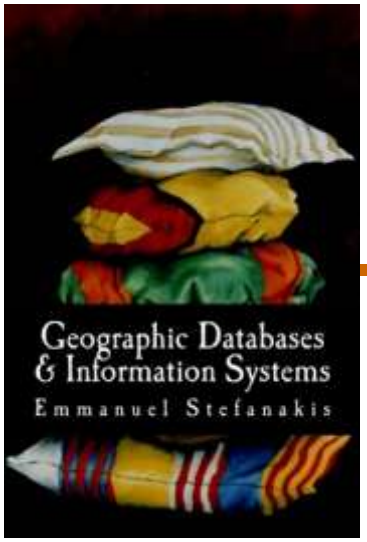

Stefanakis, E., 2014. *Geographic Databases and Information Systems*. CreateSpace Independent Publ. [In English], pp.386.

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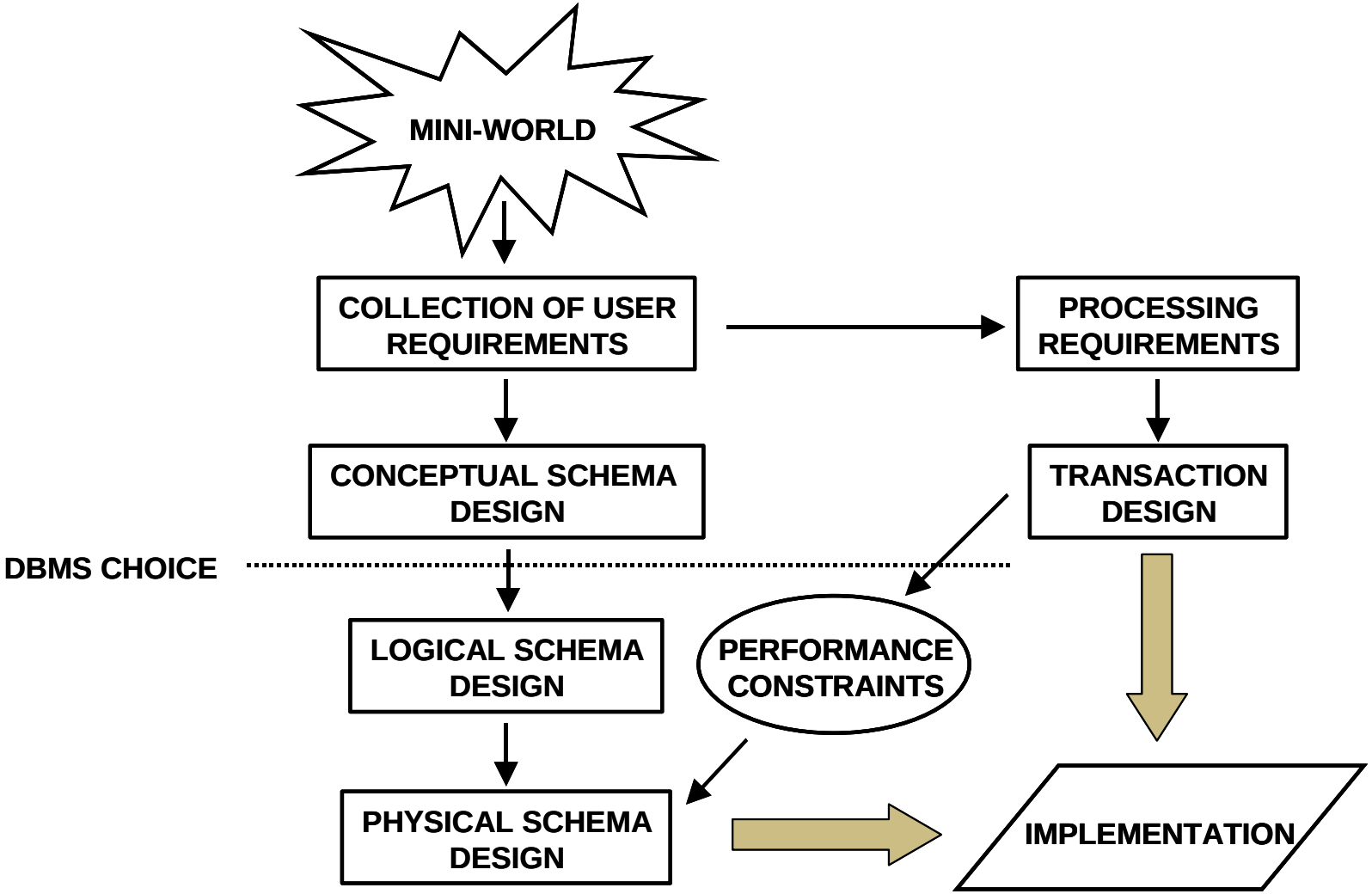
Chapter 6

Database System Design

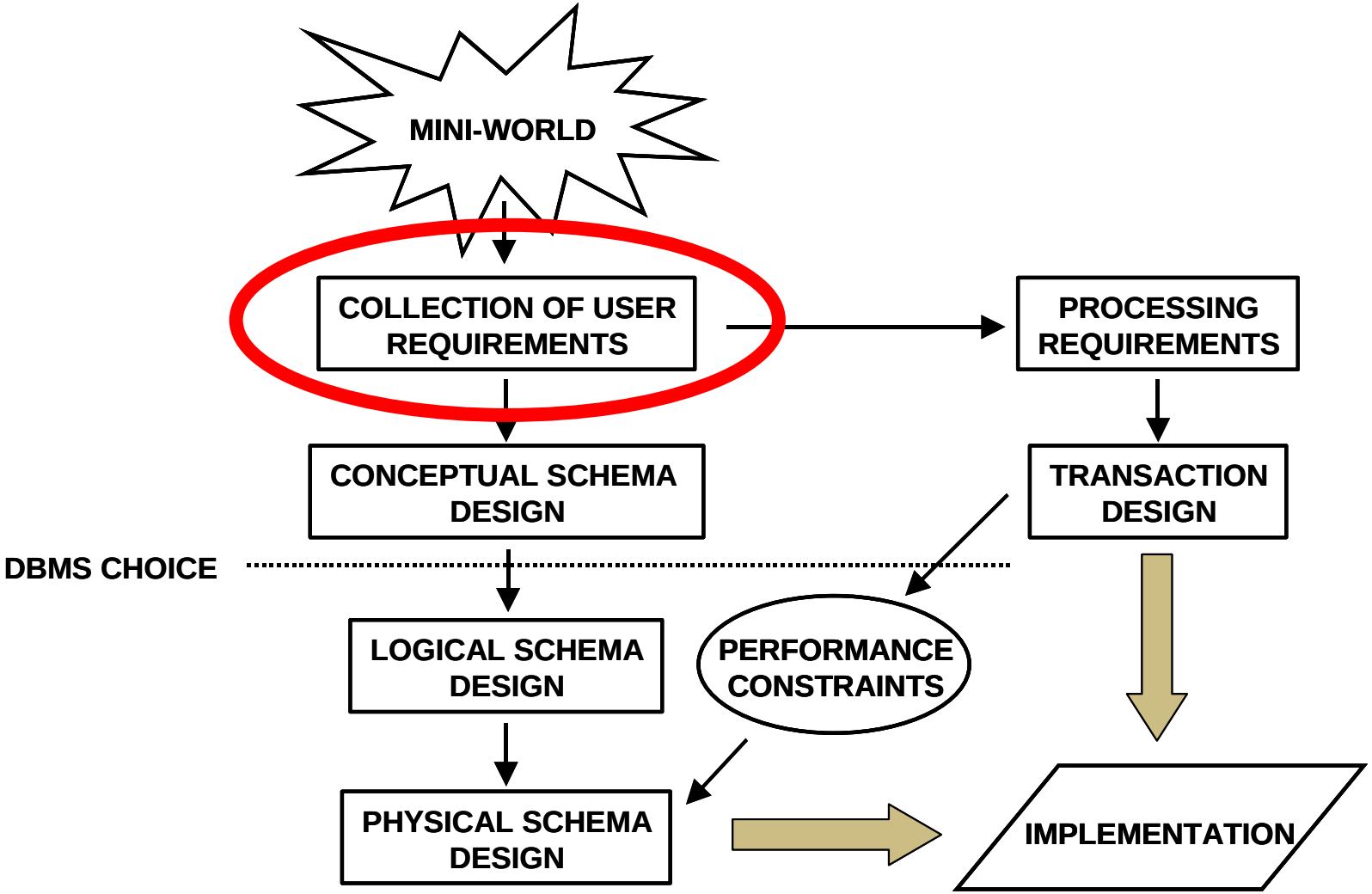
Emmanuel Stefanakis

http://www2.unb.ca/~estef/

Database System Design

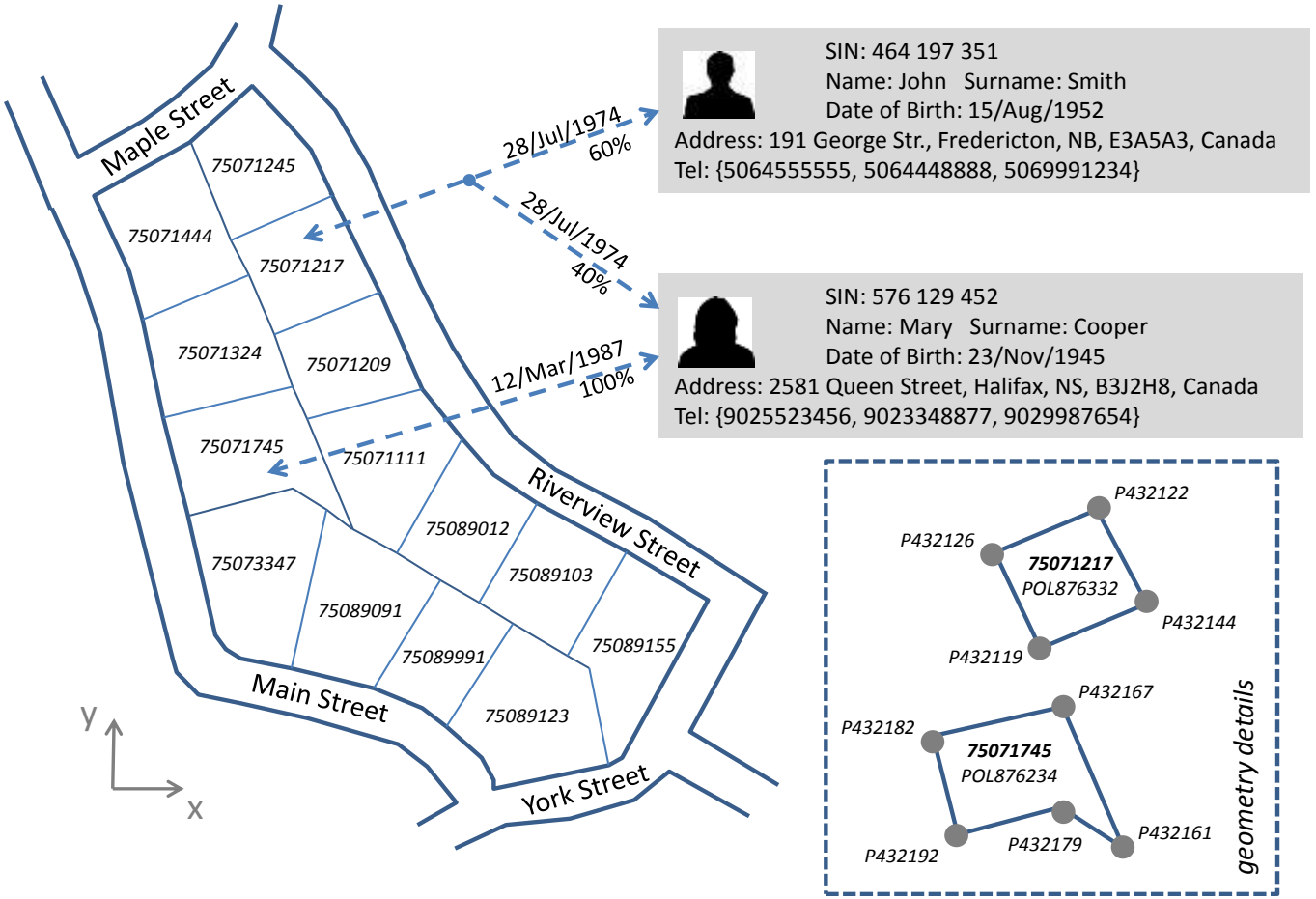


Database System Design

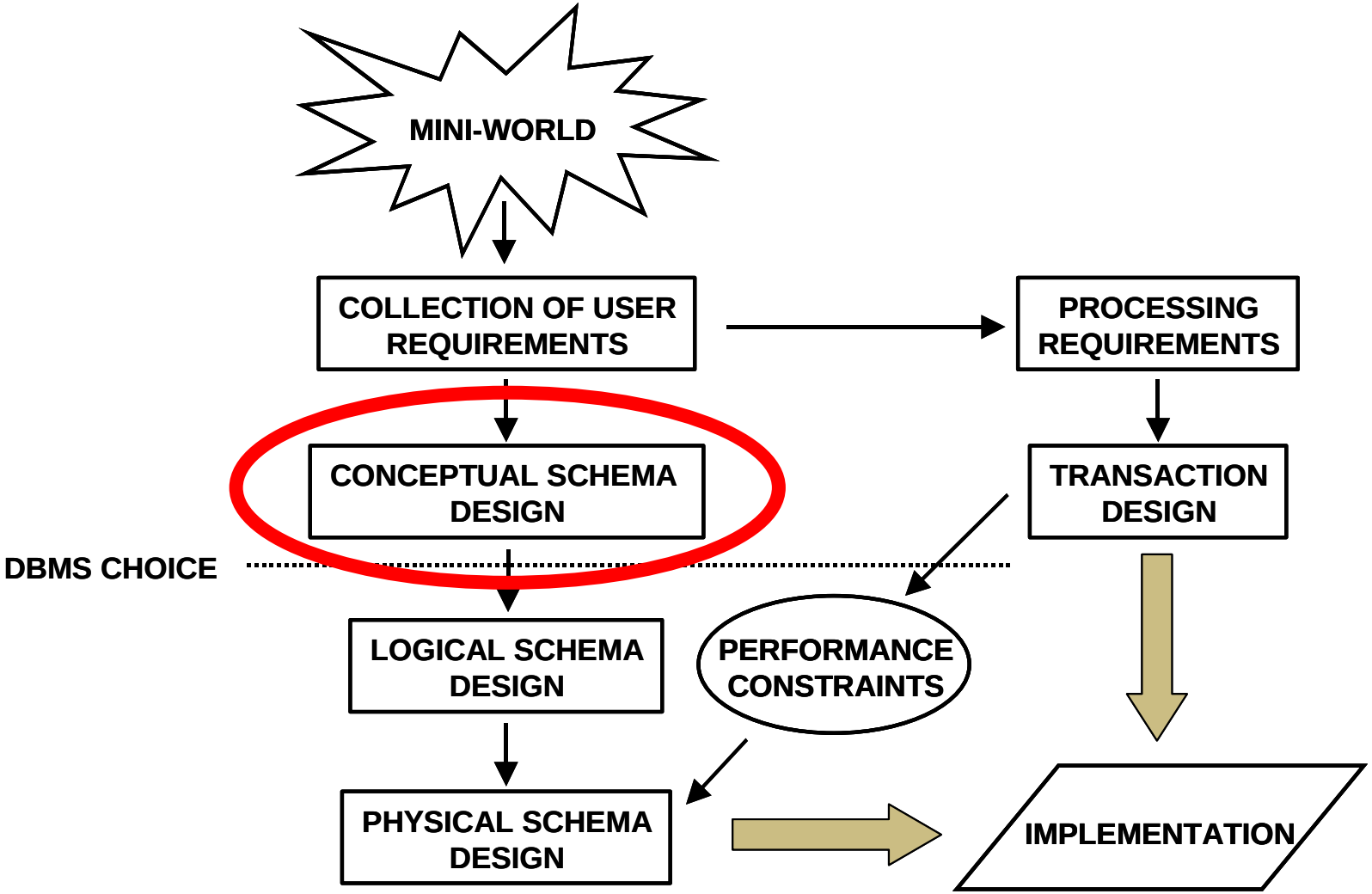


Collection of User Requirements

- Mini-world: the world of cadastre…



Database System Design



Database System Design

Domain Experts

Application needs
Applied methods (knowhow)
Existing tools (experience)

Customize existing methods
Develop new methods
Develop standard tools

Data Analysts

Conceptual Schema Design

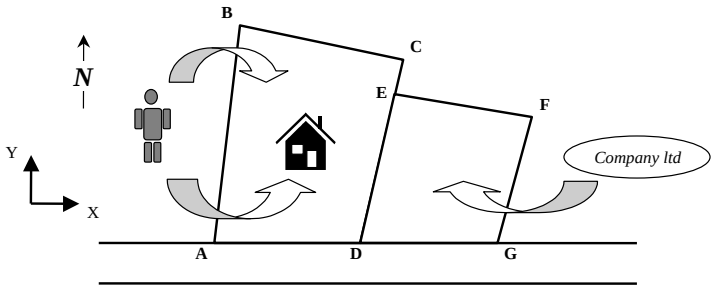
- Conceptual **Schema** …
  - a clear description of the database schema
  - a means for users/designers/analysts and programmers to communicate
- Conceptual **data models**
  - simple and expressive
  - diagrammatic representation
  - few diagrammatic constructs

Conceptual Schema Design

- Entity-Relationship Model (**ER Model**)
  - World is described as a set of **entities** along with their **relationships**
  - **Entities** …
    - objects with either physical or conceptual existence
      - an owner or a title respectively
    - described by **attributes**
      - **simple**, e.g., name = Mary
      - **multivalued**, e.g., telephone = { 12345678, 23456781, …}
      - **composite**, e.g., addr = { street = Main, no = 22, …}
      - **derived**, e.g., age = today() – birth_date
      - **key**, e.g., id = 56712945

Conceptual Schema Design

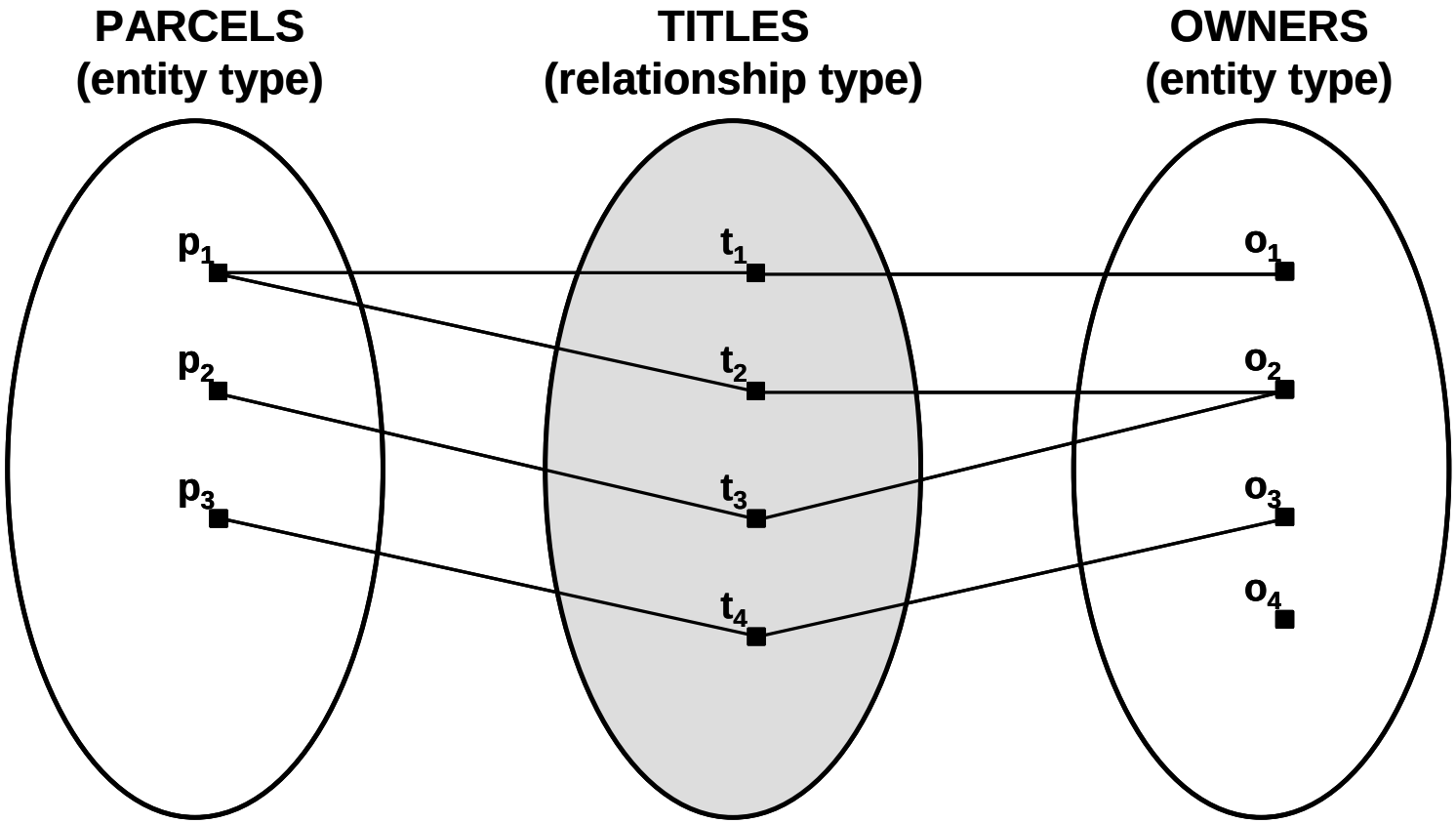
- Entity-Relationship Model
  - **Relationships** …



    - the relationships that occur between entities
      - e.g., a parcel is related with one or more owners
    - a relationship …
      - connects the instances of one or more sets of entities types (i.e., sets of entities with the same attributes)
      - the number of sets defines the **relationship degree**

Conceptual Schema Design

- Entity-Relationship Model

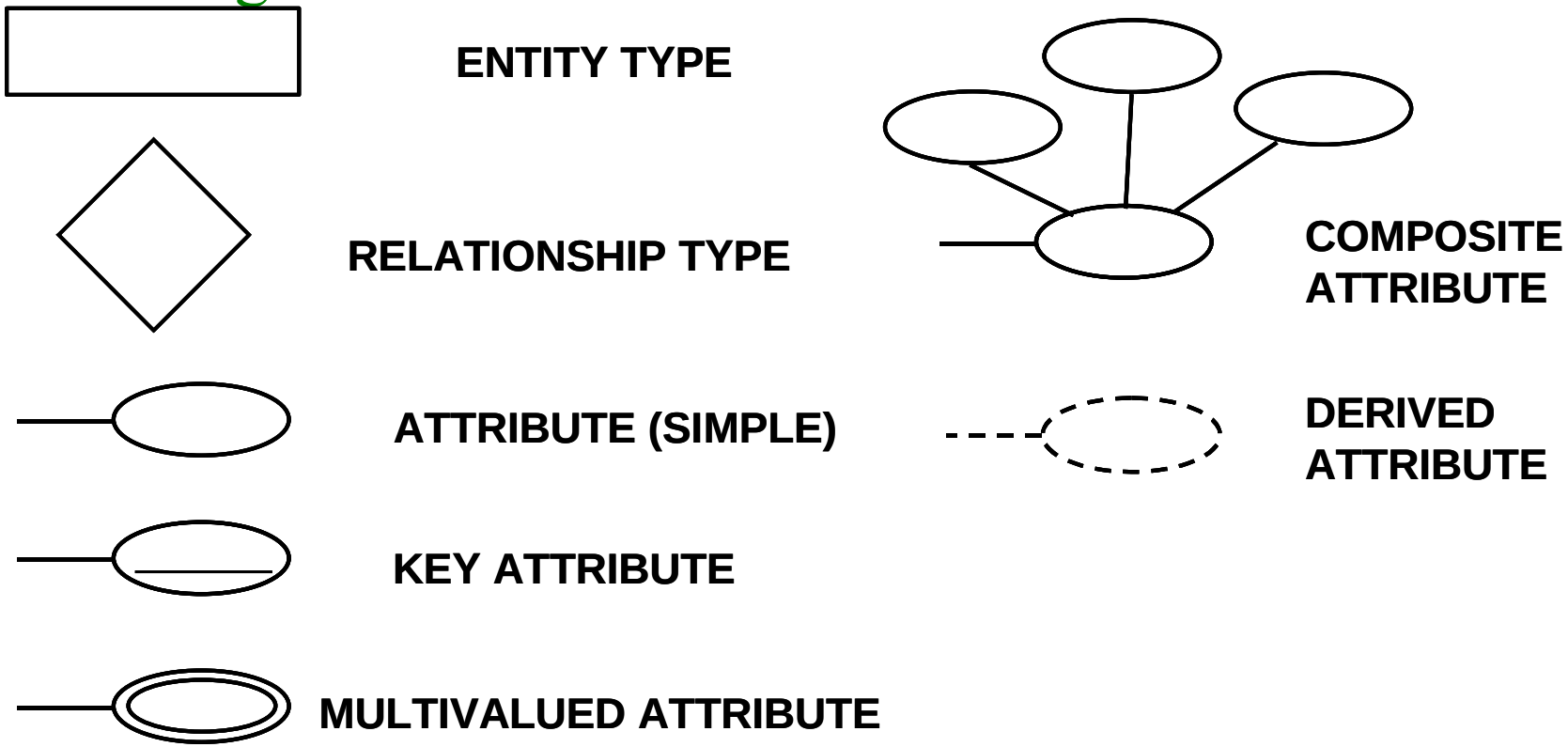


Conceptual Schema Design

- Entity-Relationship Model
  - **Relationships** …
    - may have **attributes** …
      - e.g., title date, or percentage of ownership
    - have a **cardinality ratio** …
      - specifies the number of relationship instances that an entity can participate in, e.g., 1:1, 1:N, N:M (for binary relationships)
    - have a **participation constraint** …
      - specifies whether the existence of an entity depends on being related to another entity via the relationship type

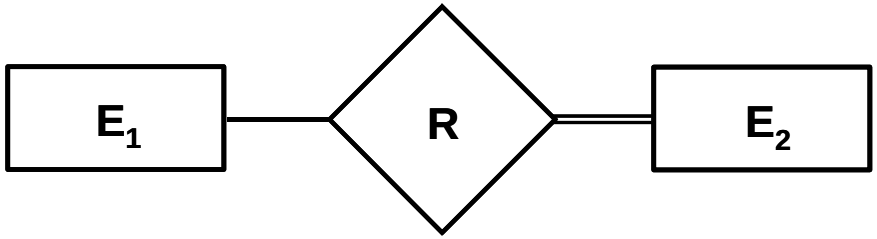
Conceptual Schema Design

- Entity-Relationship Model
  - Diagram notation …

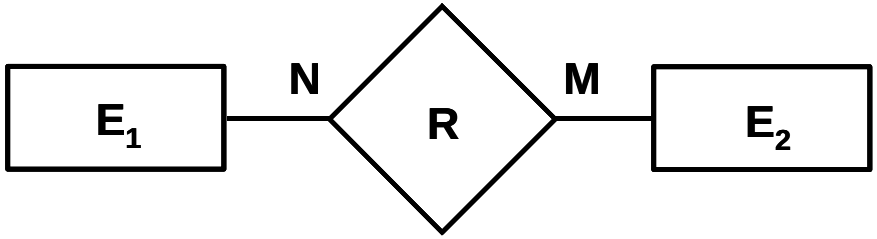


Conceptual Schema Design

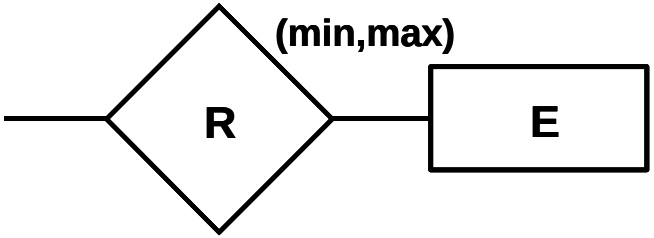
- Entity-Relationship Model
  - Diagram notation …



Total (partial) participation of E_2 (E_1) in R



Cardinality ration N:M for E_1:E_2 in R



Structural constraint (min,max) for the participation of E in R

Conceptual Schema Design

- Entity-Relationship Model
  - Examples …

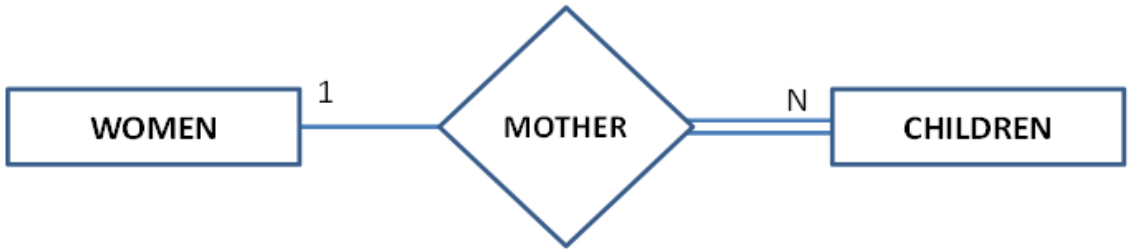
(a) Married couples.

(b) All adults.

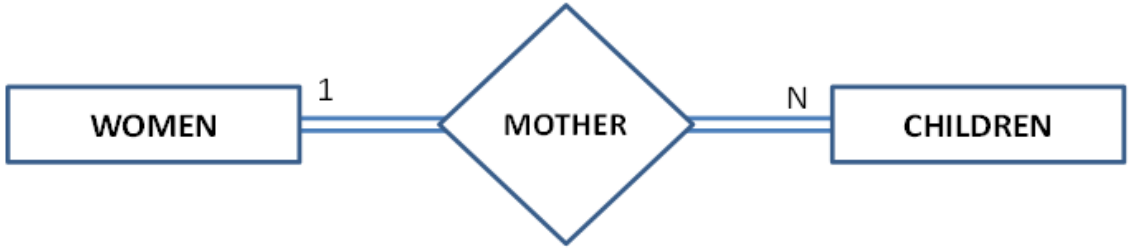
(c) All (married and single) men and all married women.

Conceptual Schema Design

- Entity-Relationship Model
  - Examples …



(d) All women and children.

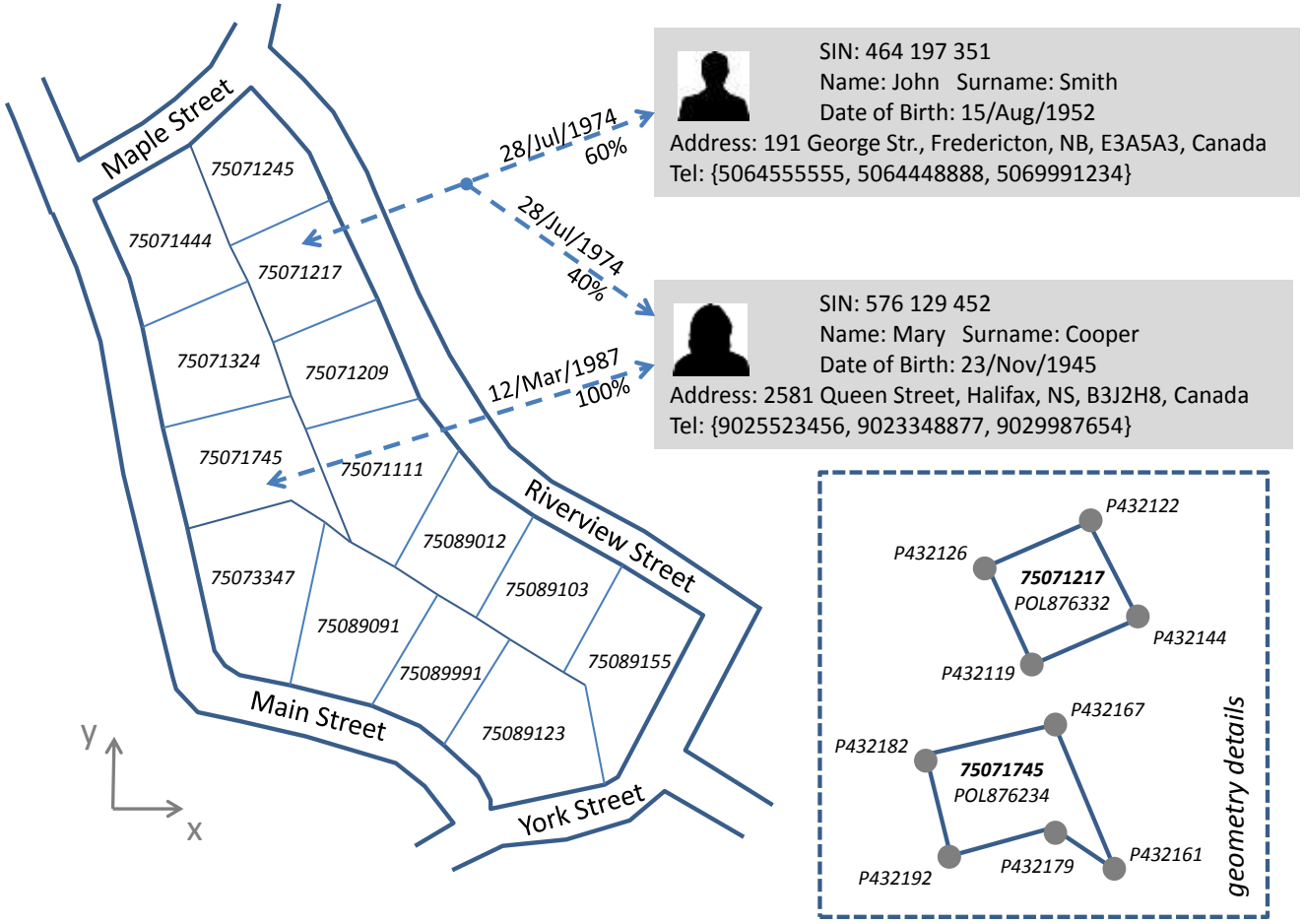


(e) All mothers and children.

(f) The history of all religious marriages for all adults.

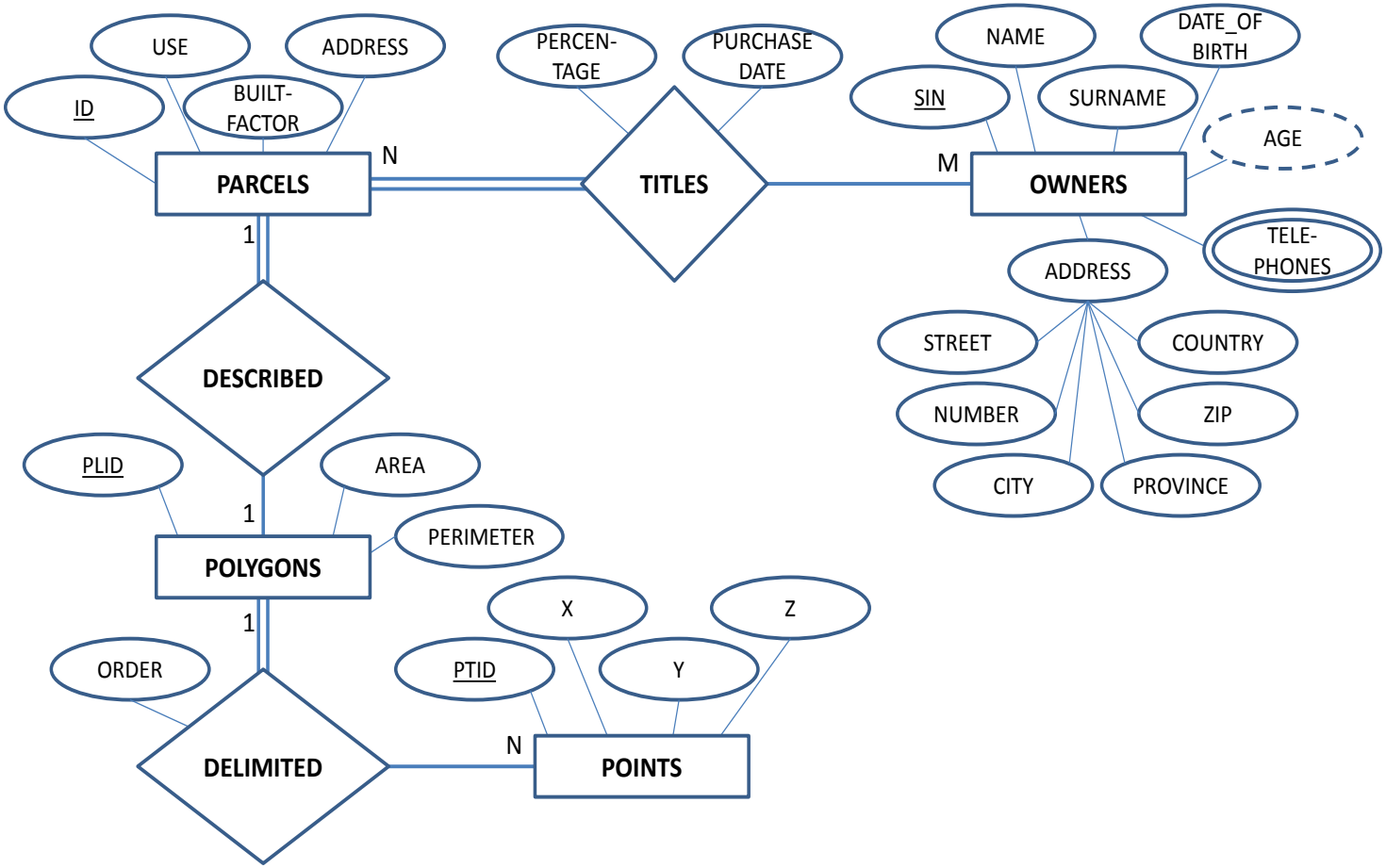
Conceptual Schema Design

- How to express this situation in ER?

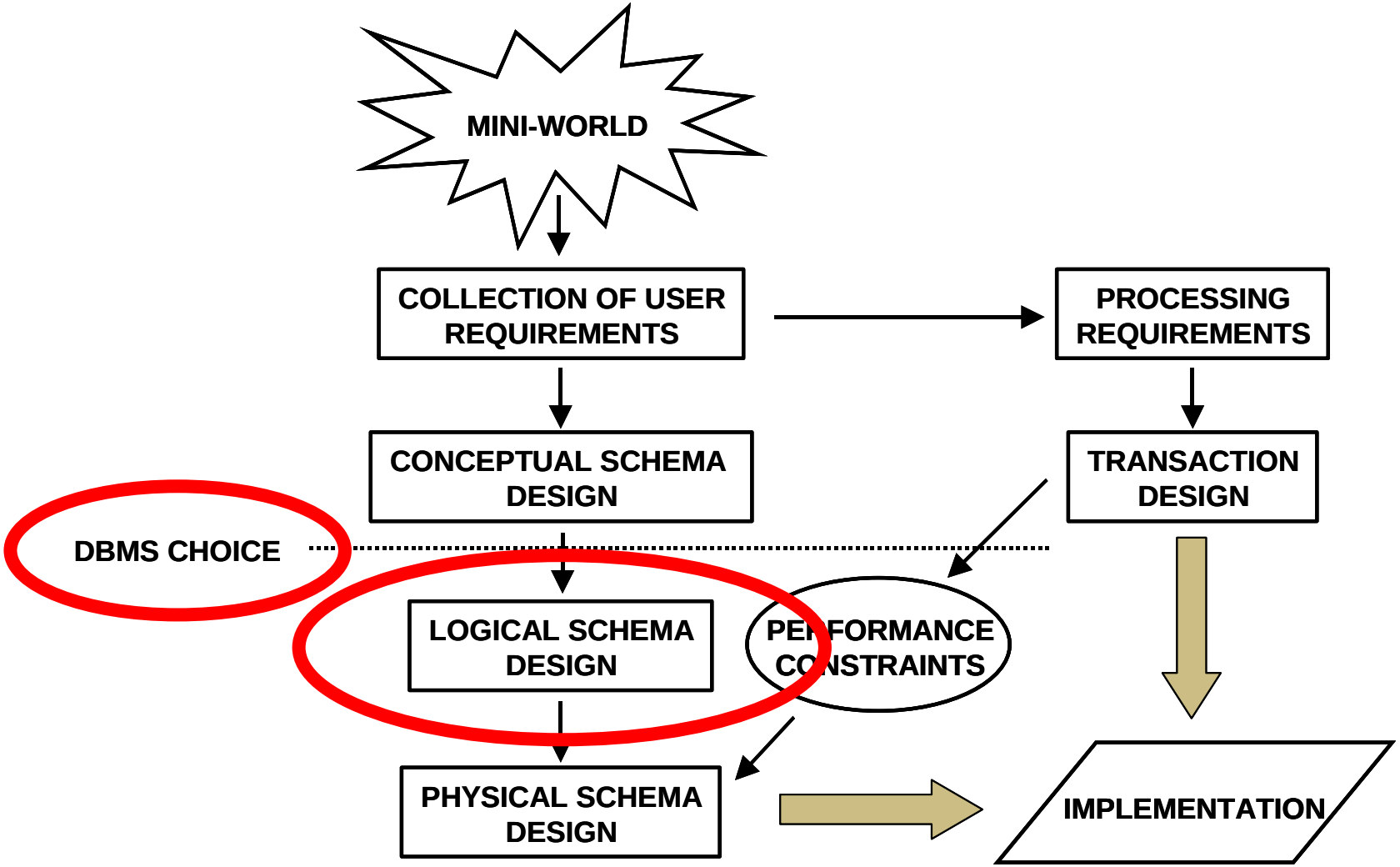


Conceptual Schema Design

- Entity-Relationship Diagram



Database System Design



Logical Schema Design

- Logical Schema …
  - hides the details at the physical level
  - it can be implemented directly
  - dependent on the DBMS (model) chosen
- One of the most popular …
  - the **relational model**
  - adopted in all traditional DBMS (Oracle, Ingres, Informix, etc.)

Logical Schema Design

- The **relational model**
  - Introduced by Codd 1970
  - Database consists of …
    - A set of **relations** (tables)
    - Each relation consists of …
      - Tuples (records)
      - Attributes (columns)

OWNERS

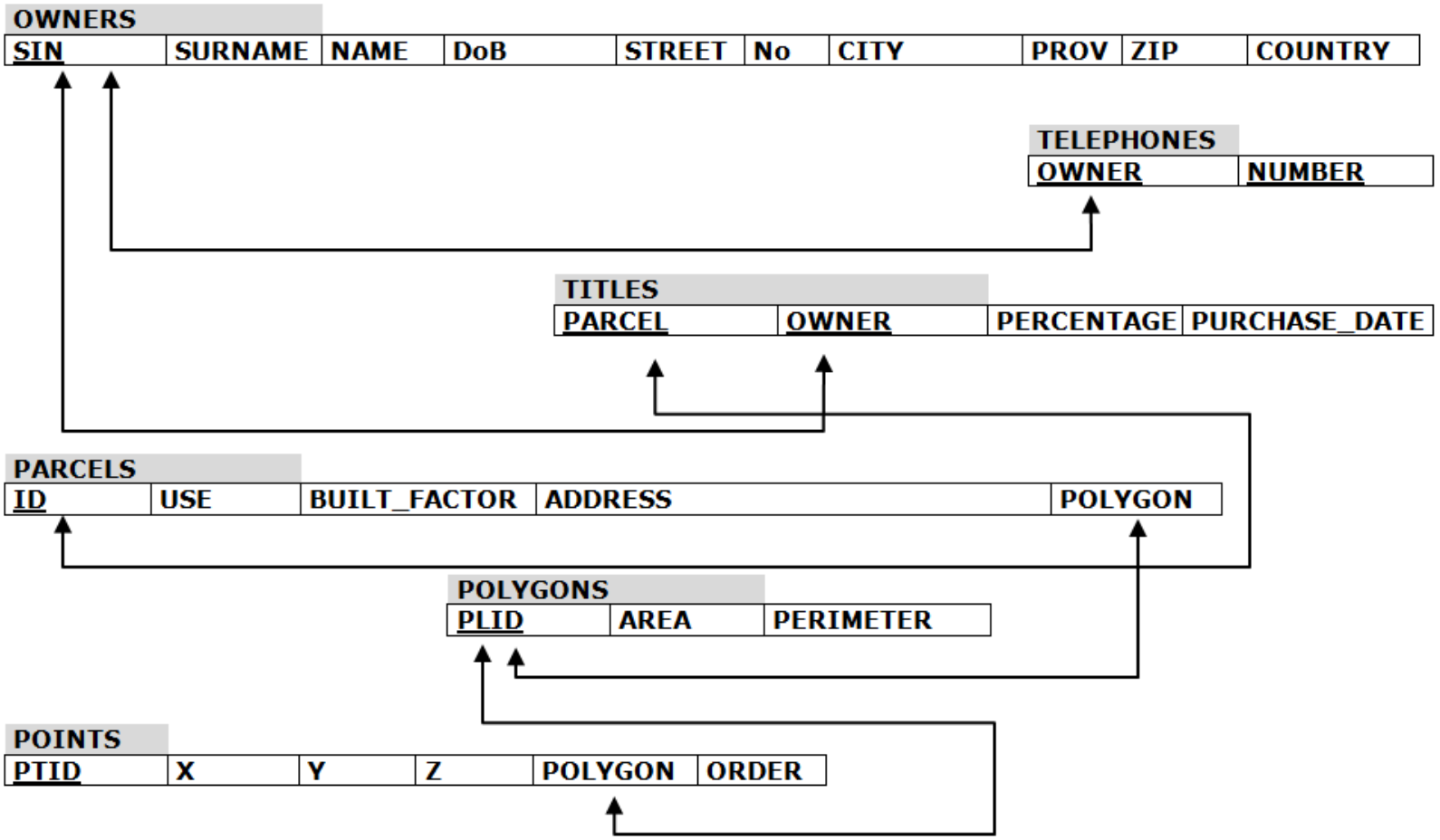
SIN	**SURNAME**	**NAME**	**DoB**	**STREET**	**No**	**CITY**	**PROV**	**ZIP**	**COUNTRY**
464197351	SMITH	JOHN	08/15/1952	GEORGE	191	FREDERICTON	NB	E3A5A3	CANADA
576129452	COOPER	MARY	11/23/1945	QUEEN	2581	HALIFAX	NS	B3J2H8	CANADA
…	…	…	…	…	…			…	…

Logical Schema Design

- The **relational model**
  - Each tuple is unique
  - **Key** …
    - the attribute or combination of attributes that
      - appear once in a relation
      - identify each tuple
    - if more than one (candidate keys) …
      - we choose the one with the fewer attributes (underlined)
  - Relations are "**related**"
    - through common attributes (Cartesian product)

Logical Schema Design

- The **relational model (schema)**



Logical Schema Design

- The **relational model (instance/snapshot)**

OWNERS

SIN	SURNAME	NAME	DoB	STREET	No	CITY	PROV	ZIP	COUNTRY
464197351	SMITH	JOHN	08/15/1952	GEORGE	191	FREDERICTON	NB	E3A5A3	CANADA
576129452	COOPER	MARY	11/23/1945	QUEEN	2581	HALIFAX	NS	B3J2H8	CANADA
...	...	...	...	...	...			...	...

TELEPHONES

OWNER	NUMBER
464197351	5064555555
464197351	5064448888
464197351	5069991234
576129452	9025523456
576129452	9023348877
576129452	9029987654
...	...

TITLES

PARCEL	OWNER	PERCENTAGE	PURCHASE_DATE
75071217	464197351	60%	07/28/1974
75071217	576129452	40%	07/28/1974
75071745	576129452	100%	03/12/1987
...	...	...	...

PARCELS

ID	USE	BUILT_FACTOR	ADDRESS	POLYGON
75071217	HOUSING	1.40	542 RIVERVIEW STREET, FREDERICTON	POL876332
75071745	PARKING	1.20	323 MAIN STREET, FREDERICTON	POL876234
...	...	...	...	...

POLYGONS

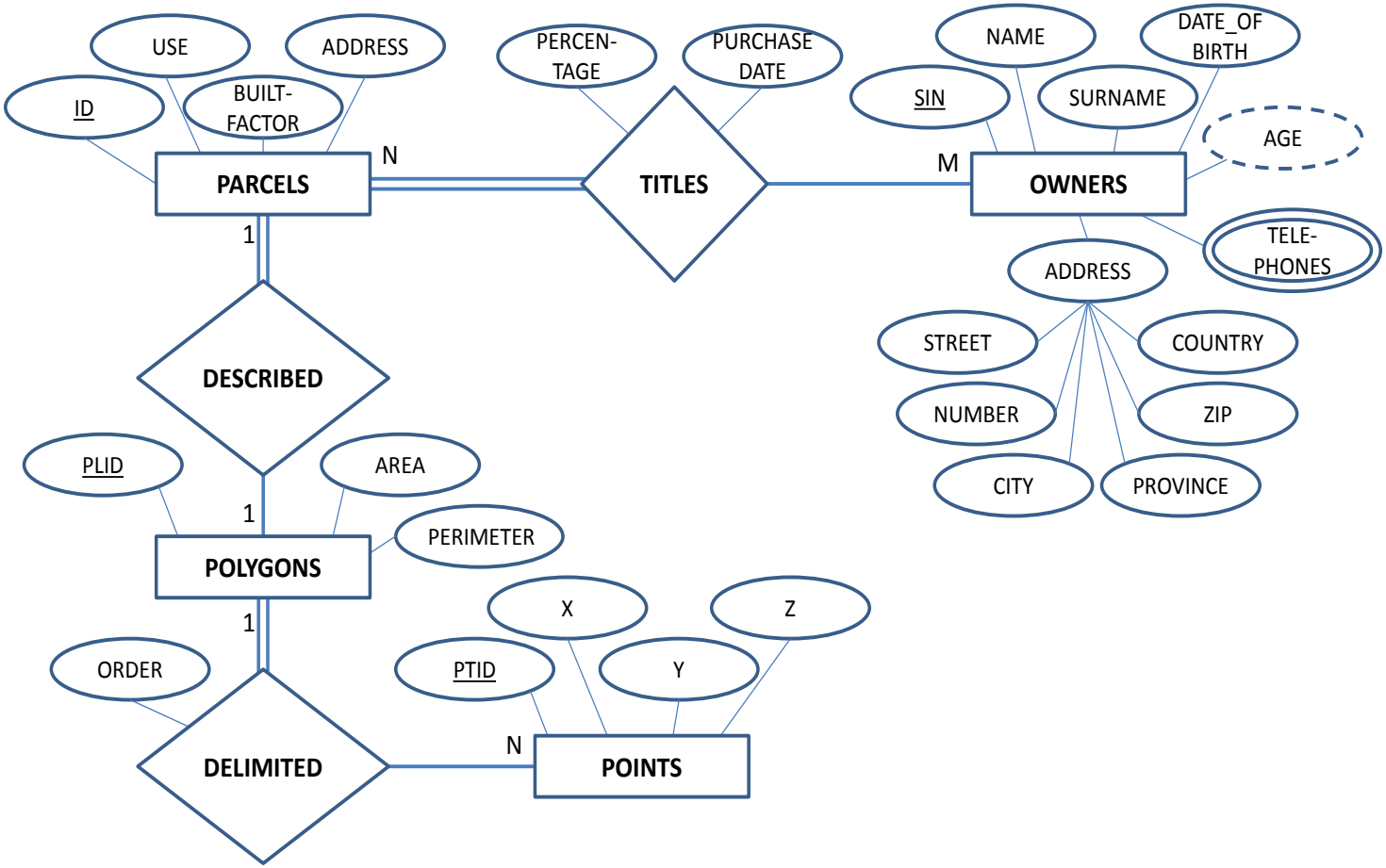
PLID	AREA	PERIMETER
POL876332	1.235	142
POL876234	1.440	169
...	...	...

POINTS

PTID	X	Y	Z	POLYGON	ORDER
P432122	45678.34	8938.89	34.20	POL876332	1
P432144	45705.56	8879.67	32.85	POL876332	2
P432119	45621.12	8845.87	31.97	POL876332	3
P432126	45592.56	8910.91	32.88	POL876332	4
P432167	45650.33	8813.12	30.71	POL876234	1
P432161	45692.11	8726.44	28.12	POL876234	2
P432179	45653.98	8749.92	28.65	POL876234	3
P432192	45550.19	8730.51	27.92	POL876234	4
P432182	45539.87	8802.01	29.33	POL876234	5
...	...	...	...	...	...

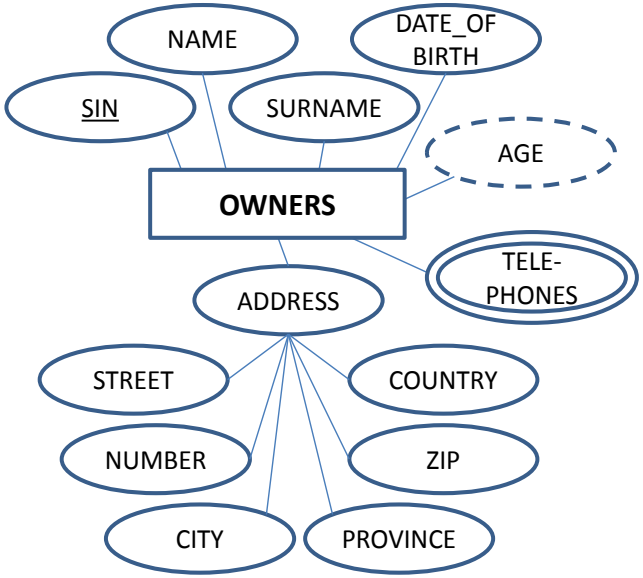
Logical Schema Design

- How to map ER Model to Relational Model?



Mapping ER to Relational schema

- Standard steps…
  - Step 1:
    - For each entity type form one relation
      - composite attributes as simple
      - ignore derived attribute

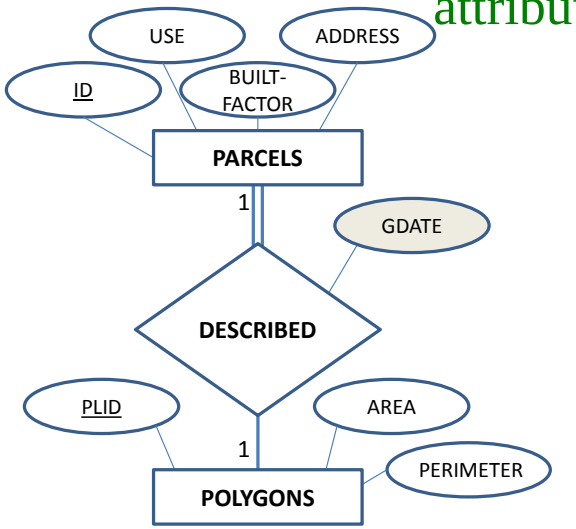


OWNERS

SIN	SURNAME	NAME	DoB	STREET	No	CITY	PROV	ZIP	COUNTRY

Mapping ER to Relational schema

- Standard steps…
  - Step 2:
    - For each 1:1 relationship …
      - include in the relation with full participation the key of the other (as foreign key)
      - include also the attributes of the relationship (if any) as attributes in this relation



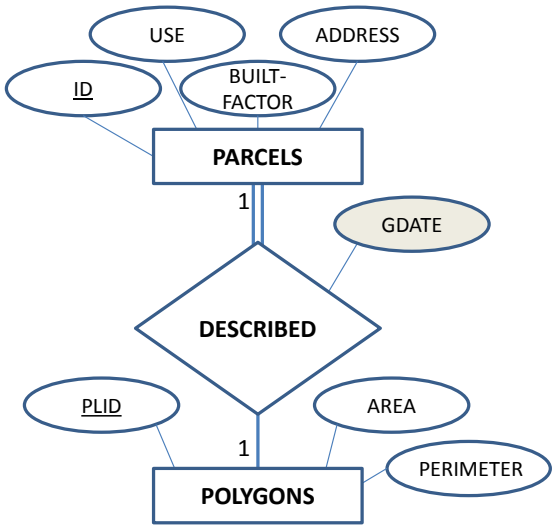
PARCELS			
ID	USE	BUILT_FACTOR	ADDRESS

POLYGONS		
PLID	AREA	PERIMETER

PARCELS				*foreign key*	*rel. attribute*
ID	USE	BUILT_FACTOR	ADDRESS	POLYGON	GDATE

Mapping ER to Relational schema

- Step 2



PARCELS				*foreign key*	*rel.attribute*
ID	**USE**	**BUILT_FACTOR**	**ADDRESS**	**POLYGON**	**GDATE**
75071217	HOUSING	1.40	542 RIVERVIEW STREET, FREDERICTON	POL876332	05/25/1969
75071745	PARKING	1.20	323 MAIN STREET, FREDERICTON	POL876234	07/01/2000

POLYGONS		
PLID	**AREA**	**PERIMETER**
POL876332	1.235	142
POL876234	1.440	169
POL555555	5.234	1345
POL555556	12.341	4322

(a)

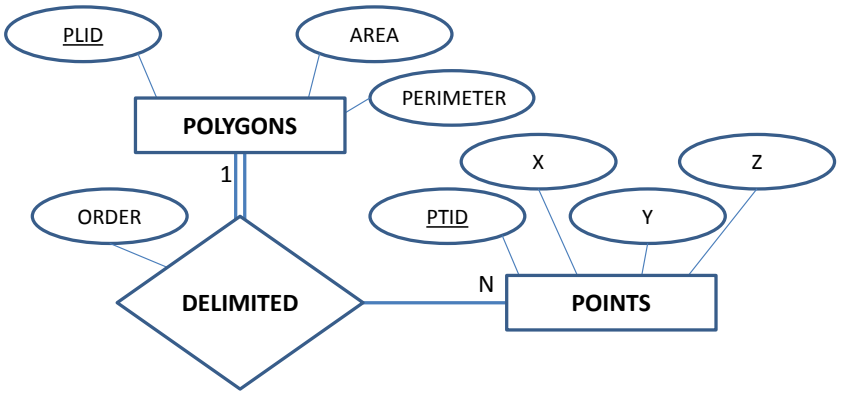
PARCELS			
ID	**USE**	**BUILT_FACTOR**	**ADDRESS**
75071217	HOUSING	1.40	542 RIVERVIEW STREET, FREDERICTON
75071745	PARKING	1.20	323 MAIN STREET, FREDERICTON

POLYGONS			*foreign key*	*rel.attribute*
PLID	**AREA**	**PERIMETER**	**PARCEL**	**GDATE**
POL876332	1.235	142	75071217	05/25/1969
POL876234	1.440	169	75071745	07/01/2000
POL555555	5.234	1345		
POL555556	12.341	4322		

(b)

Mapping ER to Relational schema

- Standard steps…
  - Step 3:
    - For each 1:N relationship …
      - include in the relation with the N participation the key of the other (as foreign key)
      - include also the attributes of the relationship (if any) as attributes in this relation



POLYGONS

PLID	AREA	PERIMETER

POINTS

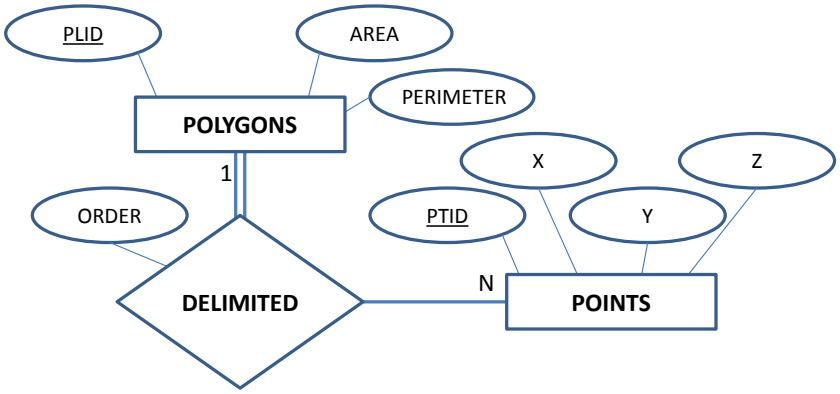
PTID	X	Y	Z

POINTS

				foreign key	*rel. attribute*
PTID	X	Y	Z	POLYGON	ORDER

Mapping ER to Relational schema

- Step 3:



POLYGONS

PLID	AREA	PERIMETER
POL876332	1.235	142
POL876234	1.440	169

POINTS *foreign key* *rel.attribute*

PTID	X	Y	Z	POLYGON	ORDER
P432122	45678.34	8938.89	34.20	POL876332	1
P432144	45705.56	8879.67	32.85	POL876332	2
P432119	45621.12	8845.87	31.97	POL876332	3
P432126	45592.56	8910.91	32.88	POL876332	4
P432167	45650.33	8813.12	30.71	POL876234	1
P432161	45692.11	8726.44	28.12	POL876234	2
P432179	45653.98	8749.92	28.65	POL876234	3
P432192	45550.19	8730.51	27.92	POL876234	4
P432182	45539.87	8802.01	29.33	POL876234	5

POLYGONS *foreign key* *rel.attribute*

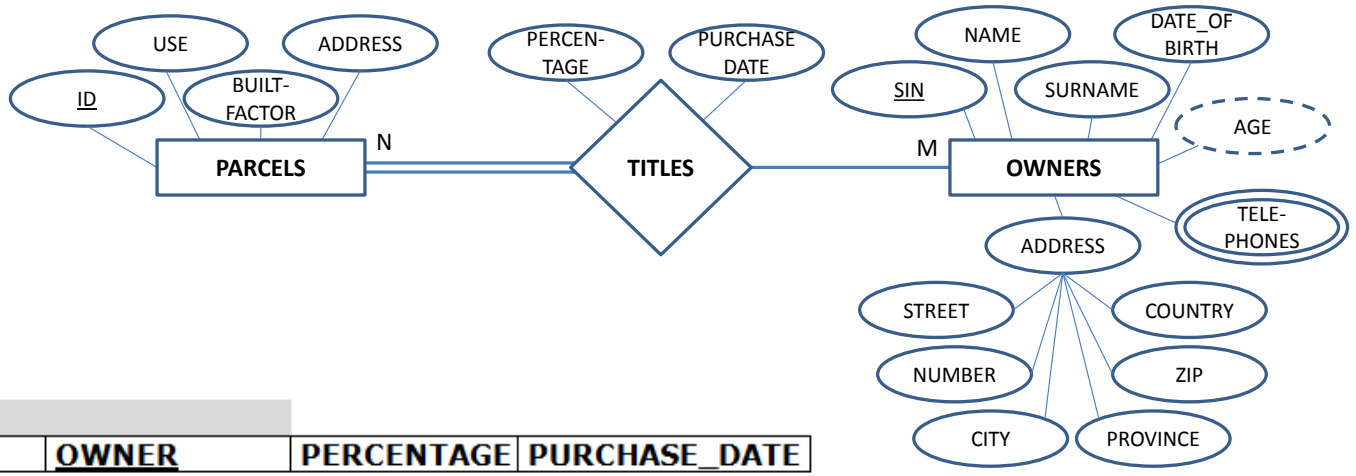
PLID	AREA	PERIMETER	POINT	ORDER
POL876332	1.235	142	P432122	1
POL876332	1.235	142	P432144	2
POL876332	1.235	142	P432119	3
POL876332	1.235	142	P432126	4
POL876234	1.440	169	P432167	1
POL876234	1.440	169	P432161	2
POL876234	1.440	169	P432179	3
POL876234	1.440	169	P432192	4
POL876234	1.440	169	P432182	5

POINTS

PTID	X	Y	Z
P432122	45678.34	8938.89	34.20
P432144	45705.56	8879.67	32.85
P432119	45621.12	8845.87	31.97
P432126	45592.56	8910.91	32.88
P432167	45650.33	8813.12	30.71
P432161	45692.11	8726.44	28.12
P432179	45653.98	8749.92	28.65
P432192	45550.19	8730.51	27.92
P432182	45539.87	8802.01	29.33

Mapping ER to Relational schema

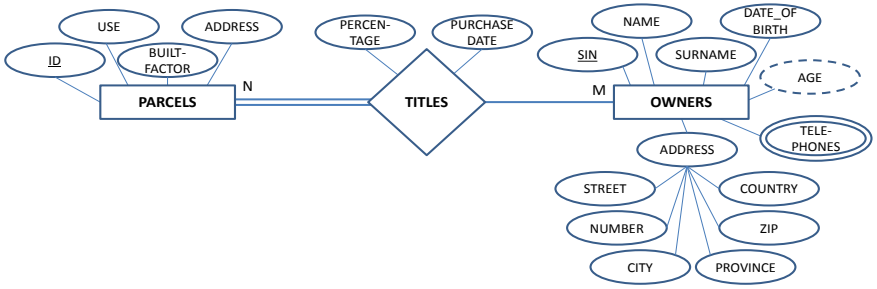
- Standard steps…
  - Step 4:
    - For each N:M relationship …
      - create **a new relation** with the keys of the two entities participating in the relationship
      - also include the relationship attributes



TITLES			
PARCEL	OWNER	PERCENTAGE	PURCHASE_DATE

Mapping ER to Relational schema

- Step 4:



OWNERS

SIN	SURNAME	NAME	DoB
464197351	SMITH	JOHN	08/15/1952
576129452	COOPER	MARY	11/23/1945

TITLES

PARCEL	OWNER	PERCENTAGE	PURCHASE_DATE
75071217	464197351	60%	07/28/1974
75071217	576129452	40%	07/28/1974
75071745	576129452	100%	03/12/1987

PARCELS

ID	USE	BUILT_FACTOR
75071217	HOUSING	1.40
75071745	PARKING	1.20

(a)

OWNERS

SIN	SURNAME	NAME	DoB
464197351	SMITH	JOHN	08/15/1952
576129452	COOPER	MARY	11/23/1945

PARCELS

			foreign key	*rel.attribute*	*rel.attribute*
ID	USE	BUILT_FACTOR	OWNER	PERCENTAGE	PURCHASE_DATE
75071217	HOUSING	1.40	464197351	60%	07/28/1974
75071217	HOUSING	1.40	576129452	40%	07/28/1974
75071745	PARKING	1.20	576129452	100%	03/12/1987

(b)

OWNERS

				foreign key	*rel.attribute*	*rel.attribute*
SIN	SURNAME	NAME	DoB	PARCEL	PERCENTAGE	PURCHASE_DATE
464197351	SMITH	JOHN	08/15/1952	75071217	60%	07/28/1974
576129452	COOPER	MARY	11/23/1945	75071217	40%	07/28/1974
576129452	COOPER	MARY	11/23/1945	75071745	100%	03/12/1987

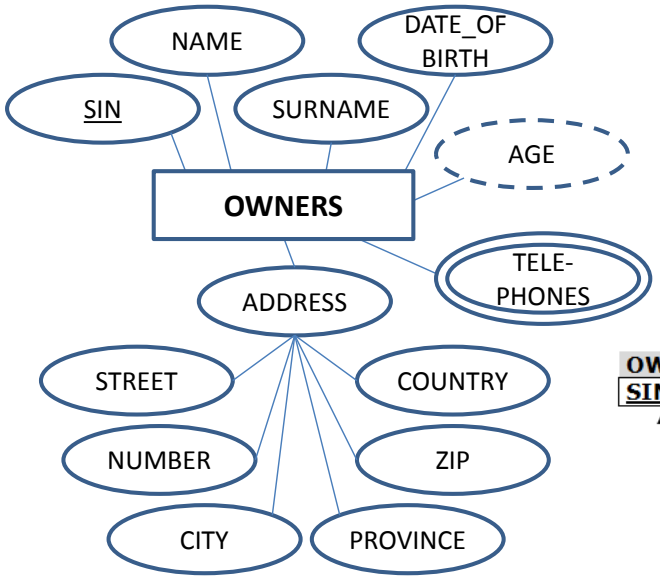
PARCELS

ID	USE	BUILT_FACTOR
75071217	HOUSING	1.40
75071745	PARKING	1.20

(c)

Mapping ER to Relational schema

- Standard steps…
  - Step 5:
    - For each multivalued attribute …
      - create **a new relation** with the key of the entity and the multivalued attribute



OWNERS

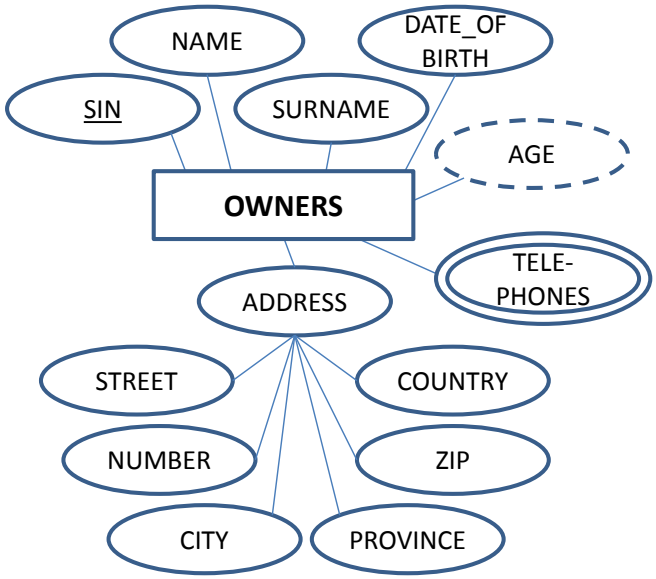
SIN	SURNAME	NAME	DoB	STREET	No	CITY	PROV	ZIP	COUNTRY

TELEPHONES

OWNER	NUMBER

Mapping ER to Relational schema

- Step 5:



OWNERS

SIN	SURNAME	NAME	DoB	TELEPHONE
464197351	SMITH	JOHN	08/15/1952	5064555555
464197351	SMITH	JOHN	08/15/1952	5064448888
464197351	SMITH	JOHN	08/15/1952	5069991234
576129452	COOPER	MARY	11/23/1945	9025523456
576129452	COOPER	MARY	11/23/1945	9023348877
576129452	COOPER	MARY	11/23/1945	9029987654

(a)

OWNERS

SIN	SURNAME	NAME	DoB	NUMBER_1	NUMBER_2	NUMBER_3	NUMBER_4
464197351	SMITH	JOHN	08/15/1952	5064555555	5064448888	5069991234	
576129452	COOPER	MARY	11/23/1945	9025523456	9023348877	9029987654	

(b)

OWNERS

SIN	SURNAME	NAME	DoB
464197351	SMITH	JOHN	08/15/1952
576129452	COOPER	MARY	11/23/1945

TELEPHONES

OWNER	NUMBER
464197351	5064555555
464197351	5064448888
464197351	5069991234
576129452	9025523456
576129452	9023348877
576129452	9029987654

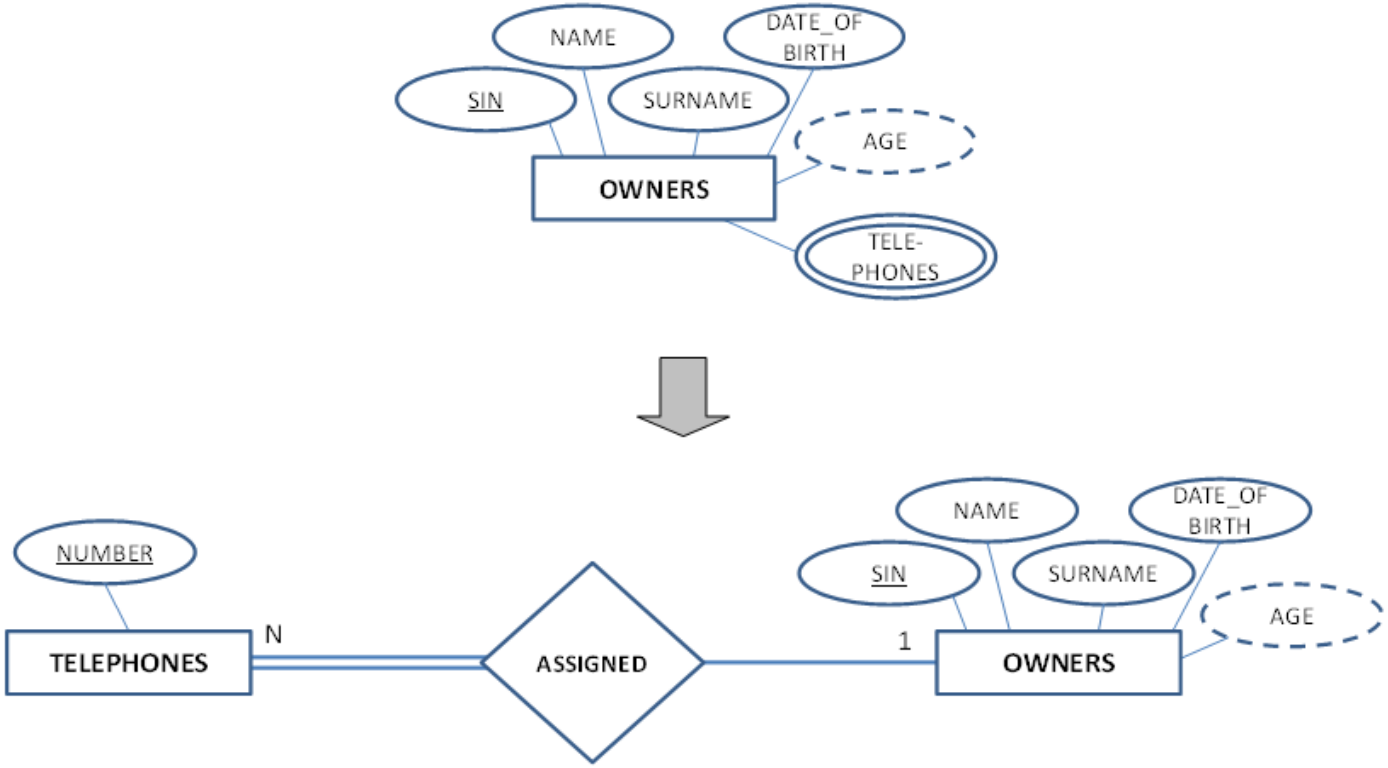
(c)

OWNERS

SIN	SURNAME	NAME	DoB	TELEPHONES
464197351	SMITH	JOHN	08/15/1952	5064555555; 5064448888; 5069991234
576129452	COOPER	MARY	11/23/1945	9025523456; 9023348877; 9029987654

Mapping ER to Relational schema

- Step 5:



Normal Forms

- Rules that assure …
  - the organization of data into tables, without duplications…
- NF-1…
  - Each cell accommodate one atomic values
  - No nested relations allowed

POLYGONS

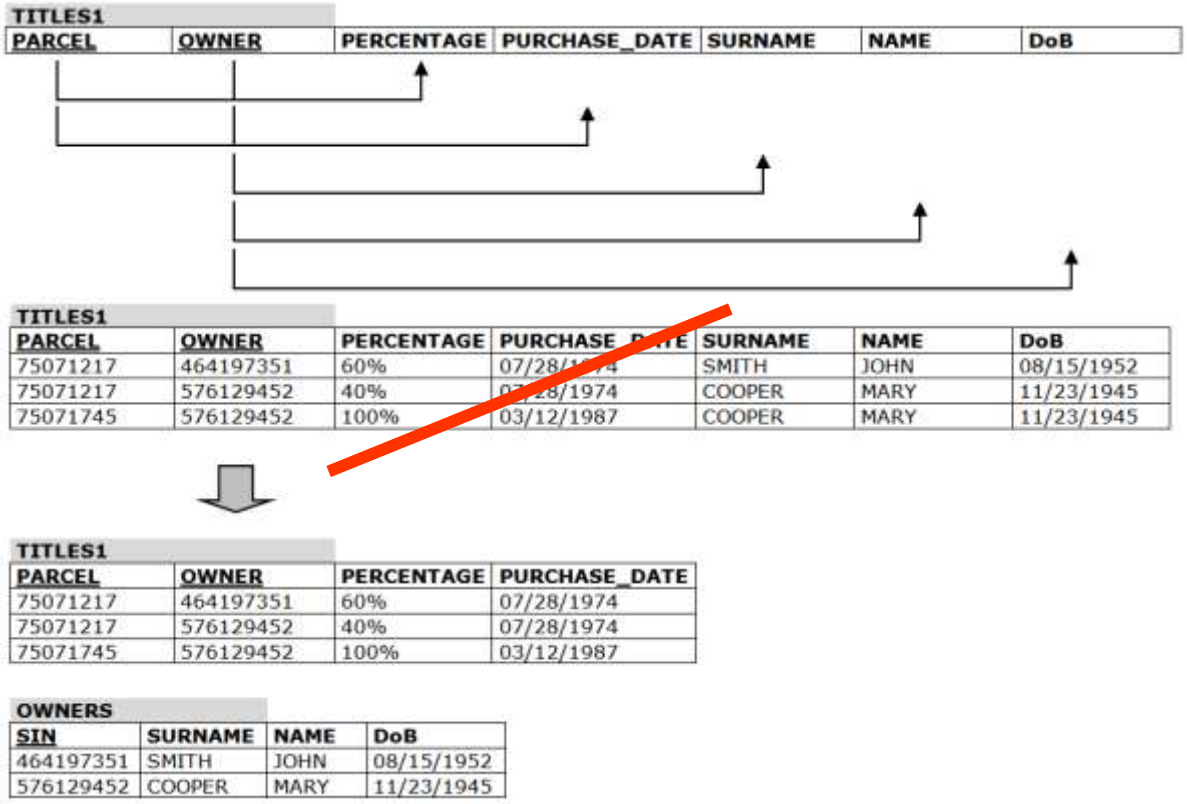
PLID	AREA	PERIMETER	POINT	ORDER
POL876332	1.235	142	P432122	1
			P432144	2
			P432119	3
			P432126	4
POL876234	1.440	169	P432167	1
			P432161	2
			P432179	3
			P432192	4
			P432182	5

POLYGONS

PLID	AREA	PERIMETER	POINT	ORDER
POL876332	1.235	142	P432122	1
POL876332	1.235	142	P432144	2
POL876332	1.235	142	P432119	3
POL876332	1.235	142	P432126	4
POL876234	1.440	169	P432167	1
POL876234	1.440	169	P432161	2
POL876234	1.440	169	P432179	3
POL876234	1.440	169	P432192	4
POL876234	1.440	169	P432182	5

Normal Forms

- NF-2…
  - All attributes should be fully (and no partially) dependent on the composite key



TITLES1

PARCEL	OWNER	PERCENTAGE	PURCHASE_DATE	SURNAME	NAME	DoB

TITLES1

PARCEL	OWNER	PERCENTAGE	PURCHASE_DATE	SURNAME	NAME	DoB
75071217	464197351	60%	07/28/1974	SMITH	JOHN	08/15/1952
75071217	576129452	40%	07/28/1974	COOPER	MARY	11/23/1945
75071745	576129452	100%	03/12/1987	COOPER	MARY	11/23/1945

TITLES1

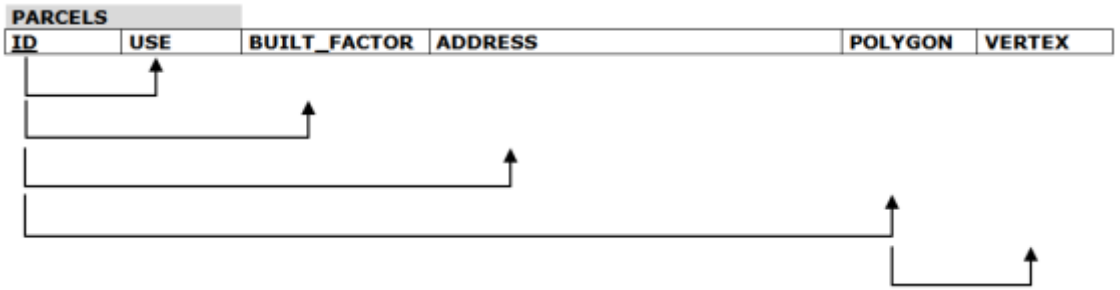
PARCEL	OWNER	PERCENTAGE	PURCHASE_DATE
75071217	464197351	60%	07/28/1974
75071217	576129452	40%	07/28/1974
75071745	576129452	100%	03/12/1987

OWNERS

SIN	SURNAME	NAME	DoB
464197351	SMITH	JOHN	08/15/1952
576129452	COOPER	MARY	11/23/1945

Normal Forms

- NF-3…
  - All attributes should be directly (and no transitional) dependent on the primary key

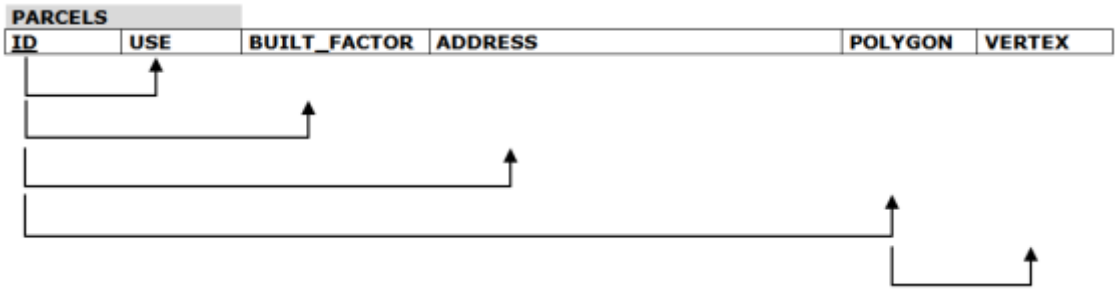


PARCELS

ID	USE	BUILT_FACTOR	ADDRESS	POLYGON	VERTEX
75071217	HOUSING	1.40	542 RIVERVIEW STREET, FREDERICTON	POL876332	P432122
75071217	HOUSING	1.40	542 RIVERVIEW STREET, FREDERICTON	POL876332	P432144
75071217	HOUSING	1.40	542 RIVERVIEW STREET, FREDERICTON	POL876332	P432119
75071217	HOUSING	1.40	542 RIVERVIEW STREET, FREDERICTON	POL876332	P432126
75071745	PARKING	1.20	323 MAIN STREET, FREDERICTON	POL876234	P432167
75071745	PARKING	1.20	323 MAIN STREET, FREDERICTON	POL876234	P432161
75071745	PARKING	1.20	323 MAIN STREET, FREDERICTON	POL876234	P432179
75071745	PARKING	1.20	323 MAIN STREET, FREDERICTON	POL876234	P432192
75071745	PARKING	1.20	323 MAIN STREET, FREDERICTON	POL876234	P432182

Normal Forms

- NF-3…
  - All attributes should be directly (and no transitional) dependent on the primary key



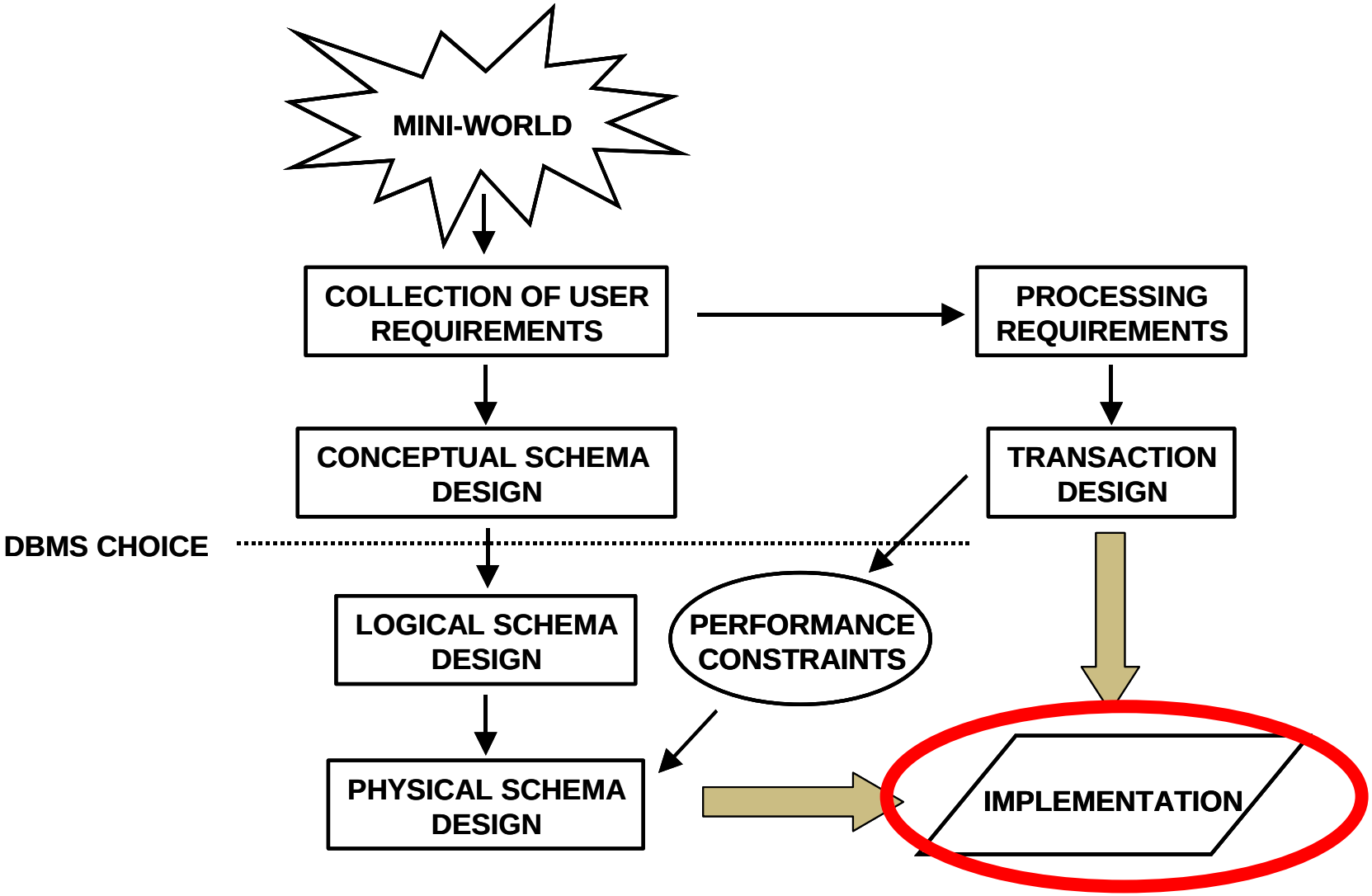
PARCELS

ID	USE	BUILT_FACTOR	ADDRESS	POLYGON
75071217	HOUSING	1.40	542 RIVERVIEW STREET, FREDERICTON	POL876332
75071745	PARKING	1.20	323 MAIN STREET, FREDERICTON	POL876234

POINTS

PTID	POLYGON
P432122	POL876332
P432144	POL876332
P432119	POL876332
P432126	POL876332
P432167	POL876234
P432161	POL876234
P432179	POL876234
P432192	POL876234
P432182	POL876234

Database System Design



Relational Algebra

- Describes the operations for the manipulation of relations
  - Relational operations
    - SELECT: selection of tuples (rows)
    - PROJECT: selection of attributes (columns)
    - JOIN: combines tuples from two relations
  - Set operations
    - UNION: unify two relations
    - INTERSECTION: finds the common tuples
    - DIFFERENCE: removes common tuples

Relational Algebra

- Describes the operations for the manipulation of relations
  - Aggregate operations
    - AVERAGE, SUM, MAX, MIN, COUNT
  - Update operations
    - INSERT, DELETE, UPDATE

SQL

- Structured Query Language
  - based on the relational algebra
  - declarative (non procedural) language
  - DBMS optimizer is responsible for the execution plan
  - consists of
    - the data definition language (DDL)
      - create tables and indices over table fields (attributes)
    - The data manipulation language (DML)
      - insert, delete, modify values in tables

SQL

- Data Definition Language (DDL)
  - CREATE TABLE
  - CREATE INDEX
  - CREATE VIEW

  - DROP TABLE
  - DROP INDEX
  - DROP VIEW

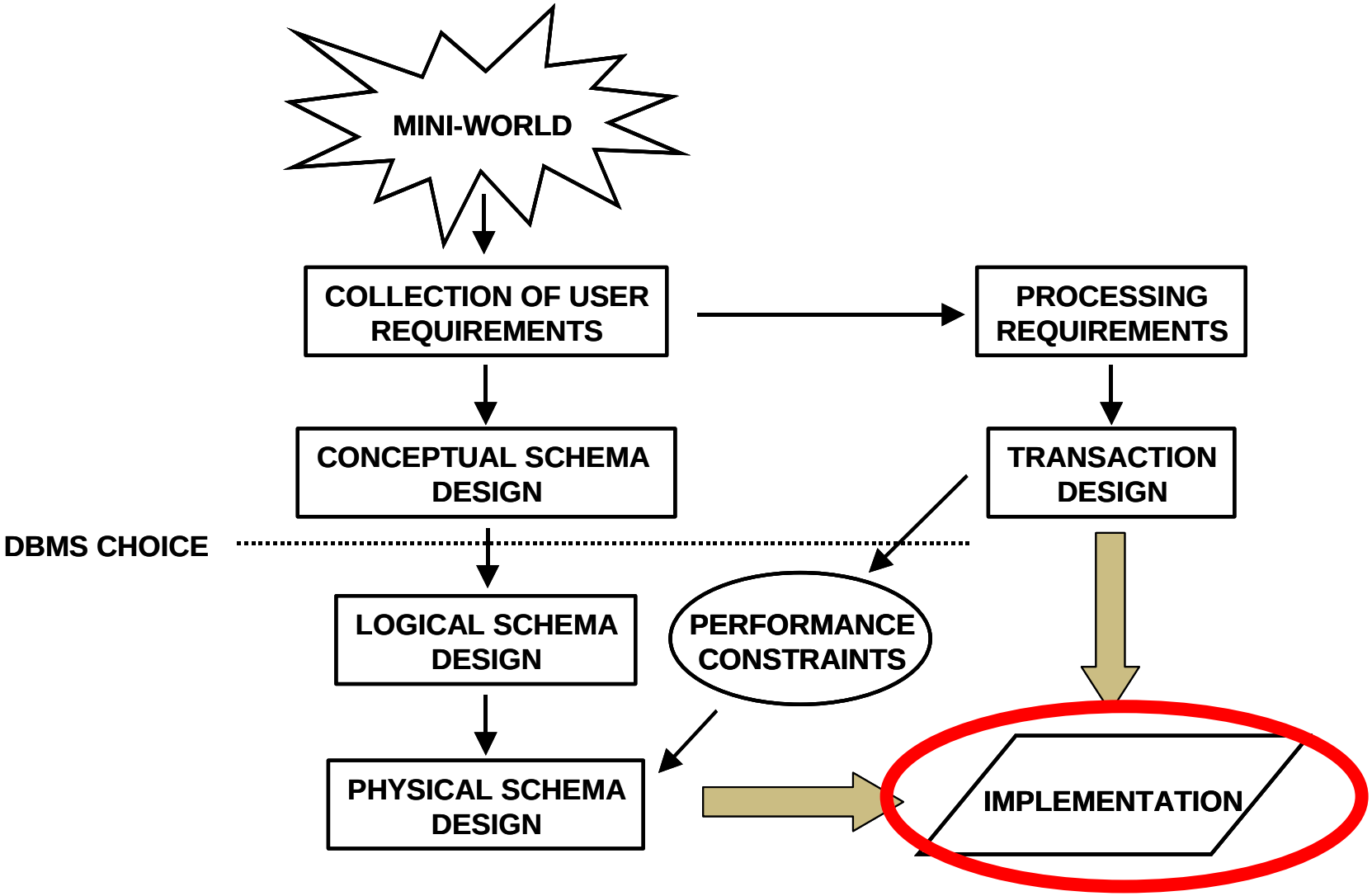
  - MODIFY

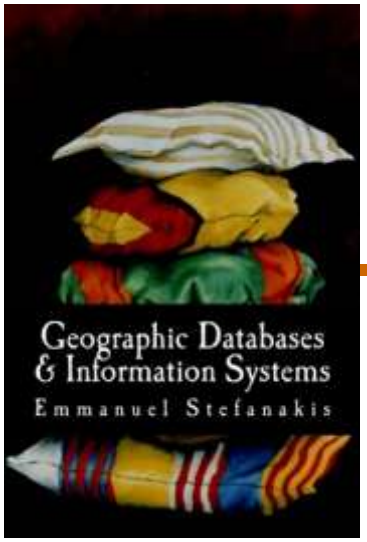
SQL

- Data Manipulation Language (DML)
  - SELECT
  - INSERT
  - DELETE
  - UPDATE

  - COMMIT WORK (store changes)
  - ROLLBACK WORK (until last COMMIT)

Database System Design





Stefanakis, E., 2014. *Geographic Databases and Information Systems*. CreateSpace Independent Publ. [In English], pp.386.

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Chapter 6

Database System Design

Emmanuel Stefanakis

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