CHAPTER 9

RANKING OF BITUMINOUS MIXES

9.1 Preamble

Previous chapters assessed the performance of various bituminous mixes against several distresses. It was observed that it is difficult to rank the overall suitability of various mixes since the mix which performs well in a particular type of distress might perform poorly against the other. At present, there is no methodology that can be used for the logical prediction of the overall suitability of the mixes. Hence, a novel ranking method is proposed in this chapter to determine overall suitability ranking of all sixteen types of mixes, based on their laboratory results and possible field conditions. It would be helpful for the designers and field engineers to choose the most optimum type of filler and its content in the bituminous mix.

9.2 Details of Ranking Methodology

Testing of bituminous mixes in various aspects was done to estimate its suitability in that particular aspect (e.g., rutting). However, based on the obtained set of test results, it was very difficult to identify the mix, which should be considered as "best" in overall aspects. The term "best" is relative, and it not only depends on the properties of the material but also by the field conditions on the pavement site (Saboo et al., 2018). The bituminous mix that gives the best performance against particular distress (e.g., rutting) does not necessarily deliver similar performance against another distress (e.g., moisture sensitivity). Hence, it is critical to identify the crucial distresses in every scenario, and then select the best filler which forms distress resistant mix. For instance, in the scenario of possible waterlogging, it is logical to give priority to the filler which form moisture resistant mixes with higher OBC over the filler which creates moisture susceptible mixes with lower OBC (much more economical). However, in case of arid regions with little or no rainfall, it is logical to choose filler which creates economical mixes. Hence, the designer must give suitable priority to each bituminous mix property to choose the overall best filler. This study proposed a simple methodology based on this principle to rank various mixes based on different test results of bituminous mixes. The brief outline of the method is provided below.

Step I: Representation of test results in form of parameter matrix

In this study, the performance of the 16 types of mixes (4 fillers × 4 filler contents) was assessed in 9 different primary test parameters (OBC, Marshall stability, Marshall quotient, indirect tensile strength, tensile strength ratio, active adhesion, passive adhesion, fatigue life, and Cantabro loss). The resilient modulus was not taken in the analysis since it was used in the calculation of pavement layer thickness and not in its performance assessment against any distress. Similarly, ageing indices were not taken in the analysis since ageing doesn't directly responsible for any distress. These results were represented in the form of a table or matrix of order 16×9, in which each cell represented an individual test result ($R_{m,t}$) (1<m<16 and 1<t<9) obtained in the corresponding test. The representative parameter matrix and the actual test matrix is shown in Table 9.1 and 9.2, respectively.

Step II: Preparation of normalized parameter matrix

It is commonly known that different tests generate results with different units (e.g., kN and seconds in case of Marshall Stability and active adhesion respectively), and hence there was a need to normalize all values to a standard scale. Each result value

($R_{m,t}$) was normalized using the Equation 9.1. The normalized matrix is shown Table 9.3.

$$NV_{m,t} = \frac{R_{m,t} - \min R_{m,t}}{\max R_{m,t} - \min R_{m,t}} \times 100 \quad [9.1]$$

Where $NV_{m,t}$ = Normalized result value

$R_{m,t}$ = Test result obtained experimentally in a particular test

max$R_{m,t}$ = Maximum test result value

min$R_{m,t}$ = Minimum test result value

Step III: Assessment of possible field conditions and assigning priorities

Apart from material properties, external factors like traffic loading and environmental conditions also influence the performance of bituminous mixes. To consider the effect of these factors, sixteen different hypothetical scenarios were assumed by varying external parameters namely, vehicular load, traffic intensity, average pavement temperature, and rainfall intensity. Every factor is subdivided into two categories (high and low) to cover a wide spectrum of possible scenarios. P_H indicated that the pavement site in consideration has the average ambient temperature greater than or equal to 40ºC. At this temperature, the rutting is one of the most predominant distresses. Similarly, P_L specified the pavement site which has average ambient temperature lower than or equal to 10ºC. At this temperature, fatigue and low temperature cracking can be considered as dominant modes of pavement failure. Average annual rainfall intensity greater than 1200 mm is assumed as average high rainfall intensity (R_H), while average annual rainfall intensity lower than 1000 mm is categorized as average low rainfall intensity (R_L) (MoRTH, 2013).

A failure such as rutting is majorly observed in places having a predominance of overloaded vehicles (vehicles having a gross weight higher than legal limits). Hence, average heavy vehicle loading (V_H) is assumed as pavements having a predominance of overloaded vehicles, while, average low vehicle loading (V_L) is assumed in places having a predominance of vehicles way below than legal load limits. Finally, high traffic intensity (T_H) and low traffic intensity (T_L) is assumed in places having traffic intensity higher than 6000 and lower than 3000 commercial vehicles per day, respectively. For instance, $P_LR_LV_LT_L$ signifies field conditions having with low ambient temperature, low average rainfall, low average vehicle loading, and low traffic intensity. Hence assuming every possible hypothetical scenario based on variation in each external factor, sixteen different possible scenarios were observed.

To determine the ranking of each mix it is necessary for a designer to assign priority value for each test. This priority was given to each test using priority value (P_t) ($1 \leq t \leq 9$). P_t is an integer that should start from 1 and whose maximum value was always less than or equal to 9. Test having lower P was assigned the higher priority and vice versa. The assignment of the priority to a particular test was done as per logical judgment of the designer. This could be understood by the following example. For instance, in case of $P_LR_LV_LT_L$, there is a very low possibility of failure due to rutting and overloading due to the lesser vehicle loading and lower average pavement temperature, hence lower priority values were assigned to Marshall Quotient and Marshall stability values. Similarly, lower priority values were assigned to tensile strength ratio and passive adhesion test results, because of lower possibility of moisture damage due to low rainfall. However, there is a relatively higher possibility of low temperature cracking due to low ambient temperature, hence higher priority amongst all parameters was given to fatigue life and indirect tensile strength. The priority values assigned in all cases were displayed in Table 9.4.

Step IV: Calculation of Weightage Factors (*F*)

Based on the assigned *P* value, another parameter known as the weightage factor (*F*) was calculated for each test as per Equation 9.2.

$$F_t = \frac{P_i}{\sum_{i=1}^{9} P_i} \qquad [9.2]$$

In some cases, it was required to assign the same priority to two test parameters (P_t=P_{t+p}). In such cases, the same *F* values were yielded to both test parameters as per Equation 9.2. In the foregoing expression, ΣF_t =1. In cases where the higher value of test result represented the superior mixes (Marshall stability, Marshall Quotient, indirect tensile strength, tensile strength ratio, passive adhesion, and fatigue life), weighing factor calculated as per Equation 9.2 is taken in analysis. However, in situations where lower test values represented a better mix (OBC, active adhesion, and Cantabro loss), the reciprocal of the obtained weightage factor was used.

Step V: Calculation of Ranked Values (*RV*) and Total Rank Values (*TRV*)

Depending upon the assigned priority and the calculated weightage factor, the rank value (*RV*) for each test parameter of every mix was determined as:

$$RV_{mt} = \frac{NV_{m,t}}{F_i} \qquad [7.3]$$

Where, $NV_{m,t}$ is the Normalized result value of each parameter (1<*m*<16 and 1<*t*<9)

The summation of *RV* of all 9 test parameters can be termed as the total rank value (TRV_m)

$$TRV_m = \sum RV_{m,t} \qquad [7.4]$$

The mixes having higher *TRV* values are ranked as superior and vice versa. The assignment of priority values, calculation of weightage factor, and calculation of *RV* and *TRV* values for $P_LR_LV_LT_L$ case is shown in Table 9.5. Similar to $P_LR_LV_LT_L$, different set of priority values were assigned for other cases, which in turn generated the other set of *TRV* values. In "*n*" different possible cases produce "*n*" different sets of *TRV* values for each mix. In this study, there are a total of 16 different cases, so, 16 sets of *TRV* values were calculated and shown in Table 9.6.

Step VI: Calculation of Global Total Rank Values ($GTRV$)

Finally, the summation of all "*n*" different *TRV* values was done as follows:

$$GTRV = \sum_{i=1}^{i=n} TRV_i \qquad [7.5]$$

Where, $GTRV$ is termed as global test rank value of each mix, based on "*n*" different sets of priorities. In this study, summation of all sixteen set of *TRV* values gave the *GTRV* of all mixes. The magnitude of *GTRV* was used to compare the overall performance of mixes in a much logical manner, in which mix having higher *GTRV* value corresponded to superior performance/ranking and vice versa.

Table 9.1 Table showing representative parameter matrix

Type of Mix	Test Parameters								
	OBC	Marshall Stability	Marshall Quotient	Indirect Tensile Strength	Tensile Strength Ratio	Active Adhesion	Passive Adhesion	Fatigue Life	Cantabro Loss
SD 4	$R_{1,1}$	$R_{1,2}$	$R_{1,3}$	$R_{1,4}$	$R_{1,5}$	$R_{1,6}$	$R_{1,7}$	$R_{1,8}$	$R_{1,9}$
SD 5.5	$R_{2,1}$	$R_{2,2}$	$R_{2,3}$	$R_{2,4}$	$R_{2,5}$	$R_{2,6}$	$R_{2,7}$	$R_{2,8}$	$R_{2,9}$
SD 7	$R_{3,1}$	$R_{3,2}$	$R_{3,3}$	$R_{3,4}$	$R_{3,5}$	$R_{3,6}$	$R_{3,7}$	$R_{3,8}$	$R_{3,9}$
SD 8.5	$R_{4,1}$	$R_{4,2}$	$R_{4,3}$	$R_{4,4}$	$R_{4,5}$	$R_{4,6}$	$R_{4,7}$	$R_{4,8}$	$R_{4,9}$
GP 4	$R_{5,1}$	$R_{5,2}$	$R_{5,3}$	$R_{5,4}$	$R_{5,5}$	$R_{5,6}$	$R_{5,7}$	$R_{5,8}$	$R_{5,9}$
GP 5.5	$R_{6,1}$	$R_{6,2}$	$R_{6,3}$	$R_{6,4}$	$R_{6,5}$	$R_{6,6}$	$R_{6,7}$	$R_{6,8}$	$R_{6,9}$
GP 7	$R_{7,1}$	$R_{7,2}$	$R_{7,3}$	$R_{7,4}$	$R_{7,5}$	$R_{7,6}$	$R_{7,7}$	$R_{7,8}$	$R_{7,9}$
GP 8.5	$R_{8,1}$	$R_{8,2}$	$R_{8,3}$	$R_{8,4}$	$R_{8,5}$	$R_{8,6}$	$R_{8,7}$	$R_{8,8}$	$R_{8,9}$
KS 4	$R_{9,1}$	$R_{9,2}$	$R_{9,3}$	$R_{9,4}$	$R_{9,5}$	$R_{9,6}$	$R_{9,7}$	$R_{9,8}$	$R_{9,9}$
KS 5.5	$R_{10,1}$	$R_{10,2}$	$R_{10,3}$	$R_{10,4}$	$R_{10,5}$	$R_{10,6}$	$R_{10,7}$	$R_{10,8}$	$R_{10,9}$
KS 7	$R_{11,1}$	$R_{11,2}$	$R_{11,3}$	$R_{11,4}$	$R_{11,5}$	$R_{11,6}$	$R_{11,7}$	$R_{11,8}$	$R_{11,9}$
KS 8.5	$R_{12,1}$	$R_{12,2}$	$R_{12,3}$	$R_{12,4}$	$R_{12,5}$	$R_{12,6}$	$R_{12,7}$	$R_{12,8}$	$R_{12,9}$
GL 4	$R_{13,1}$	$R_{13,2}$	$R_{13,3}$	$R_{13,2}$	$R_{13,5}$	$R_{13,6}$	$R_{13,7}$	$R_{13,8}$	$R_{13,9}$
GL 5.5	$R_{14,1}$	$R_{14,2}$	$R_{14,3}$	$R_{14,4}$	$R_{14,5}$	$R_{14,6}$	$R_{14,7}$	$R_{14,8}$	$R_{14,9}$
GL 7	$R_{15,1}$	$R_{15,2}$	$R_{15,3}$	$R_{15,4}$	$R_{15,5}$	$R_{15,6}$	$R_{15,7}$	$R_{15,8}$	$R_{15,9}$
GL 8.5	$R_{16,1}$	$R_{16,2}$	$R_{16,3}$	$R_{16,4}$	$R_{16,5}$	$R_{16,6}$	$R_{16,7}$	$R_{16,8}$	$R_{16,9}$

Table 9.2 Table representing test results of this study

Type of mix	Test parameters								
	OBC (%)	Marshall stability (kN)	Marshall quotient (kN/mm)	Indirect tensile strength (kPa)	Tensile strength ratio (%)	Active adhesion (s)	Passive adhesion (%)	Fatigue life (cycles)	Cantabro loss (%)
SD 4	6.20	12.22	3.57	2614	94.23	84	100	2491	4.74
SD 5.5	5.95	13.99	3.96	2774	93.28	89	100	4201	3.86
SD 7	5.38	15.96	4.57	3124	89.26	97	97	6036	3.42
SD 8.5	5.34	16.58	5.16	3312	85.59	108	93	6964	5.32
GP 4	6.03	12.98	3.38	2964	54.05	107	75	4324	3.94
GP 5.5	5.81	13.46	4.24	3108	39.47	133	68	5932	3.56
GP 7	5.48	14.93	4.66	3452	17.65	153	55	6432	5.16
GP 8.5	5.26	14.52	4.93	3654	9.18	192	42	5321	5.84
KS 4	5.96	12.65	4.45	2823	93.82	82	100	3551	3.16
KS 5.5	5.53	14.42	4.91	3156	91.34	91	100	5391	2.34
KS 7	4.98	15.60	5.19	3542	86.65	102	95	7022	4.27
KS 8.5	4.89	16.34	5.74	3694	83.87	126	92	6481	6.23
GL 4	5.65	14.32	3.77	3024	88.58	90	95	4971	4.22
GL 5.5	5.38	15.04	4.61	3392	85.34	120	85	6326	4.00
GL 7	5.12	16.78	5.10	3712	81.12	142	82	7422	5.75
GL 8.5	5.05	16.10	5.64	3796	71.27	183	68	6886	5.95

Table 9.3 Normalized parameter matrix

Type of Mix	Test parameters								
	OBC	Marshall stability	Marshall quotient	Indirect tensile strength	Tensile strength ratio	Active adhesion	Passive adhesion	Fatigue life	Cantabro loss
SD 4	0.125	0.000	0.422	0.000	16.000	0.002	16.000	0.000	0.077
SD 5.5	0.101	2.070	1.304	2.166	15.821	0.008	16.000	5.549	0.049
SD 7	0.047	4.374	2.687	6.904	15.065	0.017	15.172	11.503	0.035
SD 8.5	0.043	5.099	4.010	9.448	14.375	0.029	14.069	14.514	0.096
GP 4	0.109	0.889	0.000	4.738	8.441	0.028	9.103	5.948	0.051
GP 5.5	0.088	1.450	1.932	6.687	5.698	0.058	7.172	11.165	0.039
GP 7	0.056	3.170	2.887	11.343	1.593	0.081	3.586	12.788	0.091
GP 8.5	0.035	2.690	3.508	14.078	0.000	0.125	0.000	9.183	0.112
KS 4	0.102	0.503	2.420	2.829	15.923	0.000	16.000	3.439	0.026
KS 5.5	0.061	2.573	3.462	7.337	15.456	0.010	16.000	9.410	0.000
KS 7	0.009	3.953	4.077	12.562	14.574	0.023	14.621	14.702	0.062
KS 8.5	0.000	4.819	5.333	14.619	14.051	0.050	13.793	12.947	0.125
GL 4	0.073	2.456	0.882	5.550	14.937	0.009	14.621	8.047	0.060
GL 5.5	0.047	3.298	2.782	10.531	14.328	0.044	11.862	12.444	0.053
GL 7	0.022	5.333	3.882	14.863	13.534	0.069	11.034	16.000	0.110
GL 8.5	0.015	4.538	5.103	16.000	11.681	0.116	7.172	14.261	0.116

Table 9.4 Priority assigned to various tests in different cases

Case No	Case	Priority Assigned								
		OBC	Marshall stability	Marshall quotient	Indirect tensile strength	Tensile strength ratio	Active adhesion	Passive adhesion	Fatigue life	Cantabro loss
1	$P_LR_LV_LT_L$	2	2	3	1	3	2	3	1	2
2	$P_LR_LV_LT_H$	2	2	3	1	3	2	3	1	2
3	$P_LR_LV_HT_L$	2	1	1	1	3	2	3	1	2
4	$P_LR_LV_HT_H$	2	1	1	1	3	2	3	1	2
5	$P_HR_LV_LT_L$	2	1	1	3	3	3	3	3	3
6	$P_HR_LV_LT_H$	2	1	1	1	3	3	3	1	3
7	$P_HR_LV_HT_L$	2	1	1	3	3	3	3	3	3
8	$P_HR_LV_HT_H$	2	1	1	1	3	3	3	1	3
9	$P_HR_HV_HT_H$	2	1	1	1	1	2	1	1	2
10	$P_HR_HV_HT_L$	2	1	1	2	1	3	1	2	3
11	$P_HR_HV_LT_H$	3	2	2	1	1	2	1	1	2
12	$P_HR_HV_LT_L$	3	2	2	3	1	2	1	3	2
13	$P_LR_HV_HT_H$	3	1	2	1	1	2	1	1	2
14	$P_LR_HV_HT_L$	3	1	2	2	1	2	1	2	2
15	$P_LR_HV_LT_H$	3	2	2	1	1	2	1	1	2
16	$P_LR_HV_LT_H$	2	3	3	1	1	2	1	1	2

Table 9.5 Weightage factors and Total Rank Value (TRV) for case $P_L R_L V_L T_L$

Priority Value (P) assigned by designer	2	2	3	1	3	2	3	1	2	TRV
Weightage Factor (F) calculated	0.105	0.105	0.158	0.053	0.158	0.105	0.158	0.053	0.105	
Type of Mix	Calculate Rank Values (RV) of different mixes correspond to different test parameters									
	OBC	Marshall stability	Marshall quotient	Indirect tensile strength	Tensile strength ratio	Active adhesion	Passive adhesion	Fatigue life	Cantabro loss	
SD 4	0.105	0.000	0.501	0.000	6.333	0.002	6.333	0.000	0.065	13.340
SD 5.5	0.085	3.688	1.549	2.572	6.263	0.007	6.333	6.589	0.041	27.126
SD 7	0.039	7.792	3.190	8.198	5.963	0.014	6.006	13.660	0.029	44.892
SD 8.5	0.036	9.083	4.762	11.220	5.690	0.025	5.569	17.235	0.081	53.701
GP 4	0.092	1.583	0.000	5.626	3.341	0.024	3.603	7.063	0.043	21.376
GP 5.5	0.074	2.583	2.294	7.941	2.256	0.049	2.839	13.259	0.033	31.328
GP 7	0.047	5.646	3.429	13.470	0.631	0.068	1.420	15.185	0.076	39.972
GP 8.5	0.030	4.792	4.165	16.717	0.000	0.105	0.000	10.904	0.095	36.809
KS 4	0.086	0.896	2.873	3.360	6.303	0.000	6.333	4.084	0.022	23.958
KS 5.5	0.051	4.583	4.111	8.712	6.118	0.009	6.333	11.174	0.000	41.092
KS 7	0.007	7.042	4.842	14.917	5.769	0.019	5.787	17.459	0.052	55.894
KS 8.5	0.000	8.583	6.333	17.360	5.562	0.042	5.460	15.374	0.105	58.820
GL 4	0.061	4.375	1.047	6.591	5.913	0.008	5.787	9.556	0.051	33.388
GL 5.5	0.039	5.875	3.303	12.506	5.671	0.037	4.695	14.777	0.045	46.949
GL 7	0.018	9.500	4.610	17.650	5.357	0.058	4.368	19.000	0.092	60.653
GL 8.5	0.013	8.083	6.060	19.000	4.624	0.097	2.839	16.935	0.098	57.749

Table 9.6 TRV values and Global Total Rank Values (GTRV) values of different mixes

Type of Mix	TRV values in all 16 cases																Final GTRV
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
SD 4	13.34	13.34	12.14	12.14	16.59	13.64	16.59	13.64	25.22	33.51	30.88	38.98	28.86	32.90	30.88	32.63	365
SD 5.5	27.13	27.13	28.60	28.60	32.18	32.17	32.18	32.17	37.46	45.99	42.03	47.03	41.98	44.05	42.03	43.07	584
SD 7	44.89	44.89	49.77	49.77	51.51	55.99	51.51	55.99	52.50	60.75	55.66	55.87	57.71	56.72	55.66	55.80	855
SD 8.5	53.70	53.70	60.94	60.94	61.76	68.57	61.76	68.57	60.03	67.98	62.14	59.65	64.72	61.93	62.14	61.68	990
GP 4	21.38	21.38	19.39	19.39	16.77	21.80	16.77	21.80	23.42	25.78	27.97	26.85	27.31	25.80	27.97	29.31	353
GP 5.5	31.33	31.33	32.47	32.47	28.20	36.53	28.20	36.53	30.90	32.18	33.80	28.57	33.49	29.27	33.80	34.29	513
GP 7	39.97	39.97	44.26	44.26	38.65	49.81	38.65	49.81	35.91	35.73	36.27	26.71	38.05	31.34	36.27	35.60	621
GP 8.5	36.81	36.81	42.13	42.13	36.51	47.43	36.51	47.43	31.75	30.61	30.83	20.49	32.35	25.25	30.83	29.73	558
KS 4	23.96	23.96	25.81	25.81	29.66	29.01	29.66	29.01	35.39	43.97	40.11	45.75	38.12	40.38	40.11	41.24	542
KS 5.5	41.09	41.09	45.41	45.41	47.04	51.07	47.04	51.07	49.83	58.01	53.79	54.82	53.59	52.84	53.79	54.31	800
KS 7	55.89	55.89	61.18	61.18	59.10	68.84	59.10	68.84	60.54	67.05	64.33	59.85	65.24	60.90	64.33	64.58	997
KS 8.5	58.82	58.82	67.48	67.48	67.46	75.95	67.46	75.95	64.63	72.35	66.41	62.21	68.33	64.26	66.41	65.74	1070
GL 4	33.39	33.39	33.61	33.61	33.68	37.80	33.68	37.80	40.07	46.55	45.34	46.58	45.57	45.23	45.34	46.63	638
GL 5.5	46.95	46.95	50.09	50.09	47.75	56.36	47.75	56.36	50.74	56.11	54.82	51.17	55.52	51.91	54.82	55.39	833
GL 7	60.65	60.65	66.90	66.90	63.63	75.29	63.63	75.29	62.58	67.94	65.15	57.98	67.84	62.03	65.15	64.85	1046
GL 8.5	57.75	57.75	65.72	65.72	62.55	73.98	62.55	73.98	58.86	63.27	59.87	51.75	61.88	55.51	59.87	59.00	990

9.3 Ranking of Various Mixes

Based on the obtained *GTRV*, the final overall rankings of all mixes are given in Table 9.7. As per *GTRV* values, KS 8.5, GL 7 and KS 7 were proven to be amongst the three best performing mixes. All these mixes not only exhibited better strength, rutting, fatigue and cracking resistance, but also showed satisfactory moisture sensitivity, active adhesion, Cantabro loss at a relatively lower OBC. This was attributed to their fine nature and due to presence of adhesion promoter minerals like Calcite and Portlandite in their composition. GP 8.5, SD 4, and GP 7 were amongst the worst performing mix. Although GP mixes displayed good resistance against rutting, fatigue, and cracking than convention SD mixes, they also displayed abysmal performance in terms of moisture sensitivity and adhesions due to high silica content. They might be beneficially used in the regions having arid climates. It seemed that the utilization of fillers in large quantity (7 and 8.5%) produced bituminous mixes with overall superior performance. However, it is essential to choose the appropriate type of filler to ensure satisfactory performance of mixes.

Table 9.7 Overall ranking of various mixes

Type of Mix	GTRV	Ranking
KS 8.5	1070	1
GL 7	1046	2
KS 7	997	3
SD 8.5	990	4
GL 8.5	990	5
SD 7	855	6
GL 5.5	833	7
KS 5.5	800	8
GL 4	638	9
GP 7	621	10
SD 5.5	584	11
GP 8.5	558	12
KS 4	542	13
GP 5.5	513	14
SD 4	365	15
GP 4	353	16

9.4 Summary

This section proposed a novel ranking method assess based on the experimental properties of the mixes and priorities assigned by the designer, to assess overall suitability of bituminous mixes. This procedure of the method was explained and method was adopted to rank all sixteen types of mixes based on their overall performance. The final ranking suggested that the mixes prepared with KS and GL at higher filler contents deliver much superior performance than conventional SD mixes. On the other hand, GP mixes displayed overall poor performance. The proposed method can also be used by other researchers to analyze the other types of mixes.