). In the presented algorithm, the video frame extracted out of a raw video clip is subjected to various image processing techniques, supported by user defined decision logic for accurate detection of road surface distresses. The main steps in this algorithm are the segmentation of distress pixels from the background pixels of a video frame using an adaptive thresholding technique and the development of a user defined decision logic for categorization of the video frame based on the area covered by the distress pixels. The result is two different types of frames category viz. *frames with distress* and *frames without distress*. In this algorithm, a road video frame is considered for *frames without distress* category if total area of objects (distress pixels) is less than 177 sq.cm. The remaining frames which do not belong to *frames without distress* are grouped into *frames with distress* category (*5*). Based on the total number of frames with distress (D) resulted from this algorithm and the rating based of pavement surface condition mentioned in Section 1, a decision logic is developed for estimation of five different ratings of PCI (Equation 1-5).

$$\text{Rating (PCI)} = \begin{cases} \text{(a) } 5, \text{ if } \%D = 0; & (1) \\ \text{(b) } 4, \text{ if } 1 <= \%D < 10; & (2) \\ \text{(c) } 3, \text{ if } 10 <= \%D < 25; & (3) \\ \text{(d) } 2, \text{ if } 25 <= \%D < 50; & (4) \\ \text{(d) } 1, \text{ if } \%D >= 25; & (5) \end{cases}$$

Where D = Number of video frames with distress generated by AutoDistress software
%D = D / Total number of video frames in the video

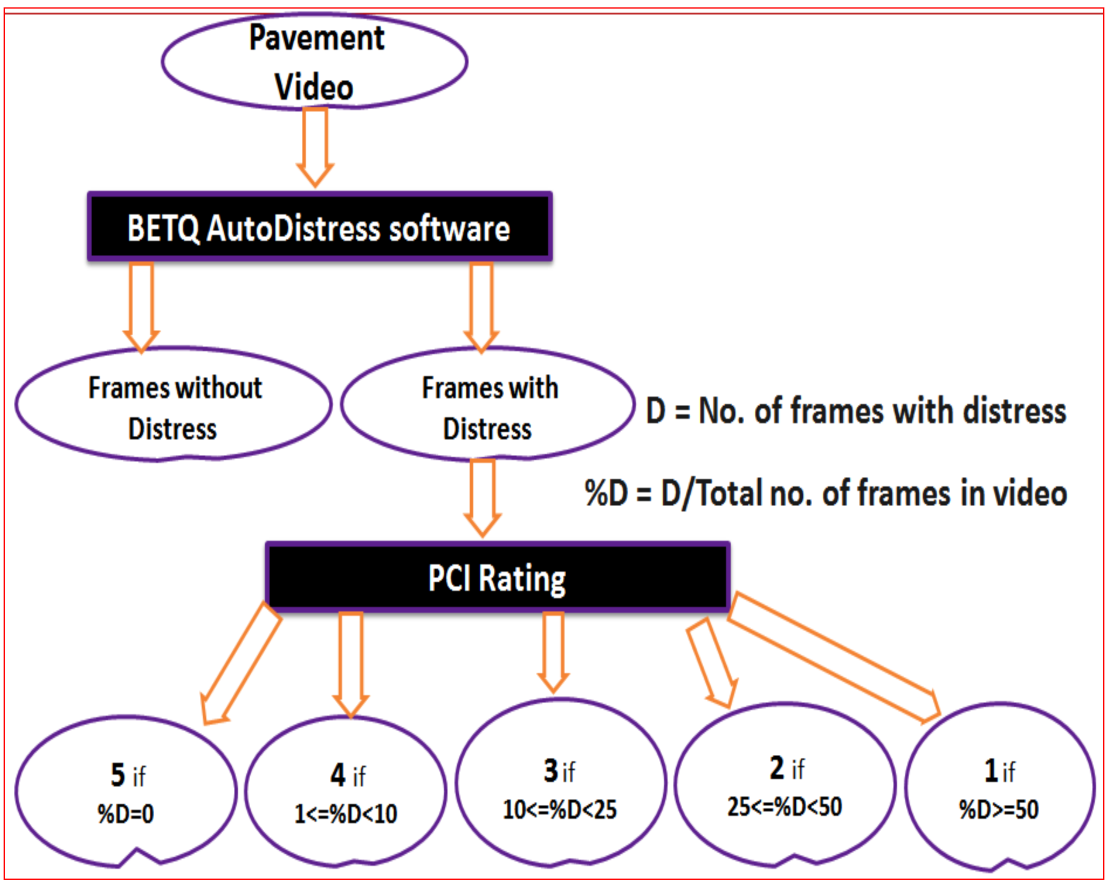


FIGURE 3 Automated PCI rating from pavement video using AutoDistress software

3. IMPLEMENTATION RESULTS AND DISCUSSIONS

For testing its performance, the proposed method presented in this paper was implemented using a PARSS-2016 for pavement video data collection while AutoDistress software was used for automated estimation of PCI rating from the raw pavement video data. Using a PARSS-2016 mounted on a WagonR car, a pavement condition survey was carried out on a PMGSY road for 1.1 km length road section in Imphal West District, Manipur state in July 2016 and a raw pavement view video data was captured / collected at the vehicle speed of 30 km/hr with video resolution of 1080p and frame rate of 30fps. Each pavement video image covers approximately 3.5m width by 2.0m length of the road section with a frame resolution of 1920x1080 pixels and pixel coverage of 1.8mm x1.8mm. The video images contain features such as normal roads, distress like potholes, cracks, patches, discoloration, dark spots and shadows of trees etc.

Later, the collected raw pavement video was processed automatically using AutoDistress 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, AutoDistress 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 (Table 4) and it contains detailed analysis report for each video frames such as Chainage, Frame Number, Frame Type (Frame with Distress, D or Frame without Distress, N), Total Distresses Area and Percentage of total distresses area in the frame (Area Extent) . The other report is called Kilometre or 100m Wise Report (Table 5) and it contains summary of the analysis report for each 100m road chainage / section. Besides, AutoDistress software was able to categorize all the frames in the video into two different categories and saved them in their respective folders viz. *frames with distress* and *frames without distress.*

Total processing time taken by the software on a pavement video clip having 552 frames was found to be only 3 to 4 minutes. The same sequence when analyzed frame by frame using a semi-automated software like ImageJ toolkit, an open source video image processing software was taken around 552 to 1104 minutes. The average processing time taken per frame by AutoDistress has been found to be 0.38 seconds while each frame has taken 90 seconds approximately when analyzed manually using ImageJ toolkit depending upon the number of distresses. Thus, we are able to save considerable time and manpower resources in processing of pavement video clips, using AutoDistress software. Much more savings can be done if we can afford a higher speed computer with a larger memory at a little extra cost.

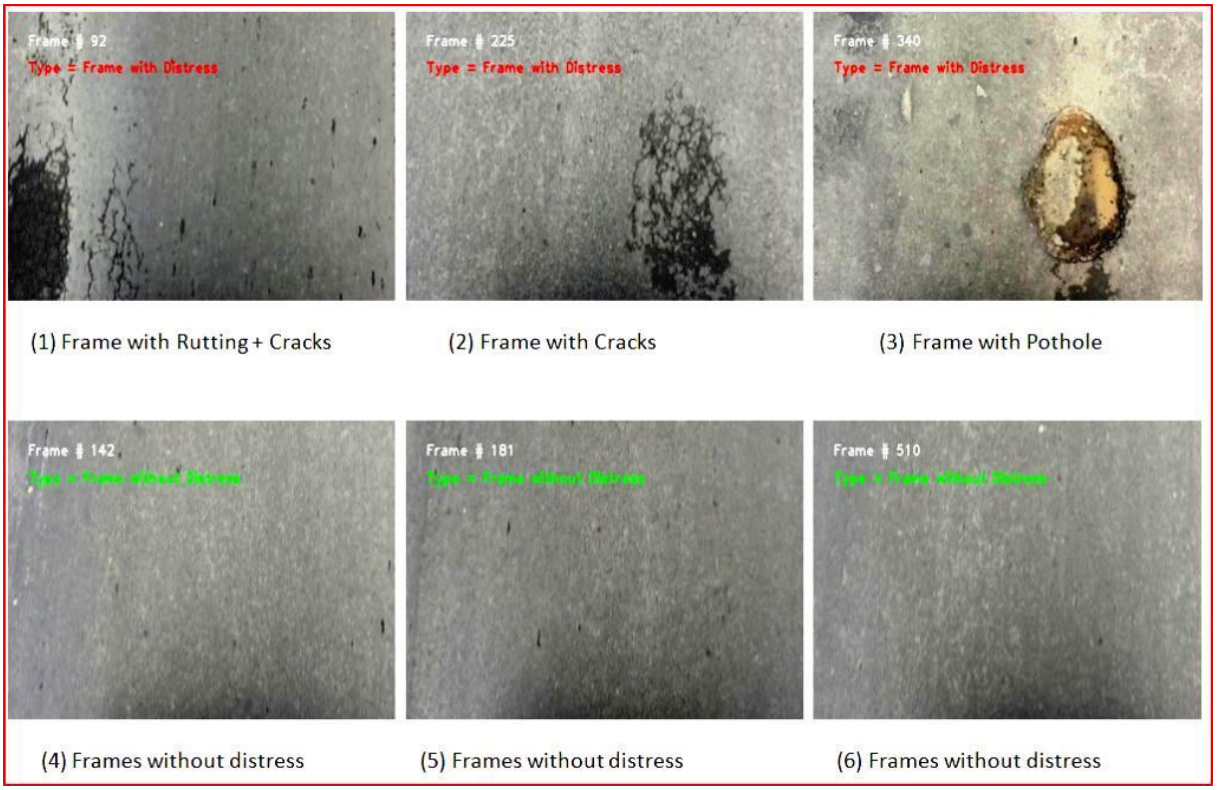
Further, AutoDistress software was able to retrieve frames with distress with accuracy up to 94%. Some examples of results obtained by AutoDistress are illustrated in Figure 4. However, the authors have observed some false detections and this has been mostly due to presence of shadows or images of trees, manholes, poles, vehicles and their parts in the video clips. Some of these features when distributed non-uniformly over the road surfaces, their shapes and sizes look very similar to that of potholes in the video images. The total number of false detections found in *frames with distress* folder was 15 frames only while the total number of false detections found in *frames without distress* was 18 frames only.

TABLE 4 Video frame wise report generated automatically by AutoDistress software

	A	B	C	D	E	F	G	H	I	J
1	Start of Report Generation....									
2	Date : 3-8-2016									
3	Time : 7:43:37									
4	File PathC:\Users\betq\Desktop\Pavement-XE-Mayailambi-WagonR\0047.avi									
5										
6	Chainage(m	Frame Count	Frame Type (D=	Object Area(sq m)	Area Extent(%)					
7	2	1	D	0.012118	0.29585		Overall information:			
8	4	2	D	0.016398	0.400342					
9	6	3	D	0.013095	0.319702		Total No. Of Frames=552			
10	8	4	D	0.018212	0.444629		Frames with Distress=91			
11	10	5	D	0.018277	0.446216		Frames without Distress=461			
12	12	6	D	0.019262	0.470264		% Of Frame With Distress=16.485507			
13	14	7	D	0.012088	0.295117		Distress Area(sq m)=0.933535			
14	16	8	D	0.007515	0.183472		PCI=3			
15	18	9	D	0.012991	0.317163		End of Report Generation....			
16	20	10	D	0.02286	0.558105		Date : 3-8-2016			
17	22	11	D	0.013402	0.327197		Time : 7:47:31			
18	24	12	N	0.002075	0.050659					
19	26	13	N	0.000304	0.007422					
20	28	14	N	0.000584	0.014258					
21	30	15	N	0.000735	0.017944					
22	32	16	N	0.002385	0.058228					
23	34	17	N	0.000632	0.01543					
24	36	18	N	0.000476	0.011621					
25	38	19	N	0.000414	0.010107					
26	40	20	N	0.000927	0.022632					
27	42	21	N	0.001598	0.039014					
28	44	22	N	0.001996	0.04873					
29	46	23	D	0.004982	0.121631					
30	48	24	D	0.004971	0.121362					
31	50	25	D	0.00506	0.123535					

TABLE 5 100m wise report generated automatically by AutoDistress software

	A	B	C	D	E	F
1	Start of Report Generation....					
2	Date : 3-8-2016					
3	Time : 7:43:37					
4	File PathC:\Users\betq\Desktop\Pavement-XE-Mayailambi-WagonR\0047.avi					
5						
6	Km	Frame Nos.	Frames with Distress	Distress Area(sq m)	Extent(%)	PCI
7	0.1	01 to 50	31	0.279375	62	1
8	0.2	51 to 100	3	0.047637	6	4
9	0.3	101 to 150	5	0.030331	10	3
10	0.4	151 to 200	3	0.021039	6	4
11	0.5	201 to 250	9	0.051064	18	3
12	0.6	251 to 300	2	0.009884	4	4
13	0.7	301 to 350	2	0.04518	4	4
14	0.8	351 to 400	15	0.269126	30	2
15	0.9	401 to 450	11	0.103732	22	3
16	1	451 to 500	8	0.059312	16	3
17	1.1	501 to 550	2	0.016855	4	4
18						
19	Overall information:					
20						
21	Total No. Of Frames=552					
22	Frames with Distress=91					
23	Frames without Distress=461					
24	% Of Frame With Distress=16.485507					
25	Distress Area(sq m)=0.933535					
26	End of Report Generation....					
27	Date : 3-8-2016					
28	Time : 7:47:31					
29						



(1) Frame with Rutting + Cracks (2) Frame with Cracks (3) Frame with Pothole

(4) Frames without distress (5) Frames without distress (6) Frames without distress

FIGURE 4 Examples of video frames processed by AutoDistress software

4. CONCLUSIONS AND FUTURE WORK

In this paper, authors proposed a new methodology for automated estimation of PCI for PMGSY roads using pavement videos. Using the proposed methodology, geo-tagged pavement view video of a PMGSY road in Manipur state was captured without any artificial lighting systems using BETQ PARSS-2016. Then, the collected raw video was processed automatically using BETQ AutoDistress software for accurate estimation of PCI rating using pavement distress information extracted out of the pavement video. The test results indicated that the proposed methodology has a significant capability in estimating PCI rating automatically as well as its further verification in less time and effort. And the proposed methodology for automation in PCI rating can be readily applied in professional practice as a reliable and accurate approach. This will enables us to save a considerable amount of time, money and resources in qualitative assessment of road networks in India. Further, use of video imaging based road survey equipment for pavement condition survey is found to be more objective, speedy and accurate as compared to the traditional field inspection method and it also gives a powerful and effective data collection, visualization and verification whenever / wherever required.

In future, the proposed methodology will be extended to the automated estimation of new road condition rating which is being formulated for PMGSY roads. Unlike PCI, the new road condition rating provides a three point numerical ratings for the condition of road sections within the road network, where 1 is the poor condition, 2 is the fair condition and 3 is the good condition.

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