

Chapter 9

**Methodology
Physical Database Design
Transparencies**

Chapter 9 - Objectives

- ◆ **The purpose of physical database design.**
- ◆ **How to map the logical database design to a physical database design.**
- ◆ **How to design base relations for the target DBMS.**
- ◆ **How to design enterprise constraints for the target DBMS.**
- ◆ **How to select appropriate file organizations based on analysis of transactions.**

Chapter 9 - Objectives

- ◆ When to use secondary indexes to improve performance.
- ◆ When to denormalize to improve performance.
- ◆ How to estimate the size of the database.
- ◆ How to design security mechanisms to satisfy user requirements.
- ◆ The importance of monitoring and tuning the operational system.

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Logical and Physical Database Design

- ◆ Sources of information for the physical design process includes global logical data model and documentation that describes model.
- ◆ Logical database design is concerned with the *what*, physical database design is concerned with the *how*.

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Physical Database Design

- ◆ **The process of producing a description of the implementation of the database on secondary storage.**
- ◆ **Describes the storage structures and access methods used to achieve efficient access to the data.**

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Step 4 Translate Global Logical Data Model for Target DBMS

- ◆ **To produce a basic working relational database schema from the global logical data model**

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Step 4 Translate Global Logical Data Model for Target DBMS

- ◆ **Step 4.1 Design base relations for target DBMS**
 - To decide how to represent the base relations we have identified in the global logical data model in the target DBMS.
- ◆ **Step 4.2 Design enterprise constraints for target DBMS**
 - To design the enterprise constraints for the target DBMS.

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DBDL for the Property_for_Rent Relation

```
domain property_number: variable length character string length 5
domain street:          variable length character string maximum length 25
domain area:            variable length character string maximum length 15
domain city:            variable length character string maximum length 15
domain post_code:       variable length character string maximum length 8
domain property_type:   single character, must be one of 'B', 'C', 'D', 'E', 'F', 'M', 'S'
domain property_rooms:  integer, in the range 1 to 15
domain property_rent:   monetary value, in the range 0.00-9999.00
domain owner_number:    variable length character string length 5
domain staff_number:    variable length character string length 5
domain branch_number:   variable length character string length 3

property_for_rent(
  pno: property_number NOT NULL,
  street: street NOT NULL,
  area: area,
  city: city NOT NULL,
  pcode: post_code,
  type: property_type NOT NULL DEFAULT: 'F',
  rooms: property_rooms NOT NULL DEFAULT: 4,
  rent: property_rent NOT NULL DEFAULT: 600,
  ono: owner_number NOT NULL,
  sno: staff_number,
  bno: branch_number NOT NULL)
PK pno
FK sno REFERENCES staff(sno) on delete SET NULL on update CASCADE
FK ono REFERENCES owner(ono) on delete NO ACTION on update
      CASCADE
FK bno REFERENCES branch(bno) on delete NO ACTION on update CASCADE
```

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SQL to create Property_for_Rent Relation

```
CREATE DOMAIN owner_number AS VARCHAR(5)
CHECK (VALUE IN (SELECT ono FROM owner))
CREATE DOMAIN staff_number AS VARCHAR(5)
CHECK (VALUE IN (SELECT sno FROM staff))
CREATE DOMAIN branch_number AS VARCHAR(3)
CHECK (VALUE IN (SELECT bno FROM branch))
CREATE DOMAIN property_number AS VARCHAR(5)
CREATE DOMAIN street AS VARCHAR(25)
CREATE DOMAIN area AS VARCHAR(15)
CREATE DOMAIN city AS VARCHAR(15)
CREATE DOMAIN post_code AS VARCHAR(8)
CREATE DOMAIN property_type AS CHAR(1)
CHECK(VALUE IN ('B', 'G', 'D', 'E', 'F', 'M', 'S'))
CREATE DOMAIN property_rooms AS SMALLINT
CHECK(VALUE BETWEEN 1 AND 15)
CREATE DOMAIN property_rent AS DECIMAL(6,2)
CHECK(VALUE BETWEEN 0 AND 9999)

CREATE TABLE property_for_rent (
  pno          PROPERTY_NUMBER    NOT NULL,
  street       STREET             NOT NULL,
  area         AREA,
  city         CITY               NOT NULL,
  pcode       POST_CODE,
  type         PROPERTY_TYPE      NOT NULL DEFAULT 'F',
  rooms        PROPERTY_ROOMS     NOT NULL DEFAULT 4,
  rent         PROPERTY_RENT      NOT NULL DEFAULT 600,
  ono          OWNER_NUMBER       NOT NULL,
  sno          STAFF_NUMBER,
  bno          BRANCH_NUMBER      NOT NULL,
  PRIMARY KEY (pno),
  FOREIGN KEY (sno) REFERENCES staff on delete SET NULL on update CASCADE,
  FOREIGN KEY (ono) REFERENCES owner on delete NO ACTION on update CASCADE,
  FOREIGN KEY (bno) REFERENCES branch on delete NO ACTION on update CASCADE
)
```

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Step 5 Design Physical Representation

- ◆ To determine the file organizations and access methods that will be used to store the base relations; that is, the way in which relations and tuples will be held on secondary storage.

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Step 5 Design Physical Representation

- ◆ **Step 5.1 Analyze transactions**
 - To understand the functionality of the transactions that will run on the database and to analyze the important transactions.
- ◆ **Step 5.2 Choose file organizations**
 - To determine an efficient file organization for each base relation.

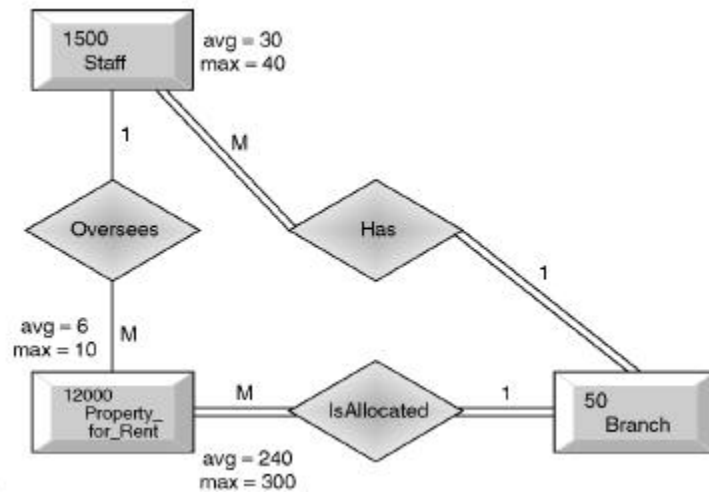
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Example - Sample Transactions

- (A) Insert details for a new member of staff, given the branch address.
- (B) List rental properties handled by each staff member at a given branch address.
- (C) Assign a rental property to a member of staff, checking that a staff member does not manage more than 10 properties already.
- (D) List rental properties handled by each branch office.

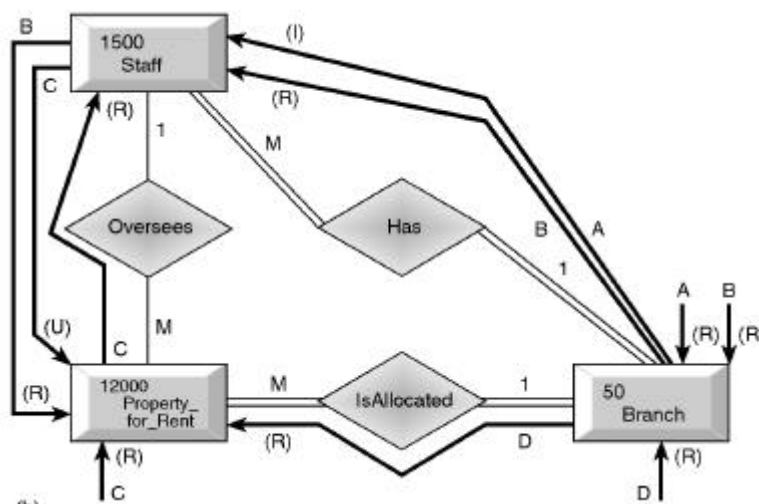
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ER Model for Sample Transactions showing Expected Occurrences



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Transaction Usage Map for Sample Transactions



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Analysis of Selected Transaction A

<i>Transaction A</i>				
	<i>Day</i>	<i>Time</i>	<i>No of runs per hour</i>	
Peak	–	–	–	
Ave	–	–	occasionally only	
<i>From relation</i>	<i>To relation</i>	<i>Attributes</i>	<i>Access</i>	<i>No of times accessed</i>
–	Branch	Address	R(E)	1
		Bno	R	
Branch	Staff	I		1
		(all)		

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Analysis of Selected Transaction B

<i>Transaction B</i>				
	<i>Day</i>	<i>Time</i>	<i>No of runs per hour</i>	
Peak	Mon	9–10 am	2	
	Wed	2–4 pm	2	
Ave	–	–	–	
<i>From relation</i>	<i>To relation</i>	<i>Attributes</i>	<i>Access</i>	<i>No of times accessed</i>
–	Branch	Address	R(E)	1
		Bno	R	
Branch	Staff	Bno	R(E)*	8–20
		Sno	R	
		FName	R	
		LName	R	
		•		
Staff	Property_for_Rent	Sno	R(E)*	48–200
		Pno	R	
		Address	R	
		•		

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Analysis of Selected Transaction C

<i>Transaction C</i>				
	<i>Day</i>	<i>Time</i>	<i>No of runs per hour</i>	
Peak	Mon	9–11 am	4	
Ave	Rest of week		1	
<i>From relation</i>	<i>To relation</i>	<i>Attributes</i>	<i>Access</i>	<i>No of times accessed</i>
–	Property_for_Rent	Pno Address • Bno Sno	R(E) R R U	2
Property_for_Rent	Staff	Sno FName LName • Bno	R R R R(E)*	8–20
Staff	Property_for_Rent	Sno	R(E)*	6–200

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Step 5 Design Physical Representation

◆ Step 5.3 Choose secondary indexes

- To determine whether adding secondary indexes will improve the performance of the system.

◆ Step 5.4 Consider the introduction of controlled redundancy

- To determine whether introducing redundancy in a controlled manner by relaxing the normalization rules will improve the performance of the system.

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Cross-referencing Transactions and Relations

Transaction/ Relation	Maintain properties				List properties for for each branch				List viewings with comments			
	I	R	U	D	I	R	U	D	I	R	U	D
Branch		X				X				X		
Staff		X										
Property_for_Rent	X	X	X	X		X				X		
Owner	X	X	X	X		X						
Viewing	X	X	X	X						X		
Renter		X	X	X						X		

I = Insert; R = Read; U = Update; D = Delete

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Simplified Staff Relation with Derived Attribute No_of_Properties

PROPERTY_FOR_RENT

Pno	Street	Area	City	Pcode	Type	Rooms	Rent	Ono	Sno	Bno
PA14	16 Holhead	Dee	Aberdeen	AB7 5SU	House	6	650	CO46	SA9	B7
PL94	6 Argyll St	Kilburn	London	NW2	Flat	4	400	CO87	SL41	B5
PG4	6 Lawrence St	Partick	Glasgow	G11 9QX	Flat	3	350	CO40	SG14	B3
PG36	2 Manor Rd		Glasgow	G32 4QX	Flat	3	375	CO93	SG37	B3
PG21	18 Dale Rd	Hyndland	Glasgow	G12	House	5	600	CO87	SG37	B3
PG16	5 Novar Dr	Hyndland	Glasgow	G12 9AX	Flat	4	450	CO93	SG14	B3

STAFF

Sno	FName	LName	Address	NIN	Bno	No_of_Properties
SL21	John	White	19 Taylor St, Cranford, London	WK442011B	B5	0
SG37	Ann	Beech	81 George St, Glasgow PA1 2JR	WL432514C	B3	2
SG14	David	Ford	63 Ashby St, Partick, Glasgow G11	WL220658D	B3	2
SA9	Mary	Howe	2 Elm Pl, Aberdeen AB2 3SU	WM532187D	B7	1
SG5	Susan	Brand	5 Gt Western Rd, Glasgow G12	WK588932E	B3	0
SL41	Julie	Lee	28 Malvern St, Kilburn NW2	WA290573K	B5	1

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Original Renter and Interview Relations

RENTER

<i>Rno</i>	<i>FName</i>	<i>LName</i>	<i>Pref_Type</i>	<i>Max_Rent</i>	<i>Bno</i>
CR76	John	Kay	Flat	425	B5
CR56	Aline	Stewart	Flat	350	B3
CR74	Mike	Ritchie	House	750	B3
CR62	Mary	Tregear	Flat	600	B7

INTERVIEW

<i>Rno</i>	<i>Sno</i>	<i>Date</i>	<i>Comment</i>
CR62	SA9	14-May-98	needs property urgently
CR56	SG37	28-Apr-98	current lease ends in June

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Combined Renter and Interview Relations

RENTER

<i>Rno</i>	<i>FName</i>	<i>LName</i>	<i>Pref_Type</i>	<i>Max_Rent</i>	<i>Bno</i>	<i>Sno</i>	<i>Date</i>	<i>Comment</i>
CR76	John	Kay	Flat	425	B5	null	null	null
CR56	Aline	Stewart	Flat	350	B3	SG37	28-Apr-98	current lease ends in June
CR74	Mike	Ritchie	House	750	B3	null	null	null
CR62	Mary	Tregear	Flat	600	B7	SA9	14-May-98	needs property urgently

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Original Property_for_Rent and Owner Relations

PROPERTY_FOR_RENT

<i>Pno</i>	<i>Street</i>	<i>Area</i>	<i>City</i>	<i>Pcode</i>	<i>Type</i>	<i>Rooms</i>	<i>Rent</i>	<i>Ono</i>	<i>Sno</i>	<i>Bno</i>
PA14	16 Holhead	Dee	Aberdeen	AB7 5SU	House	6	650	CO46	SA9	B7
PL94	6 Argyll St	Kilburn	London	NW2	Flat	4	400	CO87	SL41	B5
PG4	6 Lawrence St	Partick	Glasgow	G11 9QX	Flat	3	350	CO40	SG14	B3
PG36	2 Manor Rd		Glasgow	G32 4QX	Flat	3	375	CO93	SG37	B3
PG21	18 Dale Rd	Hyndland	Glasgow	G12	House	5	600	CO87	SG37	B3
PG16	5 Novar Dr	Hyndland	Glasgow	G12 9AX	Flat	4	450	CO93	SG14	B3

OWNER

<i>Ono</i>	<i>FName</i>	<i>LName</i>	<i>Address</i>	<i>Tel_No</i>
CO46	Joe	Keogh	2 Fergus Dr, Banchory, Aberdeen AB2 7SX	01224-861212
CO87	Carol	Farrel	6 Achray St, Glasgow G32 9DX	0141-357-7419
CO40	Tina	Murphy	63 Well St, Shawlands, Glasgow G42	0141-943-1728
CO93	Tony	Shaw	12 Park Pl, Hillhead, Glasgow G4 0QR	0141-225-7025

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Duplicating LName Attribute in the Property_for_Rent Relation

PROPERTY_FOR_RENT

<i>Pno</i>	<i>Street</i>	<i>Area</i>	<i>City</i>	<i>Pcode</i>	<i>Type</i>	<i>Rooms</i>	<i>Rent</i>	<i>Ono</i>	<i>LName</i>	<i>Sno</i>	<i>Bno</i>
PA14	16 Holhead	Dee	Aberdeen	AB7 5SU	House	6	650	CO46	Keogh	SA9	B7
PL94	6 Argyll St	Kilburn	London	NW2	Flat	4	400	CO87	Farrel	SL41	B5
PG4	6 Lawrence St	Partick	Glasgow	G11 9QX	Flat	3	350	CO40	Murphy	SG14	B3
PG36	2 Manor Rd		Glasgow	G32 4QX	Flat	3	375	CO93	Shaw	SG37	B3
PG21	18 Dale Rd	Hyndland	Glasgow	G12	House	5	600	CO87	Farrel	SG37	B3
PG16	5 Novar Dr	Hyndland	Glasgow	G12 9AX	Flat	4	450	CO93	Shaw	SG14	B3

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Lookup Table for Property_Type Attribute

PROPERTY_TYPE

Type	Description
1	House
2	Flat

PROPERTY_FOR_RENT

Pno	Street	Area	City	Pcode	Type	Rooms	Rent	Ono	Sno	Bno
PA14	16 Holhead	Dee	Aberdeen	AB7 5SU	1	6	650	CO46	SA9	B7
PL94	6 Argyll St	Kilburn	London	NW2	2	4	400	CO87	SL41	B5
PG4	6 Lawrence St	Partick	Glasgow	G11 9QX	2	3	350	CO40	SG14	B3
PG36	2 Manor Rd		Glasgow	G32 4QX	2	3	375	CO93	SG37	B3
PG21	18 Dale Rd	Hyndland	Glasgow	G12	1	5	600	CO87	SG37	B3
PG16	5 Novar Dr	Hyndland	Glasgow	G12 9AX	2	4	450	CO93	SG14	B3

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Modified Property_for_Rent Relation with Duplicated Description Attribute

PROPERTY_FOR_RENT

Pno	Street	Area	City	Pcode	Type	Description	Rooms	Rent	Ono	Sno	Bno
PA14	16 Holhead	Dee	Aberdeen	AB7 5SU	1	House	6	650	CO46	SA9	B7
PL94	6 Argyll St	Kilburn	London	NW2	2	Flat	4	400	CO87	SL41	B5
PG4	6 Lawrence St	Partick	Glasgow	G11 9QX	2	Flat	3	350	CO40	SG14	B3
PG36	2 Manor Rd		Glasgow	G32 4QX	2	Flat	3	375	CO93	SG37	B3
PG21	18 Dale Rd	Hyndland	Glasgow	G12	1	House	5	600	CO87	SG37	B3
PG16	5 Novar Dr	Hyndland	Glasgow	G12 9AX	2	Flat	4	450	CO93	SG14	B3

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Duplicating Foreign Key Bno in Owner Relation

OWNER

<i>Ono</i>	<i>FName</i>	<i>LName</i>	<i>Address</i>	<i>Tel_No</i>	<i>Bno</i>
CO46	Joe	Keogh	2 Fergus Dr, Banchory, Aberdeen AB2 7SX	01224-861212	B7
CO87	Carol	Farrel	6 Achray St, Glasgow G32 9DX	0141-357-7419	B5
CO40	Tina	Murphy	63 Well St, Shawlands, Glasgow G42	0141-943-1728	B3
CO93	Tony	Shaw	12 Park Pl, Hillhead, Glasgow G4 0QR	0141-225-7025	B3

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Original Property_for_Rent, Renter, and Viewing Relations

PROPERTY_FOR_RENT

<i>Pno</i>	<i>Street</i>	<i>Area</i>	<i>City</i>	<i>Pcode</i>	<i>Type</i>	<i>Rooms</i>	<i>Rent</i>	<i>Ono</i>	<i>Sno</i>	<i>Bno</i>
PA14	16 Holhead	Dee	Aberdeen	AB7 5SU	House	6	650	CO46	SA9	B7
PL94	6 Argyll St	Kilburn	London	NW2	Flat	4	400	CO87	SLA1	B5
PG4	6 Lawrence St	Partick	Glasgow	G11 9QX	Flat	3	350	CO40	SG14	B3
PG36	2 Manor Rd		Glasgow	G32 4QX	Flat	3	375	CO93	SG37	B3
PG21	18 Dale Rd	Hyndland	Glasgow	G12	House	5	600	CO87	SG37	B3
PG16	5 Novar Dr	Hyndland	Glasgow	G12 9AX	Flat	4	450	CO93	SG14	B3

RENTER

<i>Rno</i>	<i>FName</i>	<i>LName</i>	<i>Address</i>	<i>Tel_No</i>	<i>Pref_Type</i>	<i>Max_Rent</i>	<i>Bno</i>
CR76	John	Kay	56 High St, Putney, London SW1 4EH	0171-774-5632	Flat	425	B5
CR56	Aline	Stewart	64 Fern Dr, Pollock, Glasgow G42 0BL	0141-848-1825	Flat	350	B3
CR74	Mike	Ritchie	18 Tain St, Gourrock PA1G 1YQ	01475-392178	House	750	B3
CR62	Mary	Tregear	5 Tarbot Rd, Kildary, Aberdeen AB9 3ST	01224-196720	Flat	600	B7

VIEWING

<i>Rno</i>	<i>Pno</i>	<i>Date</i>	<i>Comment</i>
CR56	PA14	24-May-98	too small
CR76	PG4	20-Apr-98	too remote
CR56	PG4	26-May-98	
CR62	PA14	14-May-98	no dining room
CR56	PG36	28-Apr-98	

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Duplicating Street Attribute in Viewing Relation

RENTER

<i>Rno</i>	<i>FName</i>	<i>LName</i>	<i>Address</i>	<i>Tel_No</i>	<i>Pref_Type</i>	<i>Max_Rent</i>	<i>Bno</i>
CR76	John	Kay	56 High St, Putney, London SW1 4EH	0171-774-5632	Flat	425	B5
CR56	Aline	Stewart	64 Fern Dr, Pollock, Glasgow G42 0BL	0141-848-1825	Flat	350	B3
CR74	Mike	Richie	18 Tain St, Gourrock PA14 1YQ	01475-392178	House	750	B3
CR62	Mary	Tregear	5 Tarbot Rd, Kildary, Aberdeen AB9 3ST	01224-196720	Flat	600	B7

VIEWING

<i>Rno</i>	<i>Pno</i>	<i>Street</i>	<i>Date</i>	<i>Comment</i>
CR56	PA14	16 Holhead	24-May-98	too small
CR76	PG4	163 Main St	20-Apr-98	too remote
CR56	PG4	163 Main St	26-May-98	
CR62	PA14	16 Holhead	14-May-98	no dining room
CR56	PG36	2 Manor Rd	28-Apr-98	

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Original Branch and Branch_Cars Relations

BRANCH

<i>Bno</i>	<i>Street</i>	<i>Area</i>	<i>City</i>	<i>Pcode</i>	<i>Tel_No</i>	<i>Fax_No</i>
B5	22 Deer Rd	Sidcup	London	SW1 4EH	0171-886-1212	0171-886-1214
B7	16 Argyll St	Dyce	Aberdeen	AB2 3SU	01224-67125	01224-67111
B3	163 Main St	Partick	Glasgow	G11 9QX	0141-339-2178	0141-339-4439
B4	32 Manse Rd	Leigh	Bristol	BS99 1NZ	0117-916-1170	0117-776-1114
B2	56 Clover Dr		London	NW10 6EU	0181-963-1030	0181-453-7992

BRANCH_CARS

<i>Bno</i>	<i>Registration_No</i>
B5	M109 ABG
B5	M670 BFT
B5	N64 SAB
B7	M536 XRT
B7	N90 BDC

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Revised Branch Relation with Repeating Group

BRANCH

<i>Bno</i>	<i>Street</i>	<i>Area</i>	<i>City</i>	<i>Pcode</i>	<i>Tel_No</i>	<i>Car1</i>	<i>Car2</i>	<i>Car3</i>	<i>Car4</i>	<i>Fax_No</i>
B5	22 Deer Rd	Sidcup	London	SW1 4EH	0171-886-1212	M109 ABG	M670 BFT	N64 SAB	null	0171-886-1214
B7	16 Argyll St	Dyce	Aberdeen	AB2 3SU	01224-67125	M536 XRT	N90 BDC	null	null	01224-67111
B3	163 Main St	Partick	Glasgow	G11 9QX	0141-339-2178	0141-339-4439
B4	32 Manse Rd	Leigh	Bristol	BS99 1NZ	0117-916-1170	0117-776-1114
B2	56 Clover Dr		London	NW10 6EU	0181-963-1030	0181-453-7992

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Step 5 Design Physical Representation

- ◆ **Step 5.5 Estimate disk space requirements**
 - **To estimate the amount of disk space that will be required by the database.**

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Comparison of Space Requirements for Property_for_Rent Relation

	<i>10 000</i>	<i>20 000</i>	<i>30 000</i>	<i>40 000</i>	<i>50 000</i>
Heap	2 356	4 708	7 060	9 412	11 768
Hash	10 000	20 000	30 000	40 000	50 000
ISAM	2 684	5 360	8 032	10 712	13 388
B ⁺ -Tree	3 340	6 592	9 844	13 100	16 352

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Step 6 Design Security Mechanisms

- ◆ To design the security measures for the database as specified by the users.
- ◆ Step 6.1 Design user views
 - that were identified in Step 1 of the conceptual database design methodology.
- ◆ Step 6.2 Design access rules
 - to the base relations and user views.

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Staff3 View Listing

<i>Sno</i>	<i>FName</i>	<i>LName</i>	<i>Address</i>	<i>Tel_no</i>	<i>Position</i>	<i>Sex</i>
SG37	Ann	Beech	81 George St, Glasgow PA1 2JR	0141-848-3345	Snr Asst	F
SG14	David	Ford	63 Ashby St, Partick, Glasgow G11	0141-339-2177	Deputy	M
SG5	Susan	Brand	5 Gt Western Rd, Glasgow G12	0141-334-2001	Manager	F