NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA

Department of Information Technology

Advanced Database Systems

Assignment 1

ADBS - 1 CAR RENTAL SYSTEM

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Problem Description:

Data Sources :

According to the problem statement, there can be four different data sources.

1. User Information:
   - It has all the information about customers. It also has the details of the trips completed by the users. The 'USER' entity has attributes like id, name, contact no., gender, age etc. The 'TRIP' entity has details like id, source, destination, start time, end time, date, distance etc.
2. Driver Information :
   - It has the driver's details which is handled by company 'B'.
3. Cab Information:
   - This location has the data about the cabs and their owners managed by company 'A'.
4. Payment Information :
   - All the payments related data is maintained at a specific location by company 'C'.

Actors :

- Users/Customers
- Drivers
- Owners

Queries :

- Simple Queries:

1. Who owns more than 5 cabs?
2. List out all available taxies of type 'SUV'.
3. How many 'Male' drivers are having the rating greater than 3.
4. What is the source and destination of the longest trip?

- Complex Queries:

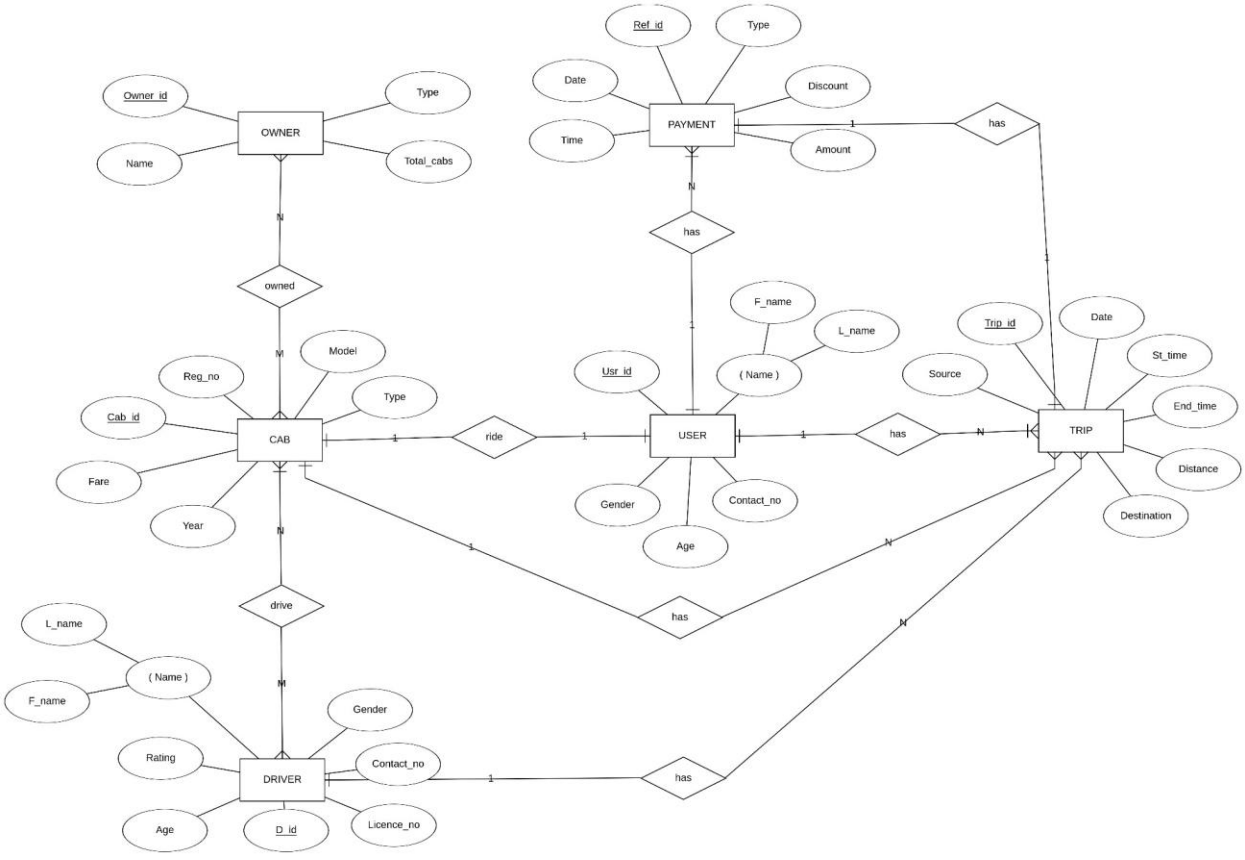
5. How many female users had female drivers?

6. During which trip the most discount was given?
7. Which type of cab is most preferred by customers?

Constraints :

1. Age of the customer should be greater than 15 years.
2. Age of the driver should be between 18 - 50 years.
3. Discount can not be more than the bill amount.
4. Distance must be more than 1 kilometer.

Entity-Relationship Diagram:



Conceptual Schema:

1. User

User-id	Name	Contact_no	Age	Gender

2. Payment

Ref-id	User-id	Trip_id	Date	Time	Type	Amount	Discount

3. Driver

D-id	Name	Contact_no	Age	Gender	Rating	Licence_no

4. Cab

Cab-id	Owner_id	Reg_no	Model	Type	Year	Fare

5. Owner

Owner-id	Name	Type	Total_cabs

6. Trip

Trip -id	Cab _id	User _id	Source	Destination	Distance	Start_ time	End_ time	Date

7. Cab-Driver

Cab-id	D-id

Normalization:

Why do we need normalization in a database? Normalization removes any type of error, redundancy or anomaly that might exist in the tables of our database. In addition, normalization makes the database more logical, reducing their size and simplifying the schema of the tables to make things easier to operate upon. Objectives of Normalization:

- To correct duplicate data and anomalies.
- To avoid creating and updating any unwanted data dependencies.
- To optimize storage space.
- To facilitate the access and interpretation of data to users and applications thatmake use of databases

1st Normal Form:

If a relation contains multi-valued or composite attributes, it violates 1st normal form. A relation is in 1st normal form if every attribute in that relation is a single valued attribute. In our schema design orders table violates 1st normal form. Conditions of 1st normal form:

- No multi-valued attribute.
- No composite attributes.
- Identify a primary key

There is no such attribute having multiple values and neither of them are composite. So all the tables are already in 1st Normal form.

2nd Normal Form:

A relation in 2nd normal form if it follows the below conditions.

- It is already in the second normal form.
- Every non-prime attribute is fully functionally dependent on the primary key.

Basically, we want to eliminate all the partial functional dependencies in our database. All our relations in the database are already in 2nd normal form because every relation has a single attribute primary key, due to which we can say that all non-prime attributes will be functionally dependent on the primary key. Hence, all our relations are already in 2nd Normal Form.

3rd Normal Form:

For a relation to be in 3rd normal form it should satisfy the following conditions

- It should already be in 2nd Normal Form.
- The relation shouldn't contain any transitive dependencies: non-prime attributes transitively depending on the key.

3 rd Normal form should hold the condition, if X->Y then: Either X is a super key or Y is a prime attribute. By using this rule, we can eliminate all transitive functional dependencies.

There are no transitive dependencies in our database so all are in 3rd Normal Form.

Global Schema:

- User

Attribute name	size
User-id	int(8)
Name	char(20)
Contact_no	int(10)

Age	int(2)
Gender	char(6)

- Payment

Attribute name	size
Ref-id	int(8)
User_id	int(8)
Trip_id	int(8)
Date	date(10)
Time	int(4)
Type	char(20)
Amount	int(8)
Discount	int(8)

- Driver

Attribute name	size
D-id	int(8)
Name	char(20)
Contact_no	int(10)
Age	int(2)
Gender	char(6)
Rating	int(2)
Licence_no	int(15)

- Cab

Attribute name	size
Cab-id	int(8)
Reg_no	int(8)

Model	char(20)
Type	char(20
Year	int(4)
Fare	int(8)

- Owner

Attribute name	size
Owner-id	int(8)
Name	char(20)
Type	char(6)
Total_cabs	int(4)

- Trip

Attribute name	size
Trip-id	int(8)
Cab-id	int(8)
User-id	int(8)
Source	char(20)
Destination	char(20)
Distance	int(5)
Start_time	time(4)
End_time	time(4)
Date	date(10)

- Cab-Driver

Attribute name	size
Cab-id	int(8)
D-id	int(8)

Fragmentation:

The main goal of DDBMS is to provide the data to the user involving less overhead and as quickly as possible. This is provided by fragmentation of data. Data Fragmentation provides distribution transparency of the data over the database. Dividing the whole table into smaller chunks and storing them in different Databases in the Distributed Database Management System is called data fragmentation.

Fragmentation of data provides the following advantages:

- Storage will not be exhausted quickly.
- Provides parallel processing.
- Provides Load balancing.
- Improves query response time.
- Provides better local processing.
- Better availability of data.

Decomposed fragments are placed into some other site to facilitate query and optimize other quality of services. These fragments permit a number of transactions concurrently. Taking a copy of a relation and maintaining it in another site is called replication. One can combine fragmentation and replication for better service provision. There are two kinds of fragmentation: horizontal and vertical.

They must satisfy the following properties:

- Completeness: all rows or columns must be present in at least one site.
- Reconstruction: while reconstructing the relation, there should not be any inconsistency or loss of data.
- Dis-jointness: row or column must be present in at most one site, else will lead to inconsistent data.

Fragmentation takes place in a relation based on the query and its frequency. The predicates used in the query servers are an important statistical input for fragments.

Following are the lists of queries depicting the transactions in the ICC Database Management system.

Query 1 : Who owns more than 5 cabs?

```
SELECT Owner_id, Name
FROM Owner
WHERE Total_cabs > 5 ;
```

Query 2 : List out all available taxies of type ‘SUV’.

```
SELECT Cab_id, Model
FROM Cab
WHERE Type = ‘SUV’ ;
```

Query 3 : How many ‘Male’ drivers are having the rating greater than 3.

```
SELECT COUNT(*)
FROM Driver
WHERE Gender = ‘Male’ AND Rating > 3 ;
```

Query 4 : What is the source and destination of the longest trip?

```
SELECT Source, Destination
FROM Trip
WHERE Distance = ( SELECT MAX(Distance) FROM Trip ) ;
```

Query 5 :How many female users had female drivers?

```
SELECT count(*) as count
FROM ( SELECT U_id FROM User AS U WHERE U.Gender=’Female’ ) AS A
WHERE A.U_id IN
      (SELECT U_id FROM Trip AS T WHERE T.D_id IN
          (SELECT D_id FROM Driver AS D WHERE D.Gender=’Female’)) ;
```

Query 6 :During which trip the most discount was given?

```
SELECT Trip_id, Source, Destination, MAX(Distance)
FROM Payment AS P
INNER JOIN Trip AS T
        ON P.Trip_id = T.Trip_id ;
```

Query 7 : Which type of cab is most preferred by customers?

```
SELECT  C.Type, COUNT(*) AS Count
FROM CAB AS C
INNER JOIN TRIP AS T
        ON C.Cab_id = T.Cab_id
GROUP BY C.Type
ORDER BY Count DESC LIMIT 1 ;
```

Horizontal Fragmentation:

Horizontal fragmentation partitions the relation along its tuples of the relations. Every fragment will have the same number of attributes. There are two ways of doing it. Primary and derived horizontal fragmentation. But it is usually done using the predicate defined on the queries. For example, consider Cab relation and it's attribute Type.

- Fragmentation of Cab relation.
  Type from **Cab** relation:

  Cab 1 : All cabs of type 'SUV'
  Cab 2 : All cabs of type 'Sedan'

- Fragmentation of Driver Relation.
  Rating from **Driver** relation**.**

  Driver 1 = All drivers with rating > 3.
  Driver 2 = All drivers with rating <= 3.

In the same way, based on the other splitting attributes we can horizontally fragment all our other relations:. But, we restrict the horizontal fragmentation to the above mentioned tables.

Vertical Fragmentation:

The vertical fragmentation of a relation R produces subschemas R1, R2, R2,…Rn. Each of which contains a subset of attributes, and only one fragment has a candidate key. To satisfy reconstruction, we need to use a joining attribute common between the sub schema. There are two methods to perform vertical fragmentation:

- Grouping (bottom up): performed by combining every two attributes at a timeand takes a long time if the number of attributes are over 100 to get desired fragments.
- Splitting (top down): given all attributes together is taken as a fragment and splitthem as many fragments as you want to get. This is much quicker than the first method.

Inputs to the Vertical Fragmentation step are the Frequency Matrix, the Usage Matrix and the Attribute Affinity Matrix.

- ➔ Frequency matrix specifies the frequency measure of each query from each site.
- ➔ Usage Matrix specifies the attributes of a relation that a query access.
- ➔ Attribute Affinity Matrix specifies the affinity measure of each pair of attributes

• Frequency Matrix

	S1	**S2**	**S3**	**S4**	**Total Query**
Q1	0	10	20	0	30
Q2	30	0	10	0	40
Q3	20	25	20	0	65
Q4	15	10	0	5	30
Q5	0	20	15	5	40
Q6	20	0	0	30	50
Q7	30	20	25	0	75

• Attribute Usage Matrix:

	Trip-id A1	Cab_ id A2	User _id A3	Source A4	Destination A5	Distance A6	Start_ time A7	End_ time A8	Date A9
Q1	0	0	0	0	0	0	0	0	0
Q2	0	0	0	0	0	0	0	0	0
Q3	0	0	0	0	0	0	0	0	0
Q4	0	0	0	1	1	1	0	0	0
Q5	0	1	1	0	0	0	0	0	0
Q6	1	0	0	1	1	0	0	0	0
Q7	0	1	0	0	0	0	0	0	0

• Attribute Affinity Matrix:

	Trip-id A1	Cab_ id A2	User_ id A3	Source A4	Destination A5	Distance A6	Start_ time A7	End_ time A8	Date A9
A1	50	0	0	50	50	0	0	0	0

A2	0	115	40	0	0	0	0	0	0
A3	0	40	40	0	0	0	0	0	0
A4	50	23	0	80	80	30	0	0	0
A5	50	0	0	80	80	30	0	0	0
A6	0	0	0	30	30	30	0	0	0
A7	0	0	0	0	0	0	0	0	0
A8	0	0	0	0	0	0	0	0	0
A9	0	0	0	0	0	0	0	0	0

Ordering of the attributes:

- Attribute A3:
  CONT(031): 2[Bond(03)+Bond(31)-Bond(01)] : 0
  CONT(132): 2[Bond(13)+Bond(32)-Bond(12)] : 12400
  CONT(234): 2[Bond(23)+Bond(34)-Bond(24)] : 12400

The value of CONT(132) is larger. So the order will be T(132).

- Attribute A4:
  CONT(041): 2[Bond(04)+Bond(41)-Bond(01)] : 16000
  CONT(142): 2[Bond(14)+Bond(42)-Bond(12)] : 16000
  CONT(243): 2[Bond(24)+Bond(43)-Bond(23)] : -12400
  CONT(345): 2[Bond(34)+Bond(45)-Bond(35)] : 32000

The value of CONT(345) is larger, so the order of this attribute need not be changed, the order is T(1324).

- Attribute A5:
  CONT(051)=2[Bond(05)+Bond(51)-Bond(01)] : 16000
  CONT(152)=2[Bond(15)+Bond(52)-Bond(12)] : 16000
  CONT(253)=2[Bond(25)+Bond(53)-Bond(23)] : -12400
  CONT(354)=2[Bond(35)+Bond(54)-Bond(34)] : 32400
  CONT(456)=2[Bond(45)+Bond(56)-Bond(46)] : 32400

The value of CONT(354) is larger. So the order will be T(13254)

- Attribute A6:
  CONT(061)=2[Bond(06)+Bond(61)-Bond(01)] : 0
  CONT(162)=2[Bond(16)+Bond(62)-Bond(12)] : 0

CONT(263)=2[Bond(26)+Bond(63)-Bond(23)] : -12400
CONT(364)=2[Bond(36)+Bond(64)-Bond(34)] : 5700
CONT(465)=2[Bond(46)+Bond(65)-Bond(45)] : -9600
CONT(567)=2[Bond(56)+Bond(67)-Bond(57)] : 11400

The value of CONT(567) is larger. So the order will be same T(132546)

- Attribute A7:

  CONT(071)=2[Bond(07)+Bond(71)-Bond(01)] : 0
  CONT(172)=2[Bond(17)+Bond(72)-Bond(12)] : 0
  CONT(273)=2[Bond(27)+Bond(73)-Bond(23)] : 0
  CONT(374)=2[Bond(37)+Bond(74)-Bond(34)] : 0
  CONT(475)=2[Bond(47)+Bond(75)-Bond(45)] : 0
  CONT(576)=2[Bond(57)+Bond(76)-Bond(56)] : 0
  CONT(678)=2[Bond(67)+Bond(78)-Bond(58)] : 0

- Attribute A8:

  All the values are zero, same as the previous attribute.

- Attribute A9:

  All the values are zero, same as the previous attribute.

So, overall the final order of the attributes in the relation is T(132546789).

Reordering the attributes based on the above values will give us:

	A1	**A3**	**A2**	**A5**	**A4**	**A6**	**A7**	**A8**	**A9**
A1	50	0	0	50	50	0	0	0	0
A3	0	40	115	0	0	0	0	0	0
A2	0	40	40	0	0	0	0	0	0
A5	50	23	0	80	80	30	0	0	0
A4	50	0	0	80	80	30	0	0	0
A6	0	0	0	30	30	30	0	0	0
A7	0	0	0	0	0	0	0	0	0

A8	0	0	0	0	0	0	0	0	0
A9	0	0	0	0	0	0	0	0	0

Partition Algorithm:

1. **TA= {A1}** **BA= {A3, A2, A5, A4, A6, A7, A8, A9}**
   TQ= { } CTQ=0
   BQ= { Q4, Q5, Q7 } CBQ=145
   OQ= { Q6 } COQ=50
   Z = -2500

2. **TA= {A1, A3}** **BA= {A2, A5, A4, A6, A7, A8, A9}**
   TQ= { } CTQ=0
   BQ= { Q4, Q7 } CBQ=105
   OQ= { Q5, Q6 } COQ=90
   Z = -8100

3. **TA= {A1, A3, A2}** **BA= {A5, A4, A6, A7, A8, A9}**
   TQ= { Q5, Q7 } CTQ=115
   BQ= { Q4 } CBQ=30
   OQ= { Q6 } COQ=50
   Z = 950

4. **TA= {A1, A3, A2, A5}** **BA= {A4, A6, A7, A8, A9}**
   TQ= { Q5, Q7 } CTQ=115
   BQ= { } CBQ=0
   OQ= { Q4, Q6 } COQ=80
   Z = -6400

5. **TA= {A1, A3, A2, A5, A4}** **BA= {A6, A7, A8, A9}**
   TQ= { Q5, Q7, Q6 } CTQ=165
   BQ= { } CBQ=0
   OQ= { Q4 } COQ=30
   Z = -900

6. **TA= {A1, A3, A2, A5, A4,A6}** **BA= {A7, A8, A9}**
   TQ= { Q4, Q5, Q7, Q6 } CTQ=195
   BQ= { } CBQ=0

OQ= { } COQ=0

Z = 0

7. **TA= {A1, A3, A2, A5, A4, A6, A7} BA= {A8, A9}**

TQ= { Q4, Q5, Q7, Q6 } CTQ=195
BQ= { } CBQ=0
OQ= { } COQ=0

Z = 0

8. **TA= {A1, A3, A2, A5, A4,A6, A7, A8} BA= {A9}**

TQ= { Q4, Q5, Q7, Q6 } CTQ=195
BQ= { } CBQ=0
OQ= { } COQ=0

Z = 0

Based on the above procedure of vertical fragmentation on the TRIP relation, we will vertically fragment the TRIP relation: **TRIP1(132) and TRIP2(546789).**

Similarly we will check for other relation table like Cabs , Driver , User , Payment , Owner , Cab-Driver. As we have already horizontally fragment the Cab and Driver.

The frequency matrix will be as its, now we have to calculate the attribute usage matrix, attribute affinity matrix, and cluster affinity matrix

Attribute usage Matrix for User:

	A1	**A2**	**A3**	**A4**	**A5**
Q1	**0**	**0**	**0**	**0**	**0**
Q2	**0**	**0**	**0**	**0**	**0**
Q3	**0**	**0**	**0**	**0**	**0**
Q4	**0**	**0**	**0**	**0**	**0**
Q5	**1**	**0**	**0**	**0**	**1**
Q6	**0**	**0**	**0**	**0**	**0**

Q7	**0**	**0**	**0**	**0**	**0**

Attribute affinity matrix for user:

	A1	**A2**	**A3**	**A4**	**A5**
A1	**40**	**0**	**0**	**0**	**40**
A2	**0**	**0**	**0**	**0**	**0**
A3	**0**	**0**	**0**	**0**	**0**
A4	**0**	**0**	**0**	**0**	**0**
A5	**40**	**0**	**0**	**0**	**40**

cont(A 0 , A 3 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 3 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 3 , A 4) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 0 , A 4 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 4 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 4 , A 3) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 3 , A 4 , A 5) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 0 , A 5 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 5 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 5 , A 3) = 2 * (0.0 + 3200.0 - 0.0) = 6400.0
cont(A 3 , A 5 , A 4) = 2 * (3200.0 + 0.0 - 0.0) = 6400.0
cont(A 4 , A 5 , A 6) = 2 * (0.0 + 0 - 0) = 0.0
so final **cluster affinity matrix** is:

	A4		**A3**	**A5**	**A1**	**A2**

A4	**40**		**0**	**0**	**0**	**40**
A3	**0**		**0**	**0**	**0**	**0**
A5	**0**		**0**	**0**	**0**	**0**
A1	**0**		**0**	**0**	**0**	**0**
A2	**40**		**0**	**0**	**0**	**40**

Partition Algorithm:

Fragments = [A4] [A3 A5 A1 A2]
TQ = []
BQ = [5]
OQ = [1, 2, 3, 4, 6, 7]
z = -84100.0

Fragments = [A4 A3] [A5 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 0, 0, 0, 1, 0, 0]
TQ = []
BQ = [A5]
OQ = [A1, A2, A3, A4, A6,A7]
z = -84100.0

Fragments = [A4 A3 A5] [A1 A2]
TA = [0, 0, 0, 0, 1, 0, 0]
TB = [0, 0, 0, 0, 1, 0, 0]
TQ = []
BQ = []
OQ = [A1, A2, A3, A4, A5, A6, A7]
z = -108900.0

Fragments = [A4 A3 A5 A1] [A2]

TA = [0, 0, 0, 0, 1, 0, 0]
TB = [0, 0, 0, 0, 0, 0, 0]
TQ = [A5]
BQ = []
OQ = [A1, A2, A3, A4, A6, A7]
z = -84100.0
so here we see in every case z is negative so fragmentation is not possible.

Attribute usage matrix for Payment:

	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**
Q1	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Q2	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Q3	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Q4	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Q5	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Q6	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**
Q7	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Attribute affinity Matrix for Payment:

	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**

A1	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A2	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A3	**0**	**0**	**50**	**0**	**0**	**0**	**0**	**0**
A4	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A5	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A6	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A7	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A8	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

To find the cluster affinity matrix we have to use Bond energy algorithm.

cont(A 0 , A 3 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 3 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 3 , A 4) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 0 , A 4 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 4 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 4 , A 3) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 3 , A 4 , A 5) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 0 , A 5 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 5 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 5 , A 3) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 3 , A 5 , A 4) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 4 , A 5 , A 6) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 0 , A 6 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 6 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 2 , A 6 , A 3) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 3 , A 6 , A 4) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 4 , A 6 , A 5) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 5 , A 6 , A 7) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 0 , A 7 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 7 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 7 , A 3) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 3 , A 7 , A 4) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 4 , A 7 , A 5) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 5 , A 7 , A 6) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 6 , A 7 , A 8) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 0 , A 8 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 8 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 8 , A 3) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 3 , A 8 , A 4) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 4 , A 8 , A 5) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 5 , A 8 , A 6) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 6 , A 8 , A 7) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 7 , A 8 , A 9) = 2 * (0.0 + 0 - 0) = 0.0

Cluster Affinity matrix for payment:

	A8	**A7**	**A6**	**A5**	**A4**	**A3**	**A1**	**A2**
A8	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A7	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A6	**0**	**0**	**50**	**0**	**0**	**0**	**0**	**0**
A5	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

A4	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A3	**0**	**0**	**0**	**0**	**0**	**50**	**0**	**0**
A1	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A2	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Partition Algorithm:

Fragments = [A8] [A7 A6 A5 A4 A3 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 0, 0, 0, 0, 1, 0]
TQ = []
BQ = [A6]
OQ = [A1, A2, A3, A4, A5, A7]
z = -78400.0
Fragments = [A8 A7] [A6 A5 A4 A3 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 0, 0, 0, 0, 1, 0]
TQ = []
BQ = [A6]
OQ = [A1, A2, A3, A4, A5, A7]
z = -78400.0
Fragments = [A8 A7 A6] [A5 A4 A3 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 0, 0, 0, 0, 1, 0]
TQ = []
BQ = [A6]
OQ = [A1, A2, A3, A4, A5, A7]
z = -78400.0
Fragments = [A8 A7 A6 A5] [A4 A3 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 0, 0, 0, 0, 1, 0]

TQ = []
BQ = [A6]
OQ = [A1, A2, A3, A4, A5, A7]
z = -78400.0
Fragments = [A8 A7 A6 A5 A4] [A3 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 0, 0, 0, 0, 1, 0]
TQ = []
BQ = [A6]
OQ = [A1, A2, A3, A4, A5, A7]
z = -78400.0
Fragments = [A8 A7 A6 A5 A4 A3] [A1 A2]
TA = [0, 0, 0, 0, 0, 1, 0]
TB = [0, 0, 0, 0, 0, 0, 0]
TQ = [A6]
BQ = []
OQ = [A1, A2, A3, A4, A5, A7]
z = -78400.0
Fragments = [A8 A7 A6 A5 A4 A3 A1] [A2]
TA = [0, 0, 0, 0, 0, 1, 0]
TB = [0, 0, 0, 0, 0, 0, 0]
TQ = [A6]
BQ = []
OQ = [A1, A2, A3, A4, A5, A7]
z = -78400.0
so here we see in every case z is negative so Vertical Fragmentation not possible.

Attribute usage matrix for Driver relation:

	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
Q1	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Q2	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Q3	**0**	**0**	**0**	**0**	**1**	**1**	**0**
Q4	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Q5	**1**	**0**	**0**	**0**	**0**	**1**	**0**
Q6	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Q7	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Attribute affinity matrix for driver:

	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
A1	**40**	**0**	**0**	**0**	**40**	**0**	**0**
A2	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A3	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A4	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A5	**40**	**0**	**0**	**0**	**105**	**65**	**0**
A6	**0**	**0**	**0**	**0**	**65**	**65**	**0**
A7	**0**	**0**	**0**	**0**	**0**	**0**	**0**

cont(A 0 , A 3 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 3 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 3 , A 4) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 0 , A 4 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 4 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 4 , A 3) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 3 , A 4 , A 5) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 0 , A 5 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 5 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 5 , A 3) = 2 * (0.0 + 5800.0 - 0.0) = 11600.0
cont(A 3 , A 5 , A 4) = 2 * (5800.0 + 0.0 - 0.0) = 11600.0
cont(A 4 , A 5 , A 6) = 2 * (0.0 + 11050.0 - 0.0) = 0.0

cont(A 0 , A 6 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 6 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 6 , A 3) = 2 * (0.0 + 11050.0 - 0.0) = 22100.0
cont(A 3 , A 6 , A 4) = 2 * (11050.0 + 2600.0 - 5800.0) = 15700.0
cont(A 4 , A 6 , A 5) = 2 * (2600.0 + 0.0 - 0.0) = 5200.0
cont(A 5 , A 6 , A 7) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 0 , A 7 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 7 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 7 , A 3) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 3 , A 7 , A 4) = 2 * (0.0 + 0.0 - 11050.0) = -22100.0
cont(A 4 , A 7 , A 5) = 2 * (0.0 + 0.0 - 5800.0) = -11600.0
cont(A 5 , A 7 , A 6) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 6 , A 7 , A 8) = 2 * (0.0 + 0 - 0) = 0.0

Cluster Affinity matrix for Driver:

	A7	**A4**	**A3**	**A6**	**A5**	**A1**	**A2**
A7	**40**	**0**	**0**	**0**	**40**	**0**	**0**
A4	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A3	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A6	**0**	**0**	**0**	**65**	**65**	**0**	**0**
A5	**40**	**0**	**0**	**65**	**105**	**40**	**0**

A1	**0**	**0**	**0**	**0**	**40**	**40**	**0**
A2	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Fragments = [A7] [A4 A3 A6 A5 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 0, 1, 0, 1, 0, 0]
TQ = []
BQ = [A3, A5]
OQ = [A1, A2, A4, A6, A7]
z = -50625.0
Fragments = [A7 A4] [A3 A6 A5 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 0, 1, 0, 1, 0, 0]
TQ = []
BQ = [A3, A5]
OQ = [A1, A2, A4, A6, A7]
z = -50625.0
Fragments = [A7 A4 A3] [A6 A5 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 0, 1, 0, 1, 0, 0]
TQ = []
BQ = [A3, A5]
OQ = [A1, A2, A4, A6, A7]
z = -50625.0
Fragments = [A7 A4 A3 A6] [A5 A1 A2]
TA = [0, 0, 1, 0, 0, 0, 0]
TB = [0, 0, 1, 0, 1, 0, 0]
TQ = []
BQ = [A5]
OQ = [A1, A2, A3, A4, A6, A7]
z = -84100.0
Fragments = [A7 A4 A3 A6 A5] [A1 A2]
TA = [0, 0, 1, 0, 1, 0, 0]
TB = [0, 0, 0, 0, 1, 0, 0]

TQ = [A3]
BQ = []
OQ = [A1, A2, A4, A5, A6, A7]
z = -70225.0
Fragments = [A7 A4 A3 A6 A5 A1] [A2]
TA = [0, 0, 1, 0, 1, 0, 0]
TB = [0, 0, 0, 0, 0, 0, 0]
TQ = [A3, A5]
BQ = []
OQ = [A1, A2, A4, A6, A7]
z = -50625.0

so here we see in every case z is negative so Vertical Fragmentation not possible.

Attribute usage matrix for Cab:

	A1	**A2**	**A3**	**A4**	**A5**	**A6**
Q1	**0**	**0**	**0**	**0**	**0**	**0**
Q2	**1**	**0**	**1**	**1**	**0**	**0**
Q3	**0**	**0**	**0**	**0**	**0**	**0**
Q4	**0**	**0**	**0**	**0**	**0**	**0**
Q5	**0**	**0**	**0**	**0**	**0**	**0**
Q6	**0**	**0**	**0**	**0**	**0**	**0**
Q7	**1**	**0**	**0**	**1**	**0**	**0**

Attribute affinity matrix for cab:

	A1	A2	A3	A4	A5	A6
A1	**115**	**0**	**40**	**115**	**0**	**0**
A2	**0**	**0**	**0**	**0**	**0**	**0**
A3	**40**	**0**	**40**	**40**	**0**	**0**
A4	**115**	**0**	**40**	**115**	**0**	**0**
A5	**0**	**0**	**0**	**0**	**0**	**0**
A6	**0**	**0**	**0**	**0**	**0**	**0**
A7	**0**	**0**	**0**	**0**	**0**	**0**

cont(A 0 , A 3 , A 1) = 2 * (0 + 10800.0 - 0) = 21600.0
cont(A 1 , A 3 , A 2) = 2 * (10800.0 + 0.0 - 0.0) = 21600.0
cont(A 2 , A 3 , A 4) = 2 * (0.0 + 10800.0 - 0.0) = 0.0

cont(A 0 , A 4 , A 1) = 2 * (0 + 10800.0 - 0) = 21600.0
cont(A 1 , A 4 , A 2) = 2 * (10800.0 + 28050.0 - 10800.0) = 56100.0
cont(A 2 , A 4 , A 3) = 2 * (28050.0 + 0.0 - 0.0) = 56100.0
cont(A 3 , A 4 , A 5) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 0 , A 5 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 5 , A 2) = 2 * (0.0 + 0.0 - 10800.0) = -21600.0
cont(A 2 , A 5 , A 3) = 2 * (0.0 + 0.0 - 28050.0) = -56100.0
cont(A 3 , A 5 , A 4) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 4 , A 5 , A 6) = 2 * (0.0 + 0.0 - 0.0) = 0.0

cont(A 0 , A 6 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 6 , A 2) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 2 , A 6 , A 3) = 2 * (0.0 + 0.0 - 10800.0) = -21600.0
cont(A 3 , A 6 , A 4) = 2 * (0.0 + 0.0 - 28050.0) = -56100.0
cont(A 4 , A 6 , A 5) = 2 * (0.0 + 0.0 - 0.0) = 0.0
cont(A 5 , A 6 , A 7) = 2 * (0.0 + 0 - 0) = 0.0

Cluster affinity matrix for cab:

	A6	**A5**	**A3**	**A4**	**A1**	**A2**
A6	**0**	**0**	**0**	**0**	**0**	**0**
A5	**0**	**0**	**0**	**0**	**0**	**0**
A3	**0**	**0**	**40**	**40**	**40**	**0**
A4	**0**	**0**	**40**	**115**	**115**	**0**
A1	**0**	**0**	**40**	**115**	**115**	**0**
A2	**0**	**0**	**0**	**0**	**0**	**0**

Partition Algorithm:

Fragments = [A6] [A5 A3 A4 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 1, 0, 0, 0, 0, 1]
TQ = []
BQ = [A2, A7]
OQ = [A1, A3, A4, A5, A6]
z = -46225.0
Fragments = [A6 A5] [A3 A4 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [0, 1, 0, 0, 0, 0, 1]

TQ = []
BQ = [A2, A7]
OQ = [A1, A3, A4, A5, A6]
z = -46225.0
Fragments = [A6 A5 A3] [A4 A1 A2]
TA = [0, 1, 0, 0, 0, 0, 0]
TB = [0, 1, 0, 0, 0, 0, 1]
TQ = []
BQ = [A7]
OQ = [A1, A2, A3, A4, A5, A6]
z = -65025.0
Fragments = [A6 A5 A3 A4] [A1 A2]
TA = [0, 1, 0, 0, 0, 0, 1]
TB = [0, 1, 0, 0, 0, 0, 1]
TQ = []
BQ = []
OQ = [A1, A2, A3, A4, A5, A6, A7]
z = -108900.0
Fragments = [A6 A5 A3 A4 A1] [A2]
TA = [0, 1, 0, 0, 0, 0, 1]
TB = [0, 0, 0, 0, 0, 0, 0]
TQ = [A2, A7]
BQ = []
OQ = [A1, A3, A4, A5, A6]
z = -46225.0
so here we see in every case z is negative so Vertical Fragmentation not possible.

Attribute usage matrix for Owner table:

	A1	**A2**	**A3**	**A4**
Q1	**1**	**1**	**0**	**1**
Q2	**0**	**0**	**0**	**0**

Q3	**0**	**0**	**0**	**0**
Q4	**0**	**0**	**0**	**0**
Q5	**0**	**0**	**0**	**0**
Q6	**0**	**0**	**0**	**0**
Q7	**0**	**0**	**0**	**0**

Attribute affinity matrix for owner:

	A1	**A2**	**A3**	**A4**
A1	**30**	**30**	**0**	**30**
A2	**30**	**30**	**0**	**30**
A3	**0**	**0**	**0**	**0**
A4	**30**	**30**	**0**	**30**

cont(A 0 , A 3 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 3 , A 2) = 2 * (0.0 + 0.0 - 2700.0) = -5400.0
cont(A 2 , A 3 , A 4) = 2 * (0.0 + 0.0 - 2700.0) = 0.0

cont(A 0 , A 4 , A 1) = 2 * (0 + 0.0 - 0) = 0.0
cont(A 1 , A 4 , A 2) = 2 * (0.0 + 2700.0 - 0.0) = 5400.0
cont(A 2 , A 4 , A 3) = 2 * (2700.0 + 2700.0 - 2700.0) = 5400.0
cont(A 3 , A 4 , A 5) = 2 * (2700.0 + 0 - 0) = 5400.0

Cluster Affinity matrix for Owner relation table:

	A3	**A4**	**A1**	**A2**
A3	**0**	**0**	**0**	**0**
A4	**0**	**30**	**30**	**30**
A1	**0**	**30**	**30**	**30**
A2	**0**	**30**	**30**	**30**

Partition algorithm:

Fragments = [A3] [A4 A1 A2]
TA = [0, 0, 0, 0, 0, 0, 0]
TB = [1, 0, 0, 0, 0, 0, 0]
TQ = []
BQ = [A1]
OQ = [A2, A3, A4, A5, A6, A7]
z = -90000.0
Fragments = [A3 A4] [A1 A2]
TA = [1, 0, 0, 0, 0, 0, 0]
TB = [1, 0, 0, 0, 0, 0, 0]
TQ = []
BQ = []
OQ = [A1, A2, A3, A4, A5, A6, A7]
z = -108900.0
Fragments = [A3 A4 A1] [A2]
TA = [1, 0, 0, 0, 0, 0, 0]
TB = [1, 0, 0, 0, 0, 0, 0]
TQ = []
BQ = []
OQ = [A1, A2, A3, A4, A5, A6, A7]
z = -108900.0
so here we see in every case z is negative so Vertical Fragmentation not possible.

There is no any query that uses the attribute related to **cab-driver** table so there is no any need to fragment this table

As we have seen above for the remaining relations Cabs, Driver, User etc where vertical fragmentation has been tried based on the inputs and usage of our queries, I am getting only negative values. So, based on the queries used in this design approach, vertical fragmentation will be done only on the Trip relation. It is fragmented into 2 parts: Trip1 and Trip2.

Data Allocation & Replication:

As the described applications are all read queries, we will be using local read and remote read time only.

Time Matrix for Fragments

Fragment	Local Update	Remote Update	Local Read	Remote Read	(Remote - Local)
Fragment 1	250	400	200	350	150
Fragment 2	250	400	200	350	150
Fragment 3	250	350	200	300	100
Fragment 4	200	300	150	250	100
Fragment 5	600	800	575	750	175
Fragment 6	350	450	300	425	125
Fragment 7	600	800	575	750	175
Fragment 8	600	800	575	750	175
Fragment 9	250	400	200	350	150

Fragment 10	250	300	150	270	120

Transaction	Originating Sites	Frequency	Fragment access
Q1	S2, S3	30	F10-1 Read, 2 Write
Q2	S1,S3	40	F1-1 Read F2-1 Read, 2 Write
Q3	S1,S2,S3	65	F3-1Read F4-1 Read, 1 Write
Q4	S1,S2,S4	30	F7-1 Read F8-1 Read, 2 Write
Q5	S2,S3,S4	40	F3-1Read F4-1 Read F6-1 Read F7-1 Read F8-1 Read
Q6	S1,S4	50	F5-1 Read, 1 Write F7-1 Read, 2 Write F8-1 Read
Q7	S1,S2,S3	75	F1-1 Read, 1 Write F2-1 Read F7-1 Read F8-1 Read

Redundant All Beneficial Site method:

Redundant all beneficial site method is used for allocating fragments to a particular site. This method operates by calculating both benefit and cost associated with allocating a fragment to a particular site. Based on the values obtained, fragments are allocated.

In our query there is no any Write or update quey so **cost = 0**

So, Benefit-cost = Benefit-0

= Benefit

For this method we need,

Remote Read Time - Local Read Time which is (2 * Propagation Delay) + Packet - Transmission Time = (2*60)+2

= 122

Fragment	Site	Update Transaction		# Write * Freq * time	Cost (ms)
		Remote	Local		
F1	S1	T7 from S3, S2	T7	(2*75*1*400)+(1*75*250)	78750
	S2	T7 from S1, S3	T7	(2*75*1*400)+(1*75*250)	78750
	S3	T7 from S1, S2	T7	(2*75*1*400)+(1*75*250)	78750
	S4	T7 from S1,S2,S3	-	(1*75*3)*400	90000
F2	S1	T2 from S3	T2	(40*2*400)+(2*40*250)	52000
	S2	T2 from S1,S3	-	(2*40*2*400)	64000
	S3	T3 from S1	T2	(40*2*400)+(2*40*250)	52000
	S4	T2 from S1,S3	-	(2*40*2*400)	64000
F3	S1	-	-	-	-
	S2	-	-	-	-
	S3	-	-	-	-
	S4	-	-	-	-
F4	S1	T3 from S2,S3	T3	(65*1*2*300)+(65*1*200)	52000
	S2	T3 from S1,S3	T3	(65*1*2*300)+(65*1*200)	52000
	S3	T3 from S2,S1	T3	(65*1*2*300)+(65*1*200)	52000
	S4	T3 from S1,S2,S3	-	(1*65*3*300)	58500
F5	S1	T6 from S4	T6	(1*50*800)+(1*50*600)	70000
	S2	T6 from S1,S4	-	(2*50*800)	80000
	S3	T6 from S1,S4	-	(2*50*800)	80000
	S4	T6 from S1	T6	(1*50*800)+(1*50*600)	70000
F6	S1	-	-	-	-
	S2	-	-	-	-
	S3	-	-	-	-
	S4	-	-	-	-
F7	S1	T6 from S4	T6	(1*50*2*800)+(1*2*50*600)	140000
	S2	T6 from S1,S4	-	(2*1*50*2*800)	160000
	S3	T6 from S1,S4	-	(2*1*50*2*800)	160000
	S4	T6 from S1	T6	(1*50*2*800)+(1*2*50*600)	140000

F8	S1	T4 from S2,S4	T4	(2*30*2*800)+(30*2*600)	96000
	S2	T4 from S1,S4	T4	(2*30*2*800)+(30*2*600)	96000
	S3	T4 from S1,S2,S3	-	(3*30*2*800)	144000
	S4	T4 from S2,S1	T4	(2*30*2*800)+(30*2*600)	96000
F9	S1	-	-	-	-
	S2	-	-	-	-
	S3	-	-	-	-
	S4	-	-	-	-
F10	S1	T1 from S2,S3	-	2*2*30*300	36000
	S2	T1 from S3	T1	1*2*30*200	12000
	S3	T1 from S2	T1	1*2*30*200	12000
	S4	T1 from S2,S3	-	2*2*30*300	36000

Fragment	Site	Query	Benefit	Benefit - Cost
F1	S1	Q2, Q7	(1*40+1*75)*122	-64720
	S2	Q7	(1*75)*122	-69600
	S3	Q2, Q7	(1*40+1*75)*122	-64120
	S4	-	-	-90000
F2	S1	Q2, Q7	(1*40+1*75)*122	-37970
	S2	Q7	(1*75)*122	-54850
	S3	Q2, Q7	(1*40+1*75)*122	-37970
	S4	-	-	-64000
F3	S1	Q3	(1*65)*122	7930
	S2	Q3, Q5	(1*65+1*40)*122	12810
	S3	Q3, Q5	(1*65+1*40)*122	12810
	S4	Q5	(1*40)*122	4880
F4	S1	Q3	(1*65)*122	-44070
	S2	Q3, Q5	(1*65+1*40)*122	-39190
	S3	Q3, Q5	(1*65+1*40)*122	-39190

	S4	Q5	(1*40)*122	-50570
F5	S1	Q6	(1*50)*122	-63900
	S2	-	-	-80000
	S3	-	-	-80000
	S4	Q6	(1*50)*122	-63900
F6	S1	-	-	0
	S2	Q5	(1*40)*122	7930

F6	S3	Q5	(1*40)*122	7930
	S4	Q5	(1*40)*122	7930
F7	S1	Q4, Q6, Q7	(1*30+1*50+1*75)*122	-121090
	S2	Q4, Q5, Q7	(1*30+1*40+1*75)*122	-142310
	S3	Q5, Q7	(1*40+1*75)*122	-145970
	S4	Q4, Q5, Q6	(1*30+1*40+1*50)*122	-125360
F8	S1	Q4, Q6, Q7	(1*30+1*50+1*75)*122	-77090
	S2	Q4, Q5, Q7	(1*30+1*40+1*75)*122	-77090
	S3	Q5, Q7	(1*40+1*75)*122	-129970
	S4	Q4, Q5, Q6	(1*30+1*40+1*50)*122	-81360
F9	S1	-	-	0
	S2	-	-	0
	S3	-	-	0
	S4	-	-	0
F10	S1	-	-	-36000
	S2	Q1	(1*30)*122	-8340
	S3	Q1	(1*30)*122	-8340
	S4	-	-	-36000

Fragment Allocation:

Based on the above values obtained from doing redundant beneficial site method, the fragments are allocated as follows:

Site	Fragment
S1	F2, F5,F7,F8,F9
S2	F3,F4,F6,F8,F9,F10
S3	F1,F2,F3,F4,F6,F9,F10
S4	F5,F6,F9

- For Fragment 9 there is no query in our assumption so for all sites it's benefit-cost value is zero that's why we will allocate Fragment 9 at any site randomly.

Physical Design:

Until now we have discussed and designed the database from a logical point of view. Now, with some fixed assumptions we will discuss the physical design of the distributed database. Physical memory primarily constitutes the secondary memory. So, after all our fragmentation and its after processing is done, where do the fragments get stored. Based on their storage, what will be their seek times, rotational latency and the data transfer rate. As said before, following are the assumptions based on which we will be doing the physical design.

- Assumptions:
  - Fixed length records are considered for all relations.
  - The delimiter for each field is the length of the field.
  - The total number of records in each fragment will be given below.
  - Block size is 1024 bytes.
  - A single record does not span over multiple blocks.
  - Block pointer is 4 bytes.
  - Average seek time is 40 milliseconds irrespective of the sites.
  - Average disk rotation time is 20 milliseconds irrespective of the site.
  - Block transfer rate is 1 milliseconds irrespective of the site.

Fragment	Relations	No of Records	Single Record Size	Total Size	Blocking Factor	No of Blocks
Fragment 1	Cab 1	200	30	6000	27	8
Fragment 2	Cab 2	200	30	7500	27	10
Fragment 3	Driver 1	150	30	4500	31	5
Fragment 4	Driver 2	100	30	3000	31	4
Fragment 5	Payment	5000	50	250000	23	218
Fragment 6	User	2000	40	80000	25	80
Fragment 7	Trip 1	5000	30	150000	37	136
Fragment 8	Trip 2	5000	50	250000	37	136

Fragment 9	Cab-Driver	300	20	6000	31	10
Fragment 10	Owner	150	20	3000	27	6

Considering the assumption, we can easily calculate the size of a single record (tuple) of every relation with the help of Global Schema. The above table gives the number of records in each relation, size of each record, blocking factor for a particular block of that relation and number of blocks required to store the entire relation.

Fragment	**Relations**	**Indexing Type**	**Indexing Attribute**	**Is it a Key?**
Fragment 1	Cab 1	Clustered	Type	No
Fragment 2	Cab 2	Clustered	Type	No
Fragment 3	Driver 1	Clustered	Rating	No
Fragment 4	Driver 2	Clustered	Rating	No
Fragment 5	Payment	Primary	Ref_id	Yes
Fragment 6	User	Primary	User_id	Yes
Fragment 7	Trip 1	Primary	Trip_id	yes
Fragment 8	Trip 2	Primary	Trip_id	Yes
Fragment 9	Cab-Driver	Primary	Cab_id, D_id	Yes
Fragment 10	Owner	Primary	Owner_id	Yes

In some queries, we use range to filter out records. Therefore, using B+ tree would benefit in access time.Some fragments are being accessed by point queries, which can be efficient in physical access using B tree. The following table explains what is the disk block access time to extract a particular record for all the relations.

Fragment	Relations	No of Records	No of Blocks	Index size per record	Index blocking factor	No of index block	No of block access with indexing	No of block access without indexing
Fragment 1	Cab 1	200	8	4+10	73	3	3	8
Fragment 2	Cab 2	200	10	4+10	73	3	3	10
Fragment 3	Driver 1	150	5	4+10	73	3	3	5
Fragment 4	Driver 2	100	4	4+10	73	2	2	4
Fragment 5	Payment	5000	218	4+4	128	40	7	218
Fragment 6	User	2000	80	4+4	128	16	5	80
Fragment 7	Trip 1	5000	136	4+4	128	40	7	136
Fragment 8	Trip 2	5000	136	4+4	128	40	7	136
Fragment 9	Cab-Driver	300	10	4+4	128	3	3	10
Fragment 10	Owner	150	6	4+4	128	2	2	6

The above table discusses the number of access each fragment takes in case, if all the fragments are ordered and indexing exists on top of all of them. This shows that indexing drastically reduces the number of block accesses required to find a record present in a table. So, the usage of trees for indexing is justified.

Access time to Local Query:

Next, we will calculate the time taken to query each relation considering the relation is locally present. Even though in our sample SQL's are just read still provided the Local

(keyword local because it's not yet distributed) Query Time and Local Update Time formulae

1. Local Query Time = (Seek Time(40)+ Latency(20) + Block Transfer Time(0.5)) * N

2. Local Update Time = (Seek Time + Latency + Block Transfer Time) * N*2

Where:

- N is number of disk block access, which depends on the relation (we already calculated this above and will consider indexed logic # of block access).
- *2 is included in the Update time, since the data block has to be fetched into memory from the disk, updated and then written back to the disk.

Access time to remote query:

Let us consider the distance between sites. Assume that each site is located at some distance say 1200kms from the other site and the speed of the transmission media connecting the sites is 2*(10^6) meters/second.

Propagation delay between the sites is computed as below.

- Propagation delay = (Distance between sites)/ (Speed of Transmission media)

= 120 * 10^3 / 2 * 10^6

= 0.06s

=60 milliseconds.

Let us assume bandwidth of the network as 1MBps and data is exchanged between sites in the form of packets. Package size is assumed to be 2000 bytes. Transmission Time for a packet is given by,

Packet Transmission Time = (Size of packet) / Bandwidth

= (2000 B) / (10^6 B/s)

= 0.002s

= 2 milliseconds

- **Remote Query Time** = Local Query Time + 2 * Propagation Delay + Packet

Transmission Time

- **Remote Update Time** = Local Update Time + 2 * Propagation Delay

Fragment	Relations	No of Records	No of Blocks	No of index block access	Local query time(ms)	Remote query time(ms)
Fragment 1	Cab 1	200	8	3	183	305
Fragment 2	Cab 2	200	10	3	183	305
Fragment 3	Driver 1	150	5	3	183	305
Fragment 4	Driver 2	100	4	2	122	244
Fragment 5	Payment	5000	218	40	2440	2562
Fragment 6	User	2000	80	16	976	1098
Fragment 7	Trip 1	5000	136	40	2440	2562
Fragment 8	Trip 2	5000	136	40	2440	2562
Fragment 9	Cab-Driver	300	10	3	183	305
Fragment 10	Owner	150	6	2	122	244

Work Area Space and System specification:

In work area space, we would like to measure the maximum amount of buffer space required for computation.

Let's assume that the largest 4 fragments in our whole database contained 5000, 2000, 5000, 5000 records each. In a situation where we are required to operate on these four fragments, in the worst case we will be required 17,000 records.

The assumed maximum record size is 50 Bytes.

Total Maximum Buffer Size : 17,000 * 50 Bytes = **850,000 Bytes.**

For the disk space, as we will be storing all our relations in the disk, we will have to combine the size of all the relations to calculate total required space.
So, the total disk space required would be:

6000 + 7500 + 4500 + 3000 + 250000 + 80000 + 150000 + 250000 + 6000 + 3000
= 760,000 Bytes

A disk containing roughly 760 KB free space would suffice for our database.