Chapter 6:

Physical Database Design and Performance

Objectives

- Definition of terms
- Describe the physical database design process
- Choose storage formats for attributes
- Select appropriate file organizations
- Describe three types of file organization
- Describe indexes and their appropriate use
- Translate a database model into efficient structures
- Know when and how to use denormalization

Physical Database Design

- Purpose–translate the logical description of data into the *technical specifications* for storing and retrieving data
- Goal–create a design for storing data that will provide *adequate performance* and insure *database integrity*, *security*, and *recoverability*

Physical Design Process

Inputs

- Normalized relations
- Volume estimates
- Attribute definitions
- Response time expectations
- Data security needs
- Backup/recovery needs
- Integrity expectations
- DBMS technology used

Leads to

Decisions

- Attribute data types
- Physical record descriptions (doesn’t always match logical design)
- File organizations
- Indexes and database architectures
- Query optimization

Figure 6-1 Composite usage map

(Pine Valley Furniture Company)

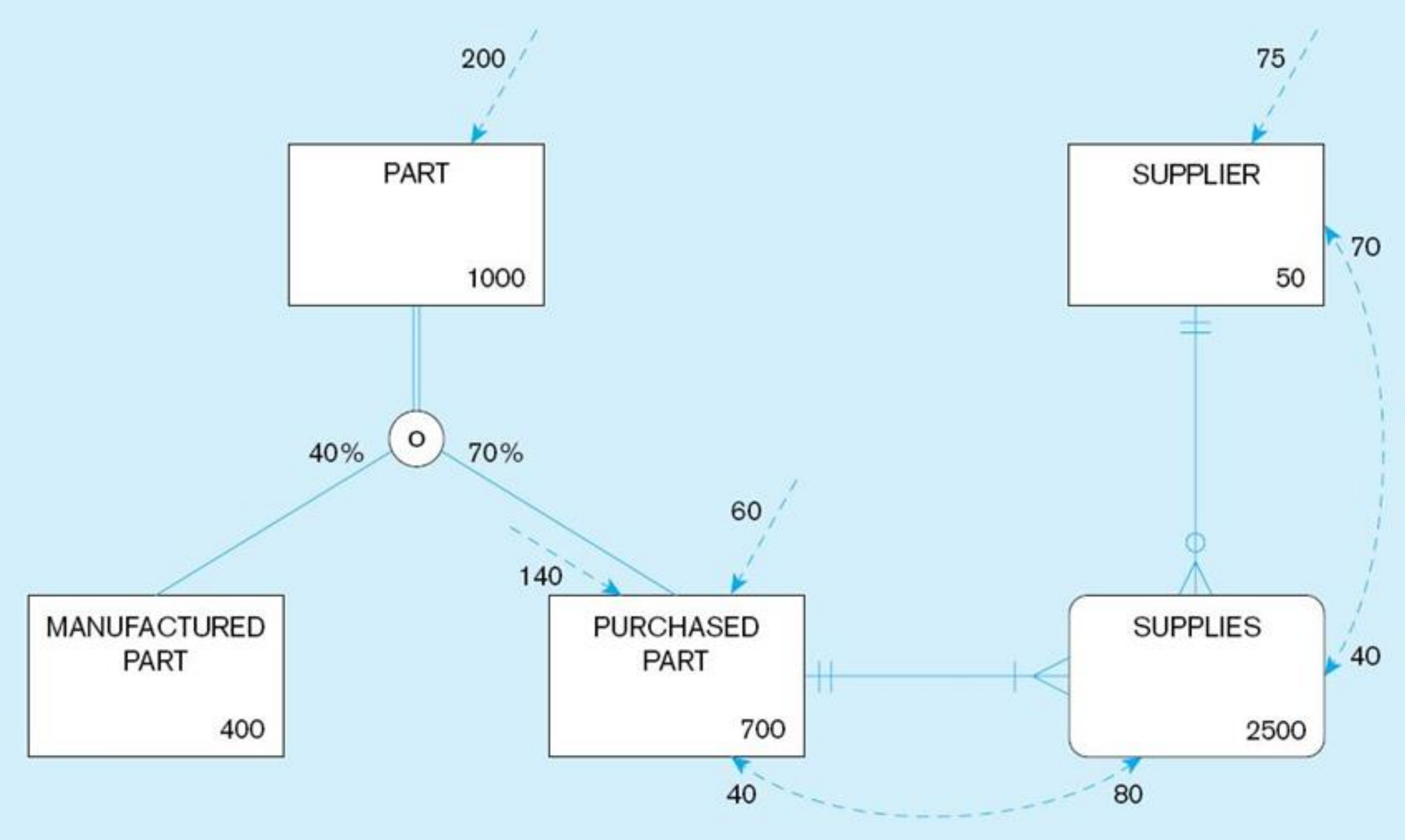


Figure 6-1 Composite usage map

(Pine Valley Furniture Company) (cont.)

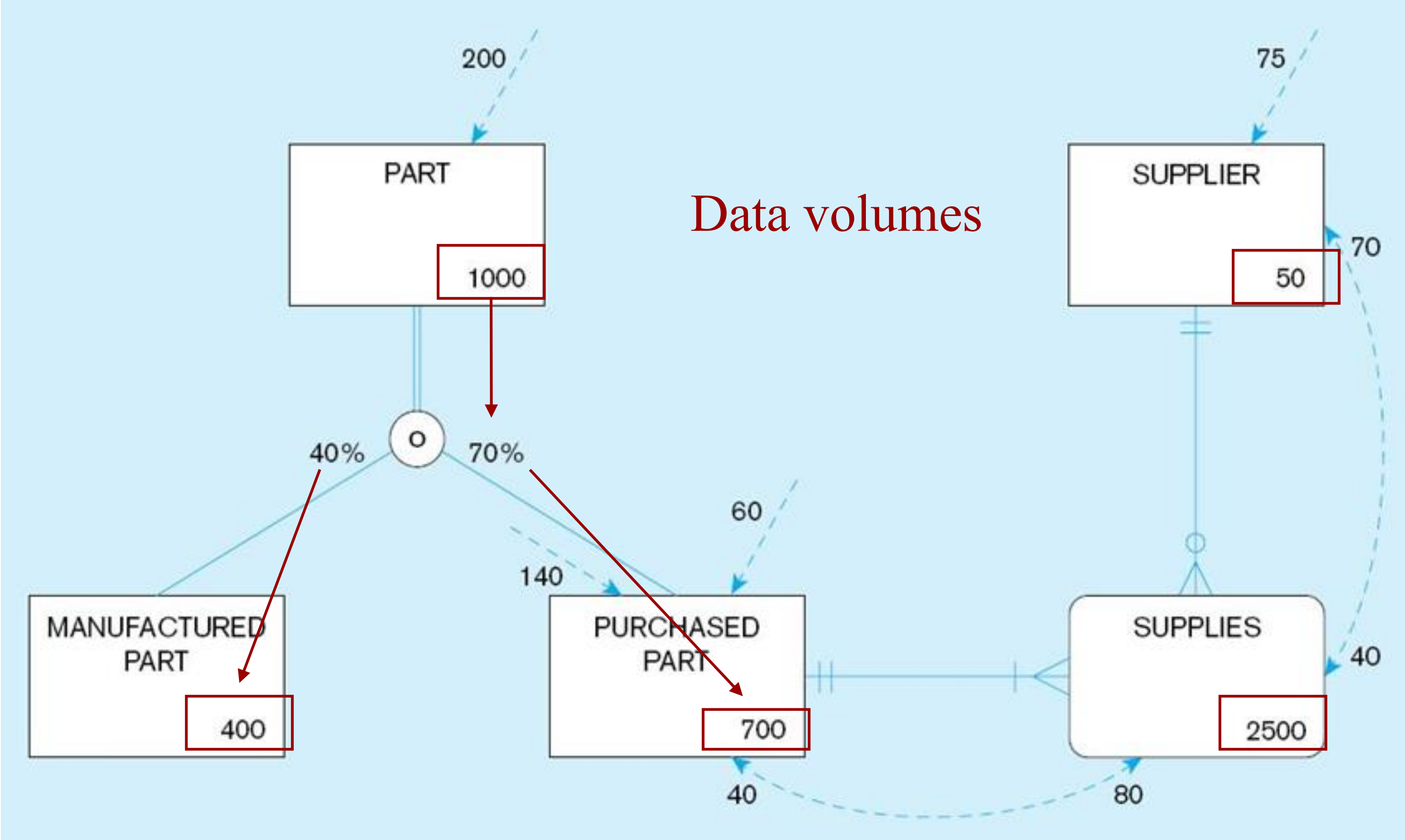


Figure 6-1 Composite usage map

(Pine Valley Furniture Company) (cont.)

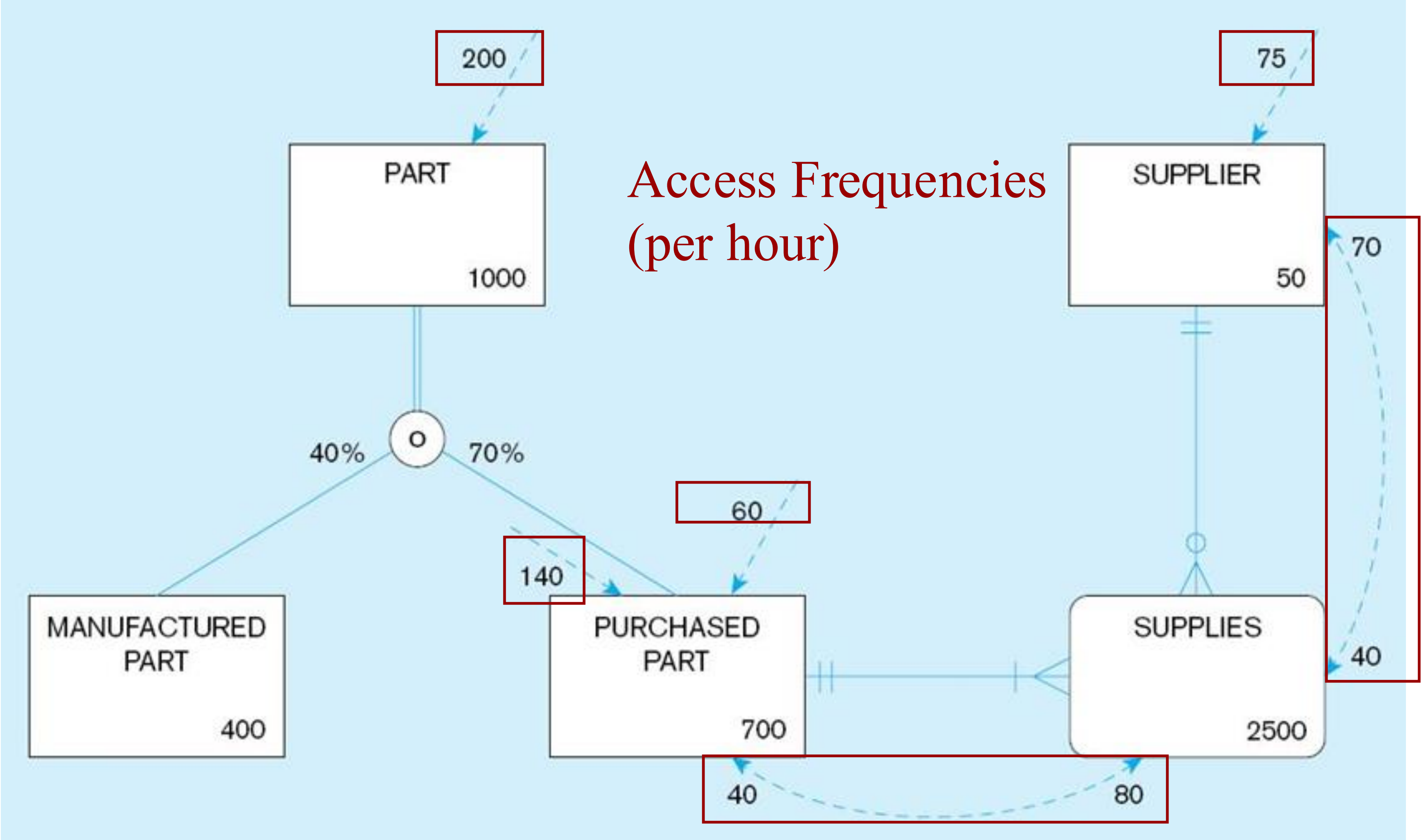
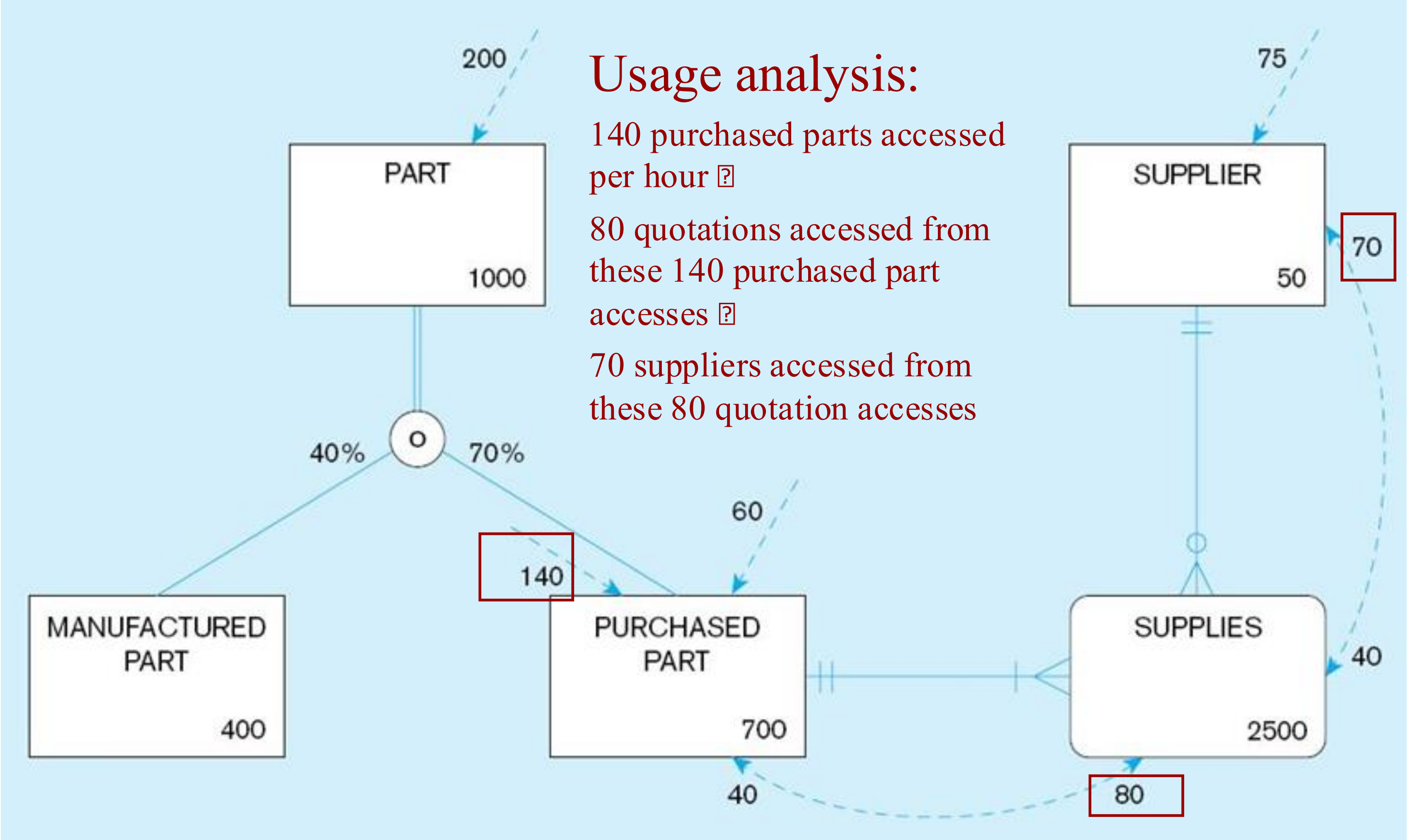


Figure 6-1 Composite usage map

(Pine Valley Furniture Company) (cont.)



Usage analysis:

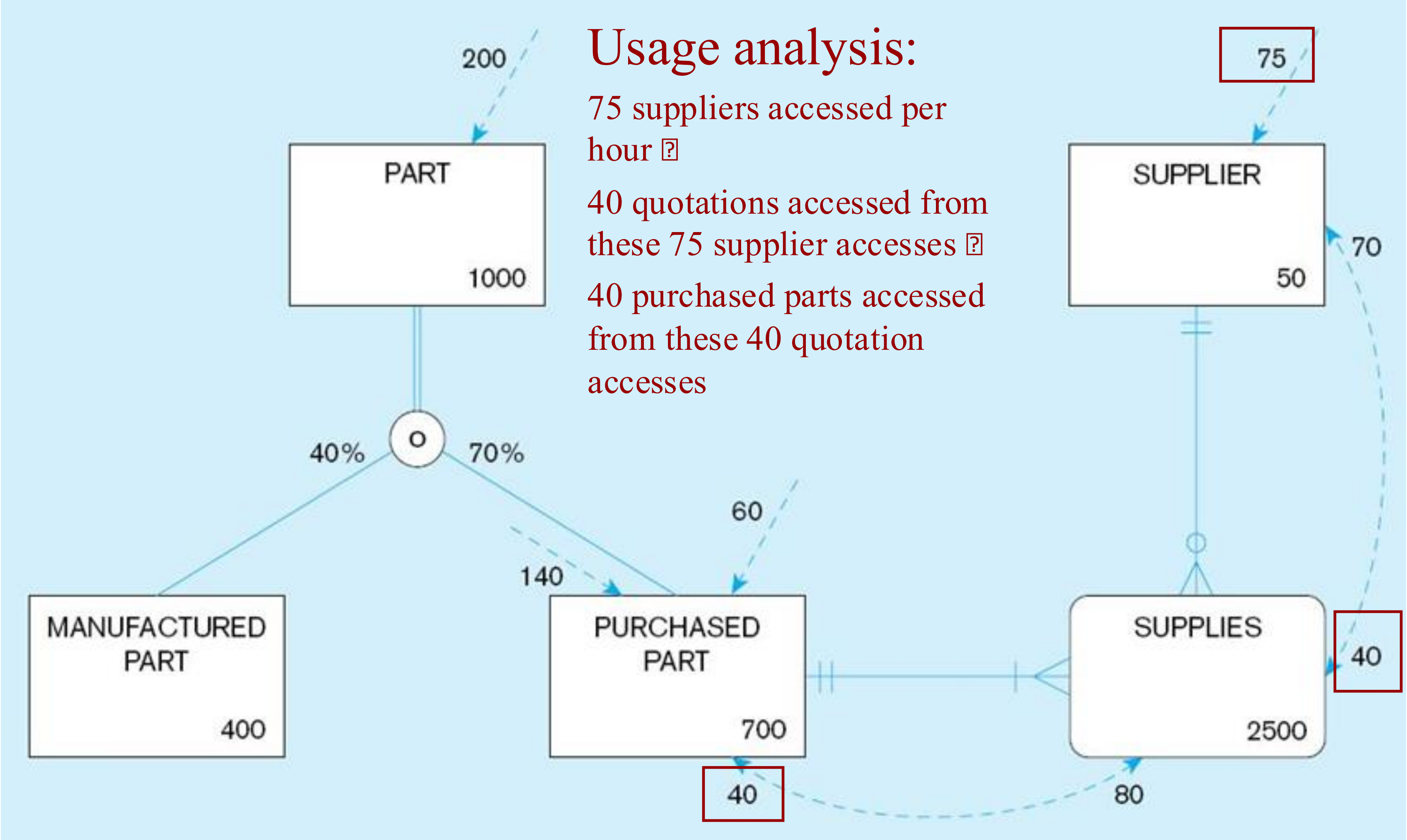
140 purchased parts accessed per hour ⍰

80 quotations accessed from these 140 purchased part accesses ⍰

70 suppliers accessed from these 80 quotation accesses

Figure 6-1 Composite usage map

(Pine Valley Furniture Company) (cont.)



Usage analysis:

75 suppliers accessed per hour

40 quotations accessed from these 75 supplier accesses

40 purchased parts accessed from these 40 quotation accesses

Designing Fields

- Field: smallest unit of data in database
- Field design
  - Choosing data type
  - Coding, compression, encryption
  - Controlling data integrity

Choosing Data Types

- CHAR–fixed-length character
- VARCHAR2–variable-length character (memo)
- LONG–large number
- NUMBER–positive/negative number
- INEGER–positive/negative whole number
- DATE–actual date
- BLOB–binary large object (good for graphics, sound clips, etc.)

TABLE 5-1 Commonly Used Data Types in Oracle 12c

Data Type	Description
VARCHAR2	Variable-length character data with a maximum length of 4,000 characters; you must enter a maximum field length (e.g., VARCHAR2(30) specifies a field with a maximum length of 30 characters). A string that is shorter than the maximum will consume only the required space. A corresponding data type for Unicode character data allowing for the use of a rich variety of national character sets is NVARCHAR2.
CHAR	Fixed-length character data with a maximum length of 2,000 characters; default length is 1 character (e.g., CHAR(5) specifies a field with a fixed length of 5 characters, capable of holding a value from 0 to 5 characters long). There is also a data type called NCHAR, which allows the use of Unicode character data.
CLOB	Character large object, capable of storing up to 4 gigabytes of one variable-length character data field (e.g., to hold a medical instruction or a customer comment).
NUMBER	Positive or negative number in the range 10^{-130} to 10^{126}; can specify the precision (total number of digits to the left and right of the decimal point to a maximum of 38) and the scale (the number of digits to the right of the decimal point). For example, NUMBER(5) specifies an integer field with a maximum of 5 digits, and NUMBER(5,2) specifies a field with no more than 5 digits and exactly 2 digits to the right of the decimal point.
DATE	Any date from January 1, 4712 B.C., to December 31, 9999 A.D.; DATE stores the century, year, month, day, hour, minute, and second.
BLOB	Binary large object, capable of storing up to 4 gigabytes of binary data (e.g., a photograph or sound clip).

Figure 6-2 Example code look-up table

(Pine Valley Furniture Company)

PRODUCT File

Product_No	Description	Finish	…
B100	Chair	C	
B120	Desk	A	
M128	Table	C	
T100	Bookcase	B	
…	…	…	

FINISH Look-up Table

Code	Value
A	Birch
B	Maple
C	Oak

Code saves space, but costs an additional lookup to obtain actual value

Field Data Integrity

- Default value–assumed value if no explicit value
- Range control–allowable value limitations (constraints or validation rules)
- Null value control–allowing or prohibiting empty fields
- Referential integrity–range control (and null value allowances) for foreign-key to primary-key match-ups

Sarbanes-Oxley Act (SOX) legislates importance of financial data integrity

Handling Missing Data

- Substitute an estimate of the missing value (e.g., using a formula)
- Construct a report listing missing values
- In programs, ignore missing data unless the value is significant (sensitivity testing)

Physical Records

- Physical Record: A group of fields stored in adjacent memory locations and retrieved together as a unit
- Page: The amount of data read or written in one I/O operation

Denormalization

- Transforming ***normalized*** relations into ***unnormalized*** physical record specifications
- Benefits:
  - Can improve performance (speed) by reducing number of table lookups (i.e. *reduce number of necessary join queries*)
- Costs (due to data duplication)
  - Wasted storage space
  - Data integrity/consistency threats
- Common denormalization opportunities
  - One-to-one relationship (Fig. 6-3)
  - Many-to-many relationship with attributes (Fig. 6-4)
  - Reference data (1:N relationship where 1-side has data not used in any other relationship) (Fig. 6-5)

Figure 6-3 A possible denormalization situation: two entities with one-to-one relationship

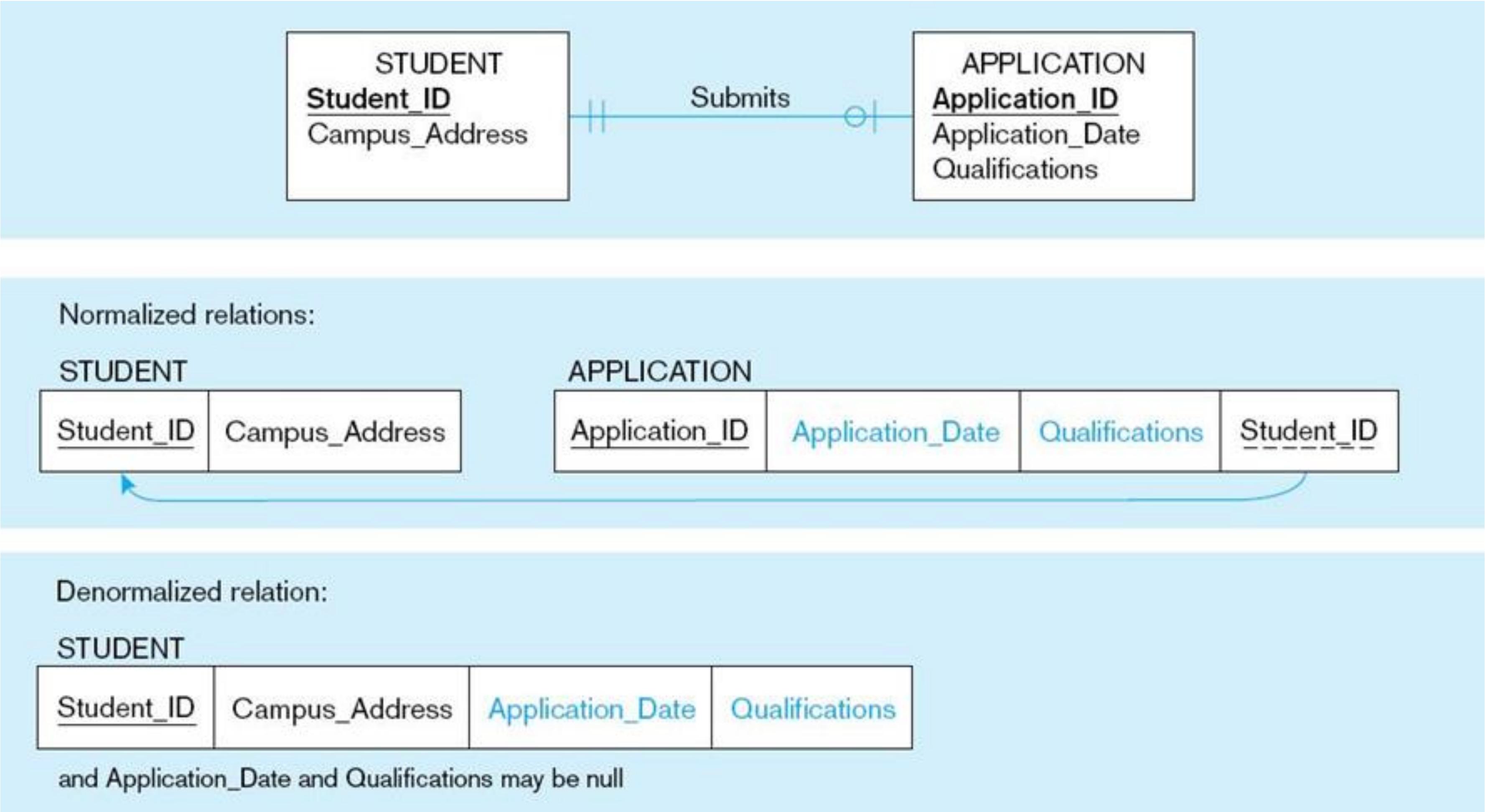


Figure 6-4 A possible denormalization situation: a many-to-many relationship with nonkey attributes

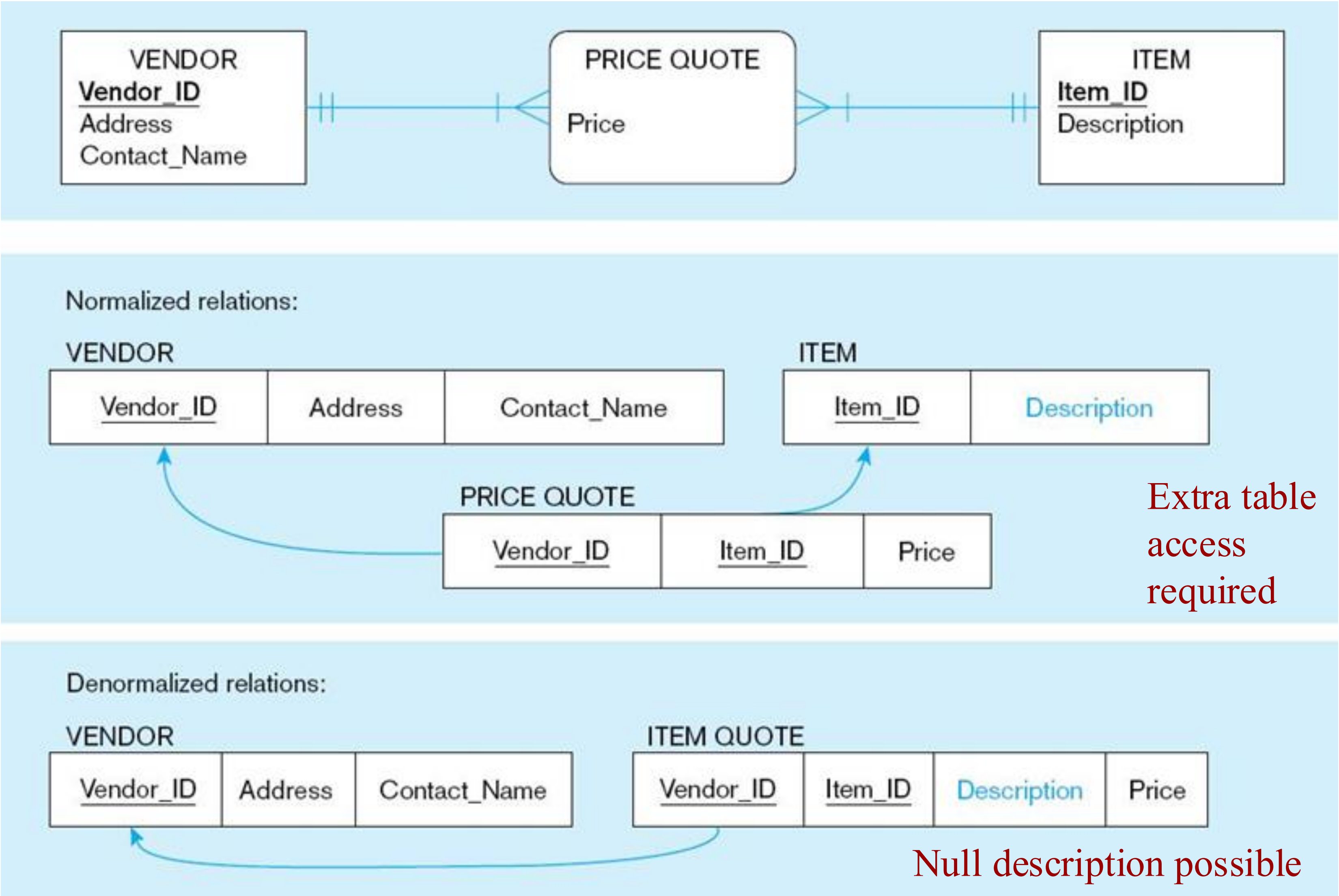


Figure 6-5

A possible denormalization situation: reference data

Normalized relations:

STORAGE

Instr_ID	Where_Store	Container_Type

ITEM

Item_ID	Description	Instr_ID

Extra table access required

Denormalized relation:

ITEM

Item_ID	Description	Where_Store	Container_Type

Data duplication

Partitioning

- Horizontal Partitioning: Distributing the rows of a table into several separate files
  - Useful for situations where different users need access to different rows
- Vertical Partitioning: Distributing the columns of a table into several separate relations
  - Useful for situations where different users need access to different columns
  - The primary key must be repeated in each file
- Combinations of Horizontal and Vertical

Partitioning (cont.)

- Advantages of Partitioning:
  - Efficiency: Records used together are grouped together
  - Local optimization: Each partition can be optimized for performance
  - Security, recovery
  - Load balancing: Partitions stored on different disks, reduces contention
  - Take advantage of parallel processing capability
- Disadvantages of Partitioning:
  - Inconsistent access speed: Slow retrievals across partitions
  - Complexity: Non-transparent partitioning
  - Extra space or update time: Duplicate data; access from multiple partitions

Data Replication

- Purposely storing the same data in multiple locations of the database
- Improves performance by allowing multiple users to access the same data at the same time with minimum contention
- Sacrifices data integrity due to data duplication
- Best for data that is not updated often