SERIES 2 - TRANSPORTATION

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Gravity Model-
Applications in Regional Transport Planning

Institute of Town Planners, India

Haryana Regional Chapter

Panchkula

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Preface

The present study is fifth study conducted by ITPI-HRC to foster the objectives of research. The objective of the study is to use Gravity Model in Regional Transport Planning and it presents a method to quantify interaction between towns with Haryana as a case study. The interaction is used to identify the traffic load on roads for augmentation purposes and to suggest the inter town public/private transportation requirements/ rationale. It also touches upon the need to rationalize the urban form according to the interaction pattern. I am sure that the present study will be a useful document for policy makers.

I am thankful to Ms. Rajdeep Kaur, Research Associate HRC for her outstanding work. I am also thankful to Sh. Raj Vir Singh for his guidance as a research guide and all the members of ITPI HRC who have made valuable contributions to this study.

(Nadim Akhtar)

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CHAPTER - 1

INTRODUCTION

Interaction is the movement over space resulting from human process. It includes movement of goods and people and transmission through telecommunication/digital technology. There have been a lot of studies and attempts to quantify this interaction. Gravity models are the most widely used types of interaction models. They are mathematical formulations that are used to analyze and forecast spatial interaction patterns. These models are of fundamental importance because they make explicit the idea of relative as opposed to absolute spatial location. All things on the face of the earth can be located in absolute terms by longitude and latitude coordinates, and the absolute position of things can be related to each other by reference to such coordinates. Distances can be specified in these absolute terms. It is then possible to talk about one location as being "thirty five kilometers from Panipat" and another as being "thirty five kilometers from Karnal." In absolute terms, these two locations are equal in that they are both thirty five kilometers from their urban area. In relative terms, however, these locations can be significantly different in a multitude of ways (for example in terms of access to shopping, access to job opportunities, access to museums and theaters, access to rural life-styles, or access to wilderness opportunities) . The gravity model allows us to measure explicitly such relative location concepts by integrating measures of distance with measures of relative scale, size or functions[1].

The importance of the relative location concept and spatial interaction can be seen in the application and refinement of the gravity model over the past fifty years. It is used by city planners, transportation analysis, retail location firms, shopping center investors, land developers, and urban social theorists. It is one of the earliest models to be applied in social sciences and continues to be used and extended. The reasons for these strong and continuing interests are easy to understand and stem from both theoretical and practical considerations.

The gravity model, which derives its name from an analogy to the gravitational interaction between planetary bodies, appears to capture and inter-relate at least two basic elements:

1 Haynes Kingsley and Fotheringham A. Stewart (1984), 'Gravity and Spatial Interaction Model', Beverly Hills, CA: Sage.

(1) scale impacts: for example, cities with large populations tend to generate and attract more activities than cities with small populations; and (2) distance impacts: for example, the farther places, people, or activities are apart, the less they interact.

These concepts are used by urban social analysts to explain why land values are high in the central areas of cities and at other easily accessible points (Hansen 1959) and why land values are higher in larger cities than in smaller cities. They are used to explain why some public service or retail locations attract more users or customers than do others and to explain the way in which shopping centers impact the areas about them in terms of traffic and customer flows. On a larger scale, they are used to explain the movement of population in the form of migrants, visitors, business and commercial travelers, and the movement of people and goods, information in the form of mail, telecommunications, and data transfers. In practical terms, these are important topics for many kinds of decision makers, both public and private A model that purports to reduce the risk in making large capital decisions related to these topics obviously is valuable.

1.1 GRAVITY MODEL: A CONCEPT

For decades, social scientists have been using a modified version of Newton's Law of Gravitation to predict movement of people, information and commodities between cities and even continents. The gravity model, as social scientists refer to the modified law of gravitation, takes into account the population size of two places and their distance. Since larger places attract people, ideas, and commodities more than smaller places and places closer together have a greater attraction. The gravity model incorporates these two features (population and distance)[2].

Gravity Model is a mathematical model based on an analogy with Newton's gravitational law which has been used to account for aggregate human behaviors related to spatial interaction, mainly migration, traffic flows and shopping activities. Newton's law states that the attractive force between two bodies is directly related to their size and inversely related to the distance between them.

Thus, the interaction between settlements is measured using 'Gravity Model concept (Zipf,

2 Sink, Todd (2010), "Gravity Model." Encyclopedia of Geography, SAGE Publications retrieved from https://www.researchgate.net/publication/261175327 Gravity Model on February 8, 2017.

G .K, 1949 and Lloyd and Dikens, 1972). It states that the magnitude of movement between any two settlements will be directly proportional to the product of their 'mass' and inversely proportional to the distance between them.

Many scholars have attempted to develop theoretical models of city region on the basis of spatial interactions of population of urban centers and their retail trade and other economic activities. An example of such studies is one by Illeris who used a gravity model to measure the interaction between the centers and their surrounding areas. In a similar way Park used Reilly's Law of Gravitation in 1929-30 to define service areas of cities taking newspaper circulation as the criterion. Another type of effort in this line has been made to find the optimum location of hinterland boundaries. Such an approach has been used by Yeates who uses a linear programming function for deriving the boundaries of school district in U.S.A., although this type of study does have limitations in defining boundaries properly. It has significance in the fact that it helps to formulate a generalized picture of hinterland and city-region boundary.

It is seen that the gravity model has wide applications but has not been frequently used in studying the transport network at a regional scale for the purpose of evolving a suitable pattern of settlements commensurating with the existing transport network of rails and roads. On a regional scale, the interaction between the settlements can be quantified by traffic surveys and census. But these surveys and census have their own limitations. The transportation network between settlements is required to be broken up into numerous sections at a regional level and then traffic survey conducted on each of the section to assess the transportation load on that section. This requires the deployment of many surveyors and the traffic census is to be conducted over a period of time to mitigate the daily/seasonal variation in traffic volume. This inter alia requires heavy expenditure which can be overcome by application of the gravity model at a regional scale.

The application of gravity model is tested at the scale of the Haryana state for the purpose of road augmentation; inter town transportation frequency and urban form.

1.2 SCOPE:

The scope of the study is to quantify the pattern of interaction between A class (1 Lakh plus) towns of Haryana in terms of road linkage, to identify the traffic load on roads for augmentation purposes and to suggest the inter town public/private transportation requirements/rationale. It also touches upon the need to rationalize the urban form according to the interaction pattern.

1.3 INTERACTION PATTERN AMONG 'A' CLASS TOWNS OF HARYANA

1.3.1 Methodology

It is presumed that all the towns are of similar characteristics for the purpose of interaction and the interaction depends upon their size of population. There cannot be any dispute about the fact that more people lead to more interaction and that the interaction decreases with the distance. For studying the interaction pattern among the A class (1 Lakh plus) towns of Haryana, gravity model is used as follows.

Gravity Model = P1 X P2 / D2

Where = P1 =Population of Town 1

P2=Population of Town 2

D2=Sq. of distance separating town1 and town 2

For analyzing the intensity of interaction of settlements with each other, interaction index is derived by multiplying the population of each settlement with the population of other and then dividing it with the square of the distance separating them. This exercise has been done for each settlement and thus an index is worked out, which shows the intensity of interaction of each settlement.

The population data used for deriving the interaction pattern has been taken from Census of India, 2011 and the shortest road distances between the settlements have been taken from the Google maps.

1.3.2 Interaction Pattern

For studying the interaction pattern in case of Haryana, 20 A class (1 Lakh plus) towns have been taken. Since, all towns have road and rail connectivity it is presumed that all the towns are equal in accessibility and have similar characteristics for the purpose of interaction which depends upon their population. Other than these settlements, interaction with major adjoining cities i.e. Delhi and Chandigarh have been also analyzed to come to know the relationship that exist among the settlements in general. The following table indicates the possible interaction pattern between the towns:

Table 1: Possible Interaction between the Towns

	Faridabad	Gurgaon	Rohtak	Hisar	Karnal	Panipat	Sonipat	Yamunanagar	Panchkula	Bhiwani	Ambala	Sirsa	Bahadurgarh	Jind	Thanesar	Kaithal	Rewari	Palwal	Jagadhari	Ambala Sadar	Delhi	Chandigarh
Faridabad	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Gurgaon		-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Rohtak			-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hisar				-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Karnal					-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Panipat						-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sonipat							-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Yamunanagar								-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Panchkula									-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Bhiwani										-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ambala											-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sirsa												-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Bahadurgarh													-	Y	Y	Y	Y	Y	Y	Y	Y	Y
Jind														-	Y	Y	Y	Y	Y	Y	Y	Y
Thanesar															-	Y	Y	Y	Y	Y	Y	Y
Kaithal																-	Y	Y	Y	Y	Y	Y
Rewari																	-	Y	Y	Y	Y	Y
Palwal																		-	Y	Y	Y	Y
Jagadhari																			-	Y	Y	Y
Ambala Sadar																				-	Y	Y
Delhi																					-	Y
Chandigarh																						-

Based on the above methodology the interaction between the towns is indicated in Annexure 1. It can be seen from the annexure that Faridabad-Delhi has the maximum interaction value of 127104 (in lakhs) whereas Rewari - Ambala Sadar and Palwal - Ambala Sadar has the minimum interaction value of 1 (in lakhs). A study of the table clearly indicates that population size of towns and distance between them plays a major role in the movement of goods and people. However, the interaction between the various towns by itself has no meaning until or unless it is applied to the existing road network.

1.3.3 Interaction Load on Road Sections

The data on the interaction between towns can be used to assess the existing geometry and status of the road viz a viz the volume of traffic on the road at different places. The analysis of the data will give a fair picture of the traffic load on different parts of the road and the road sections having high traffic load can be further investigated for improvement and augmentation. The roads having higher traffic load can be identified at a glance by this model.

Accordingly, to study the load of the traffic on the road, the interaction has been split into 53 road sections and the traffic load on each of the road section has been computed by aggregating the interaction values derived. For example, the interaction value between Faridabad-Sirsa is 30 (in lakhs) which has been loaded to the road intersections between Faridabad – Gurgaon – Bahadurgarh – Rohtak – Hisar - Sirsa sections. The interaction load on road section has been indicated on the following map (refer map 1).

It can be seen from the foregoing map that the interaction load has been divided into three categories of High, Medium and Low which have been categorized by dividing the total no. of interactions which are classified in the following table (refer table 2).

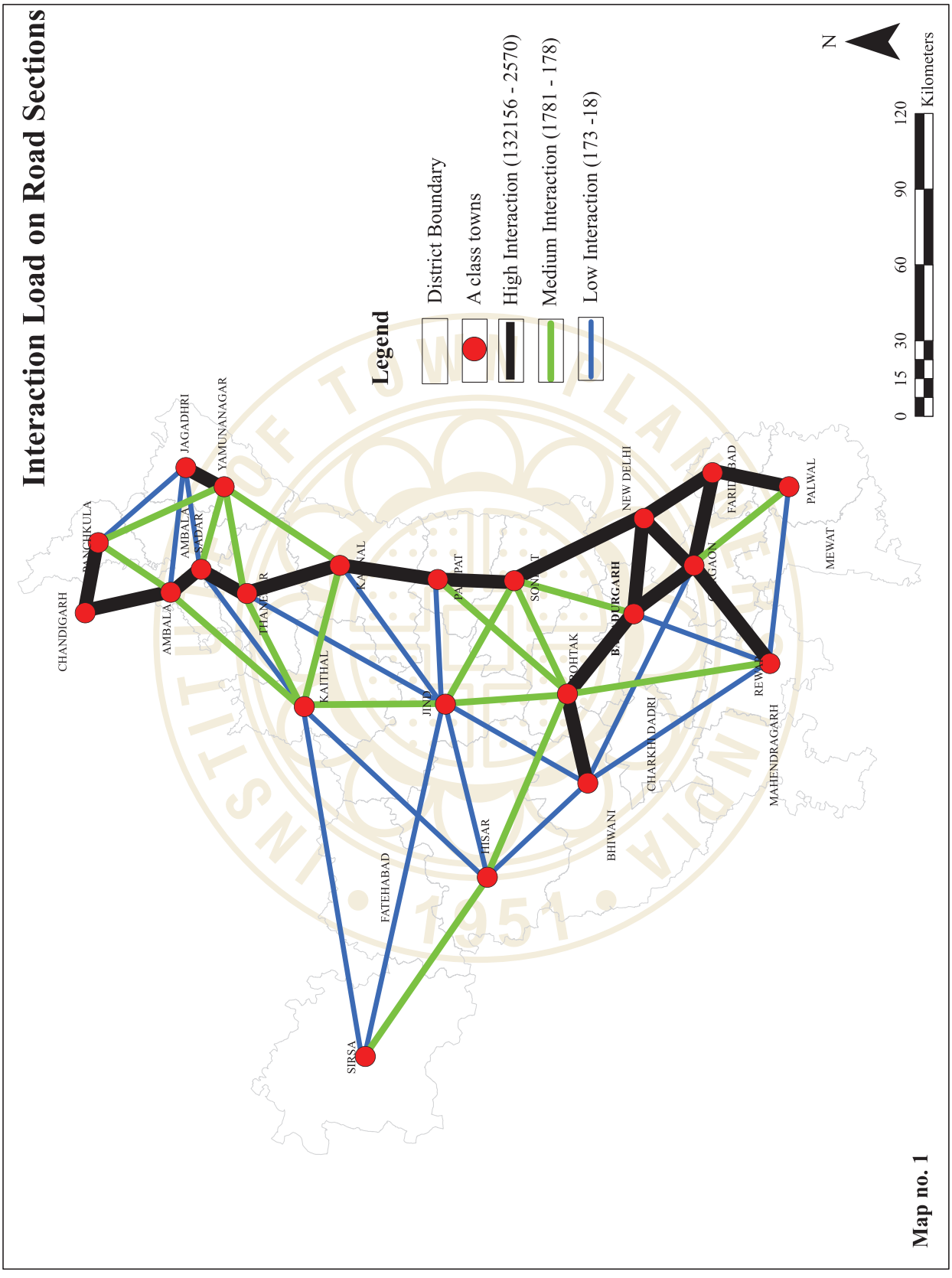
Interaction Load on Road Sections
Legend
District Boundary
A class towns
High Interaction (132156 - 2570)
Medium Interaction (1781 - 178)
Low Interaction (173 -18)
N
0 15 30 60 90 120
Kilometers
CHANDIGARH
PANCHKULA
JAGADHRI
YAMUNANAGAR
AMBALA
AMBALA CANTT
AMBALA SADAR
THANESAR
KAITHAL
KARNAL
PANIPAT
SONIPAT
NEW DELHI
GURGAON
FARIDABAD
PALWAL
MEWAT
ROHTAK
JHAJJAR
REWARI
MAHENDRAGARH
CHARKHI DADRI
BHIWANI
HISAR
FATEHABAD
SIRSA
Map no. 1

Table 2: Interaction Load on Road Interactions viz a viz Category

Sr. No.	Name and Category of Sections	Total Interaction
	High	
1	Faridabad-Delhi	132156
2	Gurgaon-Delhi	79432
3	Sonipat – Delhi	32145
4	Bahadurgarh- Delhi	31089
5	Chandigarh-Panchkula	20920
6	Faridabad- Gurgaon	12252
7	Karnal-Panipat	10487
8	Panipat – Sonipat	9957
9	Yamunanagar – Jagadhari	7830
10	Karnal –Thanesar	5526
11	Faridabad- Palwal	5346
12	Thanesar - Ambala Sadar	4539
13	Ambala - Ambala Sadar	4184
14	Gurgaon-Rewari	3411
15	Chandigarh-Ambala	3224
16	Rohtak-Bahadurgarh	3202
17	Rohtak-Bhiwani	2692
18	Gurgaon-Bahadurgarh	2570
	Medium	
19	Rohtak-Hisar	1781
20	Karnal- Yamunanagar	1621
21	Panchkula – Ambala	1578
22	Sonipat – Jind	939
23	Karnal –Kaithal	889
24	Rohtak-Panipat	647
25	Rohtak-Sonipat	508
26	Rohtak-Jind	469
27	Hisar-Sirsa	463
28	Gurgaon-Palwal	434
29	Sonipat – Bahadurgarh	350
30	Thanesar – Kaithal	261

31	Jind – Kaithal	249
32	Yamunanagar – Thanesar	245
33	Rohtak-Rewari	215
34	Yamunanagar - Ambala Sadar	184
35	Yamunanagar – Panchkula	180
36	Ambala –Kaithal	178
	Low	
37	Hisar-Jind	173
38	Hisar- Bhiwani	170
39	Hisar-Kaithal	163
40	Panipat – Jind	154
41	Bhiwani – Jind	140
42	Karnal –Jind	139
43	Gurgaon-Bhiwani	136
44	Sirsa – Kaithal	82
45	Ambala –Jagadhari	75
46	Jagadhari - Ambala Sadar	52
47	Bahadurgarh – Rewari	39
48	Sirsa – Jind	35
49	Panchkula –Jagadhari	34
50	Jind – Thanesar	32
51	Bhiwani – Rewari	28
52	Rewari –Palwal	28
53	Kaithal - Ambala Sadar	18

Source: Computed values

It can be seen from the above table that the towns surrounding Delhi and Chandigarh have high rate of interaction and therefore there is a strong need to frequently check the carrying capacity of the roads connecting these towns so as to augment the road network as soon as or before the need arises.

1.3.4 Frequency of Public Transport

At present, Haryana roadways, a public sector undertaking is engaged in the transportation of people. However, a look at the functioning of the Haryana roadways buses indicate

that there timings are not based on any operational research. Either the buses are over-crowded or run empty or in both the cases they incur operational losses. Similarly their direct settlement connectivity between A class towns is also missing.

The interaction between the towns can be further used to assess the need and requirement for public transport between these towns. The connectivity between the major towns depends upon the interaction between the towns. Therefore, the frequency of the bus service required have been fixed according to this interaction which is indicated in the Annexure 2. It can be seen from the annexure that each of the 22 towns are connected to each other and there frequency of bus service fixed according to their level of interaction. For example, the frequency of bus service between Bahadurgarh – Delhi having interaction value of 24924 (in lakhs) is fixed as 30 minutes or 24 buses per day and the frequency of bus service between Palwal – Ambala Sadar having interaction value 1 (in lakhs) is fixed as 11 hours 30 minutes or 1 bus per day. The bus frequency is fixed taking 12 operational hours and the bus frequency for the Gurgaon- Delhi; Faridabad- Delhi has not been specified due to the operation of Metro Rail System in these towns. The Metro rail System carries majority of the daily commuters and therefore the frequency of the bus service are required to be based on actual assessment of the traffic on the road.

Only inter connectivity between 22 towns has been established by the study with their bus frequencies. This connectivity is of primary order and the respective authorities can schedule their number of buses and timings to cover the other towns and villages of Haryana. It is once again reiterated that the number of scheduling of the buses done by this model should be retained and the other deployment should be subordinate to this major connectivity.

1.3.5 Evolving Urban Form

It is of common knowledge that town do not, normally expand in a circular manner. There is a natural tendency of expansion along the routes of accessibility and towards a particular side and direction. This fact is very often ignored while evolving the future urban form in planning. The sound planning principles establishes that planning is a process of regulating the natural growth and it not of controlling such natural tendencies. Study of the interaction between town and empirical verification has shown that the towns tend to grow in the

direction of maximum interaction. For example, Faridabad, Gurgaon and Bahadurgarh have maximum interaction with Delhi and therefore they have grown and touched the boundary of Delhi instead of growing in opposite direction. Similarly, if we take the case of Jind it has tendency to grow more or less in all directions due to almost similar interaction with the surroundings towns. Therefore, while evolving an urban form for planning major landuses, the interaction with the surrounding towns should invariably kept in mind.

1.4 CONCLUSION

The application of models in urban and regional planning is not a recent phenomenon but they have not been used extensively. Very often, subjective judgments are taken to arrive at the planning proposals and remedies on the ground. For example, it can easily be said that NH-1 from Delhi-Ambala is heavily loaded with traffic. But, it is pertinent to find out that the different traffic load on various sections of this road for suitable localized remedies and augmentation. Traffic survey in this regard is time consuming and expensive for which the used model is an effective remedy. Since, there are no precedents on the application of the gravity model to assess and augment road transportation; this attempt can be improved further by professional urban and regional planners.

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ANNEXURE 1

1. Interaction Value Among 'A' Class Towns of Haryana

Sr. no.	Interaction	Population of 1st town	Population of 2nd town	Distance (in Kms)	Distance (sq.)	Interaction (in lakhs)
1	Faridabad - Delhi	1411050	11034555	35	1225	127104
2	Gurgaon - Delhi	886519	11034555	36	1296	75481
3	Bahadurgarh-Delhi	217071	11034555	31	961	24924
4	Sonipat-Delhi	295970	11034555	39	1521	21472
5	Panchkula-Chandigarh	302140	960787	12	144	20159
6	Faridabad - Gurgaon	1414050	886519	34	1156	10844
7	Yamunanagar - Jagadhari	217071	124894	6	36	7530
8	Palwal -Delhi	124894	11034555	66	4356	3163
9	Rewari -Delhi	211355	11034555	91	8281	2816
10	Karnal - Delhi	374292	11034555	126	15876	2601
11	Rohtak-Delhi	131926	11034555	76	5776	2520
12	Panipat-Delhi	170767	11034555	92	8464	2226
13	Bhiwani-Delhi	307024	11034555	124	15376	2203
14	Faridabad- Palwal	1414050	131926	30	900	2072
15	Chandigarh - Delhi	960787	11034555	251	63001	1682
16	Ambala - Ambala Sadar	195153	104974	13	169	1212
17	Hisar-Delhi	289333	11034555	177	31329	1019
18	Jind-Delhi	155152	11034555	139	19321	886
19	Ambala-Chandigarh	167592	960787	45	2025	795
20	Thanesar-Delhi	195153	11034555	168	28224	762
21	Faridabad - Sonipat	1414050	289333	76	5776	708
22	Karnal - Panipat	302140	295970	37	1369	653
23	Gurgaon-Bahadurgarh	886519	170767	49	2401	630
24	Gurgaon -Sonipat	886519	289333	67	4489	571
25	Panchkula-Delhi	302140	11034555	247	61009	546
26	Jagadhari -Delhi	182534	11034555	195	38025	529
27	Gurgaon-Rohtak	886519	374292	81	6561	505
28	Kaithal-Delhi	144915	11034555	178	31684	504
29	Faridabad - Rohtak	1414050	374292	105	11025	480
30	Faridabad - Bahadurgarh	1414050	170767	71	5041	479
31	Yamunanagar-Delhi	143021	11034555	190	36100	437
32	Ambala-Delhi	167592	11034555	209	43681	423
33	Gurgaon -Palwal	886519	131926	54	2916	401
34	Rohtak - Sonipat	374292	289333	52	2704	400
35	Rohtak - Bahadurgarh	374292	170767	41	1681	380
36	Gurgaon -Rewari	886519	143021	58	3364	376
37	Chandigarh - Ambala Sadar	960787	104974	54	2916	345

38	Sonipat - Bahadurgarh	289333	170767	39	1521	324
39	Faridabad - Panipat	1414050	295970	116	13456	311
40	Sirsa-Delhi	196057	11034555	266	70756	305
41	Delhi - Ambala Sadar	11034555	104974	202	40804	283
42	Panipat - Sonipat	295970	289333	56	3136	273
43	Panchkula - Ambala	211355	195153	42	1764	233
44	Karnal - Thanesar	302140	155152	45	2025	231
45	Faridabad - Rewari	1414050	143021	96	9216	219
46	Rohtak - Bhiwani	374292	196057	59	3481	210
47	Rohtak - Panipat	374292	295970	76	5776	191
48	Karnal-Chandigarh	374292	960787	137	18769	191
49	Faridabad - Karnal	1414050	302140	150	22500	189
50	Gurgaon -Panipat	886519	295970	120	14400	182
51	Rohtak - Jind	374292	167592	59	3481	180
52	Thanesar-Chandigarh	195153	960787	102	10404	180
53	Jagadhari - Chandigarh	182534	960787	99	9801	178
54	Faridabad - Chandigarh	1411050	960787	291	84681	160
55	Karnal - Yamunanagar	302140	217071	64	4096	160
56	Hisar - Bhiwani	307024	196057	62	3844	156
57	Gurgaon -Bhiwani	886519	196057	113	12769	136
58	Yamunanagar - Thanesar	217071	155152	51	2601	129
59	Yamunanagar-Chandigarh	143021	960787	104	10816	127
60	Gurgaon -Karnal	886519	302140	154	23716	112
61	Karnal - Sonipat	302140	289333	89	7921	110
62	Faridabad - Hisar	1414050	307024	200	40000	108
63	Karnal - Kaithal	302140	144915	64	4096	106
64	Yamunanagar - Ambala	217071	195153	63	3969	106
65	Panipat - Jind	295970	167592	69	4761	104
66	Rohtak - Hisar	374292	307024	106	11236	102
67	Thanesar- Kaithal	155152	144915	47	2209	101
68	Gurgaon-Chandigarh	886519	960787	291	84681	100
69	Hisar - Jind	307024	167592	73	5329	96
70	Faridabad - Jind	1414050	167592	158	24964	94
71	Faridabad - Bhiwani	1414050	196057	173	29929	92
72	Gurgaon - Hisar	886519	307024	174	30276	89
73	Rohtak - Karnal	374292	302140	114	12996	87
74	Ambala - Thanesar	195153	155152	60	3600	84
75	Panchkula - Ambala Sadar	211355	104974	52	2704	82
76	Jind - Kaithal	167592	144915	55	3025	80
77	Karnal - Ambala	302140	195153	86	7396	79
78	Yamunanagar - Ambala Sadar	217071	104974	54	2916	78
79	Karnal - Jagadhari	302140	124894	70	4900	77
80	Ambala - Jagadhari	195153	124894	57	3249	75

81	Panipat - Thanesar	295970	155152	79	6241	73
82	Bhiwani - Jind	196057	167592	67	4489	73
83	Gurgaon - Jind	886519	167592	145	21025	70
84	Karnal - Jind	302140	167592	85	7225	70
85	Hisar - Sirsa	307024	182534	93	8649	64
86	Panipat - Yamunanagar	295970	217071	100	10000	64
87	Rohtak - Rewari	374292	143021	92	8464	63
88	Kaithal-Chandigarh	960787	144915	148	21904	63
89	Faridabad - Yamunanagar	1414050	217071	222	49284	62
90	Faridabad - Thanesar	1414050	155152	188	35344	62
91	Panipat - Kaithal	295970	144915	83	6889	62
92	Thanesar- Jagadhari	155152	124894	57	3249	59
93	Sonipat-Chandigarh	295970	960787	223	49729	57
94	Panipat-Chandigarh	170767	960787	171	29241	56
95	Thanesar- Ambala Sadar	155152	104974	54	2916	55
96	Yamunanagar - Panchkula	217071	211355	93	8649	53
97	Jagadhari - Ambala Sadar	124894	104974	50	2500	52
98	Hisar - Chandigarh	289333	960787	235	55225	50
99	Karnal - Ambala Sadar	302140	104974	80	6400	49
100	Faridabad - Ambala	1414050	195153	241	58081	47
101	Faridabad - Kaithal	1414050	144915	210	44100	46
102	Panipat - Bhiwani	295970	196057	113	12769	45
103	Sonipat - Jind	289333	167592	103	10609	45
104	Sonipat - Bhiwani	289333	196057	112	12544	45
105	Bhiwani - Bahadurgarh	196057	170767	87	7569	44
106	Ambala - Kaithal	195153	144915	81	6561	43
107	Karnal - Panchkula	302140	211355	124	15376	41
108	Faridabad - Panchkula	1414050	211355	272	73984	40
109	Gurgaon -Yamunanagar	886519	217071	217	47089	40
110	Rohtak - Kaithal	374292	144915	116	13456	40
111	Panipat - Ambala	295970	195153	120	14400	40
112	Hisar - Karnal	307024	302140	154	23716	39
113	Bahadurgarh - Rewari	170767	143021	79	6241	39
114	Hisar - Panipat	307024	295970	153	23409	38
115	Panipat - Bahadurgarh	295970	170767	115	13225	38
116	Bhiwani-Chandigarh	307024	960787	277	76729	38
117	Jind-Chandigarh	960787	155152	199	39601	37
118	Gurgaon -Thanesar	886519	155152	195	38025	36
119	Hisar - Kaithal	307024	144915	110	12100	36
120	Panchkula - Jagadhari	211355	124894	88	7744	34
121	Faridabad - Jagadhari	1414050	124894	228	51984	33
122	Hisar - Sonipat	307024	289333	164	26896	33
123	Sonipat - Palwal	289333	131926	106	11236	33

124	Yamunanagar - Kaithal	217071	144915	97	9409	33
125	Panchkula - Thanesar	211355	155152	99	9801	33
126	Panipat - Jagadhari	295970	124894	106	11236	32
127	Gurgaon -Kaithal	886519	144915	202	40804	31
128	Gurgaon - Ambala	886519	195153	236	55696	31
129	Faridabad - Sirsa	1414050	182534	291	84681	30
130	Sonipat - Rewari	289333	143021	117	13689	30
131	Sirsa-Chandigarh	196057	960787	251	63001	29
132	Faridabad - Ambala Sadar	1414050	104974	235	55225	26
133	Hisar - Bahadurgarh	307024	170767	142	20164	26
134	Sonipat - Yamunanagar	289333	217071	153	23409	26
135	Sonipat - Thanesar	289333	155152	131	17161	26
136	Bahadurgarh -Chandigarh	960787	217071	279	77841	26
137	Rohtak - Yamunanagar	374292	217071	179	32041	25
138	Karnal - Bhiwani	302140	196057	152	23104	25
139	Panipat - Panchkula	295970	211355	158	24964	25
140	Bahadurgarh - Jind	170767	167592	105	11025	25
141	Gurgaon - Panchkula	886519	211355	275	75625	24
142	Rohtak - Palwal	374292	131926	142	20164	24
143	Panipat - Ambala Sadar	295970	104974	113	12769	24
144	Jind - Thanesar	167592	155152	102	10404	24
145	Gurgaon - Sirsa	886519	182534	263	69169	23
146	Rohtak - Thanesar	374292	155152	158	24964	23
147	Gurgaon - Jagadhari	886519	124894	223	49729	22
148	Karnal - Bahadurgarh	302140	170767	154	23716	21
149	Sonipat - Kaithal	289333	144915	141	19881	21
150	Rohtak-Chandigarh	131926	960787	250	62500	20
151	Bhiwani - Rewari	196057	143021	117	13689	20
152	Rewari - Palwal	143021	131926	97	9409	20
153	Hisar - Thanesar	307024	155152	157	24649	19
154	Sonipat - Ambala	289333	195153	172	29584	19
155	Rohtak - Ambala	374292	195153	199	39601	18
156	Bhiwani - Kaithal	196057	144915	123	15129	18
157	Gurgaon - Ambala Sadar	886519	104974	230	52900	17
158	Rohtak - Sirsa	374292	182534	195	38025	17
159	Ambala - Jind	195153	167592	137	18769	17
160	Bahadurgarh - Palwal	170767	131926	115	13225	17
161	Kaithal - Jagadhari	144915	124894	103	10609	17
162	Rewari-Chandigarh	211355	960787	337	113569	17
163	Hisar - Ambala	307024	195153	191	36481	16
164	Panipat - Palwal	295970	131926	155	24025	16
165	Yamunanagar - Jind	217071	167592	150	22500	16
166	Hisar - Yamunanagar	307024	217071	206	42436	15

167	Sirsa - Jind	182534	167592	142	20164	15
168	Kaithal - Ambala Sadar	144915	104974	100	10000	15
169	Rohtak - Panchkula	374292	211355	237	56169	14
170	Panipat - Rewari	295970	143021	172	29584	14
171	Sonipat - Jagadhari	289333	124894	159	25281	14
172	Panchkula - Kaithal	211355	144915	146	21316	14
173	Bhiwani - Sirsa	196057	182534	156	24336	14
174	Rohtak - Jagadhari	374292	124894	185	34225	13
175	Sonipat - Panchkula	289333	211355	210	44100	13
176	Hisar - Rewari	307024	143021	185	34225	12
177	Hisar - Panchkula	307024	211355	232	53824	12
178	Panipat - Sirsa	295970	182534	209	43681	12
179	Palwal -Chandigarh	124894	960787	313	97969	12
180	Karnal - Sirsa	302140	182534	221	48841	11
181	Karnal - Palwal	302140	131926	188	35344	11
182	Sonipat - Ambala Sadar	289333	104974	166	27556	11
183	Bhiwani - Thanesar	196057	155152	165	27225	11
184	Sirsa - Kaithal	182534	144915	155	24025	11
185	Rohtak - Ambala Sadar	374292	104974	192	36864	10
186	Karnal - Rewari	302140	143021	212	44944	9
187	Yamunanagar - Bhiwani	217071	196057	216	46656	9
188	Bahadurgarh - Kaithal	170767	144915	162	26244	9
189	Bahadurgarh - Thanesar	170767	155152	170	28900	9
190	Jind - Rewari	167592	143021	158	24964	9
191	Hisar - Jagadhari	307024	124894	212	44944	8
192	Sonipat - Sirsa	289333	182534	254	64516	8
193	Panchkula - Jind	211355	167592	208	43264	8
194	Bhiwani - Palwal	196057	131926	176	30976	8
195	Jind - Jagadhari	167592	124894	153	23409	8
196	Hisar - Ambala Sadar	307024	104974	209	43681	7
197	Hisar - Palwal	307024	131926	236	55696	7
198	Yamunanagar - Bahadurgarh	217071	170767	219	47961	7
199	Sirsa - Thanesar	182534	155152	201	40401	7
200	Yamunanagar - Sirsa	217071	182534	250	62500	6
201	Panchkula - Sirsa	211355	182534	245	60025	6
202	Bhiwani - Ambala	196057	195153	234	54756	6
203	Ambala - Sirsa	195153	182534	227	51529	6
204	Jind - Ambala Sadar	167592	104974	160	25600	6
205	Panchkula - Bhiwani	211355	196057	274	75076	5
206	Bhiwani - Jagadhari	196057	124894	221	48841	5
207	Ambala - Bahadurgarh	195153	170767	238	56644	5
208	Sirsa - Bahadurgarh	182534	170767	235	55225	5
209	Bahadurgarh - Jagadhari	170767	124894	198	39204	5

210	Jind - Palwal	167592	131926	209	43681	5
211	Yamunanagar - Palwal	217071	131926	252	63504	4
212	Yamunanagar - Rewari	217071	143021	276	76176	4
213	Panchkula - Bahadurgarh	211355	170767	277	76729	4
214	Bahadurgarh - Ambala Sadar	170767	104974	205	42025	4
215	Kaithal - Rewari	144915	143021	214	45796	4
216	Bhiwani - Ambala Sadar	196057	104974	228	51984	3
217	Ambala - Palwal	195153	131926	271	73441	3
218	Ambala - Rewari	195153	143021	295	87025	3
219	Sirsa - Jagadhari	182534	124894	257	66049	3
220	Sirsa - Ambala Sadar	182534	104974	236	55696	3
221	Sirsa - Rewari	182534	143021	278	77284	3
222	Thanesar- Palwal	155152	131926	230	52900	3
223	Thanesar- Rewari	155152	143021	254	64516	3
224	Panchkula - Palwal	211355	131926	310	96100	2
225	Panchkula - Rewari	211355	143021	334	111556	2
226	Sirsa - Palwal	182534	131926	329	108241	2
227	Kaithal - Palwal	144915	131926	265	70225	2
228	Rewari - Jagadhari	143021	124894	283	80089	2
229	Palwal - Jagadhari	131926	124894	258	66564	2
230	Rewari - Ambala Sadar	143021	104974	290	84100	1
231	Palwal - Ambala Sadar	131926	104974	265	70225	1

ANNEXURE 2

1. Frequency of Public Transport

Sr.no.	Interaction	Interaction (in lakhs)	Estimation of Trip hours
1	Faridabad - Delhi	127104	
2	Gurgaon - Delhi	75481	
3	Bahadurgarh-Delhi	24924	0.5
4	Sonipat-Delhi	21472	
5	Panchkula-Chandigarh	20159	
6	Faridabad - Gurgaon	10844	
7	Yamunanagar - Jagadhari	7530	
8	Palwal -Delhi	3163	
9	Rewari -Delhi	2816	
10	Karnal - Delhi	2601	
11	Rohtak-Delhi	2520	
12	Panipat-Delhi	2226	
13	Bhiwani-Delhi	2203	1
14	Faridabad- Palwal	2072	
15	Chandigarh - Delhi	1682	
16	Ambala - Ambala Sadar	1212	
17	Hisar-Delhi	1019	
18	Jind-Delhi	886	
19	Ambala-Chandigarh	795	
20	Thanesar-Delhi	762	
21	Faridabad - Sonipat	708	
22	Karnal - Panipat	653	
23	Gurgaon-Bahadurgarh	630	1.5
24	Gurgaon -Sonipat	571	
25	Panchkula-Delhi	546	
26	Jagadhari -Delhi	529	
27	Gurgaon-Rohtak	505	
28	Kaithal-Delhi	504	
29	Faridabad - Rohtak	480	
30	Faridabad - Bahadurgarh	479	
31	Yamunanagar-Delhi	437	
32	Ambala-Delhi	423	
33	Gurgaon -Palwal	401	2
34	Rohtak - Sonipat	400	
35	Rohtak - Bahadurgarh	380	
36	Gurgaon -Rewari	376	
37	Chandigarh - Ambala Sadar	345	

38	Sonipat - Bahadurgarh	324	
39	Faridabad - Panipat	311	
40	Sirsa-Delhi	305	
41	Delhi - Ambala Sadar	283	
42	Panipat - Sonipat	273	
43	Panchkula - Ambala	233	2.5
44	Karnal - Thanesar	231	
45	Faridabad - Rewari	219	
46	Rohtak - Bhiwani	210	
47	Rohtak - Panipat	191	
48	Karnal-Chandigarh	191	
49	Faridabad - Karnal	189	
50	Gurgaon -Panipat	182	
51	Rohtak - Jind	180	
52	Thanesar-Chandigarh	180	
53	Jagadhari - Chandigarh	178	3
54	Faridabad - Chandigarh	160	
55	Karnal - Yamunanagar	160	
56	Hisar - Bhiwani	156	
57	Gurgaon -Bhiwani	136	
58	Yamunanagar - Thanesar	129	
59	Yamunanagar-Chandigarh	127	
60	Gurgaon -Karnal	112	
61	Karnal - Sonipat	110	
62	Faridabad - Hisar	108	
63	Karnal - Kaithal	106	3.5
64	Yamunanagar - Ambala	106	
65	Panipat - Jind	104	
66	Rohtak - Hisar	102	
67	Thanesar- Kaithal	101	
68	Gurgaon-Chandigarh	100	
69	Hisar - Jind	96	
70	Faridabad - Jind	94	
71	Faridabad - Bhiwani	92	
72	Gurgaon - Hisar	89	
73	Rohtak - Karnal	87	4
74	Ambala - Thanesar	84	
75	Panchkula - Ambala Sadar	82	
76	Jind - Kaithal	80	
77	Karnal - Ambala	79	
78	Yamunanagar - Ambala Sadar	78	
79	Karnal - Jagadhari	77	
80	Ambala - Jagadhari	75	

81	Panipat - Thanesar	73	
82	Bhiwani - Jind	73	
83	Gurgaon - Jind	70	4.5
84	Karnal - Jind	70	
85	Hisar - Sirsa	64	
86	Panipat - Yamunanagar	64	
87	Rohtak - Rewari	63	
88	Kaithal-Chandigarh	63	
89	Faridabad - Yamunanagar	62	
90	Faridabad - Thanesar	62	
91	Panipat - Kaithal	62	
92	Thanesar- Jagadhari	59	
93	Sonipat-Chandigarh	57	5
94	Panipat-Chandigarh	56	
95	Thanesar- Ambala Sadar	55	
96	Yamunanagar - Panchkula	53	
97	Jagadhari - Ambala Sadar	52	
98	Hisar - Chandigarh	50	
99	Karnal - Ambala Sadar	49	
100	Faridabad - Ambala	47	
101	Faridabad - Kaithal	46	
102	Panipat - Bhiwani	45	
103	Sonipat - Jind	45	5.5
104	Sonipat - Bhiwani	45	
105	Bhiwani - Bahadurgarh	44	
106	Ambala - Kaithal	43	
107	Karnal - Panchkula	41	
108	Faridabad - Panchkula	40	
109	Gurgaon -Yamunanagar	40	
110	Rohtak - Kaithal	40	
111	Panipat - Ambala	40	
112	Hisar - Karnal	39	
113	Bahadurgarh - Rewari	39	6
114	Hisar - Panipat	38	
115	Panipat - Bahadurgarh	38	
116	Bhiwani-Chandigarh	38	
117	Jind-Chandigarh	37	
118	Gurgaon -Thanesar	36	
119	Hisar - Kaithal	36	
120	Panchkula - Jagadhari	34	
121	Faridabad - Jagadhari	33	
122	Hisar - Sonipat	33	
123	Sonipat - Palwal	33	6.5

124	Yamunanagar - Kaithal	33	
125	Panchkula - Thanesar	33	
126	Panipat - Jagadhari	32	
127	Gurgaon -Kaithal	31	
128	Gurgaon - Ambala	31	
129	Faridabad - Sirsa	30	
130	Sonipat - Rewari	30	
131	Sirsa-Chandigarh	29	
132	Faridabad - Ambala Sadar	26	
133	Hisar - Bahadurgarh	26	7
134	Sonipat - Yamunanagar	26	
135	Sonipat - Thanesar	26	
136	Bahadurgarh -Chandigarh	26	
137	Rohtak - Yamunanagar	25	
138	Karnal - Bhiwani	25	
139	Panipat - Panchkula	25	
140	Bahadurgarh - Jind	25	
141	Gurgaon - Panchkula	24	
142	Rohtak - Palwal	24	
143	Panipat - Ambala Sadar	24	7.5
144	Jind - Thanesar	24	
145	Gurgaon - Sirsa	23	
146	Rohtak - Thanesar	23	
147	Gurgaon - Jagadhari	22	
148	Karnal - Bahadurgarh	21	
149	Sonipat - Kaithal	21	
150	Rohtak-Chandigarh	20	
151	Bhiwani - Rewari	20	
152	Rewari - Palwal	20	
153	Hisar - Thanesar	19	8
154	Sonipat - Ambala	19	
155	Rohtak - Ambala	18	
156	Bhiwani - Kaithal	18	
157	Gurgaon - Ambala Sadar	17	
158	Rohtak - Sirsa	17	
159	Ambala - Jind	17	
160	Bahadurgarh - Palwal	17	
161	Kaithal - Jagadhari	17	
162	Rewari-Chandigarh	17	
163	Hisar - Ambala	16	8.5
164	Panipat - Palwal	16	
165	Yamunanagar - Jind	16	
166	Hisar - Yamunanagar	15	

167	Sirsa - Jind	15	
168	Kaithal - Ambala Sadar	15	
169	Rohtak - Panchkula	14	
170	Panipat - Rewari	14	
171	Sonipat - Jagadhari	14	
172	Panchkula - Kaithal	14	
173	Bhiwani - Sirsa	14	9
174	Rohtak - Jagadhari	13	
175	Sonipat - Panchkula	13	
176	Hisar - Rewari	12	
177	Hisar - Panchkula	12	
178	Panipat - Sirsa	12	
179	Palwal -Chandigarh	12	
180	Karnal - Sirsa	11	
181	Karnal - Palwal	11	
182	Sonipat - Ambala Sadar	11	
183	Bhiwani - Thanesar	11	9.5
184	Sirsa - Kaithal	11	
185	Rohtak - Ambala Sadar	10	
186	Karnal - Rewari	9	
187	Yamunanagar - Bhiwani	9	
188	Bahadurgarh - Kaithal	9	
189	Bahadurgarh - Thanesar	9	
190	Jind - Rewari	9	
191	Hisar - Jagadhari	8	
192	Sonipat - Sirsa	8	
193	Panchkula - Jind	8	10
194	Bhiwani - Palwal	8	
195	Jind - Jagadhari	8	
196	Hisar - Ambala Sadar	7	
197	Hisar - Palwal	7	
198	Yamunanagar - Bahadurgarh	7	
199	Sirsa - Thanesar	7	
200	Yamunanagar - Sirsa	6	
201	Panchkula - Sirsa	6	
202	Bhiwani - Ambala	6	
203	Ambala - Sirsa	6	10.5
204	Jind - Ambala Sadar	6	
205	Panchkula - Bhiwani	5	
206	Bhiwani - Jagadhari	5	
207	Ambala - Bahadurgarh	5	
208	Sirsa - Bahadurgarh	5	
209	Bahadurgarh - Jagadhari	5	

210	Jind - Palwal	5	
211	Yamunanagar - Palwal	4	
212	Yamunanagar - Rewari	4	
213	Panchkula - Bahadurgarh	4	11
214	Bahadurgarh - Ambala Sadar	4	
215	Kaithal - Rewari	4	
216	Bhiwani - Ambala Sadar	3	
217	Ambala - Palwal	3	
218	Ambala - Rewari	3	
219	Sirsa - Jagadhari	3	
220	Sirsa - Ambala Sadar	3	
221	Sirsa - Rewari	3	
222	Thanesar- Palwal	3	
223	Thanesar- Rewari	3	11.5
224	Panchkula - Palwal	2	
225	Panchkula - Rewari	2	
226	Sirsa - Palwal	2	
227	Kaithal - Palwal	2	
228	Rewari - Jagadhari	2	
229	Palwal - Jagadhari	2	
230	Rewari - Ambala Sadar	1	
231	Palwal - Ambala Sadar	1	

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