CSIT115 Data Management and Security

Logical Design

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Logical Design

Outline

Methodology

Logical design transforms a conceptual schema into a set of relational schemas

Logical design is performed in the following steps:

(1) Multivalued attributes are replaced with classes of objects and depending on the semantics of multivalued attribute either with one-to-many or many-to-many associations

(2) Associaton classes and link attributes are replaced with the triples (one-to-many association:class-of-objects :many-to-one-association)

(3) Many-to-many associations are replaced with triples (one-to-many association:class-of-objects:many-to-one association)

(4) Qualifications are replaced with one-to-many associations and composite identifiers in object classes on "many" side of one-to-many associations

Methodology

(5) Selected identifiers are copied from classes of objects on "one" side of association to class of objects on "many" side of association and are tagged with FKn (an index "n" is used to distinguish between different foreign keys)

(6) Triples (class-of-objects:one-to-one asociation:class of objects) are merged into one class of objects and one-to-one associations are removed (continued on the next slide)

(7) Superset, subset, and association methods are used to transform generalizations

(8) Primary and candidate keys are created

(9) Associations are removed

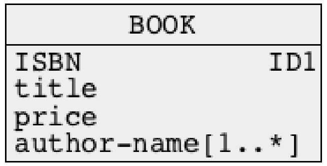
(10) Relational schemas with referential integrity constraints are created

Logical Design

Outline

Multivalued attributes

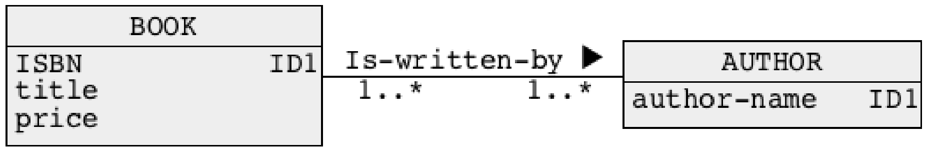
Case 1: Transformation into a class of objects and many-to-many association



A multivalued attribute `author-name` in a class of objects `BOOK` is transformed in the following way:

- An attribute `author-name` is promoted to a class of objects `AUTHOR` (such step is called as reification)
- A single valued attribute `author-name` is added as an identifier to a class `AUTHOR`
- A multivalued attribute `author-name` is removed from a class `BOOK`
- A many-to-many association `Is-written-by` is created between the classes `BOOK` and `AUTHOR`

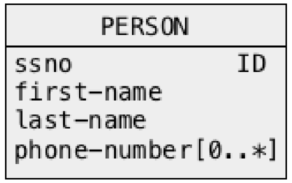
Multivalued attributes



An association `Is-written-by` is many-to-many because a book can be written by many authors and an author can write many books

Multivalued attributes

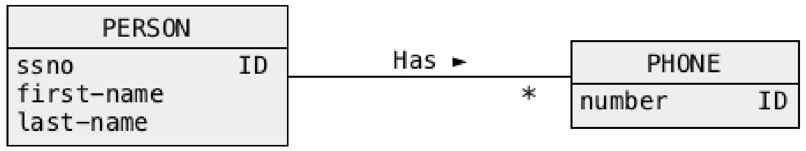
Case 2: Transformation into a class of objects and one-to-many association



A multivalued attribute `phone-number` in a class of objects `PERSON` is transformed in the following way:

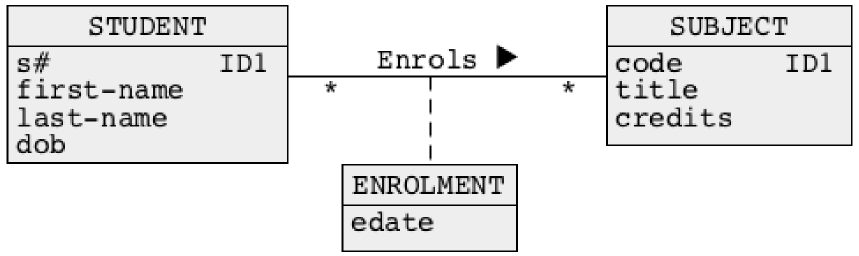
- An attribute `phone-number` is promoted to a class of objects `PHONE` (such step is called as reification)
- A single valued attribute `number` is added as an identifier to a class `PHONE`
- A multivalued attribute `phone-number` is removed from a class `PERSON`
- A one-to-many association `Has` is created between the classes `PERSON` and `PHONE`

Multivalued attributes



An association Has is one-to-many because a person can have many mobile phones and a mobile phone is owned by one person

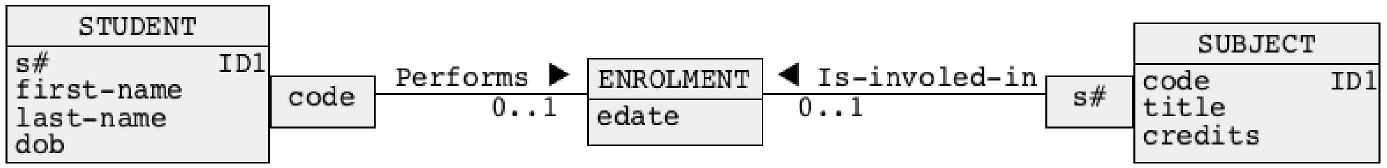
Association classes



An association class `Enrols` is transformed in the following way:

- Many-to-many association `Enrols` is removed
- A one-to-many association `Performs` is added between a class `STUDENT` and a class `ENROLMENT`
- A one-to-many association `Is-involved-in` is added between a class `SUBJECT` and a class `ENROLMENT`
- A qualification with an attribute `code` is added on `STUDENT` side of association `Performs` and a qualification with an attribute `s#` is added on `SUBJECT` side of association `Is-involved-in`

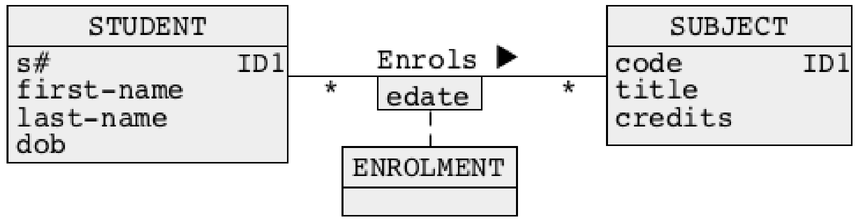
Association classes



A qualification with an attribute `code` of an association `Performs` contributes to an identifier `(s#, code)` of a class `ENROLMENT`

A qualification with an attribute `s#` of an association `Is-involved-in` also contributes to an identifier `(s#, code)` of a class `ENROLMENT`

Qualified association classess

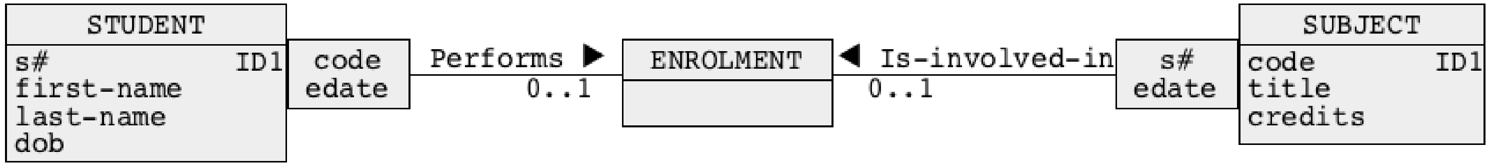


An association class `Enrols` qualified with an attribute `edate` is transformed in the following way:

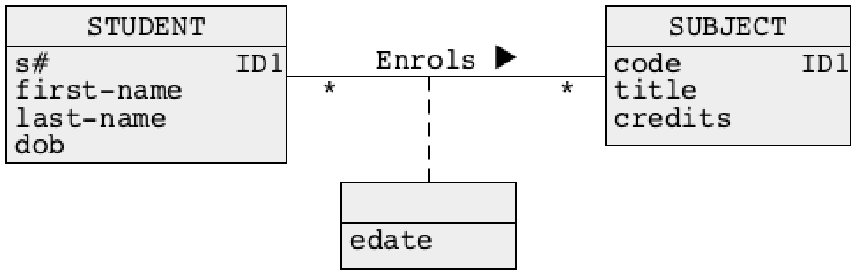
- Many-to-many association `Enrols` is removed
- A one-to-many association `Performs` is added between a class `STUDENT` and a class `ENROLMENT`
- A one-to-many association `Is-involved-in` is added between a class `SUBJECT` and a class `ENROLMENT`
- A qualification with the attributes `(code,edate)` is added on `STUDENT` side of association `Performs` and a qualification with the attributes `(s#,edate)` is added on `SUBJECT` side of association `Is-involved-in`

Qualified association classes

An attribute `edate` is removed from a class `ENROLMENT`

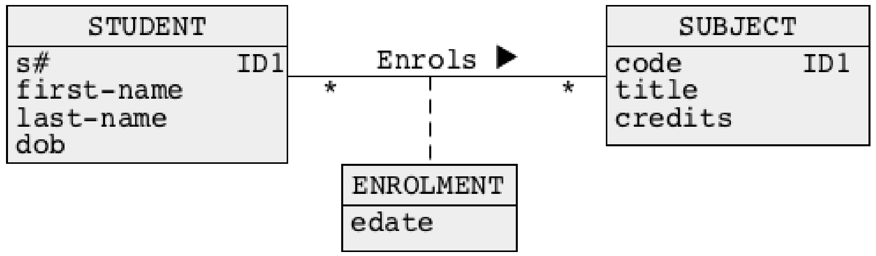


Link attributes



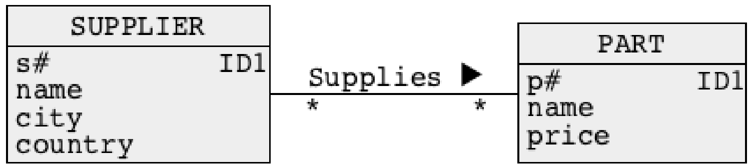
A link attribute `edate` is transformed in the following way:

- A link attribute `edate` is promoted to an association class `ENROLMENT`



- An association class `ENROLMENT` is transformed in a way explained earlier

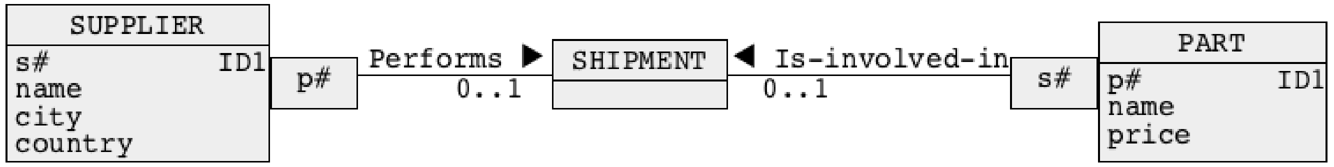
Many-to-many associations



A many-to-many association `Supplies` is transformed in the following way:

- A new class of objects `SHIPMENT` is created
- A one-to-many association `Performs` is added between a class `SUPPLIER` and a class `SHIPMENT`
- A one-to-many association `Is-involved-in` is added between a class `PART` and a class `SHIPMENT`
- A qualification with the attributes `(p#)` is added on `SUPPLIER` side of association `Performs` and a qualification with the attributes `(s#)` is added on `PART` side of association `Is-involved-in`

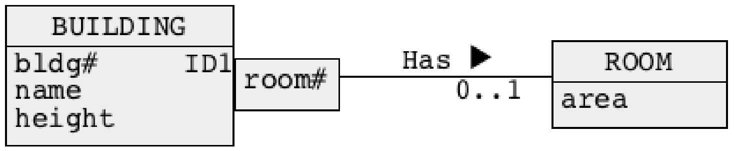
Many-to-many associations



A qualification with an attribute `p#` of an association Performs contributes to an identifier (p#, s#) of a class `SHIPMENT`

A qualification with an attribute `s#` of an association Is-involved-in also contributes to an identifier (p#, s#) of a class `SHIPMENT`

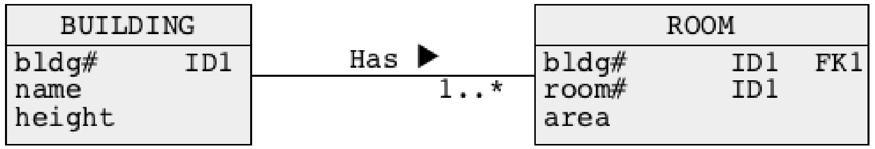
Qualifications



A qualification with the attribute room# is transformed in the following way:

- The attributes (bldg#, room#) are copied to a class ROOM
- A pair of attributes (bldg#, room#) is tagged with IDn in a class ROOM (it becomes an identifier)
- An attribute bldg# is tagged with FKn to denote a foreign key referencing an identifier bldg# in a class BUILDING
- A multiplicity on a class ROOM side of qualified association has is changed to * or 1..*
- A qualification with an attribute room# is removed

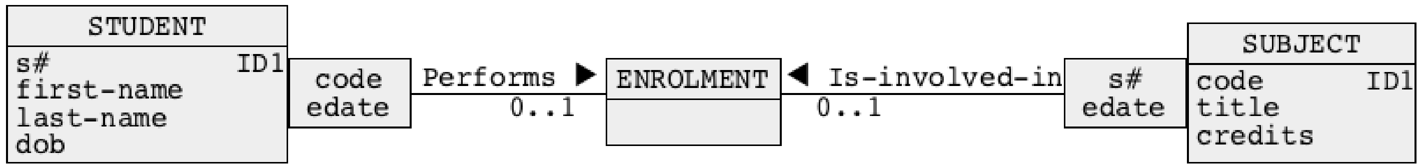
Qualifications



The attributes `(bldg#, room#)` form an identifier of a class `ROOM`

A attribute `bldg#` becomes a foreign key referencing an attribute `bldg#` in a class `BUILDING`

Qualifications

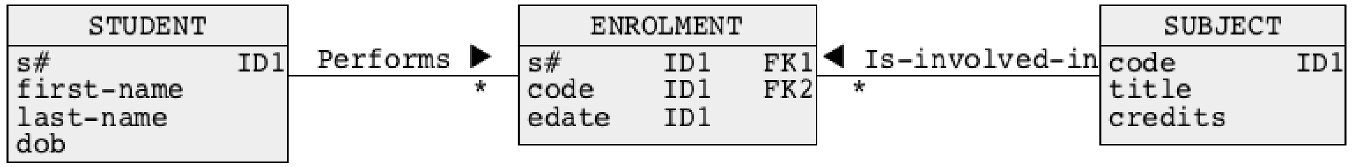


A double qualification with the attributes `(code, edate)` and `(s#, edate)` is transformed in the following way:

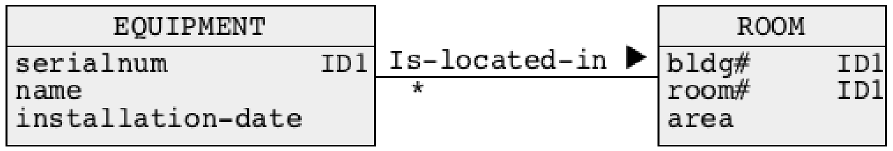
- The attributes `(code, edate)` and the attributes `(s#, edate)` are copied to a class `ENROLMENT`
- A triple of attributes `(code, s#, edate)` is tagged with `IDn` in a class `ENROLMENT` (it becomes an identifier)
- An attribute `code` is tagged with `FKn` to denote a foreign key referencing an identifier `code` in a class `SUBJECT`
- An attribute `s#` is tagged with `FKm` (where `n` <>`m`) to denote a foreign key referencing an identifier `s#` in a class `STUDENT`
- Both `0..1` multiplicities on the left and right side of a class `ENROLMENT` are changed to `*` or `1..*`

Qualifications

- Both qualifications with the attributes `(code, edate)` and `(s#, edate)` are removed

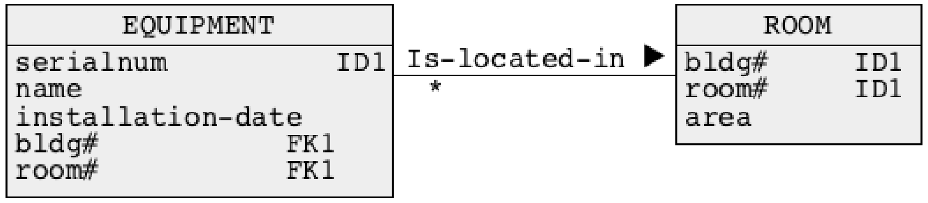


Foreign keys

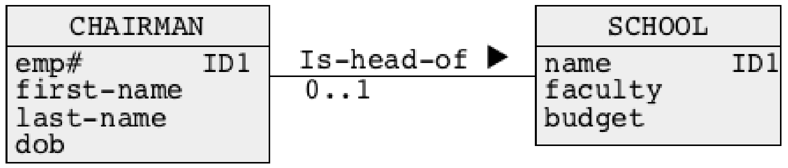


Foreign keys are created in the following way:

- An identifier (bldg#, room#) from "one" side of an association Is-located-in is copied to a class EQUIPMENT on "many" side of the association
- A pair of attributes (bldg#, room#) is tagged with FKn in a class EQUIPMENT (it becomes a composite foreign key) referencing (bldg#, room#) in a class ROOM



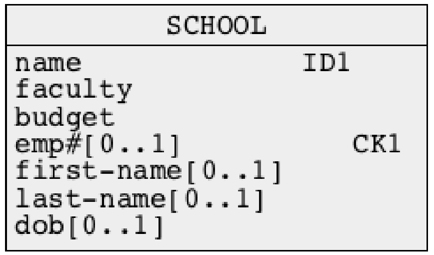
One-to-one associations



One-to-one associations are transformed in the following way:

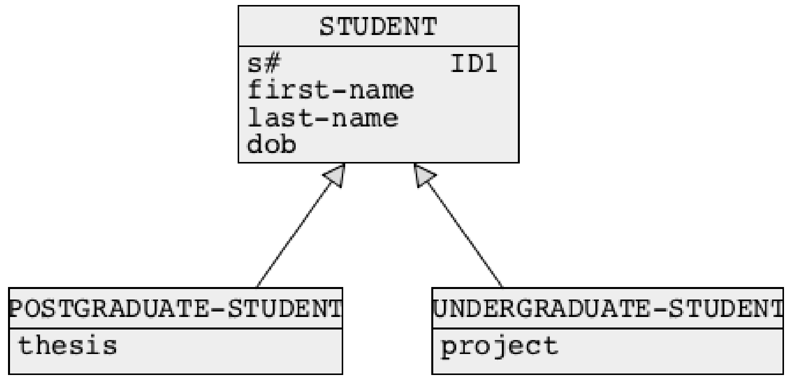
- A triple (`CHAIRMAN:Is-head-of:SCHOOL`) is merged into one class of objects `SCHOOL`
- The attributes (`emp#`, `first-name`, `last-name`, `dob`) that come from an optional 0..1 side of association `Is-head-of` are tagged with [0..1] as optional attributes
- An attribute like `name`, that was an identifier of a class on mandatory side (1..1) of and association obtains a tag `IDn`
- An attribute like `emp#`, that was an identifier of a class on an optional side of association obtains a tag `CKn`
- One-to-one association is removed

One-to-one associations



Note, that a candidate key `emp#` may have no value, i.e. it can be `NULL`

Generalizations - superset method

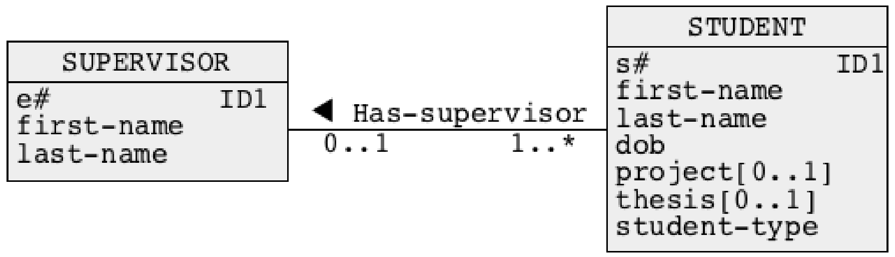


A superset method transforms entire generalization hierarchy into a single class of objects in the following way:

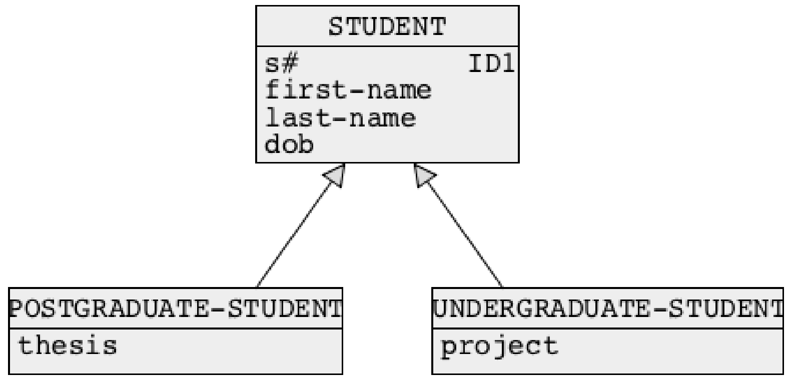
- All attributes from the classes of objects at the lowest level of generalization hierarchy are copied to an immediate higher level and become optional attributes ([0..1] tag) there, e.g. the attributes `project` and `thesis` are copied from the classes `UNDERGRADUATE-STUDENT` and `POSTGRADUATE-STUDENT` to a class `STUDENT`
- An attribute `type-of-superclass` is added to a superclass, e.g. and attribute `type-of-students` is added to a class `STUDENT`

Generalizations - superset method

- All classes at the lowest level are removed
- The steps above are repeated until only one class of objects is left



Generalizations - subset method

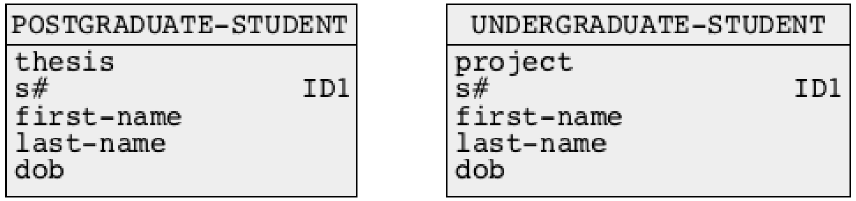


A subset method transforms entire generalization hierarchy into a number of classes of objects in the following way:

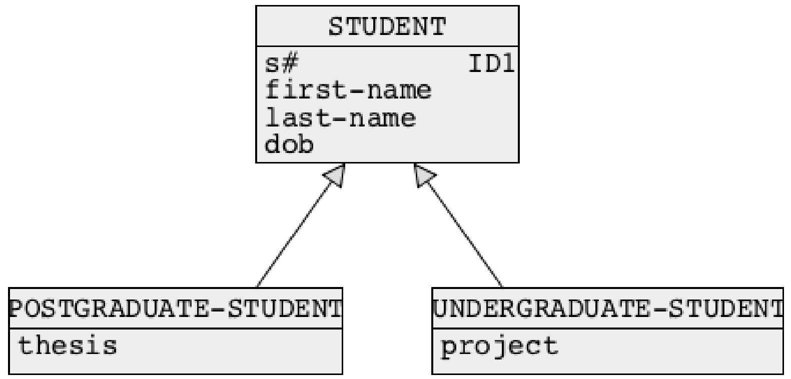
- All attributes from the classes of objects at the higher levels of generalization hierarchy are copied to the classes of objects at the lowest levels of generalization hierarchy e.g. the attributes `s#` and `first-name` last-name, dob are copied from a class `STUDENT` to the classes `POSTGRADUATE-STUDENT` and `UNDERGRADUATE-STUDENT`

Generalizations - subset method

- All classes of objects except those at the lowest levels of generalization hierachy are removed, e.g. a class STUDENT is removed



Generalizations - partitioning method

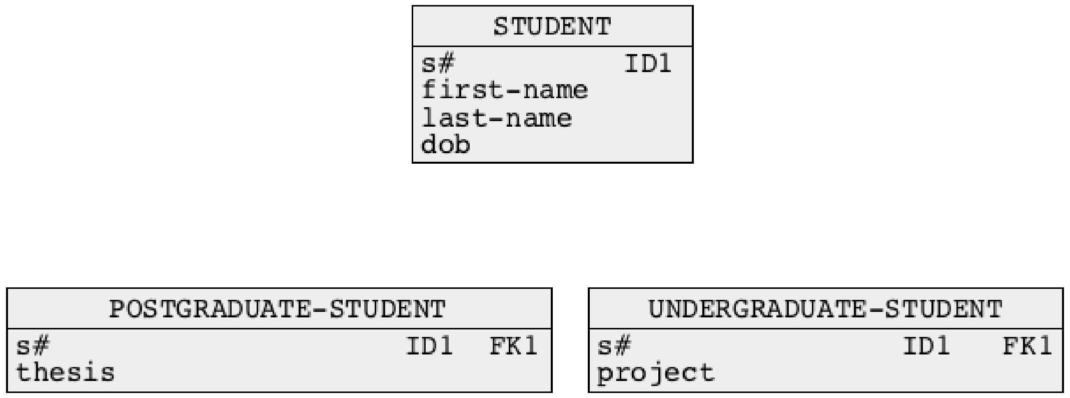


A partitioning method transforms entire generalization hierarchy into a number of classes of objects in the following way:

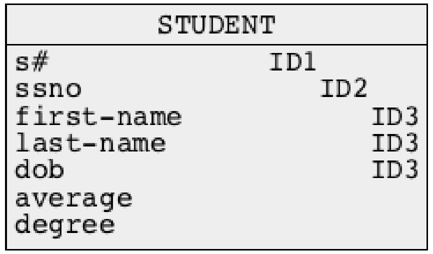
- One of the identifiers from a superclass is copied to subclasses one level below a superclass, e.g. an attribute `s#` is copied from a class `STUDENT` to the classes `UNDEGRADUATE-STUDENT and POSTGRADUATE-STUDENT`
- A copied identifier obtains a tag `FKn` in the subclasses

Generalizations - partitioning method

- A generalization level is removed from a diagram

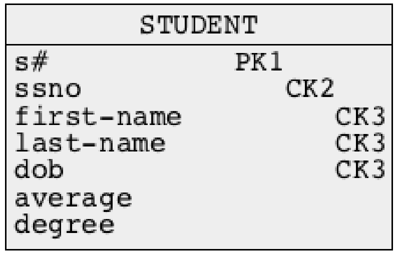


Primary keys and candidate keys

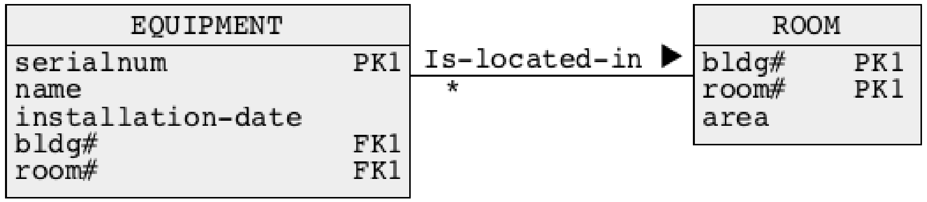


primary keys and candidate keys are created in the following way:

- In each class one of the identifiers (identifier or composite identifier), e.g. `s#` attribute is tagged with `PK` tag
- All other identifiers like `ssno`, (`first-name`, `last-name`, `dob`) are tagged with `Ckn` tags

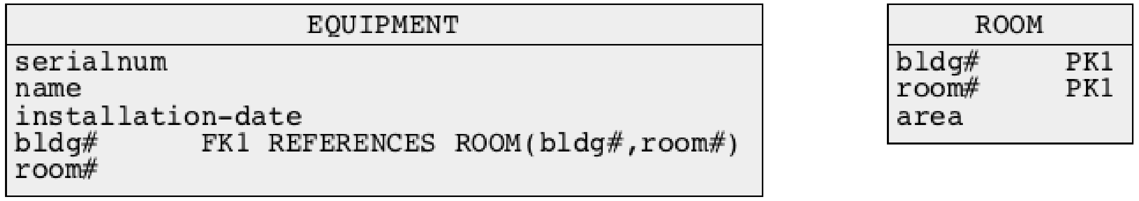


Associations

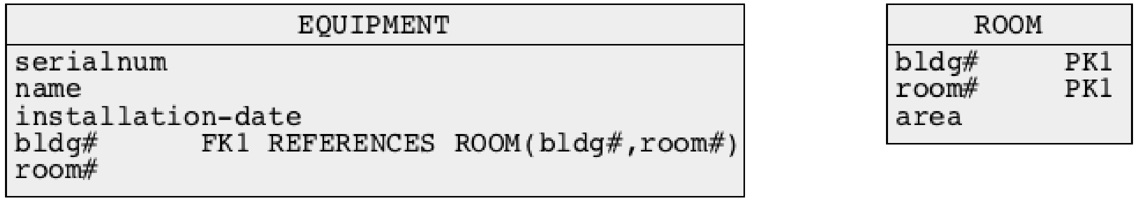


In this step association are eliminated and FKn tags are extended with REFERENCE clauses in the following way:

- Each time on-to-many association is removed a respective FKn tag is extended with REFERENCE clause refering PKn on the other side of the removed association, for example when an association Is-located-in is removed FK1:(bldg#, room#) is extened with a clause REFERENCES ROOM(blgd#, room#)



Relational schemas



In the final step the relational schemas are created in the following way:

- A relational schema is created from each object class left such that in each class the attributes tagged with `PKn` become a primary key, the attributes tagged with `CKn` become a candidate key and attributes tagged with `FKn` become a foreign key

Relational schemas ROOM and EQUIPMENT

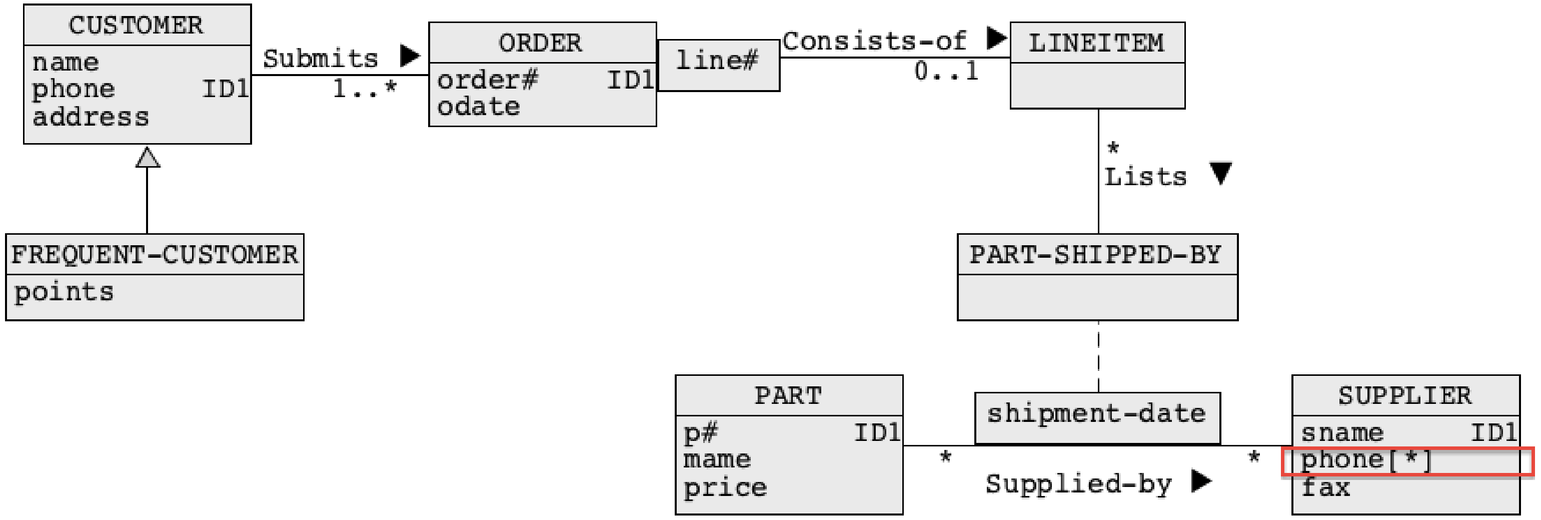
```
ROOM(bldg#, room#, area)
PRIMARY KEY = (bldg#, room#)

EQUIPMENT(serialnum, name, installation-date, bldg#, room#)
PRIMARY KEY = (serialnum)
FOREIGN KEY = (bldg#, room#)  REFERENCES ROOM(bldg#, room#)
```

Logical Design

Outline

Example

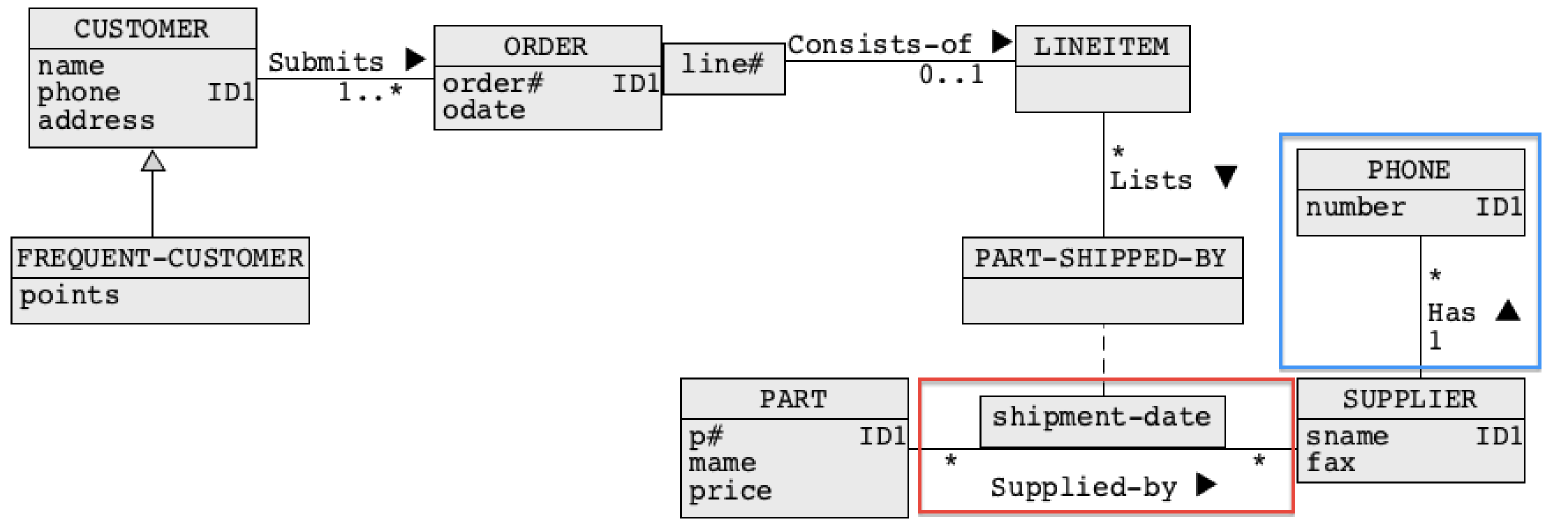
The following conceptual schema represents a simple database domain that contain information about parts, customers, orders submitted by customers, contents of each order, suppliers, and parts shipped by suppliers



First, we transform multivalued attributes

Example - multivalued attributes

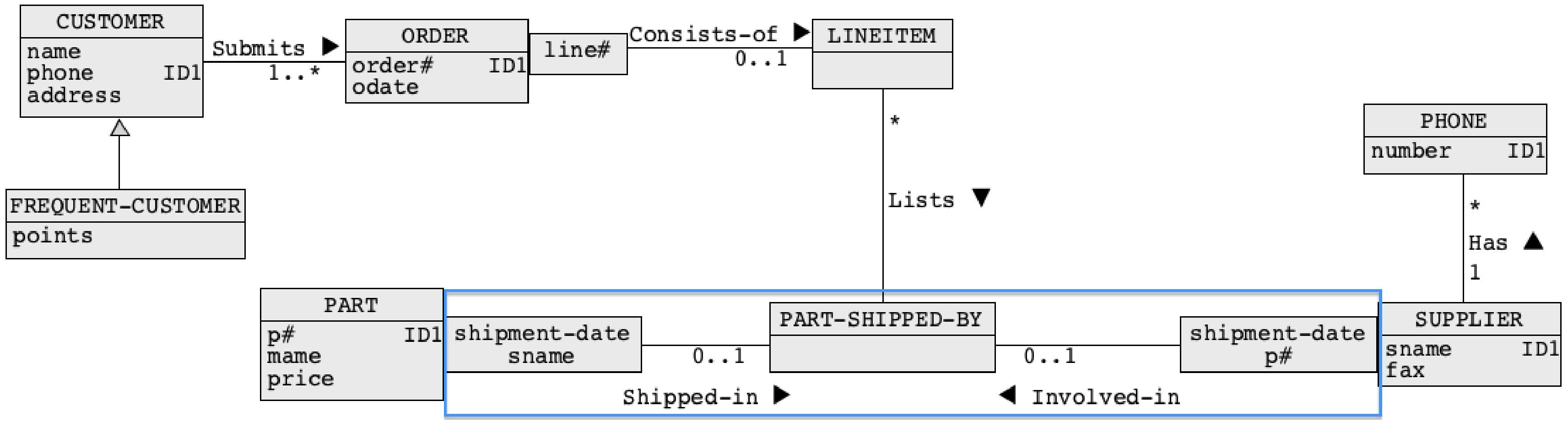
The following conceptual schema is obtained after transformation of multivalued attributes



Next, we transform association classes and link attributes

Example - Association classes and link attributes

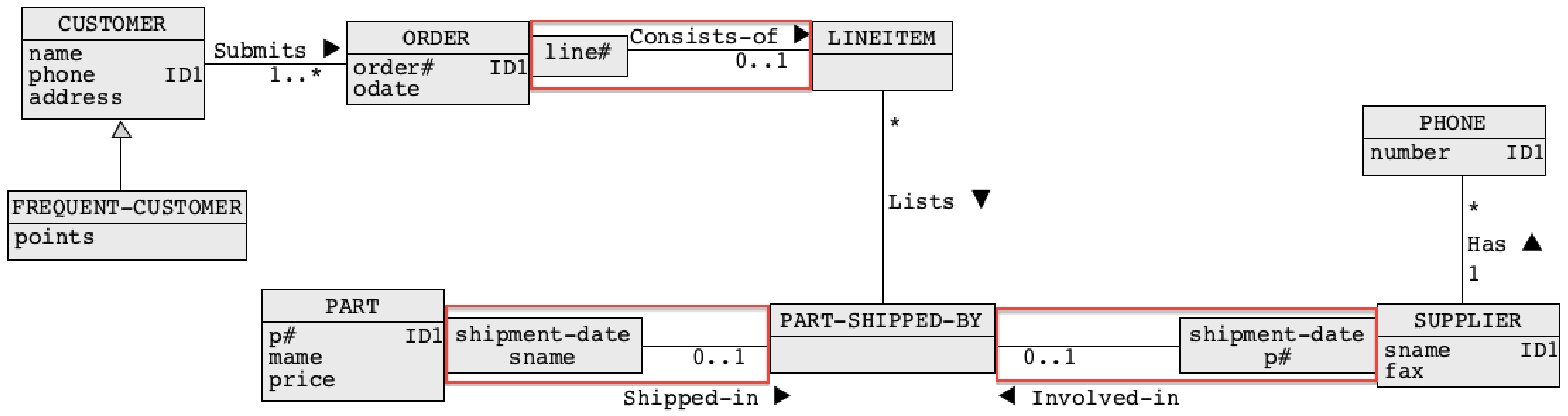
The following conceptual schema is obtained after transformation of association classes



Next, we transform many-to-many associations

Example - Many-to-many associations

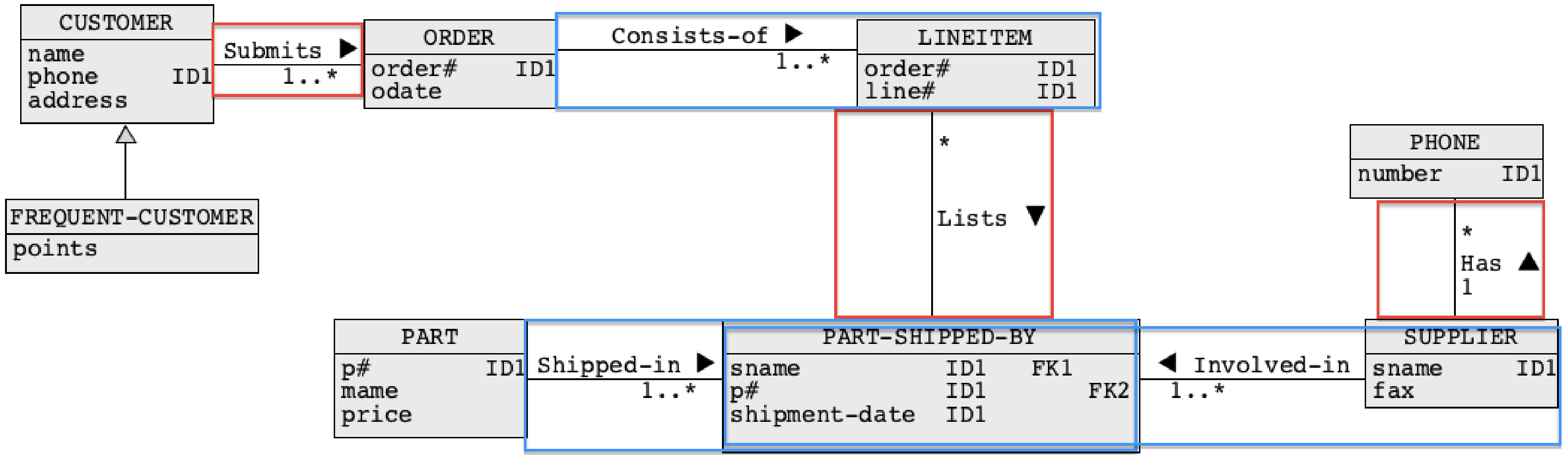
The following conceptual schema is obtained after transformation of many-to-many-associations



Next, we transform qualifications

Example - Qualifications

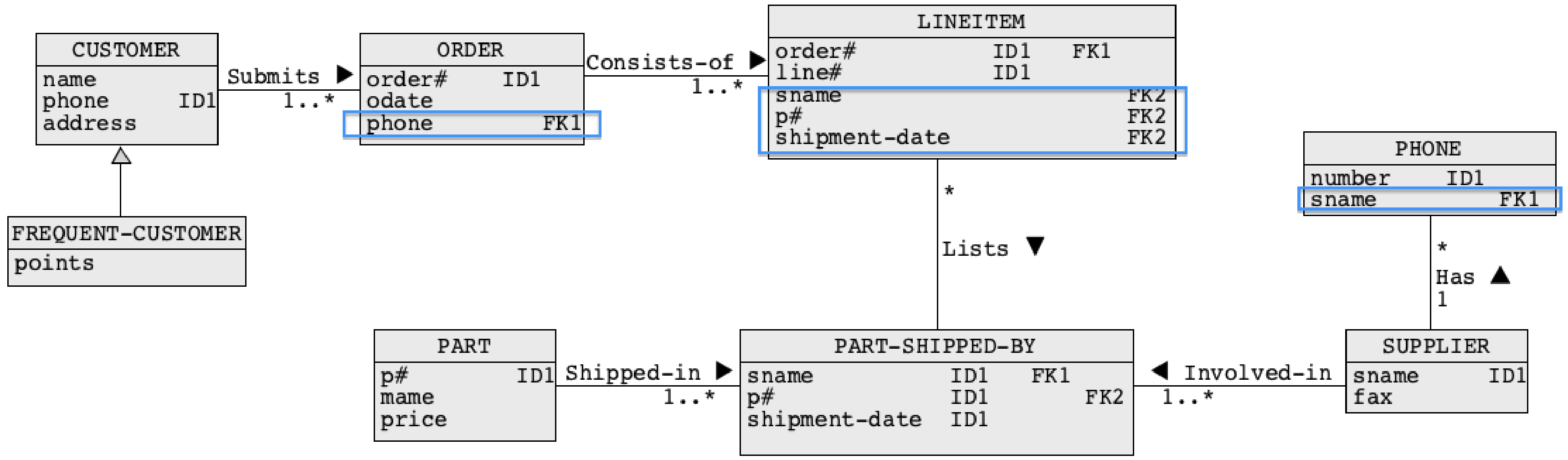
The following conceptual schema is obtained after transformation of qualifications



Next, we create foreign keys

Example - Foreign keys

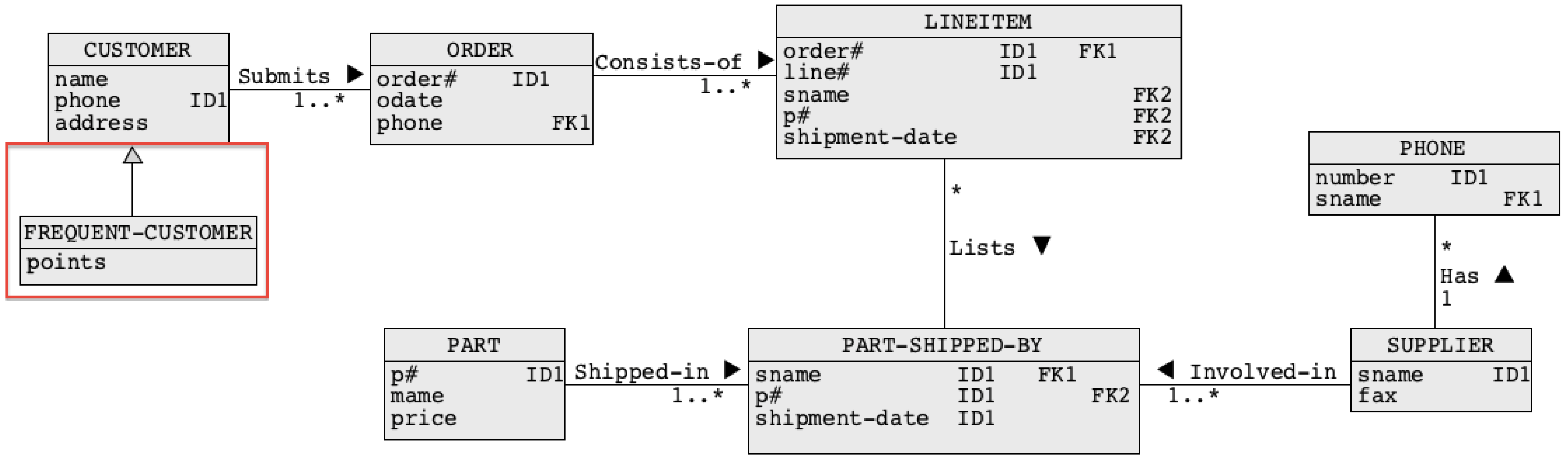
The following conceptual schema is obtained after creation of foreign keys



Next, we transform one-to-one asociations

Example - One-to-one associations

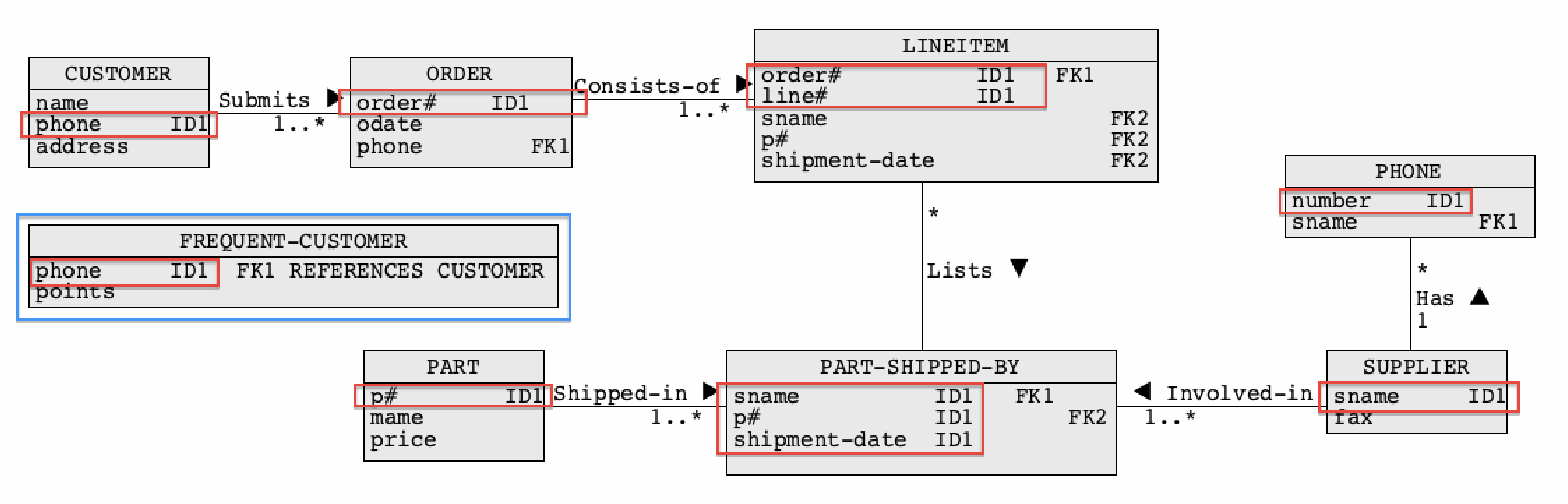
The following conceptual schema is obtained after transformation of one-to-one associations



Next, we transform generalizations

Example - Generalizations

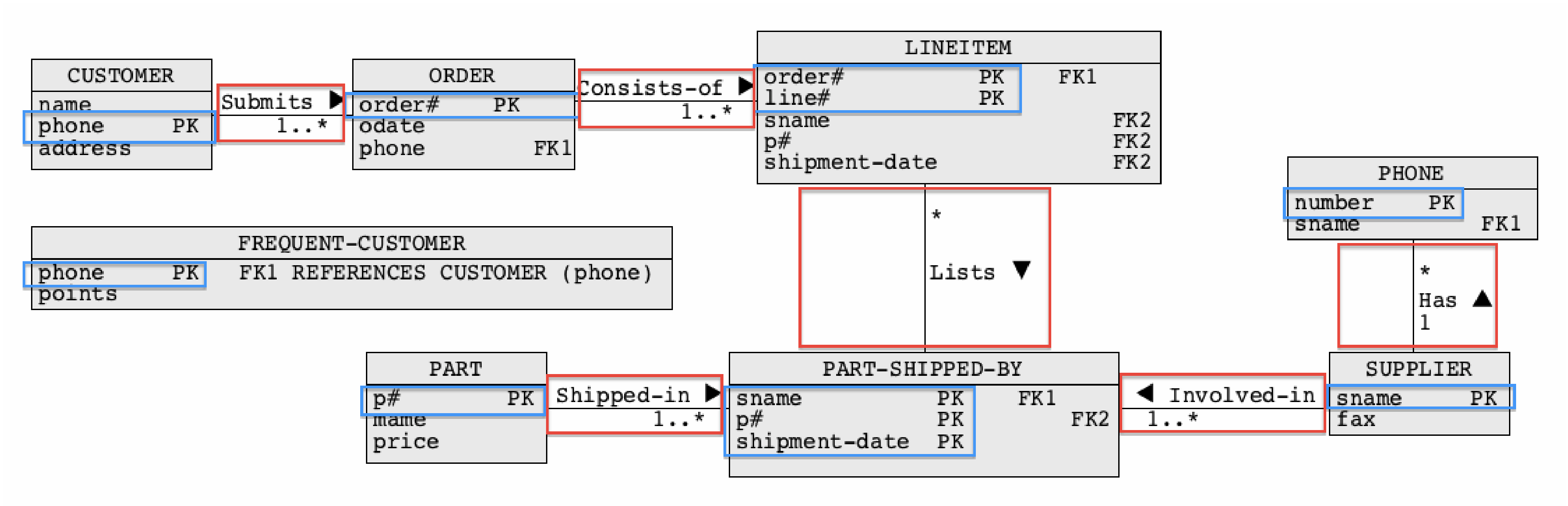
The following conceptual schema is obtained after transformation of generalizations with a partitioning method



Next, we create primary keys and candidate keys

Example - Primary keys and Candidate keys

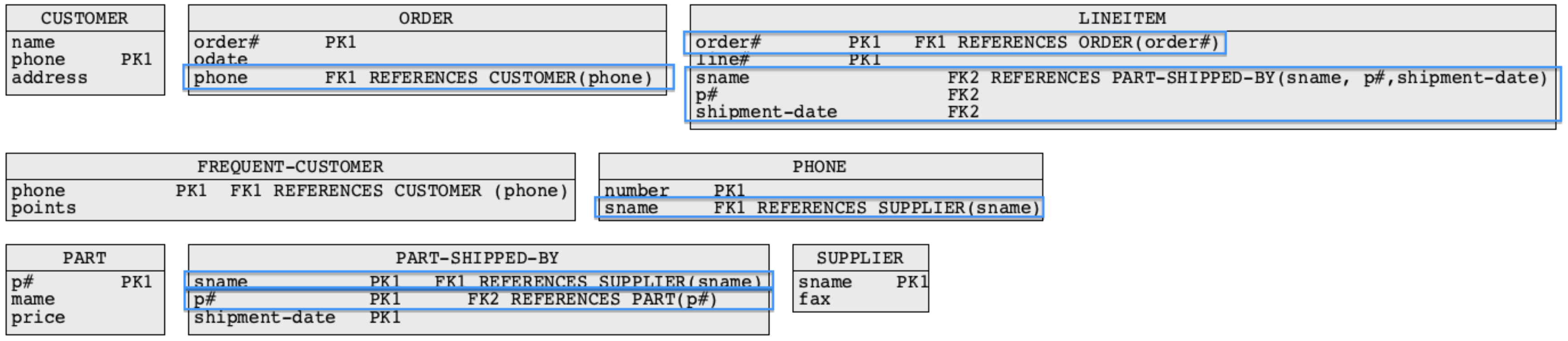
The following conceptual schema is obtained after creation of primary keys and candidate keys



Next, we transform associations

Example - Associations

The following conceptual schema is obtained after transformation of associations



```
CUSTOMER
name
phone        PK1
address

ORDER
order#       PK1
odate
phone        FK1 REFERENCES CUSTOMER(phone)

LINEITEM
order#         PK1   FK1 REFERENCES ORDER(order#)
line#          PK1
sname                    FK2 REFERENCES PART-SHIPPED-BY(sname, p#,shipment-date)
p#                       FK2
shipment-date            FK2

FREQUENT-CUSTOMER
phone             PK1   FK1 REFERENCES CUSTOMER (phone)
points

PHONE
number     PK1
sname      FK1 REFERENCES SUPPLIER(sname)

PART
p#           PK1
mame
price

PART-SHIPPED-BY
sname            PK1    FK1 REFERENCES SUPPLIER(sname)
p#               PK1       FK2 REFERENCES PART(p#)
shipment-date    PK1

SUPPLIER
sname     PK1
fax
```

Next, we create relational schemas

Example - Relational schemas (1)

At the end we obtain the following collection of relational schemas

```
                                   Relational schemas CUSTOMER, FREQUENT-CUSTOMER, ORDER, SUPPLIER, PHONE
CUSTOMER(name, phone, address)
PRIMARY KEY = (phone)

FREQUENT-CUSTOMER(phone, points)
PRIMARY KEY = (phone)
FOREIGN KEY = (phone) REFERENCES CUSTOMER(phone)

ORDER(order#, odate, phone)
PRIMARY KEY = (order#)
FOREIGN KEY = (phone) REFERENCES CUSTOMER(phone)

SUPPLIER(sname, fax)
PRIMARY KEY = (sname)

PHONE(number, sname)
PRIMARY KEY = (number)
FOREIGN KEY = (sname) REFERENCES SUPPLIER(sname)
```

Example - Relational schemas (2)

At the end we obtain the following collection of relational schemas

Relational schemas PART, PART-SHIPPED-BY, LINEITEM

```
PART(p#, name, price)
PRIMARY KEY = (p#)

PART-SHIPPED-BY(sname, p#, shipment-date)
PRIMARY KEY = (sname, p#, shipment-date)
FOREIGN KEY1 = (sname) REFERENCES SUPPLIER(sname)
FOREIGN KEY2 = (p#) REFERENCES PART(p#)

LINEITEM(order#, line#, sname, p#, shipment-date)
PRIMARY KEY = (order#, line#)
FOREIGN KEY1 = (order#) REFERENCES ORDER(order#)
FOREIGN KEY2 = (sname, p#, shipment-date)
               REFERENCES PART-SHIPPED-BY(sname, p#, shipment-date)
```

References

T. Connoly, C. Begg, Database Systems, A Practical Approach to Design, Implementation, and Management, Chapter 17 Methodology - Logical Database Design for the Relational Model, Pearson Education Ltd, 2015