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Evaluation of Road Safety for Roundabout and Signalized Intersection

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Abstract**:** ***Traditional intersections have always caused accidents. There are numerous geometric intersection designs that best fit each situation. This study performed an operational and safety comparison with different intersection like signalized, unsignalized and roundabout to decrease the overall travel delay & collision at intersection and increase the safety using case study. This dissertation describes the application of the traffic conflict technique to estimate, traffic safety at intersections. Using data collected from surveys, traffic frequency and severity standards for signalized and roundabout have been established. The methodologies are developed incorporating the relative importance of different severity of different safety indices at intersection. The relative importance (weights) of very low, low, medium and high severity condition is developed using data collection and expert opinions experience people which have knowledge in development/safety development at intersection were obtained by conducting a survey. A questionnaire was prepared to obtain the relative importance of different severity of different parameter performance. The weights are developed in such a way that their values lie between 0 and 1. In proposed work design safety parameter for intersection for enhancement of safety at intersections and all safety design is implemented on MATLAB and analysis of the geometrical design for vehicle system in the intersection by MATLAB, analyses, the status of confliction and desired value obtained by comparison of actual value with available geometric designs and to enhance the safety at intersection and explores methods to solve the problem of collision at intersections. In this paper evaluate safety parameter of roundabout. .***

Keywords **:** ***Road safety, Roundabout Intersection, Signalized Intersection, Traffic Survey***

I. INTRODUCTION

Road accidents are clearly the most frequent and major cause of damage to human lives. The severity of road accidents, measured in terms of number of persons killed per 100 accidents has increased from 28.5 in 2014, to 29.1 in 2015 (MORTH, 2015).India has only 1 % of total vehicles across globally but it has 10 percent of total deaths (Times of India 2012). The reason behind this scenario is extremely dense road traffic, lack of planning and implementation in accordance to safety factors (proper geometric design, environmental conditions and traffic rules). More than half of road accidents occur at Roundabout. This has given a thrust to redesigning of the existing Roundabout. In a recent study in America (by FHWA) it was found that out of total fatal and injury crashes 56.7% of it took place at intersections, and on an average 53.5% crashes of all crashes took place at Roundabout only. In India this data ranges between 30%-35%. And in Australia 43% of urban crashes and 11% of rural crashes are at intersections.

Vehicles moving in different directions, as well as pedestrians (wanting to cross the road) might try to occupy same space at the same time. Hence, to avoid accidents and improve overall efficiency, it is necessary to reduce this conflict for space. The conflict can be reduced by intelligent design of intersections based on evaluation of safety factors. Implementation and continued success of road-intersections depend on improved understanding of major safety factors. These factors include- traffic control devices, road and Roundabout geometry, driver behaviour, light and heavy vehicle characteristics, behaviour and requirements of other road users, traffic flow characteristics and operation of traffic control to resolve vehicle to vehicle conflicts (as well as vehicle to pedestrian conflicts). Optimization of above mentioned factors improve traffic and pedestrian safety, operational performance, environment and aesthetics. e.

II. METHODOLOGY BASED FRAMEWORK FOR ROUNDABOUT

In this section, framework for roundabouts based on the above methodology is presented in brief (similar process, applied to un-signalized intersection, is already discussed in more detail). As per the methodology, the framework is developed in four stages.

Stage I: Development of a Hierarchical Structure to Identify Safety Factors Affecting Safety at Roundabout.

For roundabouts, twelve safety factors have been identified and classified. This has been done through questionnaires answered by experts and road users.

Stage II: Determination of Relative Importance of Identified Safety Factors

In case of roundabout, it has been found that the following safety factors have higher impact on the overall safety index- height of central-island, speed of moving vehicles, and non-motorized transport compositions. This has been determined through study of literature, observation and inputs from experts and ordinary road users.

Stage III: Developing Assessment Tool (SIEM) For Evaluation of Overall Safety of Roundabout.

Formula for computing safety index values for each of the twelve safety factors is developed. These safety indices are used to compute the overall safety factor of the roundabout. The formula for the overall safety factor of roundabout is as follows:

$$RSI = \sum_{i=1}^{i=n} RSFI_i \quad \text{……Equation 1}$$

Where:

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RSI =. Overall safety index for the given roundabout
$RSFI_i$ = Roundabout safety factor index for i^{th} safety factor

Stage IV: Evaluation of Overall Safety Index, Safety Optimization and Ranking of Roundabouts using SIEM

For the given roundabout case-study, SIEM is used to evaluate the safety indices to identify following safety factors to be modified to bring the overall safety factor value to acceptable range- adequate approach width, traffic signs, approach sight distance, and absence of cross-walk. Safety factors identified for modification, by SIEM varies from one case to another.

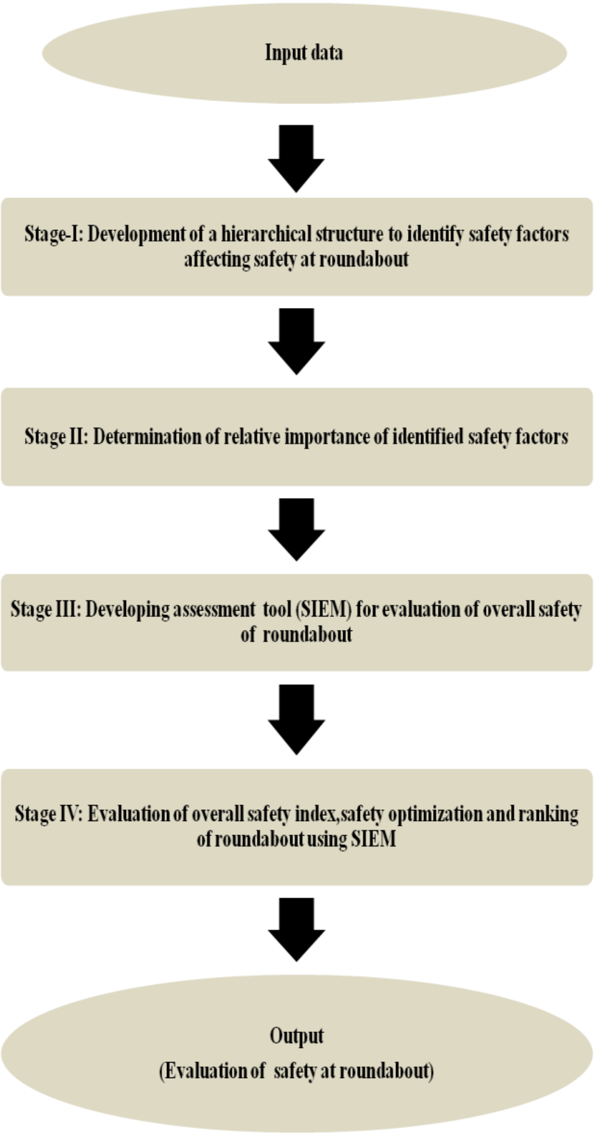

Figure 1: Methodology based framework for evaluation of overall safety index at roundabout

Traffic operational safety hazardous condition includes circulatory stream characteristics and safety furniture deficiency. In which circulatory stream characteristics is decomposed in two factors i.e. Relative speeds of entering and circulating vehicles and traffic composition. And also safety furniture deficiency is classified in 3 factors i.e. inadequate pedestrian's facilities, traffic signs and poor lighting. In this level, factor related to pedestrian safety is further categorized in 3 factors i.e. Absence of cross walk, minimum width of Pedestrian Island, and pedestrian volume.

Table 1: List of identified Roundabout Safety Hazardous Components

S. No.	Safety Component ID	Safety Component	Notation
1.	RSFI-1	Diameter of Central Island	IDCI
2.	RSFI -2	Height of Central Island	IHCI
3.	RSFI -3	Approach Width	IAW
4.	RSFI -4	Entry Angle	IEA
5.	RSFI -5	Entry Radius	IER
6.	RSFI -6	Approach Sight Distance	ASD
7.	RSFI -7	Splitter Island	ASI
8.	RSFI -8	Relative speed of Entering and Circulating Vehicles	RSECV
9.	RSFI -9	Slow Moving Vehicle Composition	SMVC
10	RSFI -10	Non-Motorized Transport Composition	NMTC
11	RSFI -11	Traffic Signs	TS
12	RSFI -12	Cross Walk	ACW
13	RSFI -13	Minimum Width of Pedestrian Island	MWPI
14	RSFI -14	Pedestrian Volume	PV
15	RSFI -15	Lighting	PL

III. ANALYSIS OF THREE DIFFERENT ROUNDABOUTS

Table 2 Input data for identified roundabout intersections RAI_1, RAI_2, RAI_3

S. No.	Safety Component ID	Safety Component	Notation	Ploy.(weight)	Mata Mandir.(weight)	P&T.(weight)
1.	RSFI-1	Diameter of Central Island	IDCI	0.2759	0.9474	0.2333
2.	RSFI-2	Height of Central Island	IHCI	0.10	0.35	0.25
3.	RSFI-3	Approach Width	IAW	0.5286	0.7143	0.3143
4.	RSFI-4	Entry Angle	IEA	0.33	0.5667	1.45
5.	RSFI-5	Entry Radius	IER	0.15	0	0.05
6.	RSFI-6	Approach Sight Distance	ASD	0.53	0.3667	0.7
7.	RSFI-7	Splitter Island	ASI	0	0.25	0.25
8.	RSFI-8	Relative speed of Entering and Circulating Vehicles	RSECV	2.833	2.27	1.7857
9.	RSFI-11	Traffic Signs	TS	0.6250	1	0.75
10	RSFI-12	Cross Walk	ACW	1	1	1
11	RSFI-13	Minimum Width of Pedestrian Island	MWPI	0.1667	0.4167	0.2917
12	RSFI-14	Poor Lighting	PL	0.3125	0.0625	0.3125

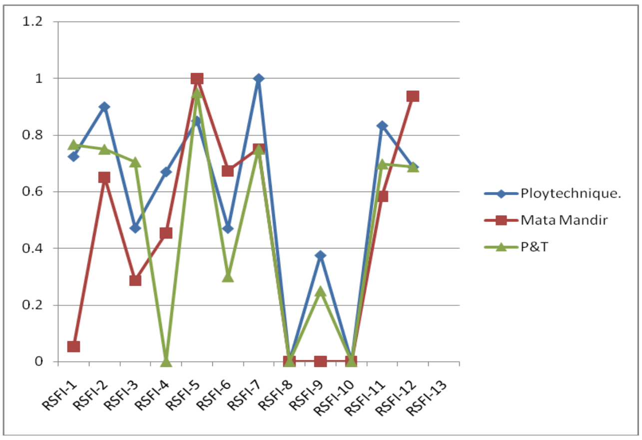

Figure 2 Comparison of different values of various safety indices between RAI_1, RAI_2, and RAI_3.

This section presents the comparison of the results of level of safety at identified roundabout intersections based on the overall safety Indices determined in pervious section. Table 1 shows the results obtained using developed methodology and figure 2 presents the rank of three identified roundabout intersections on the basis of result obtained using developed methodology.

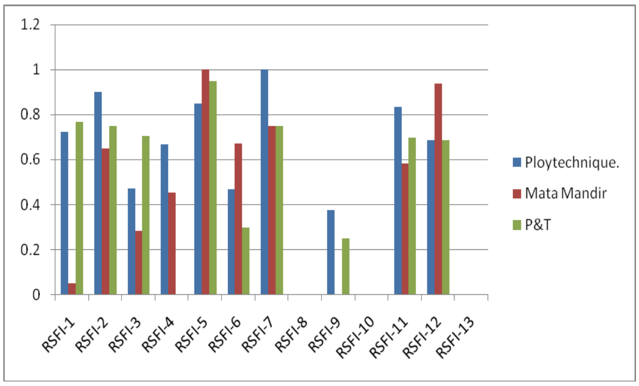

Figure 3 Bar chart Representation of different values of various safety indices between RSA_1, RSA_2, and RSA_3.

Above Figure presents the bar chart comparison of the results of level of safety at identified roundabout intersections based on the overall safety index determined in pervious section. Table 1shows the results obtained using developed methodology and figure 3 presents the rank of three identified roundabout intersections on the basis of result obtained using developed methodology.

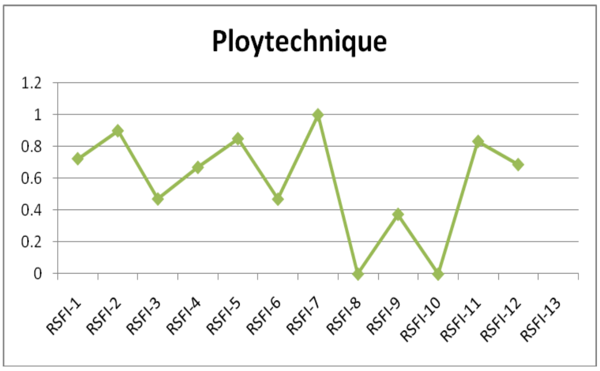

Figure 4 Representation of Available values of various safety parameter of Polytechnique Square (RSA_2),

Figure 4 presents the Available value of safety parameter identified roundabout intersections on the basis of result obtained using developed methodology for the Polytechnique square.

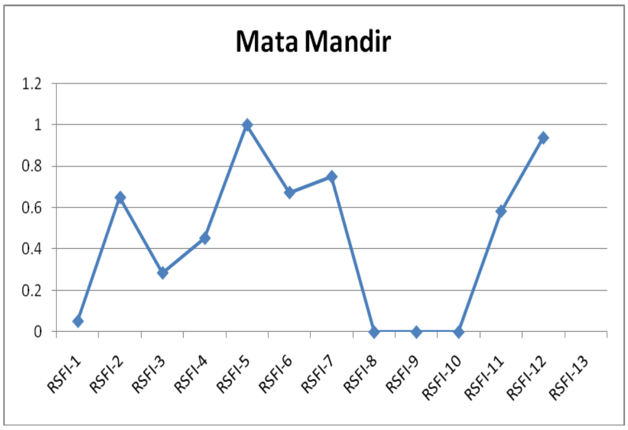

Figure 5 Representation of Available values of various safety parameter of Mata Mandir Square (RSA1),.

Figure 5 presents the Available value of safety parameter identified roundabout intersections on the basis of result obtained using developed methodology for the Mata Mandir Square.

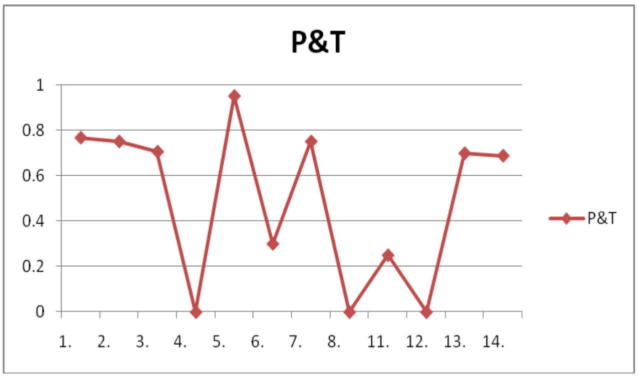

Figure 6 Representation of Available values of various safety parameter of P&T Square (RSA3),

Figure 6 presents the Available value of safety parameter identified roundabout intersections on the basis of result obtained using developed methodology for the P& T Square.

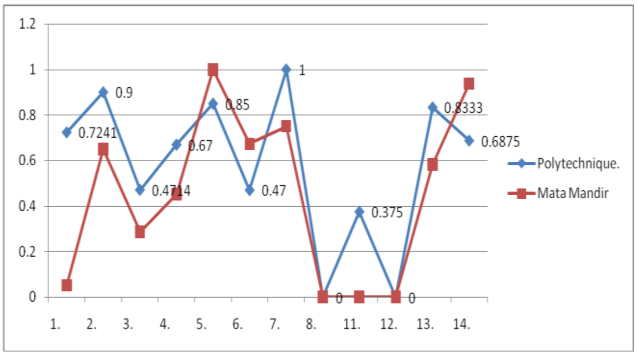

Figure 7 Comparison of different values of various Available safety indices between RAI1, & RAI2.

Figure 7 presents the Comparison of different values of various Available safety indices between roundabout intersections on the basis of result obtained using developed methodology for the polytechnique Square & Mata Mandir Square.

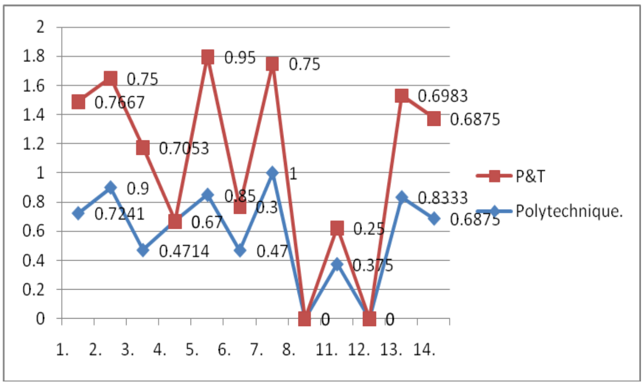

Figure 8 Comparison of different values of various Available safety iparameter between RAI1, & RAI3.

Figure 8 presents the Comparison of different values of various Available safety indices between roundabout intersections on the basis of result obtained using developed methodology for the polytechnique Square & P&T Square.

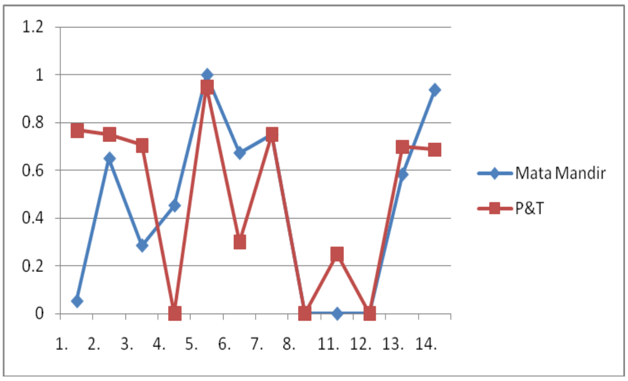

Figure 9 Comparison of different values of various Available safety indices between RAI2, & RAI3.

Figure 9 presents the Comparison of different values of various Available safety indices between roundabout intersections on the basis of result obtained using developed methodology for the P&T Square & Mata Mandir Square.

Table 3 Input data for identified roundabout intersections RAI1, RAI2, RAI and change data

S. No.	Safety Component ID	Notation	Ploy.	Change	Mata Mandir	Change	P&T	Change
1.	RSFI-1	IDCI	0.7241	0.741	0.0526	0.731	0.7667	0.7667
2.	RSFI-2	IHCI	0.9	0.9	0.65	0.65	0.75	0.75
3.	RSFI-3	IAW	0.4714	0.8571 (8)	0.2857	0.8571 (8)	0.7053	0.8571 (8)
4.	RSFI-4	IEA	0.67	0.67	0.4533	0.72	0	0.83

5.	RSFI-5	IER	0.85	0.85	1	1	0.95	0.95
6.	RSFI-6	ASD	0.47	0.67(40)	0.6733	0.6733	0.3	0.77(40)
7.	RSFI-7	ASI	1	1	0.75	0.75	0.75	0.75
8.	RSFI-8	RSECV	0	0	0	0	0	0
11.	RSFI-9	TS	0.375	0.5(4),0.75(6)	0	,0.75(6)	0.25	0.75(6)
12.	RSFI-10	ACW	0	0.75(3)	0	0.75(3)	0	0.75(3)
13.	RSFI-11	MWPI	0.8333	0.8333	0.5833	0.58	0.6983	0.698
14.	RSFI-12	PL	0.6875	0.6875	0.9375	0.9375	0.6875	0.687

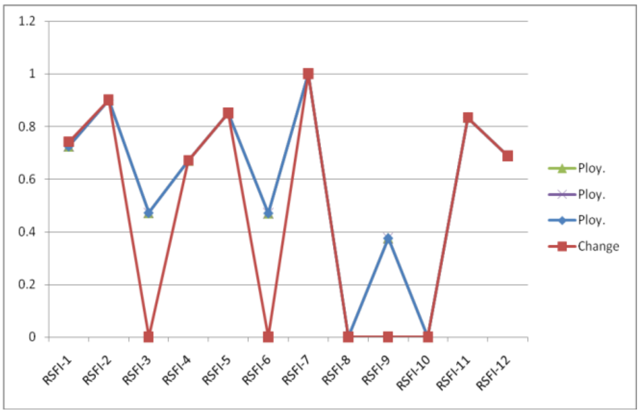

Figure 10 Desired Value of safety indices applied on Polytechnique roundabout

Figure 10 presents the Comparison of different values of various desired value for all safety indices between roundabout intersections on the basis of result obtained using developed methodology, for the polytechnique Square.

Mean while we are calculate signalized intersection and compare it with round about

Table 4 Input data for identified signalized intersection

S. No.	Safety Component ID	Notation	Desired value	Available Value		
				(I)	(II)	(III)
				Board Office Square (SI1)	Jyoti Talkies Square (SI2)	TT Nagar Tiraha (SI3)
1	SSFI-1	GM	12	10	9	10
2	SSFI-2	IEA	60	60	50	45
3	SSFI-3	IER	40	31	29	26
4	SSFI-4	LOS	80	60	50	30
5	SSFI-5	PL	20	15	10	8
8	SSFI-6	TS	14	12	10	8
9	SSFI-7	ACW	8	8	3	3
10	SSFI-8	NS	1	0	0	0.5
6	SSFI-9	SMVC				
7	SSFI-10	NMTC				

IV. CONCLUSION

In this paper, the process of development of framework for roundabout intersections have been given. The development of framework is based on the methodology described earlier. The framework is implemented over MATLAB to give Safety Index Evaluation Method (SIEM) software. SIEM improves the overall safety of intersections optimally and ranks the intersections on the basis of their overall safety index. Same process will follow on signalized intersection and compare it.

REFERENCES

1. G 1. Agarwal, P, K, (2005), "Road Condition Evaluation, Prioritization and Optimal Resource Allocation for Highway Maintenance at Network Level", Ph.D. Thesis, Indian Institute of Technology Kanpur, India.
2. Agrawal, S, Jain, S. S. and Parida, M. (2004), "Development of Pavement Management System for Indian National Highway Network" Journal of Indian Roads Congress, pp 271-326.
3. Agrawal, S, Jain, S. S. and Parida, M. (2005), "HDM-4 Pavement Deterioration Models for Indian National Highway Network" Journal of Transportation Engineering, ASCE, 131(TE8), pp 623-631.
4. Ahmed A. , Sadullah A. F. M., Yahya A. S., (2015) "Evaluating The Contribution Of Physical Parameters On The Safety Of Unsignalized Intersections", Journal of Engineering Science and Technology, Vol. 10, No. 5 654 – 666,
5. Ahmed A., Sadullah Mohd, Yahyaa Ahmad shukri, (2013)"Accident Analysis Using Count Data for Unsignalized Intersections in Malaysia", Fourth International Symposium on Infrastructure Engineering in Developing Countries, Procedia Engineering 77 (2014) 45 – 52, IEDC,
6. Ali, H. A. and Tayabji, S. D. (1998), "Evaluation of Mechanistic Empirical Performance Prediction Models for Flexible Pavements," Transportation Research Record 1629, Transportation Research Board, National Research Council, Washington, D.C., pp.169–180.

7. AL-Mansour, A. (1999), "Development of Pavement Performance Models for Riyadh Streets Network" Transportation Research Board (TRB), No.1655.
8. AL-Mansour, A. (2004), "Flexible Pavement Distress Prediction Model for the City of Riyadh, Saudi Arabia" Emirates Journal for Engineering Research, 9(1), pp 81– 88.
9. Al-Suleiman T., Al-Bandoura F.A., "Traffic safety at roundabouts in Urban Areas - Case Study in Jordan", Jordan University of Science & Technology, Irbid- 22110-Jordan, available on https://www.ncbi.nlm.nih.gov/pubmed/10576672.
10. American Association of State and Highway Transportation Officials, (1993), "AASHTO Guide for Design of Pavement Structures", Washington, D.C.
11. American Association of State Highway and Transportation Officials, (2001), "AASHTO Pavement Management Guide", Washington D.C.
12. American Association of State Highways and Transportation Officials (1981), AASHTO Interim Guide for Design of Pavement Structures, AASHTO, Washington, D.C.
13. Arndt K. Owen and Troutbeck J.Rod, "Relationship between Roundabout geometry and Accidents rates", International Symposium on Highway Geometric Design Practices, Issue Number: E-C003, Publisher: Transportation Research Board, ISSN: 0097-8515, 2000, available on http://worldcat.org/issn/00978515.
14. Bausano, J. P., Chatti, K., and Williams, R. C., (2004), "Determining Life Expectancy of Preventive Maintenance Fixes for Asphalt-Surfaced Pavements", Transportation Research Record: Journal of the Transportation Research Board, No. 1866, TRB, National Research Council, Washington, D.C. ,pp. 1-8.
15. Bhawsar U, Agarwal P.K, TR Beevi R, Khan A.B., "Evaluation of Road Safety Hazardous Conditions in a Road Network", Civil and Environmental Research (I.F- 5.52), 2015.
16. Caleb N. A, Dario J. C and John L. N, (2009), "Subsurface Drainage Manual for Pavements in Minnesota" Minnesota Department of Transportation, Minnesota.
17. California Department of Transportation, (2008), "Maintenance Technical Advisory Guide Volume I – Flexible Pavement Preservation" 2nd Edition, Office of Pavement Preservation, Division of Maintenance, Sacramento, CA.
18. Carey, W.N and Irick, P.E, (1960), "The Pavement Serviceability Performance Concept", Highway Research Bulletin 250, Highway Research Board, Washington D.C., pp. 40-58.
19. Cedergren, H.R, (1973), "Development of Guidelines for the Design of Subsurface Drainage Systems for Highway Pavement Structural Section", Report No. FHWA RD 73-14 Federal Highway Administration.
20. Cedergren, H.R, (1988), "Why all Important Pavements Should be Well Drained" Transportation Research Record 1188, Transportation Research Board, National Research Council, Washington, D.C., pp. 56-62.
21. Central Road Research Institute, (1993) Pavement Performance Study: Study on Existing Pavement Sections, Final Report Volume II, New Delhi, India.
22. Central Road Research Institute, (1993), Pavement Performance Study: Study on Existing Pavement Sections, Final Report, Volume I, New Delhi, India.
23. Central Road Research Institute, (1994), "Pavement Performance Study on Existing Pavement Sections", Final Report, CRRI, New Delhi.
24. Chakroborty, P and Das, A, (2003), "Principles of Transportation Engineering" Prentice Hall of India, New Delhi.
25. Chakroborty, P., Agarwal, K.A., and Das, A. (2006), "Simple Model to Predict the
26. Chen, Chen, Jason C. Anderson, Haizhong Wang, Yinhai Wang, Rachel Vogt, and Salvador Hernandez. "How bicycle level of traffic stress correlate with reported cyclist accidents injury severities: A geospatial and mixed logit analysis." Accident Analysis & Prevention 108 (2017): 234-24
27. Chhalotre R.K., Joshi Y. P., "An Evaluation of Rotary Intersection: A Case Study of Prabhat Square Raisen Road Bhopal", IJEDR | Volume 4, Issue 3 | ISSN: 2321-9939, 2016, available on https://www.ijedr.org/papers/IJEDR1603016.pdf.
28. Christopher, B.R., and McGuffey, V.C.C, (1997), "Pavement Subsurface Drainage Systems." NCHRP Synthesis of Highway Practice 239, Transportation National Research Council Washington, D.C.
29. Darter, M.I., (1980), "Requirements for Reliable Predictive Pavement Models", Transportation Research Record, 766, pp. 25-31.
30. Das, A., and Pandey, B.B. (1999), "Mechanistic-Empirical Design of Bituminous Roads: An Indian Perspective" Journal of Transportation Engineering, 125(5), pp 463-471.
31. Dawkins Janine M, ten Ham D, Farquharson W., "Comparative Evaluation of Roundabouts with other Intersection Control Methods in the Island of Jamaica". National Roundabout Conference 2008, Kansas City, Missouri.
32. Diefenderfer B.K, Galal K, and Mokarem D.W, (2005), Report on Effect of Subsurface Drainage on the Structural Capacity of Flexible Pavement", Virginia Transportation Research Council, Virginia Department of Transportation, Richmond, VA.
33. Federal Highway Administration, (2003), "Distress Identification Manual for the Long Term Pavement Performance Program" Publication Number FHWA-RD-03-031, U.S Department of Transportation.
34. Federal Highway Administration, FHWA (1973), "Guidelines for the Design of Subsurface Draining Systems for Highway Structural Sections" U.S Department of Transportation.
35. Forsyth, R.A, Wells, G.K., and Woodstrom, J.H. (1987), "The Economic Impact of the Pavement Subsurface Drainage." Transportation Research Record 1121, Transportation Research Board, National Research Council. Washington, D.C.
36. Gendreau, M. and Soriano, P. (1998), ''Airport Pavement Management Systems: An Appraisal of Existing Methodologies." Transportation Research Part A, 32(3), pp 197–214.
37. George, K.P., Rajagopal, A.S. and Lim, L.K. (1989), "Model for Predicting Pavement Deterioration", Transportation Research Board Report 1215, Transportation Research Board, National Research Council (National Academy Press: Washington D.C.), pp. 1-7.
38. Gharaibeh N G, Freeman T, Wimsatt A, and Zou Y (2011), "Report on Evaluation and Development of Pavement Scores, Performance Models and Needs Estimates", Texas Transportation Institute, the Texas A&M University System College Station, Texas, USA.
39. Gharaibeh N G, Zou, Y and Saliminejad S, (2010), "Assessing the Agreement Among Pavement Condition Indexes" Journal of Transportation Engineering, Vol. 136, No. 8, pp 765-772.
40. Gillespie T. D., M. W. Sayers, and L. Segel (1980), "Calibration of Response-Type Road Roughness Measuring System", National Cooperative Highway Research Program, Report 228, Transportation Research Board, Washington, D.C.
41. Global Status Report on Road Safety- Time foe Action, Department of Violence & Injury Prevention & Disability (VIP), World Health Organization, 2008, available on http://whqlibdoc.who.int/publications/2009/9789241563840_eng.pdf.
42. Golroo A and Tighe S L, (2010), "Developing an Overall Combined Condition Index for Pervious Concrete Pavements Using a Specific Panel Rating Method", 89th Annual Meeting of the Transportation Research Board, Washington, D.C.

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