Chapter 1 An Introduction to Integrated Enterprise Information Systems

What are Integrated Enterprise Information Systems?

- **Enterprise**
  - A business, an industrious effort, especially one directed toward making money
- **Information System**
  - A set of interconnected channels for communicating knowledge of specific events or situations
- **Integrated**
  - Joined together, united, made into a whole by having brought all parts together

Degrees of Integration

- How can we use both of these toy trains to carry the same toy freight? (note the differences in connectors – we can't simply unhook the freight car from one and attach it to the other)
  - Unload freight from one train, re-load onto the other
    - Too much work!
  - Tie freight car from one to the other with string
    - Unstable connection!
  - Use special building block with Lego connector on one end, K'nex connector on other end
  - Buy two special building blocks
    - one with Lego connector on one end and generic connector on the other end
    - One with K'nex connector on one end and generic connector on the other end

Aren't all enterprise systems integrated? No! why not?

- Enterprise "stove pipes" or "silos"
  - As enterprises grow, they typically become divided based on functional areas
  - Each functional area typically has its own system
  - Even within functional areas, enterprises often develop different systems for different information needs
    - If existing systems lack functionality, additional systems are built to satisfy new needs

Common Integration Attempts

- **Integrate the end results**
  - Let each functional area have its own system and require them to submit end results in a standardized format that can be merged with results from other areas
- **Integrate similar types of systems**
  - All financial areas use same system
  - All manufacturing areas use same system
  - All areas associated with human resources use same system
  - Etc……
    - ***However, each of those systems are different from each other***
- **Enterprise Systems**
  - May be created from scratch
  - May be based on packaged software (e.g. OracleApps, PeopleSoft, SAP)

Breaking Down Stovepipes by Re-engineering Business Processes

- **Reengineering Work: Don't Automate, Obliterate**
  - Michael Hammer, Harvard Business Review July/August 1990
  - "It is time to stop paving the cowpaths. Instead of embedding outdated processes in silicon and software, we should obliterate them and start over…..use the power of modern information technology to radically redesign our business processes in order to achieve dramatic improvements in their performance." (p. 104)

Ford Motor Company

- Decision Situation
  - Needed to cut costs
  - Thought A/P dept. might be a good candidate if they automated parts of it
  - Had 500 clerks, wanted to cut by 20%
  - Looked at Mazda
  - Mazda only had 5 clerks!!!!
  - Mazda was smaller than Ford, but not THAT much smaller!!!!
  - Ford realized A/P should probably be cut to 100 clerks (80% reduction)
- Existing System
  - Purchasing department created purchase order (PO), sent original to supplier and sent a copy to Accounts Payable (A/P)

  - Material control department received goods, prepared receiving document, sent copy to A/P
  - Supplier sent invoice to A/P
  - A/P matched PO to receiving document and invoice (this process is called a 3-way match); if they matched (on 14 different data items), then A/P issued payment to supplier
  - Most A/P time was spent on investigating and reconciling mismatches
- Approach taken
  - If Ford wanted to "pave the cowpaths" they could have attempted to facilitate the A/P investigation process
  - Ford chose to re-engineer by questioning why the 3-way match was necessary to begin with, and how mismatches could be prevented from the start
- What was the goal of Ford's 3-way match?
  - To make sure Ford didn't pay for things it hadn't ordered and/or it hadn't received
- Re-engineered solution that meets the above goal more efficiently and effectively
  - Enter purchase order into automated, integrated system
  - On receipt of goods, clerk enters receipt information and has computer check to see that part number, unit of measure, and supplier code match order; if not, deny acceptance of shipment
  - If there is a match, the enterprise accepts shipment and the computer flags the purchase record as ready for payment
  - Accounts Payable issues payment based on receipt of goods, not on receipt of invoices Vendors were asked not to even send invoices!
- Was this only a re-engineering of Accounts Payable?
  - NO! Ford re-engineered the goods acquisition process, which included purchasing, receiving and accounts payable
- How did this affect Ford's suppliers?
  - They liked getting prompt payment
  - They had difficulty getting used to not sending invoices, because their systems forced them to produce invoices
  - Ford pointed out that the suppliers could produce the invoices without wasting money to mail them to Ford, which would just throw them away if the suppliers sent them.
- End Result of Re-engineering Effort
  - 75% reduction in head count (to 125 clerks)
  - No discrepancies between financial record and physical record (theoretically, at least), so material control is simpler and financial information is more accurate

Mutual Benefit Life

- Decision Situation
  - Applications for life insurance took much too long
  - MBL wanted to improve customer service
  - President demanded 60% improvement in productivity
- Existing System
  - Application went through 30 steps, spanned 5 departments, involved 19 people
  - Best turnaround = 24 hours
  - Typical turnaround = 5 to 25 days
  - (actual work done estimated at 17 minutes, rest was "in-transit" time)
- Approach
  - If MBL had wanted to "pave the cowpaths" they probably would have tried to use technology to simply speed the applications along the existing transit route
  - Instead, MBL re-engineered the business processes
  - MBL created a "case manager" position who performed all tasks associated with the application supported by an expert system on a computer network (with help available from a senior underwriter or physician as needed)
- End Result of Re-engineering Effort
  - Eliminated 100 field office positions
  - Can now process twice as many new applications as they previously could process
  - Best turnaround decreased to 4 hours
  - Typical turnaround decreased to 2-5 days

Re-engineering Accounting Systems

- Most advances in accounting systems have focused on providing the same information faster and more accurately
  - General structure is still based on the double-entry bookkeeping equation Assets = Liabilities + Owners' Equity
  - Software forces each journal entry to "balance" (I.e., have equal debits and credits) before each entry is accepted, thus increasing accuracy
  - Software automatically posts journal entries to the general and/or subsidiary ledgers, thus increasing accuracy and speed
- In 1982, Bill McCarthy published a research article explaining his ideas for re-engineering accounting systems
  - He didn't call it re-engineering, but it was

- He focused on natural phenomena common to most enterprises for various types of transactions.
- He recommended eliminating artifacts such as debits, credits, and accounts
  - Artifacts are manufactured, not naturally occurring
  - Accounting artifacts obscure details of business transactions needed for non-accounting purposes
- This textbook explains and discusses McCarthy's ideas for developing integrated enterprise systems that can satisfy accounting needs while also satisfying needs of other business areas

Knowledge needed for integrated ES

- Knowledge to create integrated ES
  - Representation in general
  - Enterprise operations, general and specific
  - Conceptual modeling tools
- Knowledge to effectively use integrated ES (i.e., to be a power user)
  - All of the above PLUS
  - Information retrieval (querying) tools
- Knowledge to effectively audit integrated ES
  - All of the above PLUS
  - Audit objectives, techniques, tools
- Creativity and critical thinking! (for all of the above)

Chapter 2 Representation and Patterns: An Introduction to the REA Enterprise Ontology

Representation

- Depiction of Reality with Symbols
  - People are real things
    - Identification cards (such as drivers licenses or social security cards) are representations of those people
      - Alternatively you could say identification cards are symbols that represent those people
    - What other representations of people can you think of?
    - Which of these is likely to be the best representation?
  - Computers are real things
    - What are some representations of computers?
    - Which of these is likely to be the best representation?

Models as Representations

- What is a model?
  - A model is a simplification of something in reality
    - Created for a specific purpose
    - Hides details that are not needed for that purpose
    - Examples: model car, architect's models – paper-based and 3-dimensional
- Why do we build models of enterprise systems?
  - We build models so that we can better understand the system we are developing.
  - Most enterprise systems are too large and complex for the average person to comprehend in entirety.

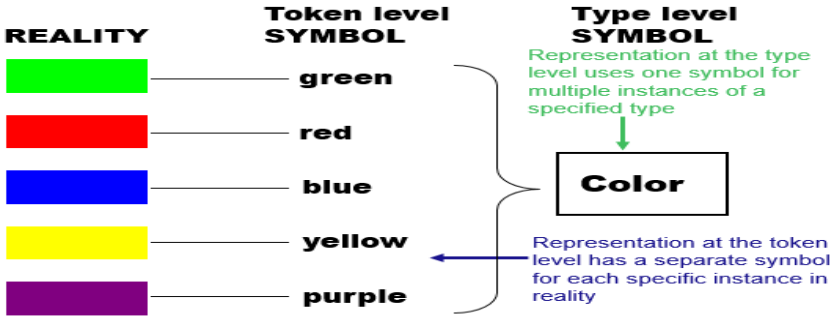
Representation in Information Systems

- In modeling enterprise systems our goal is to create representations of the "reality" of the business in a form that is computer-readable
  - We start by making a paper-based model with a set of symbols that have understood meanings and for which there are agreed upon procedures for translation into computer-readable form
  - We then translate the paper-based representation into a computerized information system
    - The information system is itself a representation of the business reality
    - The paper-based model is also a representation of the business reality

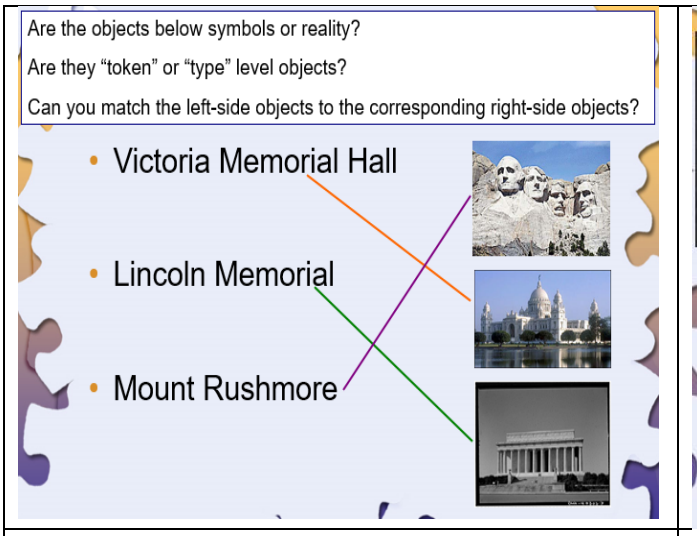
Principles of Modeling

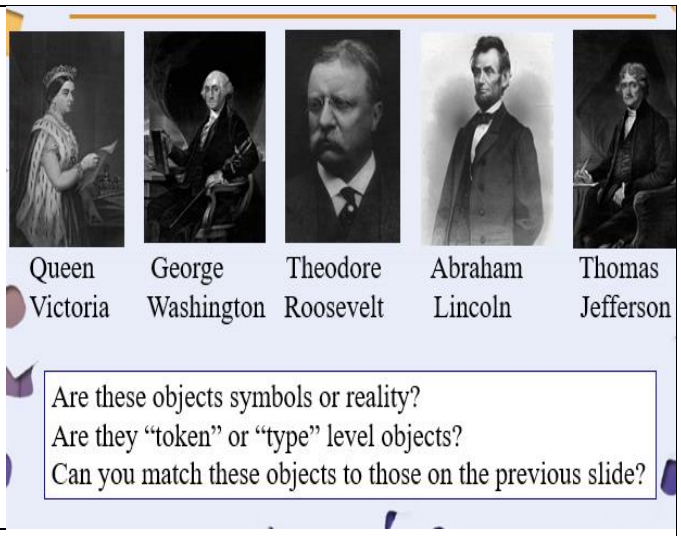
- When creating or evaluating models, how do we determine what makes "good" models?
  - This is important because if a model provides an intermediate step toward a solution or developed tool, choices in modeling partially determine the solution or tool's effectiveness.
  - Good models resemble their underlying reality as completely as possible
  - Good models can be expressed at different levels of precision
  - They can be broken down into smaller pieces for closer examination of some features and aggregated for holistic views

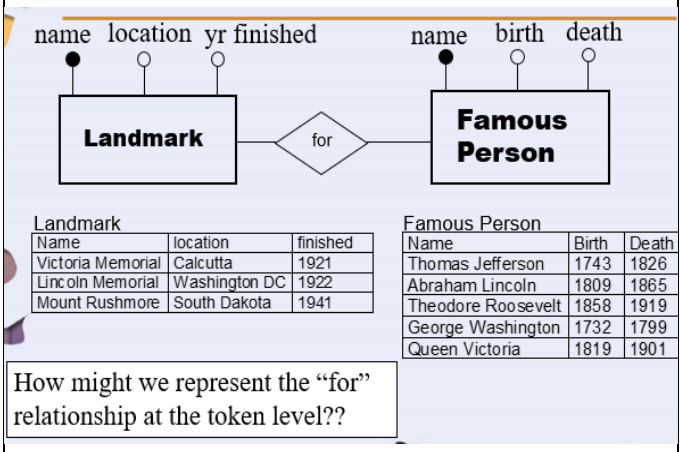
Symbol Representations at Different Levels of Abstraction



Source: Professor Bill McCarthy at Michigan State University; based on Geerts and McCarthy, "An Ontological Analysis of the Economic Primitives of the Extended-REA Enterprise Information Architecture" International Journal of Accounting Information Systems. 3:21. 1-16.







Landmark

Name	location	finished
Victoria Memorial	Calcutta	1921
Lincoln Memorial	Washington DC	1922
Mount Rushmore	South Dakota	1941

Famous Person

Name	Birth	Death
Thomas Jefferson	1743	1826
Abraham Lincoln	1809	1865
Theodore Roosevelt	1858	1919
George Washington	1732	1799
Queen Victoria	1819	1901

Landmark

Name	location	finished	For Person
Victoria Memorial	Calcutta	1921	Queen Victoria
Lincoln Memorial	Washington DC	1922	Abraham Lincoln
Mount Rushmore	South Dakota	1941	Abraham Lincoln, George Washington, Thomas Jefferson, Theodore Roosevel

Famous Person

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Thomas Jefferson	1743	1826	Mount Rushmore
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Queen Victoria	1819	1901	Victoria Memorial Hall

Landmark For Famous Person

Landmark Name	Person Name
Victoria Memorial	Queen Victoria
Lincoln Memorial	Abraham Lincoln
Mount Rushmore	Abraham Lincoln
Mount Rushmore	George Washington
Mount Rushmore	Thomas Jefferson
Mount Rushmore	Theodore Roosevelt

In Chapter 4 we will discuss which of these alternatives is the best in different situations

Object Patterns

- Pretend you are moving to a new city, and you need a place to live.
- An apartment complex in this city will provide you with two years of free rent, but you can only move in AFTER you design a database to capture its operational data and satisfy its enterprise information needs.
- You don't want to pay rent for long, so you decide to get a head start before you even start traveling to the new city.
- You know the first step in database design is to create a list of entities and relationships between them.

What is on your list of entities and relationships for the apartment complex?

How did you know what to include, when you have never been to that city or to that apartment complex before?

- Even when we don't have knowledge about something in reality, if we have knowledge (either first-hand or second-hand) about something similar in reality (and we know it is similar) we can apply our knowledge of the familiar object or situation to the unfamiliar object or situation
- This is "pattern-based thinking"
- In conceptual modeling, an object pattern is called a "stereotypical constellation of entities"
    - In other words, a group of entities and relationships between them that we expect to exist in the underlying reality
- At the business process level, REA is such a pattern, specifically created to represent enterprises and to serve as a foundation for integrated enterprise information systems

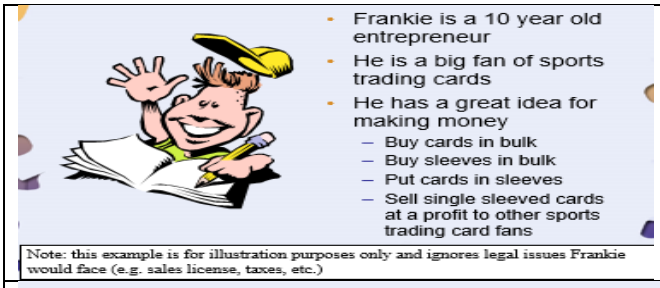
Script Patterns

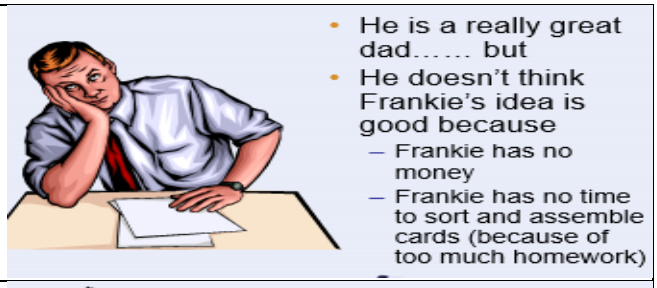
- Recall a story you have heard many times before
    - **Once upon a time**
        - A boy met a girl
        - They fell in love
        - They got married
        - They lived happily ever after
    - **This story is known as "The Romance Script"**
        - Other variations exist, but certain parts are necessary (e.g. falling in love) to qualify as an instance of the romance script
- How does the "tragic romance script" vary from the romance script?
    - Can you think of an example of a story based on the tragic romance script?
    - How about a second example?
- Script patterns, similar to object patterns, involve "pattern-based thinking" applied to sequential activities

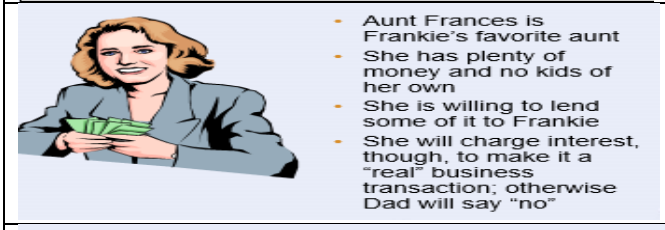
Business-Entrepreneur Script

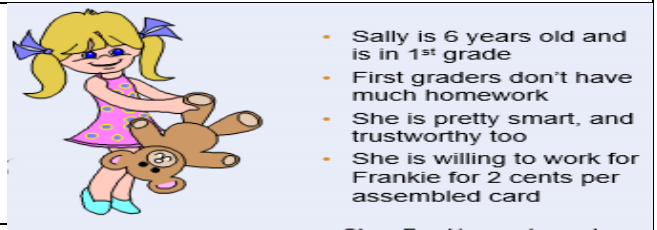
- I get some money
- I engage in value-added exchanges
    - Purchase raw materials
    - Purchase labor
    - Manufacture finished goods
    - Sell finished goods
- I pay back money and live off profit

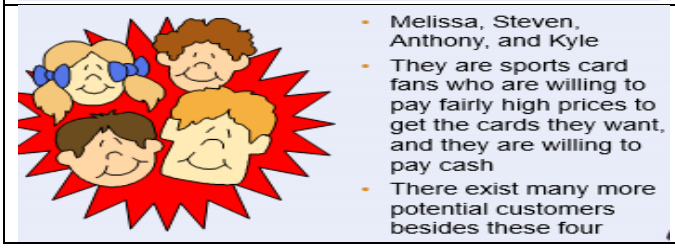
Meet Frankie

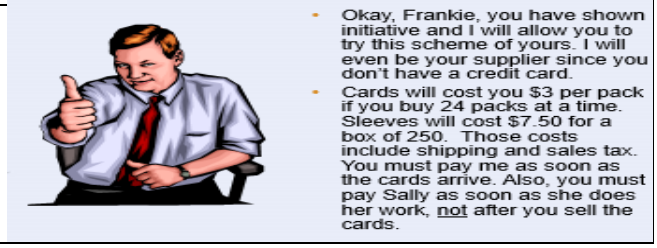












It's a Deal!

The business begins....

- Frankie borrows $180 from his Aunt Frances. He agrees to pay her 10% annual simple interest.

And then.....

- Frankie buys 48 packs of cards and 2 boxes of card protector sleeves from his dad. This purchase costs Frankie $159 in cash.
  - 48 card packs x $3 per pack
  - 2 boxes of sleeves x $7.50 per box

And then.....

- Sally takes all 432 cards out of their packages (9 cards per pack x 48 packs), puts them into card protector sleeves, and sorts them by type (super-rare, rare, common, etc.)
- Frankie pays her the agreed upon $8.64 ($.02/card x 432 cards)

And then....

- Slowly, but surely, over the next 3 months, Frankie sells all 432 cards. The total revenue he generated was $400.

At the End of the 3 Months...

- Frankie repays his Aunt Frances $180 and pays her $4.50 in interest ($180 x .10 x 3/12 = $4.50).

What was Frankie's profit?

Net Sales =	$400.00
- COGS	$165.60
= Gross Margin	$234.40
- Interest Expense	$ 4.50
= Net Income	$229.90

- Note: COGS = $144.00 raw cost of cards sold + $12.96 cost of sleeves used (432 sleeves x $.03 per sleeve) + $8.64 direct labor

What is Frankie's Ending Balance Sheet?

Cash	$227.86	
Inventory	$ 2.04	
Total Assets		$229.90
Liabilities	$ 0.00	
Retained Earnings	$229.90	
Total Liab + Equity		$229.90

- Cash = $180 in from financing + $400 in from sales - $159 cash paid for purchases - $8.64 cash paid for wages - $184.50 paid for financing
- Inventory = 68 card sleeves remaining x $.03 per sleeve
- Retained Earnings = $0 beginning balance + $229.90 net income - $0 withdrawals

Frankie's Script

1. Borrow money
2. Buy raw materials (cards and sleeves)
3. Buy labor
4. Produce finished goods (sleeved cards)
5. Sell finished goods
6. Repay borrowed money
7. Repeat steps 2-5, only resorting to steps 1 and 6 as needed

Scripts and the REA Ontology

- The business-entrepreneur script is also called a Value Chain, which we will discuss more later.
- The value chain is a sequence (chain) of scenes
  - Each scene is a business process (transaction cycle)
  - Each scene is represented by a pattern (REA)
- The REA ontology is a combination of script patterns and object patterns that together enable us to model enterprises and to understand and work with existing enterprises models

Enterprise Ontologies

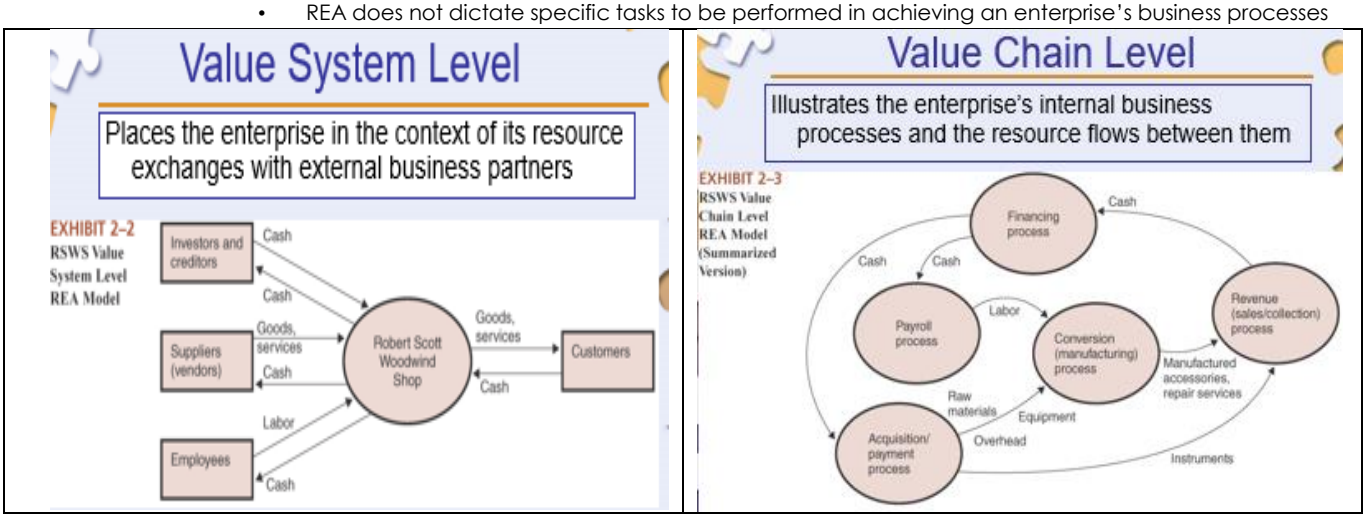
- What is an "ontology"?
  - An attempt to define what things exist in the world in general; a branch of metaphysics dealing with the nature of being
- What is an "enterprise ontology"?
  - An attempt to define what kinds of things in enterprises need to be represented
- Why do we need ontologies?
  - Ontologies improve communication, sharing, and reuse of information
  - For current information systems and e-business, these three concepts are very important!

REA Ontology Levels

- Value System Level (object-based pattern)
  - Examines enterprise in context of its external business partners
  - The combination of value systems of business partners forms a supply chain
- Value Chain Level (script-based pattern)
  - Connects business processes of an enterprise via the resource flows between the processes

REA Ontology Levels

- Business Process Level (object-based pattern)
  - A pattern to which the reality of most (perhaps all) enterprises conform
    - The key is mapping the objects in the enterprise to the pattern in order to generate the model from which a database is designed
- Task Level (script-based pattern)
  - Many different possible scripts exist
    - REA does not dictate specific tasks to be performed in achieving an enterprise's business processes

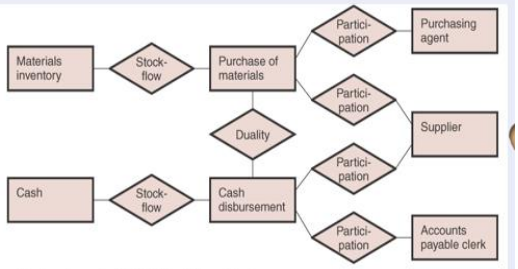


Business Process Level

- Entities
- Resources
- Economic Events
- Agents (internal and external)
- Relationships
- Stockflow (relationships between resources and events – increase or decrease)
- Duality (relationships between increment and decrement economic events)
- Control (relationships between events and the agents that participate in them)

Business Process Level

EXHIBIT 2-4
Business Process Level Core Model: Acquisition/ Payment Process



The Original REA Model
McCarthy (1982)

We will include extensions to this level of the REA ontology later in the course

Business Process Level (alternative notation)

Entity: Resource1	Relationship: Duality Connected Entities: Economic Event1 Economic Event2
Entity: Resource2	Relationship: Stockflow1 Connected Entities: Economic Event1 Resource1
Entity: Economic Event1	Relationship: Stockflow2 Connected Entities: Economic Event2 Resource2
Entity: Economic Event2	Relationship: Control1 Connected Entities: Economic Event1 Internal Agent1
Entity: Internal Agent1	Relationship: Control2 Connected Entities: Economic Event1 External Agent
Entity: External Agent	Relationship: Control3 Connected Entities: Economic Event2 External Agent
Entity: Internal Agent2	Relationship: Control4 Connected Entities: EconomicEvent2 Internal Agent2

Database tables Derived From Business Process Level

EXHIBIT 2-5 RSWS Business Process Level Database Tables: Acquisition/Payment Process

Cash

Account Number	Account type	Account Location
1223	Checking	Fourth-Second Bank
3445	Petty cash	File drawer, room 222
4556	Payroll imprest	True American Bank

Cash Disbursement

Disbursement ID	Date	Amount	Cash Account	Supplier ID	APClerk ID
CD1	November 5	$1,230.00	1223	S2	E8
CD2	November 5	$9,778.65	4556		
CD3	November 6	$2,476.00	1223	S3	E9

Materials Inventory

Item ID	Description	Standard Unit Cost
M210	Cork set, standard oboe	$5.00
M220	Spring set, standard oboe	$9.00
M321	Cane, ¼" width x 12" length	$1.00

Purchase

Purchase ID	Date	Amount	Supplier ID	PurchAgent ID	Disbursement ID
P1	November 1	$1,230.00	S2	E2	CD1
P2	November 1	$2,476.00	S3	E2	CD3
P3	November 3	$ 500.00	S1	E3	

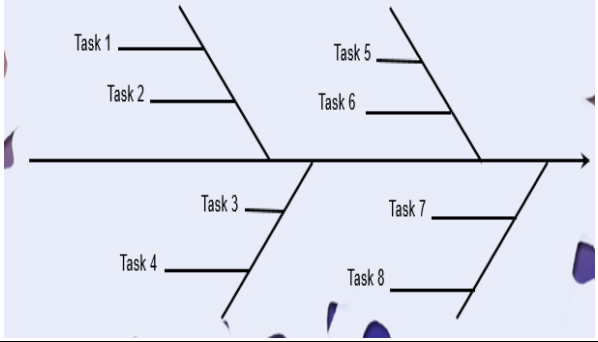
Materials Inventory—Purchase

Item ID	Purchase ID	Quantity Purchased	Actual Unit Cost
M210	P1	66	$5.00
M220	P1	100	$9.00
M220	P2	200	$9.00
M321	P2	676	$1.00

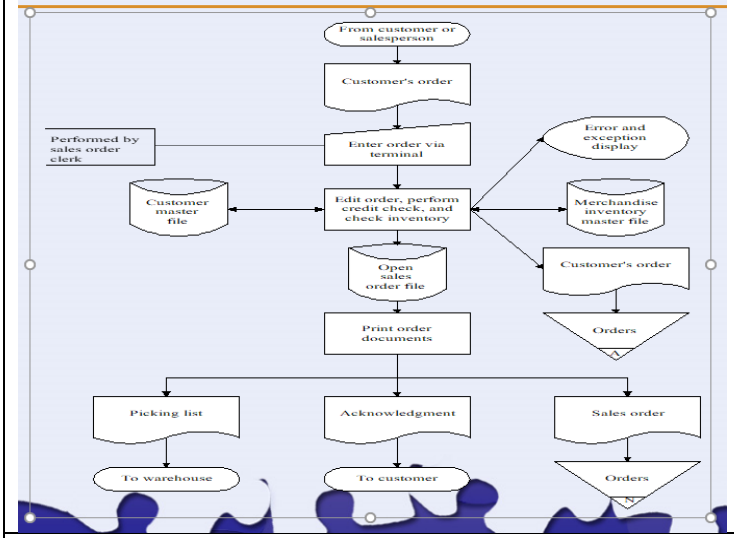
Task Level

May be depicted in various formats such as a fishbone diagram (with tasks listed in an ordered sequence), a system flowchart, a data flow diagram, a process model (with swim lanes), etc.

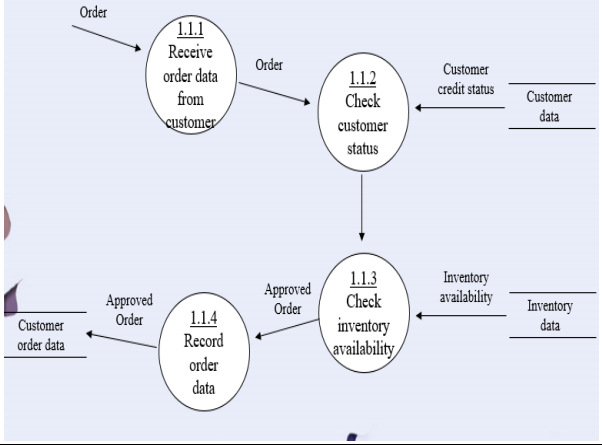
- No pattern is available, tasks are enterprise specific



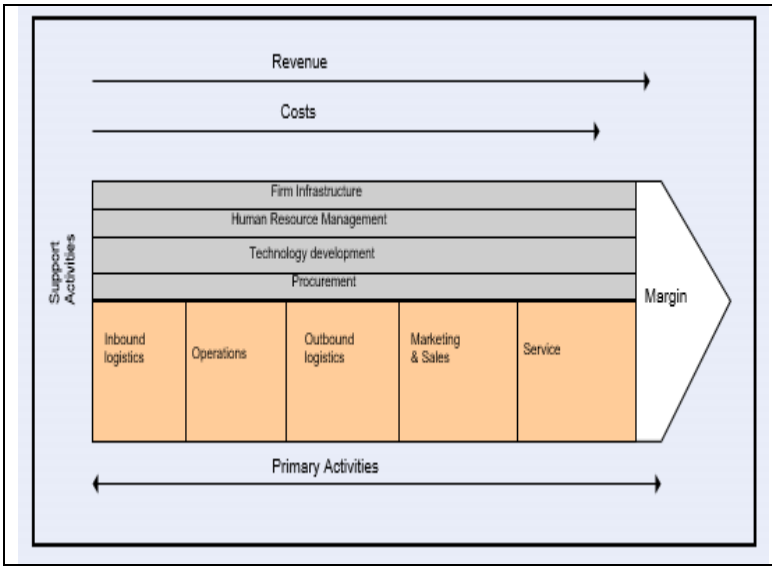
Example System Flowchart



Example Data Flow Diagram



Porter's Value Chain



- **Primary value activities**
  - Inbound logistics - activities associated with receiving, storing, and disseminating inputs to the products or services
  - Operations- activities associated with transforming inputs into the final products or services
  - Outbound logistics - activities associated with collecting, storing, and physically distributing the products or services
  - Marketing and sales - activities associated with providing a means by which customers can buy produce and the means for inducing them to buy
  - Service - activities associated with providing service to enhance or maintain the value of the products or services

Support value activities

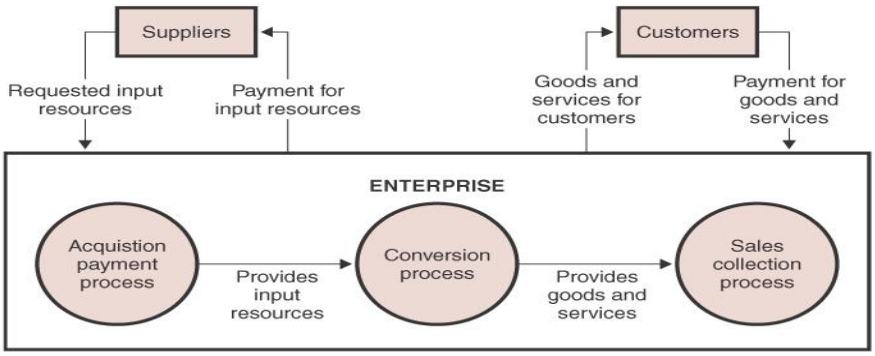
- Procurement - the function of purchasing inputs to firms value chain
- Technology Development - the know-how, procedures, or technology embedded in processes that are intended to improve the product, services, and/or process
- Human Resource Management - activities involved in recruiting, hiring, training, developing, and compensating all types of personnel
- Firm Infrastructure - activities that support the entire value chain (e.g. general management, planning, finance, accounting, legal, government affairs, quality management, etc.)

Importance of Studying Value System and Value Chain Levels in REA

- Understanding an enterprise's activities at the value system and value chain levels in the REA ontology
  - Helps keep perspective (gives the ability to "see the forest" without getting mired in the detail of the trees)
  - Provides the structure to guide lower levels of analysis
  - Requires consideration of the enterprise's mission and strategy, which should ensure that business processes and activities are constructed in a manner consistent with the mission and strategy

Value System and Value Chain

EXHIBIT 3–2
Relating Value System and Value Chain Levels



Value System Modeling

- Identify an enterprise's resource inflows and outflows
  - Focusing on the cash flows and then identifying the "reasons" for those cash flows is a good way to start
  - Although non-cash resource flows are rare, they are still important to consider
- Identify the external business partners to which and from which the resources flow

RSWS Example from Textbook

- Step 1: Create a circle in the middle of the model to represent the enterprise (RSWS)

RSWS

- Step 2: Identify cash inflows and other resource inflows that are not part of a cash-related exchange to the enterprise (by examining the narrative and applying common business sense), and note the source of the resource inflows
  - Cash inflows
    - From investors
      - For future cash flows
    - From creditors
      - For future cash flows
    - From customers
      - For merchandise
      - For repair services
      - For rentals of merchandise
  - Barter inflows
    - None noted

- Step 3: Identify cash outflows and any non-cash resource outflows that are not part of a cash-related exchange of the enterprise (by examining the narrative and applying common business sense) and note the destination of the resource outflows
  - Cash outflows
    - To investors
      - For past cash flows
    - To creditors
      - For past cash flows
    - To suppliers
      - For raw materials, parts, supplies, and merchandise
      - For property, plant & equipment
      - For various services and utilities
    - To employees
      - For labor
  - Barter outflows
    - None noted

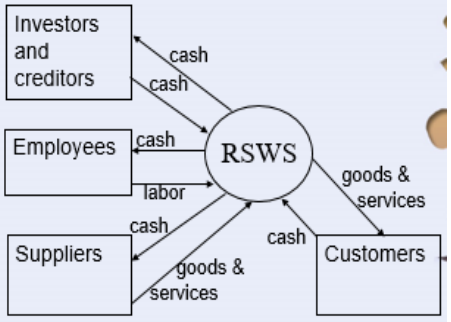
Note: no mention is made in the narrative of taxes paid to the government, but those could be assumed to exist and they could be included under outflows to suppliers for various services and utilities

- Step 4: Determine what categories to use as the enterprise's external business partners and make a box to represent each
  - Business partners of different types with whom common resources are exchanged may be combined (or left separate)
    - E.g. investors and creditors
  - Business partners of similar types with whom different resources are exchanged may be separated (or left combined)
    - E.g. inventory suppliers versus suppliers of services

Investors/ creditors | Customers | Employees | RSWS | Suppliers

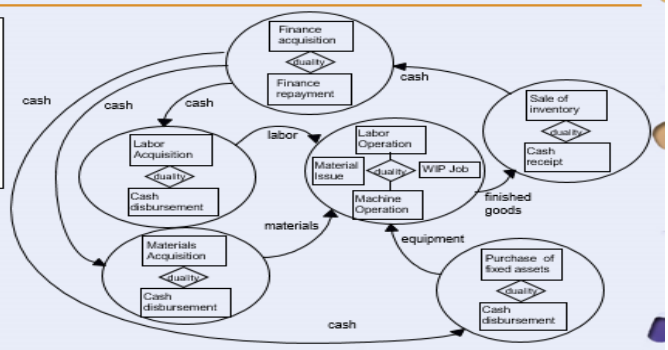
Note that the choice to separate and combine partners is subjective, as is the placement of the partners on the model; there are multiple correct value system models

- Step 5: Fill in resource inflows and outflows on the model
  - May combine resources into categories or leave separated; again, multiple correct models are possible!



REA Value Chain Modeling

Shows the interconnection of the transaction cycles in an enterprise and the resource flows between them



Value Chain Level

- Duality relationships consist of paired increment economic events and decrement economic events
  - Increment economic events increase resources (stock in-flows)
  - Decrement economic events decrease resources (stock out-flows)
- "Duality relationships are the glue that binds a firm's separate economic events together into rational economic processes, while stock-flow relationships weave these processes together into an enterprise value chain." -- Geerts & McCarthy 1997
- Each economic event in each cycle in the value chain corresponds to a resource in or out flow.
  - If there is a resource flowing into the cycle, there must be an event in the cycle that uses that resource
  - If there is a resource flowing out of the cycle, there must be an event in the cycle that provides that resource
    - Example, if there are 3 resources flowing into a cycle and only one resource flowing out, there must be 3 events (although the 3 events may be combined into less events) in the cycle that uses the three inflow resources, and there must be one event in the cycle that produces the outflow resource

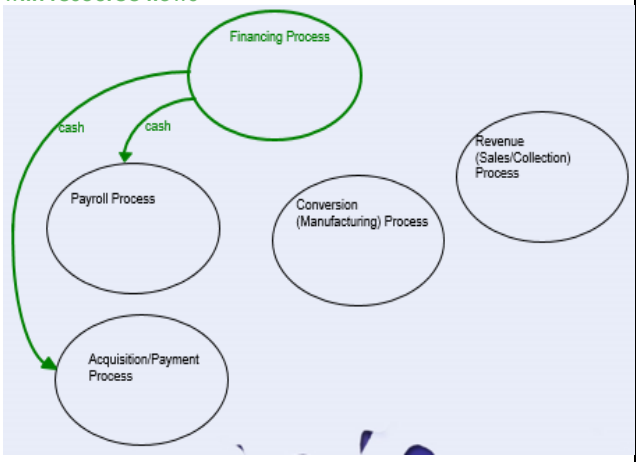
RSWS Example (from text)

Step 1: Write RSWS entrepreneurial script, based on narrative and value system model

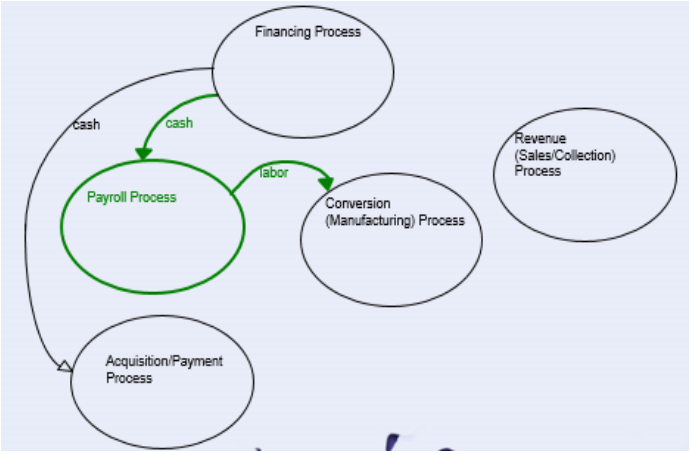
- RSWS gets cash from investors and creditors
- RSWS engages in value-adding activities
  - uses cash to buy instruments, raw materials, and overhead from vendors
  - uses cash to acquire labor from employees
  - uses materials, equipment, and overhead to manufacture accessories and to provide repair services
  - sells instruments, accessories, and repair services to customers for cash
- RSWS pays cash to investors and creditors

Step 2: Connect scenes with resource flows

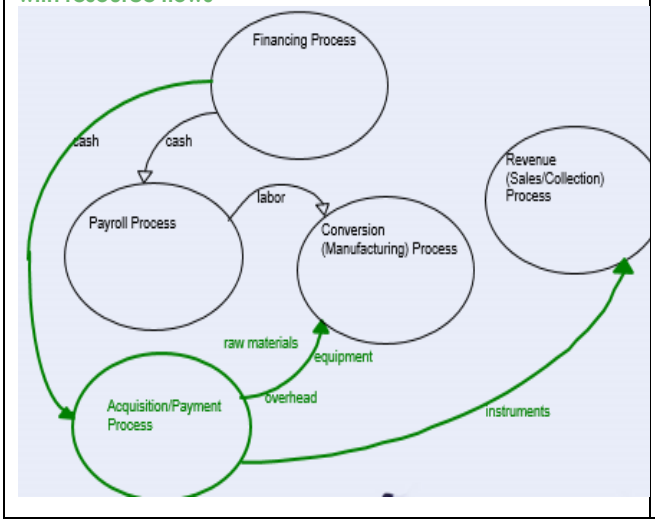
Step 2: Connect scenes with resource flows



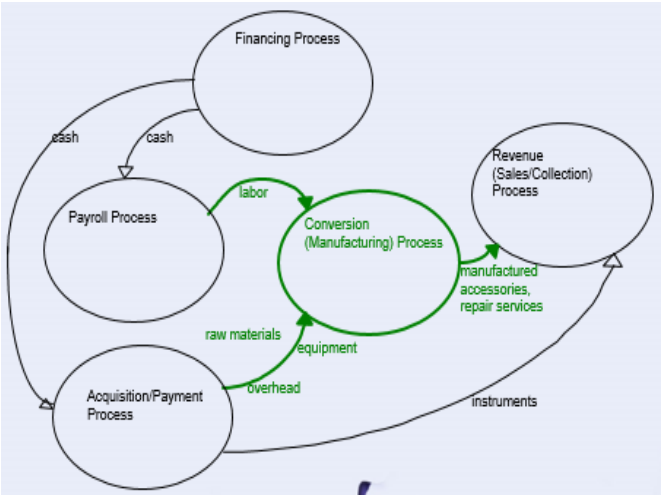
Step 2: Connect scenes with resource flows



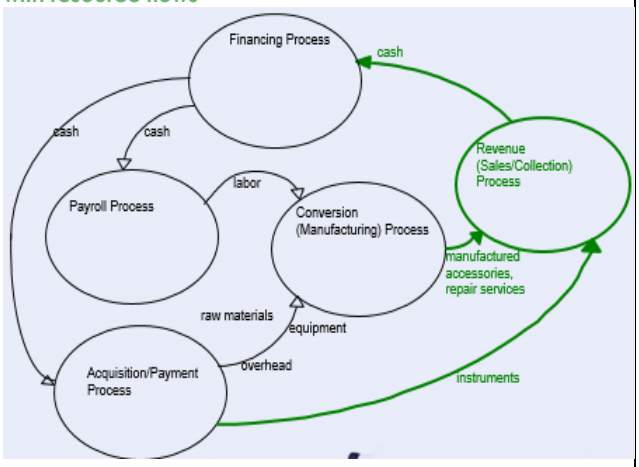
Step 2: Connect scenes with resource flows



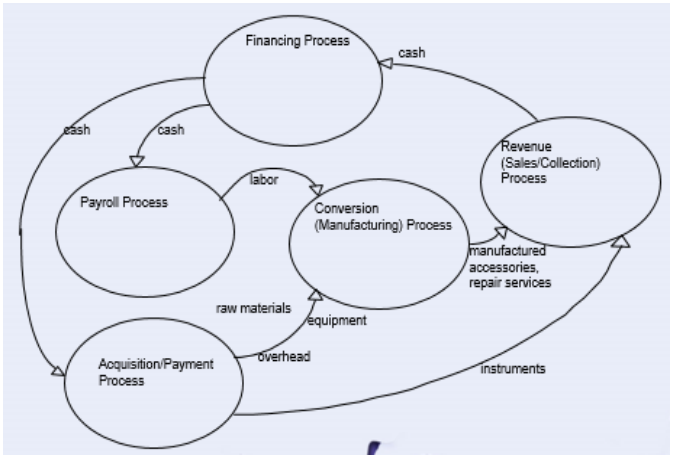
Step 2: Connect scenes with resource flows



Step 2: Connect scenes with resource flows



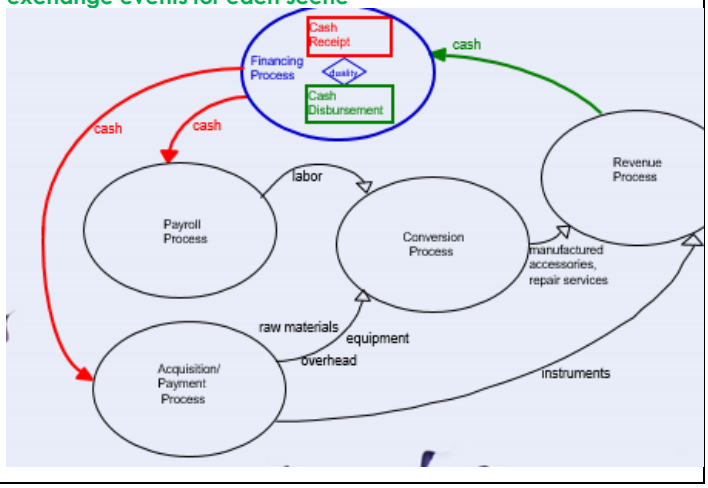
Step 2: Connect scenes with resource flows



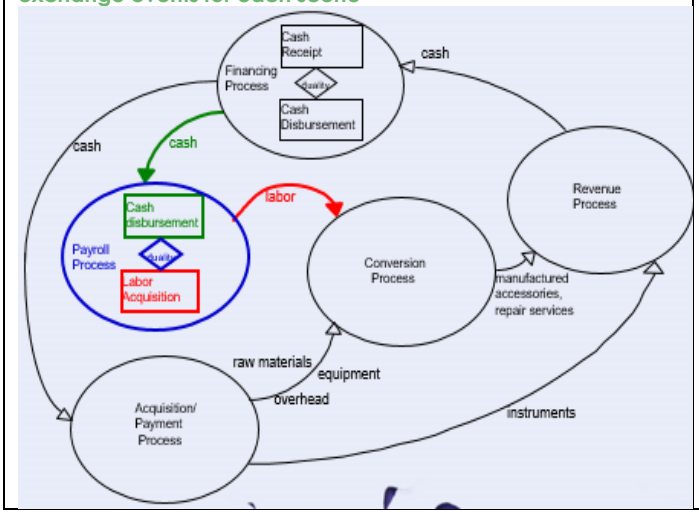
Step 3: Specify economic exchange events for each scene

- Each resource inflow must be matched to an economic decrement event
  - There must be an event within the process to "use it up"
- Each resource outflow must be matched to an economic increment event
  - There must be an event within the process to obtain or produce it

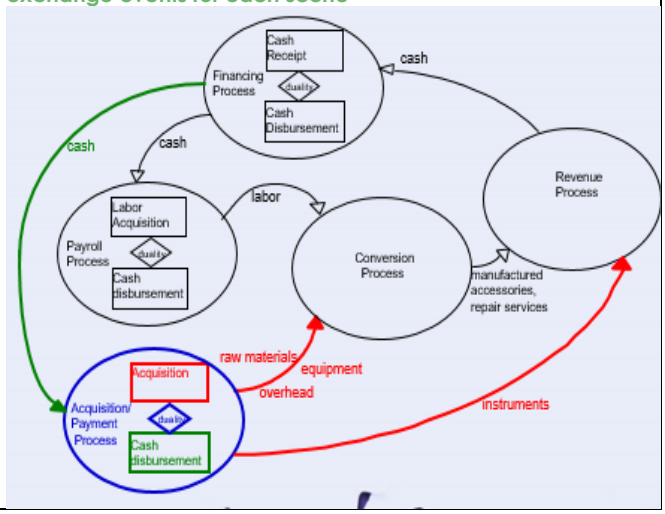
Step 3: Specify economic exchange events for each scene



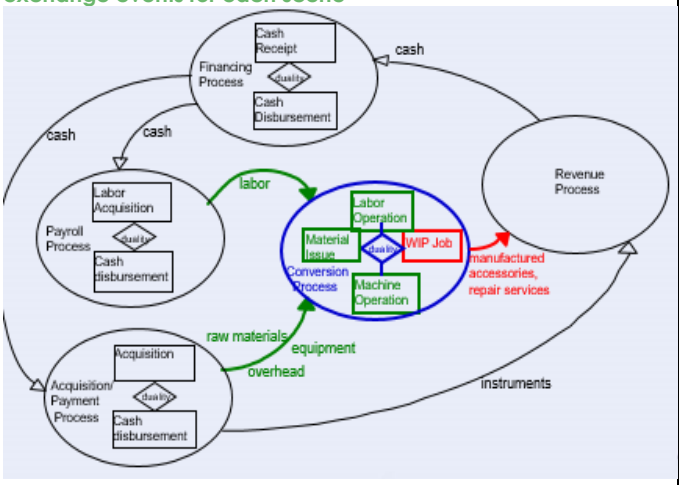
Step 3: Specify economic exchange events for each scene



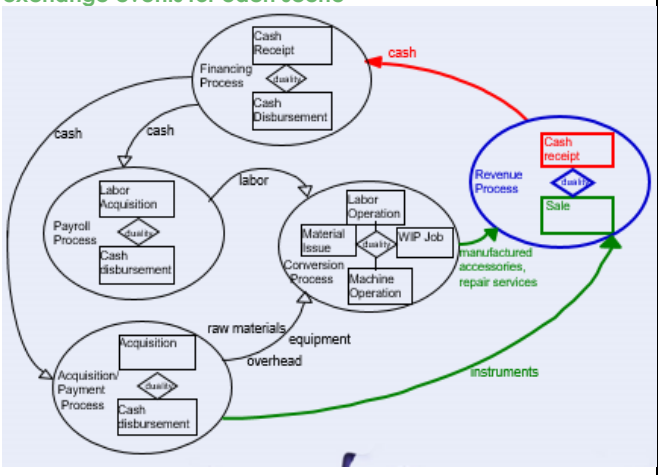
Step 3: Specify economic exchange events for each scene



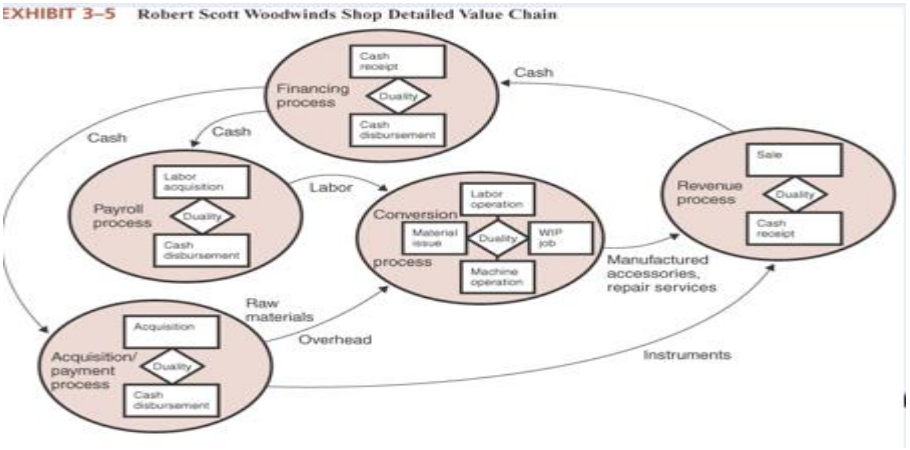
Step 3: Specify economic exchange events for each scene



Step 3: Specify economic exchange events for each scene



RSWS Completed Detailed Value Chain



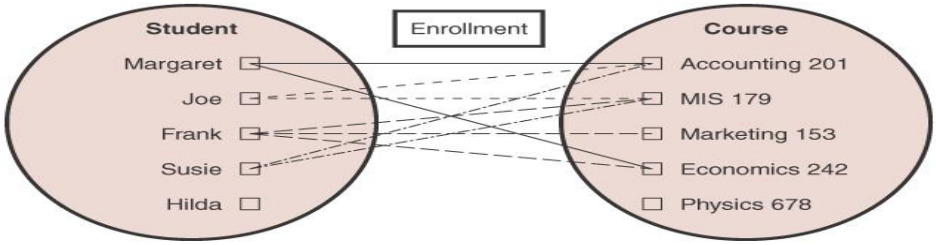
Chapter 4 The REA Enterprise Ontology: Business Process Level Modeling

Conceptual Modeling Constructs

- Entities
  - Sets of real world objects – things that have a separate existence, either physical or conceptual
    - Note SETS
- Relationships
  - Sets of associations between entities
    - Again, note SETS
  - Degrees of relationships

Example Entities and Relationships

EXHIBIT 4–1
Students, Courses, and the Enrollment Relationship



Conceptual Modeling Constructs

- Attributes
  - Characteristics or elementary properties of entities and/or relationships
  - Primary key attribute uniquely and universally identifies each instance of an entity or relationship set
  - Simple versus composite attributes
  - Derivable attributes
    - Static – will not change if new data is entered into system
    - Volatile – will change if new data is entered into system
- Participation Cardinalities (Min,Max)
  - Minimum cardinality: expresses the minimum number of times one instance of an entity set must participate in a relationship.
    0 = optional participation
    1 = mandatory participation
  - Maximum cardinality: expresses the maximum number of times one instance of an entity set may participate in a relationship
    1 = one-time only participation
    N = as many times as needed, no restrictions
- Abstraction Mechanisms
  - Typification
    - Specification of a relationship between a set of objects and a category to which the objects could be assigned on the basis of shared characteristics
    - Allows storage of characteristics that apply at the category level of detail
      - E.g. for student category, characteristics such as tuition rate per hour and maximum number of credits allowed per semester
- Abstraction mechanisms, continued
  - Generalization
    - Specification of subclass-superclass relationships, I.e., "Is-A" relationships
    - Subclass entities include contain more specific instances of superclass entities
      - E.g. Instrument as a supertype, Woodwind Instrument, Brass Instrument, and Stringed Instrument as subtypes
    - Are used when similar entity sets have enough shared attributes to warrant grouping them together, but they also have non-shared attributes that need to be stored
      - The non-shared attribute values are null if the attribute is assigned to the superclass entity; generalization avoids this problem
- Multiple notations are used to communicate the same conceptual modeling concepts
  - Just as people across the globe speak multiple languages to communicate the same general concepts – that's life!
  - People who are multi-lingual in life have an advantage over those who only speak one language
  - People who learn multiple conceptual modeling notations have an advantage over those who only learn one

Entity-Relationship (ER) Grammar notation

- Entity: ENTITY NAME
  Attributes: ATTRIBUTE NAMES
  Identifiers: PRIMARY KEY ATTRIBUTE
- Relationship: RELATIONSHIP NAME
  Connected entities: (min,max) ENTITY1
  (min,max) ENTITY2
  Attributes: ATTRIBUTE NAMES (if any)
- Objects are often stored in alphabetical order according to entity and relationship names, with all entities first, then all relationships
- Notation is sometimes called "BNF Grammar" format (Backus-Naur Form), after its creators, Backus and Naur.

Entity-Relationship (ER) Diagram Notation

- The ER Diagram is an alternative means for representing the same constructs as in the ER Grammar
- Most conceptual models are created with some version of the ER Diagram
  - Several variations exist, and notation (especially for cardinalities) differs between the variations

Conceptual Modeling Notation: Entities

- ER Grammars list entities (usually alphabetically) by name, each name is preceded by the word Entity and a colon, i.e.
  Entity: name of entity
- ER Diagrams portray entities as rectangles (each rectangle is labeled with the entity name)

Examples: Customer, Sale

- ER Grammar format
  Entity: Customer
  Entity: Sale

- ER Diagram format

Conceptual Modeling Notation: Relationships

- ER Grammars list relationships (usually alphabetically) by name, with the word Relationship and a colon, i.e., Relationship: name of relationship, followed by the words Connected Entities: and the names of the related entities
- ER Diagrams portray relationships as diamonds attached by straight lines to the entities for which the relationship depicts an association.

Example:

Sale IS-MADE-TO Customer:

- ER Grammar format

Relationship: IS-MADE-TO
Connected entities: (1,1) Sale
(0,N) Customer

- ER Diagram format

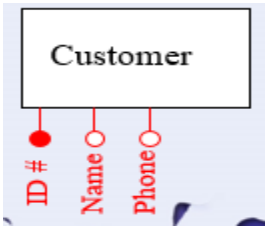
Conceptual Modeling Notation: Attribute

- ER Grammars list attributes by name within entity and/or relationship descriptions. The name of the primary key attribute(s) is also included after the word Identifiers and a colon.
- ER Diagrams depict attributes with small circles attached by short lines to the applicable entities and/or relationships. The circles for primary key attributes are darkened.

Example:

Customer Characteristics

- In ER grammar format
  Entity: Customer
  Attributes: ID#
  Customer_Name
  Customer_Phone
  Identifiers: ID#
- In ER diagram format →



Conceptual Modeling Notation: Participation Cardinalities

- ER Grammars incorporate participation cardinalities into the relationship descriptions. The participation cardinalities that apply to each entity in the relationship appear next to each entity name in the Connected Entities: statement.
- ER Diagrams include participation cardinalities as labels on the lines between the entities and the relationships for which the participation cardinalities apply.

Example:

Employee/Department cardinalities

- Employees are not necessarily assigned to departments
  - Minimum participation of employee = 0
- Every department has at least one employee assigned to it
  - Minimum participation of department = 1
- An employee can work for no more than one department
  - Maximum participation of employee = 1
- A department may have many employees assigned to it
  - Maximum participation of department = N
- In ER Grammar format
  Relationship: Assigned-to
  Connected Entities: (0,1) Employee
  (1,N) Department
- In ER Diagram format

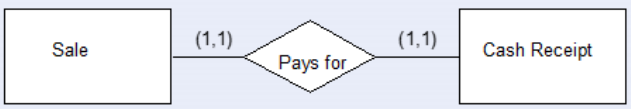
Comparison of Cardinality Notations

TABLE 4–1 Conceptual Modeling Notation Comparison

	Chen (used in current edition of textbook)	Crow's Foot	HDC
Notation for each cardinality	Min zero = (0, Min one = (1, Max one = ,1) Max many = ,N)	Min zero = Min one = Max one = Max many =	Min zero = (0, Min one = (1, Max one = ,1) Max many = ,*)
Answer placement	Sale (Q1, Q2) Customer (Q3, Q4)	Min symbol closest to relationship center on opposite entity's side; max symbol closest to opposite entity. Sale (Q4, Q3) ------ (Q1, Q2) Customer	Sale (Q3, Q4) Customer (Q1, Q2)
Solution to Exhibit 4–1 (attributes are left off to increase readability)	Diagram format Sale (1,1) Partici-pation (0,N) Customer Grammar format Relationship: participation Connected entities: (1,1) Sale (0,N) Customer	Sale Customer	Sale (0,*) (1,1) Customer

The same 4 questions are asked; the only difference in the "languages" is where the answers are placed and what symbols are used to represent the answers

Interpret cardinalities: Exercise 1



Q1: Can at least one sale exist in the database without a related instance of cash receipt? No – 1 min on sale

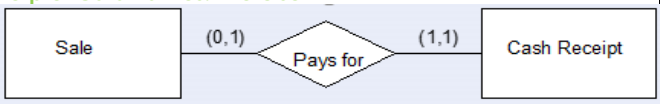
Q2: Can at least one sale in the database relate to multiple instances of cash receipt? No – 1 max on sale

Q3: Can at least one cash receipt exist in the database without a related instance of sale? No – 1 min on cash receipt

Q4: Can at least one cash receipt in the database relate to multiple instances of sale? No – 1 max on cash receipt

In other words, all sales are paid for immediately with cash, and sales are the company's only source of cash

Interpret Cardinalities: Exercise 2



Q1: Can at least one sale exist in the database without a related instance of cash receipt? Yes – 0 min on sale

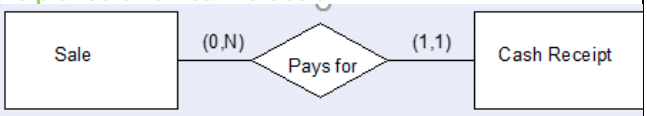
Q2: Can at least one sale in the database relate to multiple instances of cash receipt? No – 1 max on sale

Q3: Can at least one cash receipt exist in the database without a related instance of sale? No – 1 min on cash receipt

Q4: Can at least one cash receipt in the database relate to multiple instances of sale? No – 1 max on cash receipt

In other words, sales may be made on credit with no partial payments or combined payments accepted, and sales are the company's only source of cash

Interpret Cardinalities: Exercise 3



Q1: Can at least one sale exist in the database without a related instance of cash receipt? Yes – 0 min on sale

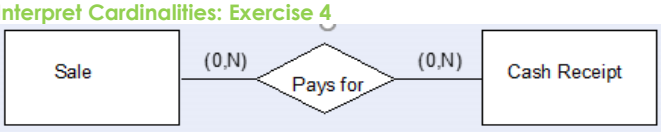
Q2: Can at least one sale in the database relate to multiple instances of cash receipt? Yes – N max on sale

Q3: Can at least one cash receipt exist in the database without a related instance of sale? No – 1 min on cash receipt

Q4: Can at least one cash receipt in the database relate to multiple instances of sale? No – 1 max on cash receipt

In other words, sales may be made on credit with partial payments but no combined payments accepted, and sales are the company's only source of cash

Interpret Cardinalities: Exercise 4



Q1: Can at least one sale exist in the database without a related instance of cash receipt? Yes – 0 min on sale

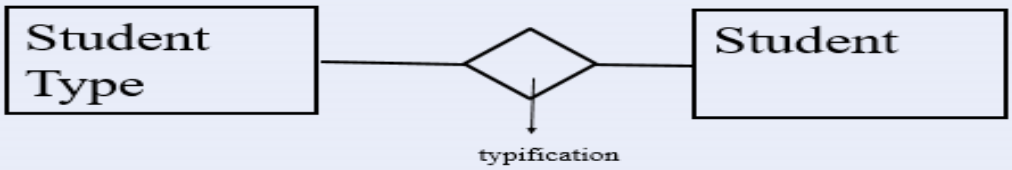
Q2: Can at least one sale in the database relate to multiple instances of cash receipt? Yes – N max on sale

Q3: Can at least one cash receipt exist in the database without a related instance of sale? Yes – 0 min on cash receipt

Q4: Can at least one cash receipt in the database relate to multiple instances of sale? Yes – N max on cash receipt

In other words, sales may be made on credit with partial payments and combined payments accepted, and cash comes from sources other than sales

Typification Example (important)



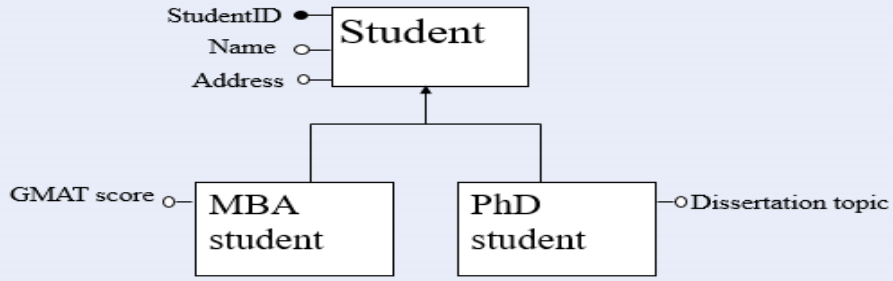
Student Type

Student Type Name	Tuition per Credit	Fee Assessment	Maximum Semester Credits
Undergraduate	$ 600	$200	21
Graduate-MBA	$1,000	$450	18
Graduate-PhD	$1,000	$350	9
Graduate-Medical	$1,500	$1,400	12
Graduate-Law	$1,100	$600	18

Student

Student ID	Last Name	First Name	Address	Telephone	Student Type
12345678	Anderson	Abigail	123 Pine	219-882-1230	Graduate-PhD
23456789	Bishop	Brian	45 Elm	219-882-1356	Bachelors
34567890	Clark	Christy	999 Oak	219-882-5126	Graduate-MBA
45678901	Davis	Danny	876 Fir	219-882-7129	Graduate-MBA
56789012	Edgar	Elizabeth	3551 Ash	219-882-8327	Bachelors
67890123	Fredericks	Faye	7623 Beech	219-882-2544	Graduate-Law

Generalization Example (important)



Student

StudentID	Name	Address	Student Type FK
111222	Joe	14 Irish St.	UG
222333	Rebecca	22 Irish St.	MBA
444555	Victor	147 Green Dr.	MBA
555666	Rob	765 Lucky Dr.	MBA
666777	Julie	912 Navy St.	PhD
777888	Sandra	577 Early Dr.	UG
888999	James	822 Rose Ave.	UG
999000	Bethany	171 Turkey St.	UG
000111	Chris	288 Park Ave.	PhD

PhD Student

StudentID	Dissertation Topic
666777	The REA ontology as a foundation for Ecommerce
000111	Stock price reactions to REA system implementations

MBA Student

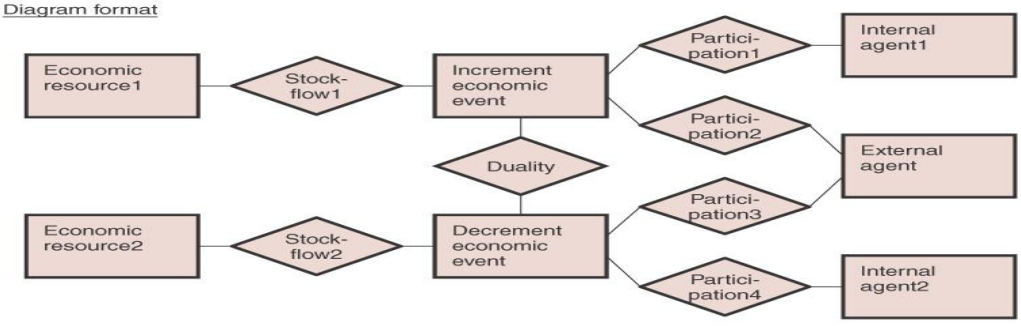
StudentID	GMAT score
222333	630
444555	670
555666	650

REA Business Process Level Pattern: Core Pattern

EXHIBIT 4–4
Core REA Pattern

Adapted from W. E. McCarthy, "The REA Accounting Model: A Generalized Framework for Accounting Systems in a Shared Data Environment," *The Accounting Review*, July 1982, pp. 554–77.

Diagram format



Grammar format

Entity: Increment economic event
Entity: Decrement economic event
Entity: Economic resource1
Entity: Economic resource2
Entity: External agent
Entity: Internal agent1
Entity: Internal agent2

Relationship: Duality
Connected entities: Increment economic event
Decrement economic event
Relationship: Stockflow1
Connected entities: Increment economic event
Economic resource1
Relationship: Stockflow2
Connected entities: Decrement economic event
Economic resource2
Relationship: Participation1
Connected entities: Increment economic event
Internal agent1
Relationship: Participation2
Connected entities: Increment economic event
External agent
Relationship: Participation3
Connected entities: Decrement economic event
External agent
Relationship: Participation4
Connected entities: Decrement economic event
Internal agent2

Steps to Create a REA Business Process Level Model

Step 1: Identify Economic Exchange Events

- Use value chain level model if you have one
- Which events provide and use up the resources in the business process you are modeling?
- Create each economic exchange event as an entity and create a duality relationship between them

- Step 2: Attach Resources to the Economic Events
  - Again, use value chain if you have one, to identify which resources are increased by the economic increment event and which are decreased by the economic decrement event
  - Create each resource as an entity and create a stockflow relationship between it and the related economic event
- Step 3: Attach External Agents to Economic Events
  - Use value system level model if you have one
  - Identify the external agent from whom resources are obtained in each economic increment event
    - Create the external agent as an entity and create a participation relationship between the event and the agent
  - Identify the external agent to whom resources are transferred in each economic decrement event
    - Create the external agent as an entity and create a participation relationship between the event and the agent
- Step 4: Attach internal agents to economic events
  - Identify the internal agent(s) who processes, accomplishes, or authorizes each economic increment event
    - Create the internal agent as an entity and create a participation relationship between the event and the agent
  - Identify the internal agent(s) who processes, accomplishes, or authorizes each economic decrement event
    - Create the internal agent as an entity and create a participation relationship between the event and the agent
- Step 5: Assign Attributes to Entities and Relationships
  - Obtain list of attributes from the enterprise or conduct a series of interviews to determine the attributes the enterprise needs to be able to capture and store
  - Make sure you understand the information each attribute is intended to communicate
  - Assign attributes to the entities and relationships
    - Determine whether the attribute describes just one thing (entity) or a combination of things (relationship)
    - Resource attributes typically include an identifier, description, and attributes indicating value or dimensions
      - Must first determine whether instances of the resource entity are type level or token level objects
    - Event attributes typically include an identifier, a date/time (or beginning and ending dates/times), and attributes indicating value or other dimensions
    - Agent attributes typically include an identifier, name, address, telephone, other contact information
- Step 6: Participation Cardinality Assignment
  - Assign cardinalities to each relationship in the model
  - Use business rules provided by enterprise in narratives or from interviews with enterprise staff
  - Heuristics – rules of thumb that usually (but don't always) apply
    - (0,N) Resource Type – (1,N) Economic Event (Stockflow)
      - Exception if alternative kinds of resource types could participate in the stockflow relationship
    - (0,1) Resource – (1,N) Economic Event
      - Exception if economic event involves rental of resource rather than permanent transfer or in case of an enterprise that handles both new and used resources
    - (1,1) Economic Event – (0,N) Agent
      - Exception if alternative agent can participate
      - Exception if multiple agents share responsibility for event
- Step 7: Validate Model
  - Review the model with a sufficiently knowledgeable enterprise representative
    Be sure to use plain language when communicating with the representative; do not assume they know the meanings of terms such as entities, attributes, cardinalities, stockflow, duality, and so on

REA business process level with extensions

- Entities
  - Resources and Resource Types
  - Events
    - Instigation Event
      - An event that initiates activities in the business process; may be internally instigated (e.g. a marketing event) or externally instigated (call from supplier's salesperson)
    - Mutual Commitment Event
      - An event in which commitments are made by the enterprise and one of its external business partners for a future economic exchange
    - Economic Exchange Event

- An event in which a resource is either given up or taken
  - » Increment economic event results in resource inflow
  - » Decrement economic event results in resource outflow

- Entities
  - Agents
    - Internal agents act on behalf of the enterprise
    - External agents are external business partners
- Relationships
  - Event-Event relationships
    - Duality (link increment and decrement economic events)
    - Reciprocal (link increment and decrement commitment events)
      - Is the commitment equivalent of duality
    - Fulfillment (link commitment and economic events)
  - Event-Resource relationships
    - Stockflow (link economic events and resources or resource types)
    - Reservation (link commitment events and resources or resource types)

REA business process pattern

- Relationships
  - Event-Agent relationships
    - Participation (link events and the agents that participate in the events)
  - Agent-Agent relationships
    - Assignment (link internal agent to external agent)
      - Use only when relationship between internal agent and external agent exists independently of their mutual participation in an event
    - Responsibility (link internal agent to internal agent)
      - Use when one internal agent is responsible for another, independent of their mutual participation in an event
- Relationships
  - Resource-Agent relationships
    - Custody (link resource and internal agent)
      - Use when an internal agent's responsibility for a resource needs to be tracked independently of any event
  - Resource-Resource relationships
    - Linkage (link two resources)
      - Use to identify resource made up of another resource
  - Typification
    - Each resource, event, or agent can be related to a resource type, event type, or agent type
  - Generalization
    - Each resource, event, agent, and commitment can also participate in a relationship with a sub-class or super-class via a generalization relationship

Chapter 5 Task Level Modeling

System Flowcharts

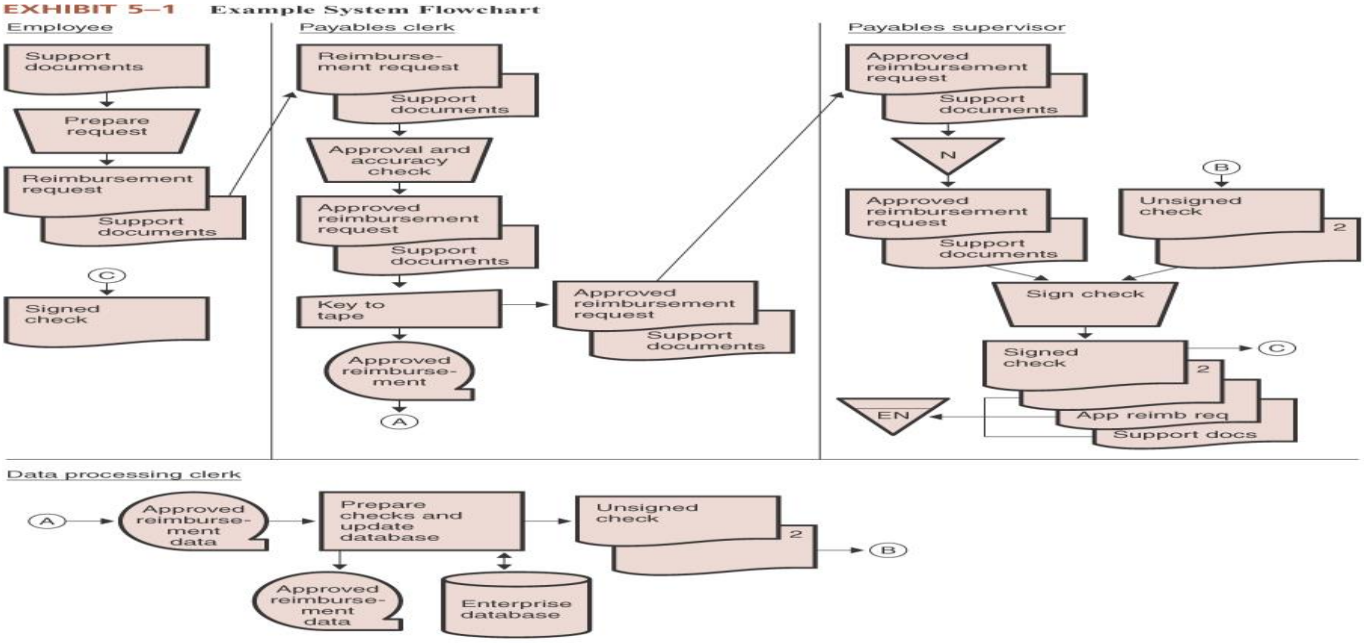
- Graphically document information systems
- Summarize pages of narrative in diagrammatic format
- Focus on the physical aspects of information flows

System Flowcharts: Basic Elements

- System flowcharts may be drawn freehand or with a plastic flowchart template/stencil tool.
- System flowcharts may be prepared using software created for that purpose.
  - E.g. SmartDraw, Visio, ABC Flowcharter
  - Microsoft Word and Powerpoint (but they are not as automated)
- System flowcharts combine three simple graphical elements to represent various types of physical information flows and processes

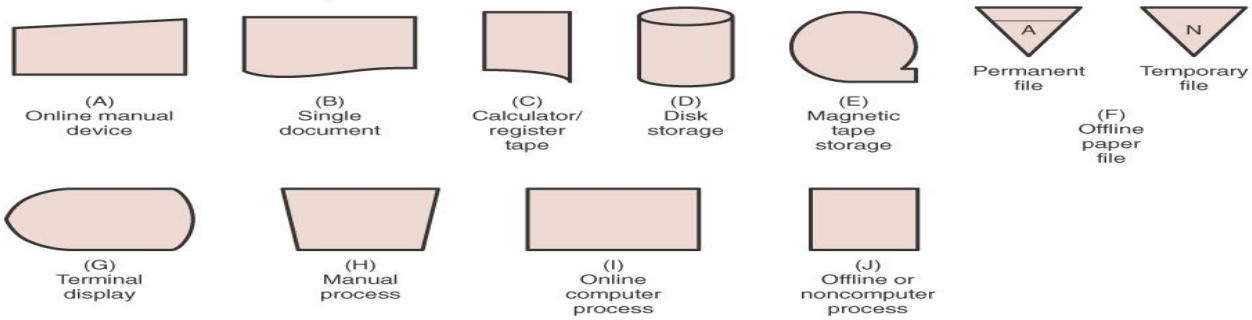
Example System Flowchart

EXHIBIT 5–1 Example System Flowchart



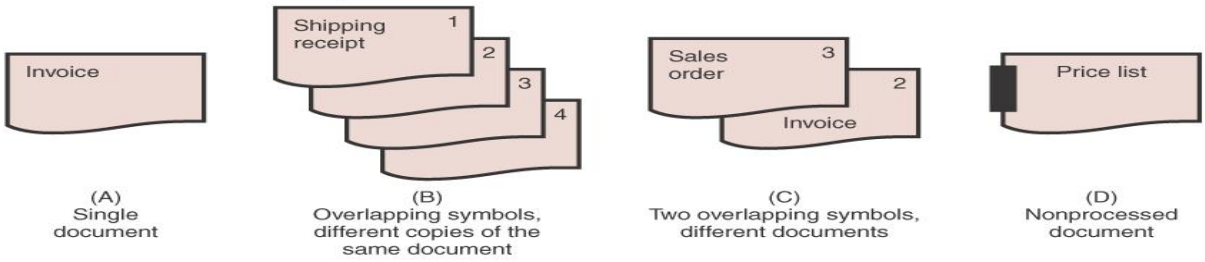
Flowchart Symbols

EXHIBIT 5–2 Flowchart Symbols



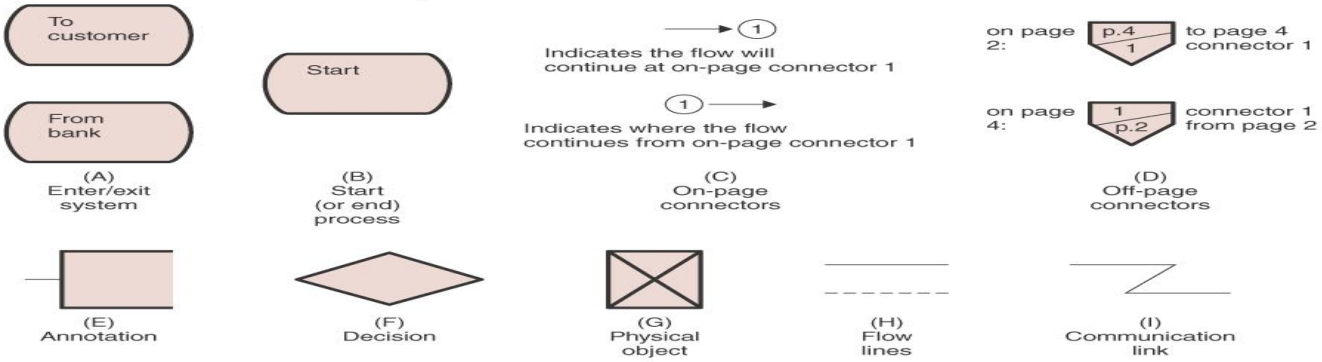
Flowchart Symbols: Documents

EXHIBIT 5–3 Flowchart Symbols: Documents



More Flowchart Symbols

EXHIBIT 5–4 More Flowchart Symbols



Flow Lines

- Flow lines are used to connect the symbols on the document flow chart.
- A solid line indicates the flow of a document or object
- A dotted or dashed symbol indicates a flow of information rather than the physical document
- Some flowcharts also show communication flows such as by telephone modem or satellite
- Arrows are used when the documents or information flow is not left-to-right or top-to-bottom

Areas of Responsibility

- Areas of responsibility are displayed to enable the flowchart reader to clearly identify changes in responsibility as the documents flow through the system.
- They are represented on flowcharts by segmenting and labeling columns.
- Areas of responsibility may be departments, sections within a department, or individual employees within a department.
- Judgment must be used in choosing the level of subdivision that one column should represent.

Flowchart Preparation Conventions

- Left-to-right, Top-to-bottom
- All documents must have an origin and termination ("cradle to grave documentation)
  - each copy of the document must flow to
    - a permanent file symbol
    - a symbol denoting an exit from the system, or
    - an off-page connector
    - a document destruction symbol (small black box)
    - Corner of originating symbol may be darkened to indicate its introduction to the system
- Keep flowcharts uncluttered
  - Place responsibility areas with frequent interchange in adjacent columns
  - Enter narrative only within symbols
  - Avoid unnecessary explanation with narrative
- Make sure progress of each document is clear.
  - Diagram a document
    - before and after each process
    - entering or leaving a file
    - entering or leaving a page or area of responsibility
- Ensure flowchart is complete

System Flowchart Summary

The Good	The Not-So-Good
– Flowcharts are relatively easy for information customers and managers to understand – Flowcharts help auditors understand business and systems controls	– Flowcharts are tied to physical information flows and system characteristics that hide procedural essence of – Flowcharts may be artifactual and tied to outdated information technology

File Types

- Master files
  - Contain the balance or status of entities
    - E.g. vendors, credit customers, inventory, assets, employees
- Transaction files
  - Contain activity data
    - E.g. orders, sales, payments
- History or archive files
  - Contain inactive past or historical data
- Reference files
  - Contain information needed for reference purposes
    - e.g., rates, prices, zip codes, chart of accounts
- Suspense files
  - Contain items awaiting action, errors, missing information

PROJECT GUIDELINES

To eliminate communication issues, guidelines must be established. The following are components of a quality project guideline:

- Daily meetings
- Idea sharing
- Keep project managers informed
- Complaint resolution

COMMUNICATION PLANNING PRINCIPALS

- Define and understand quality
- Define goals and objectives
- Establish a set of managers who:

- Understand the technical practices that support systems and software engineering
- Can clearly define and provide a scope for the team defining the development stages
- Provide a scope for the team to know what is ahead
- Involve systems and software teams to help with delivery schedules
- Can accommodate change and identify potential risks that impact on program and project planning
- Track the progress daily and adjusting if needed

Storage and Access of Data

- Sequential Storage and Sequential Access
  - Records are stored in order
  - To access a record, the access device must read through all records that are stored previous to the desired record
  - Tape cartridges and open reel tapes require sequential storage and sequential access of data
- Random Storage and Direct Access
  - Records are stored in any order
  - Any record can be retrieved directly regardless of physical position on the media; the access device need not read all the records prior to the desired record
  - Computer hard disks, floppy disks, zip disks, CD-ROMs, and DVD-ROMs allow random storage and direct access of data

Media

- Paper
  - Most common form of media
  - Most easily used by people
  - Doesn't depend on electricity to access
  - Disadvantages
    - Bulk (for storage)
    - Lack of search and automated processing capability
    - Susceptibility to destruction
  - Sequential storage (may be indexed for indexed-sequential access)
  - May update on same physical input media
    - Add information to existing document
- Magnetic tape
  - Audiocassette tapes, VHS videotapes, and 8mm video camera cassettes use magnetic tape
  - Sequential storage and sequential access
  - Sorting is important for processing (transaction file must be sorted to match the order of the master file)
  - Separate physical media must be used for input and output in an update process
    - Old master file, new master file
  - Easy backups
  - Dependent on electricity and on hardware
    - Cannot be read or processed directly by a person
- Digital (Disk) media
  - Computer hard disks, floppy disks, zip disks, CDs, DVDs, and memory cards
  - Random storage
    - Information may be stored anywhere on the media; may be broken up (fragmented) and stored in multiple places
      - "Defragging" a hard drive is the process of sorting the data to re-connect all the fragments for more efficient processing
  - Direct access
    - From index, hardware can jump directly to the desired information and proceed with processing
  - Same physical media may be used for input and output in an update process (unless disk is full)
  - Easy backups
  - Dependent on electricity and on hardware
    - Cannot be read or processed directly by a person

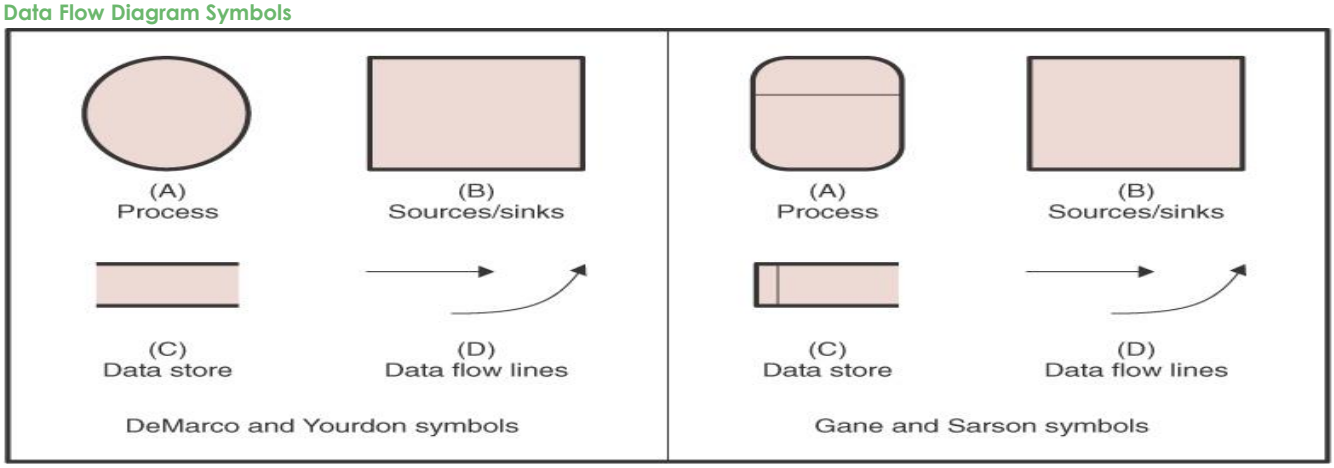
Processing Methods

- **Batch:** accumulates transaction data for a period of time. Then all of the transactions in the transaction file are posted to the master file in one processing run. (Tape processing is always batch)
- **Online:** means the computer-input device is connected to the CPU so that master files are updated as transaction data are entered
- **Real-time:** denotes immediate response to an information user; transaction data are entered and processed to update the relevant master files and a response is provided to the person conducting the business event fast enough to affect the outcome of the event
- **Report-time:** the data used to generate the requested report is processed as the report is created

Data Flow Diagrams (DFD)

- DFD symbols are used for a variety of system analysis purposes, including graphically displaying the logical flows of data through a process.
- Unlike flowcharts which represent the physical components of an information system, DFDs can provide a more conceptual, nonphysical display of the movement of data through a system.
- DFDs disregard such things as organizational units, the computer on which the data are processed, and the media on which the data are stored.
- Movements of data across offices or departments within a particular system are not represented.

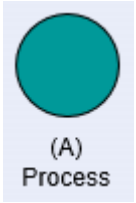
Data Flow Diagram Symbols



Dunn, Cherrington, and Hollander, 3e uses the Demarco and Yourdon symbols

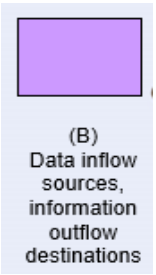
Process

- Circles are used to represent processes that take data inflows and transform them to information outflows
- Each circle contains two labels
  - a process number
  - a process name
- Alternate notations is rectangular box with rounded corners



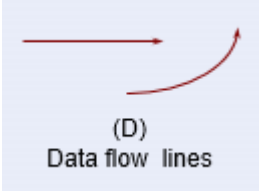
Data Sources and Sinks

- Rectangles (or squares) represent data (inflow) sources and (information outflow) sinks
- Rectangle is labeled with the name of the data source or sink/destination (e.g. Customer, Vendors, Government Agency).
- Sources and sinks are agents external to (i.e. outside the scope of) the system represented on the diagram
  - Delineate the boundaries of the system



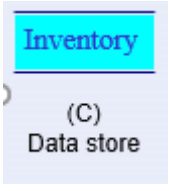
Data Flow Lines

- Data flow lines display the route of data inflow and information outflow
- Lines can be straight or curved
- Data flows are generally labeled with the name of the data (e.g. a customer order, a bill, a financial analysis)
- Arrow indicates the direction of the data flow



Data Stores

- Two parallel straight lines are used to display a store or collection of data
- Some people refer to data stores as data at rest
- A description of the data store contents is entered on the symbol
- Data stores are used anytime it is necessary to store the output from a process before sending it on to the next process
- Alternative notation uses a rectangular box that is open at one end



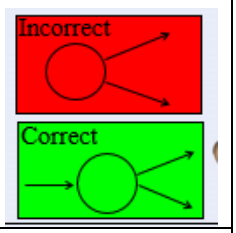
THE THREE CRITICAL FACTORS

1) All processes should have unique names
If two data flow lines (or data stores) have the same label, they should both refer to the exact same data flow (or data store)

2) The inputs to a process should differ from the outputs of a process

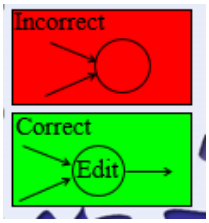
3) Any single DFD should not have more than about seven processes

4) No process can have only outputs. (This would imply that the process is making information from nothing.) If an object has only outputs, then it must be a source.

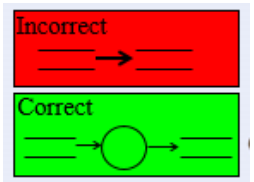


5) No process can have only inputs (referred to as a "black hole")
   - If an object has only inputs, then it must be a sink

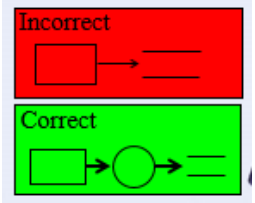
6) Process should be labeled with a verb phrase



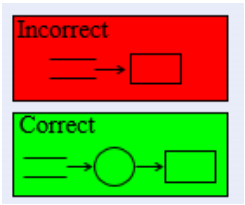
7) Data must be moved by a process; data cannot move directly from one data store to another



8) Data must be moved by a process that receives data from the source and places the data in the data store; data cannot move directly from an outside source to a data store



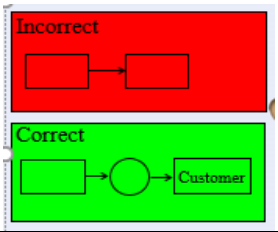
9) Data must be moved by a process; cannot move directly to an outside sink from a data store



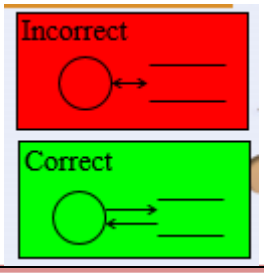
10) Data store should be labeled with a noun phrase

12) A source/sink has a noun phrase label.

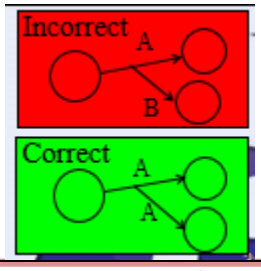
11) Data cannot move directly from a source to a sink. It must be moved by a process if the data are of any concern to the system. If data flows directly from a source to a sink (and does not involved processing) then it is outside the scope of the system and is not shown on the system data flow diagram DFD.



13) A data flow has only one direction between symbols. It may flow in both directions between a process and a data store to show a read before an update. To effectively show a read before an update, draw two separate arrows because the two steps (reading and updating) occur at separate times.



14) A fork in a data flow means exactly the same data (e.g. different copies of an invoice) goes from a common location to two or more different processes, data stores, or sources/sinks



15) A join in a data flow means exactly the same data comes from two or more different processes, data stores, or sources/sinks, to a common location.	16) A data flow cannot go directly back to the same process it leaves. At least one other process must handle the data flow, produce some other data flow, and return the original data flow to the originating process.
17) A data flow to a data store means update (i.e., delete, add, or change). 18) A data flow from a data store means retrieve or use.	19) A data flow has a noun phrase label. More than one data flow noun phrase can appear on a single arrow as long as all of the flows on the same arrow move together as one package.

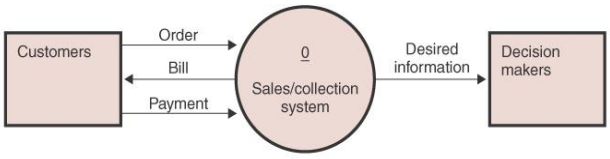
DFD Levels

- DFDs are divided into levels to keep their size and complexity manageable
- Context level shows least detail
- Each subsequent level (Level Zero, Level One, Level Two, etc.) subdivides one process on the previous diagram into more detail
- Balance must be maintained between levels
  - All inflows from and outflows to external sources/sinks must be the same from one level to the next

Context Level DFD

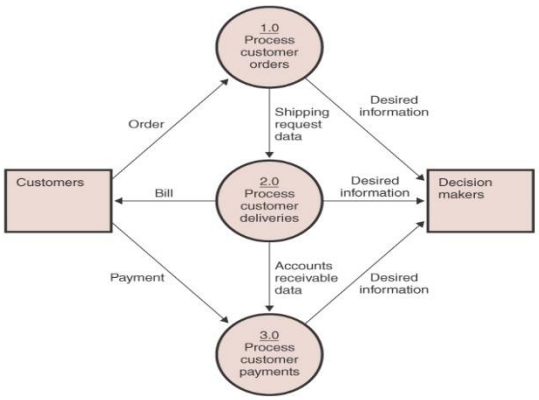
- The context diagram shows **one process** (representing the entire system) and the **sources/sinks** that represent the boundaries of the system.

EXHIBIT 5–7
Context Level DFD



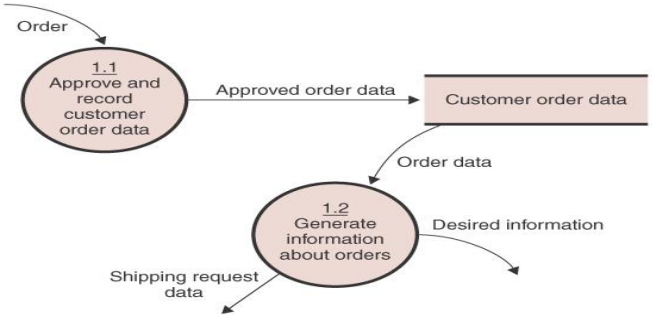
Level Zero DFD Example

EXHIBIT 5–8
Level-Zero DFD



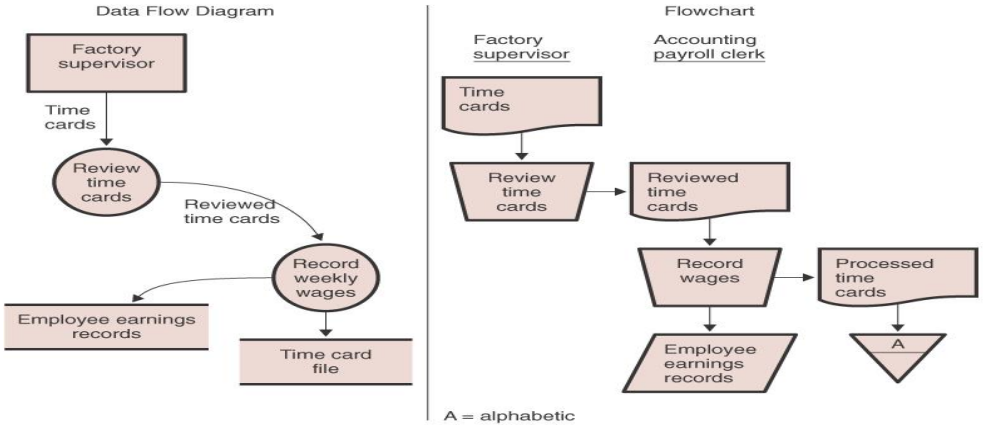
Level One DFD Example

EXHIBIT 5-9
Level-One DFD



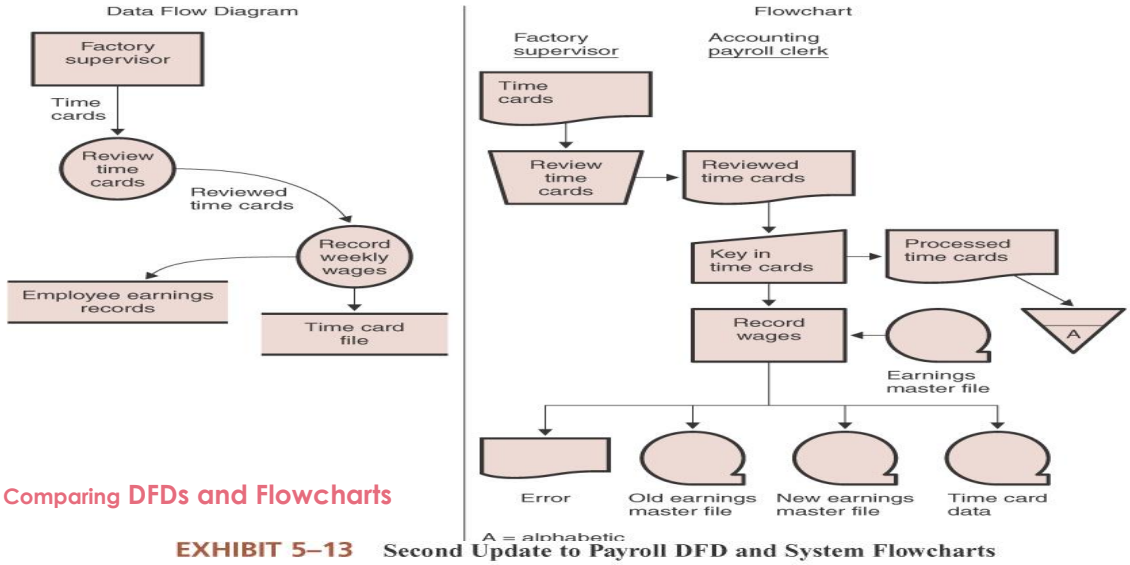
Comparing DFDs and Flowcharts

EXHIBIT 5–11 Payroll DFD versus System Flowchart



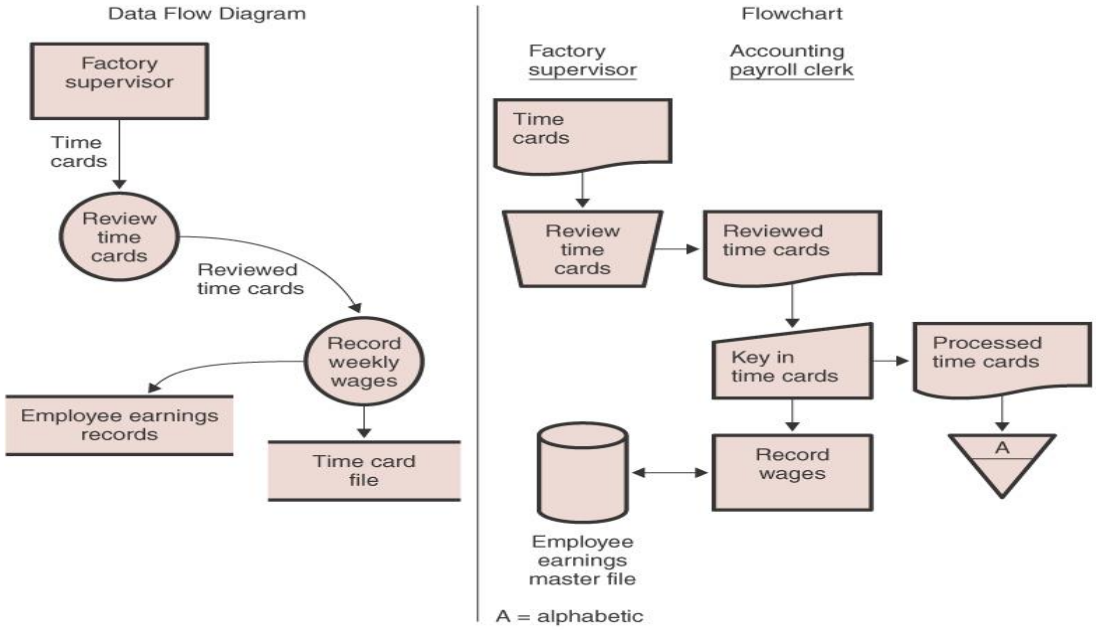
Comparing DFDs and Flowcharts

EXHIBIT 5–12 Updated Payroll DFD and System Flowcharts



Comparing DFDs and Flowcharts

EXHIBIT 5–13 Second Update to Payroll DFD and System Flowcharts



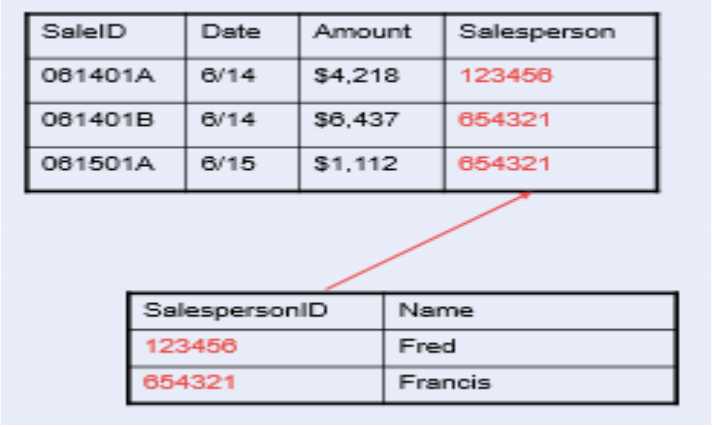
Database Model Levels

- A Conceptual model represents reality in an abstracted form that can be used in developing an information system in a wide variety of formats (e.g. relational, object-oriented, flat-file, etc.)
  - It is hardware and software independent
  - It is independent of any logical model type
- A Logical model represents reality in the format required by a particular database model (e.g. relational or object-oriented)
  - Is still hardware and software independent
  - Depends on the chosen logical model type
- A Physical model is created specifically for a particular database software package
  - Is dependent on hardware, software, and on the chosen logical model type

Relational Database Model

- The relational model is a type of logical database model that was conceived by E.F. Codd in 1969
- The relational model is based on set theory and predicate logic
  - It is well formalized, so its behavior is predictable
- A relational database consists of tables (relations) that are linked together via the use of primary and foreign keys
  - A FOREIGN KEY in a table is a primary key from a different table that has been posted into the table to create a link between the two tables
- Relational database tables are made up of rows and columns
  - Rows are called the table extension or tuples
    - The ordering of rows in a table does not matter
  - Columns are called the table intension or schema
    - The ordering of columns in a table does not matter
    - All values in a column must conform to the same data format (e.g. date, text, currency, etc.)
  - Each cell in a database table (a row-column intersection) can contain only one value
    - no repeating groups are allowed

Foreign Key Example



SaleID	Date	Amount	Salesperson
081401A	6/14	$4,218	123456
081401B	6/14	$6,437	654321
081501A	6/15	$1,112	654321

SalespersonID	Name
123456	Fred
654321	Francis

Relational Database Model

- Some principles of the relational model
  - Entity Integrity
    - A primary key in a table must not contain a null value
      - Guarantees uniqueness of entities and enables proper referencing of primary key values by foreign key values
  - Referential Integrity
    - A value for a foreign key in a table must either
      - Be null (blank)
      - Match exactly a value for the primary key in the table from which it was posted
  - One Fact, One Place
    - Fact = a pairing of a candidate key attribute value with another attribute value
      - Facts are found in the extensional data

Referential Integrity Example

EXHIBIT 6–1 **Foreign Key Examples**

(a) Meets referential integrity principle

Sale

SaleID	Date	Amount	Salesperson
061401A	6/14	$4,218	123456
061401B	6/14	$6,437	654321
061501A	6/15	$1,112	654321
061501B	6/15	$3,300	
061501C	6/15	$1,776	

Salesperson

SalespersonID	Name	Telephone
123456	Fred	555-0063
654321	Francis	555-0007

(b) Violates referential integrity principle

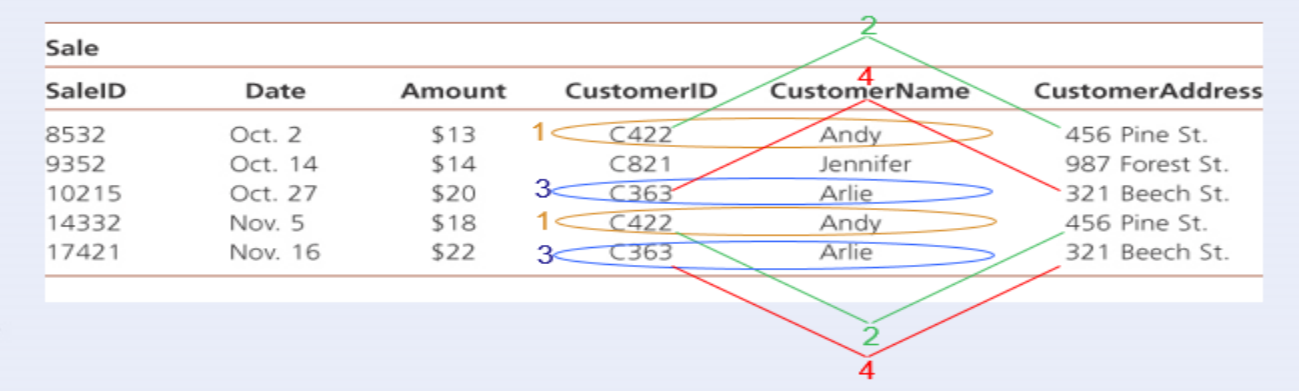
Sale

SaleID	Date	Amount	Salesperson
061401A	6/14	$4,218	123456
061401B	6/14	$6,437	654321
061501A	6/15	$1,112	654321
061501B	6/15	$3,300	
061501C	6/15	$1,776	234567

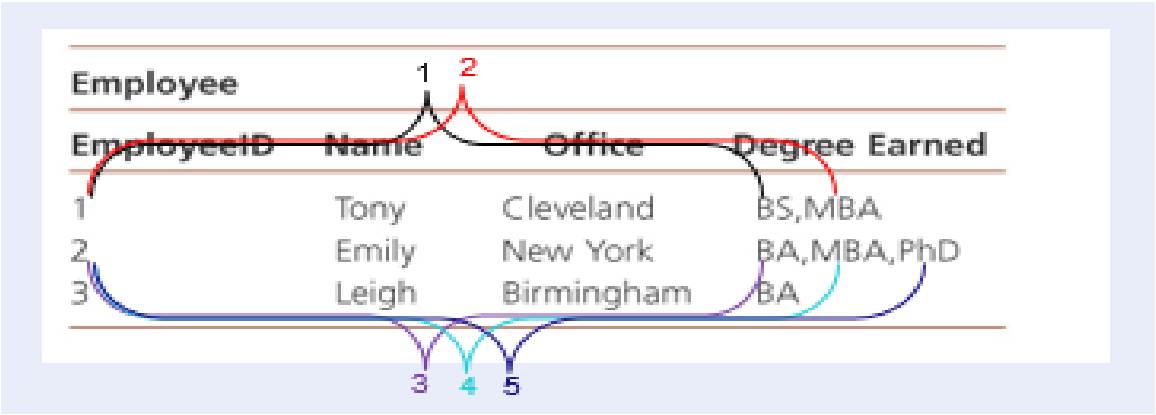
Salesperson

SalespersonID	Name	Telephone
123456	Fred	555-0063
654321	Francis	555-0007

One Fact-One Place Violations One fact in multiple places



Multiple facts in one place



Each value of each attribute in a row is paired with the primary key, so if any cell has two or more attribute values, by definition there are multiple facts in one place (also known as a *repeating group*)

Converting Conceptual to Relational

- Step 1: Create a separate table to represent each entity in the conceptual model
  - 1A: Each attribute of the entity becomes a column in the relational table
  - 2A: Each instance (member) of the entity set will become a row in the relational table
- Steps 2-4 (detailed in the next few slides) involve determining whether each relationship in the conceptual model should be represented as a separate table or as a posted foreign key
  - Redundancy and Load are important determinants
    - Redundancy = one fact in multiple places or multiple facts in one place
    - Load = the percentage of non-null values in a column
  - Participation Cardinalities communicate some of the information regarding redundancy and load

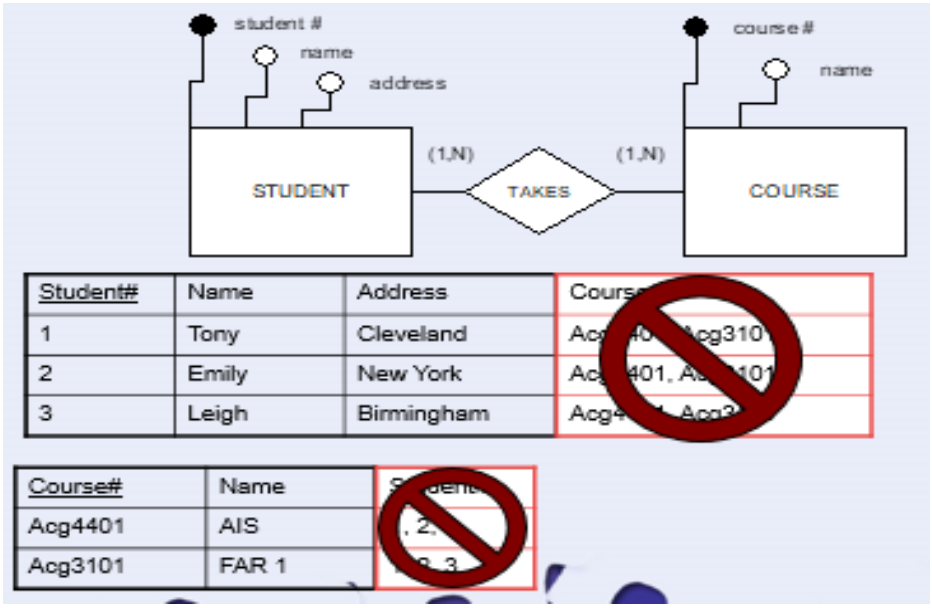
Relationship Conversion

- Maximum Cardinalities

- The general rule is to post into a "1" entity table
  - This avoids "repeating groups" redundancy
- You can NEVER post into an "N" entity
  - This causes "repeating groups" redundancy

- Minimum Cardinalities
  - The general rule is to post into a "1" (mandatory) entity table
    - This avoids null values in the foreign key column
  - This rule should be violated in some circumstances (to be discussed soon)
- Step 2: Create a separate table to represent each many-to-many relationship in the conceptual model, I.e., for the following participation cardinality patterns
  (0,N)-(0,N) (0,N)-(1,N) (1,N)-(0,N) (1,N)-(1,N)
  - You must create a separate table to represent the relationship
    - The primary keys of the related entity tables are posted into the relationship table to form its primary key. This kind of primary key is called a composite or concatenated primary key
    - This avoids redundancy
    - There are no exceptions to this rule!!!
  - If you post a foreign key in either direction, redundancy will be a problem for many-to-many relationships

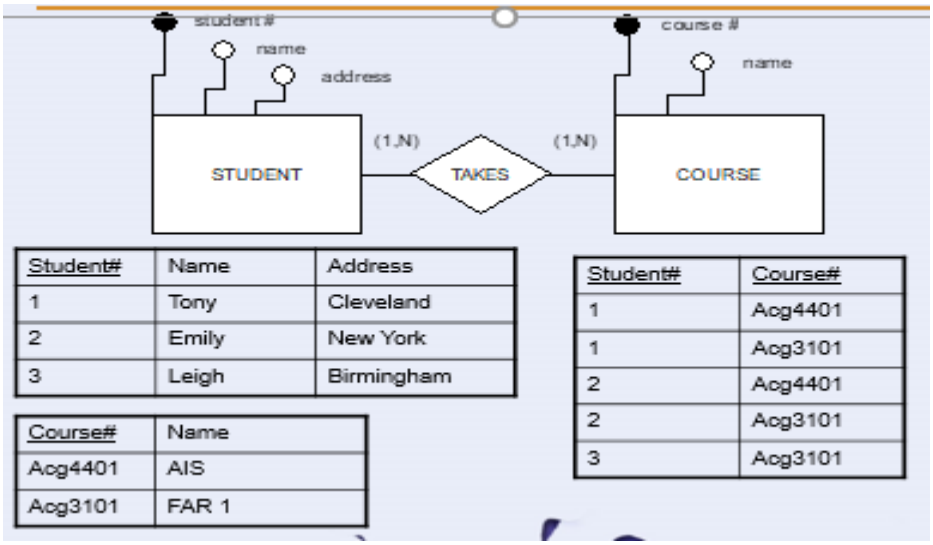
Example: Many-Many Relationships



Student#	Name	Address	Course
1	Tony	Cleveland	Acg
2	Emily	New York	Acg
3	Leigh	Birmingham	Acg

Course#	Name	Student
Acg4401	AIS	, 2,
Acg3101	FAR 1	3

Example: Many-Many Relationship



Student#	Name	Address
1	Tony	Cleveland
2	Emily	New York
3	Leigh	Birmingham

Student#	Course#
1	Acg4401
1	Acg3101
2	Acg4401
2	Acg3101
3	Acg3101

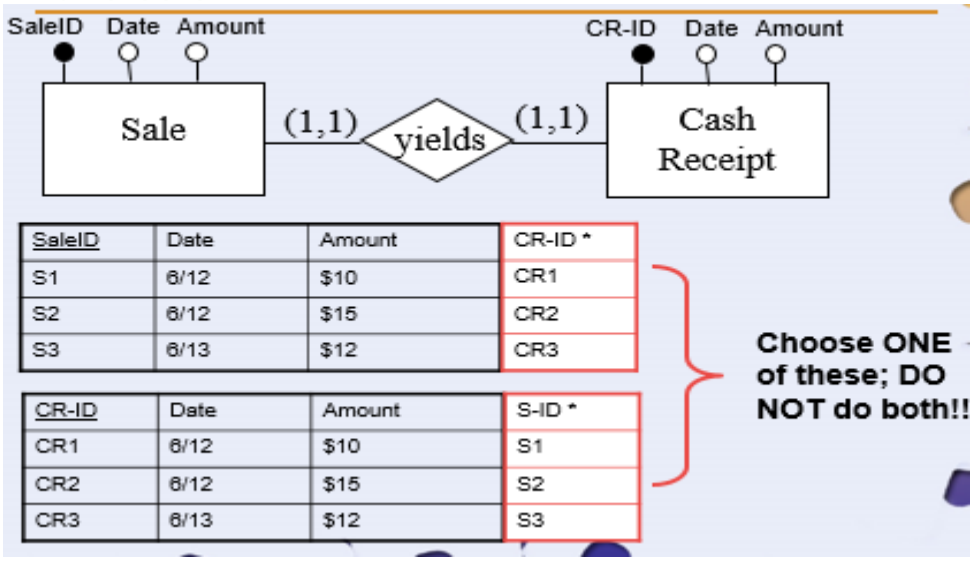
Course#	Name
Acg4401	AIS
Acg3101	FAR 1

Relationship Conversion

- Step 3: For participation cardinality pattern
  (1,1)-(1,1), consider whether the two entities are conceptually separate or whether they should be combined
- If they should remain separate, then

- 3A: Post the primary key from one entity's table into the other entity's table as a foreign key
- 3B: It doesn't matter which entity's primary key is posted into the other entity's table, but DO NOT post both
- DO NOT make a separate table
- Redundancy is automatically avoided and load is not an issue when you post a foreign key into either table in a (1,1)-(1,1) relationship

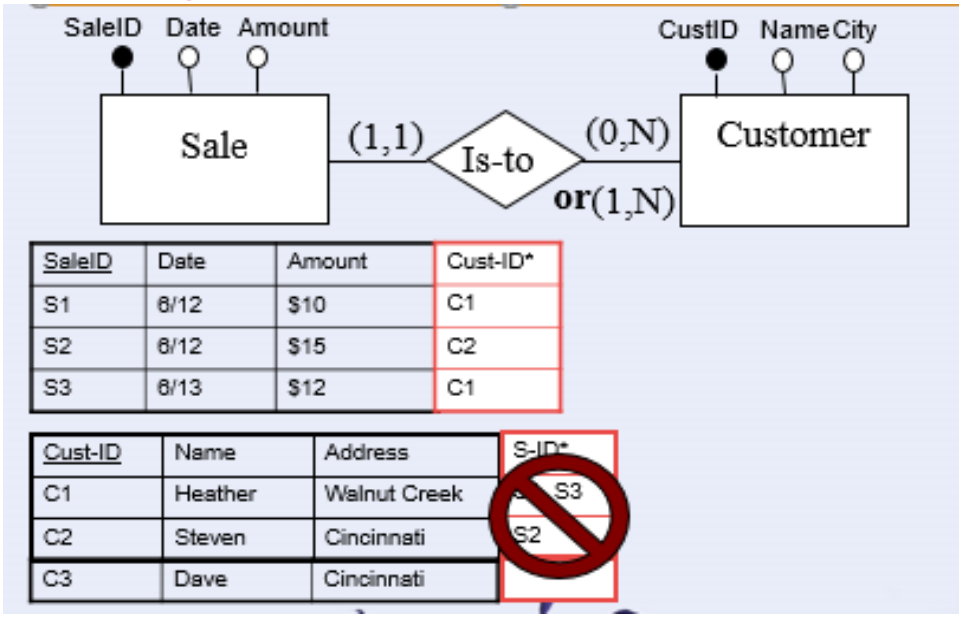
Example: (1,1)-(1,1)



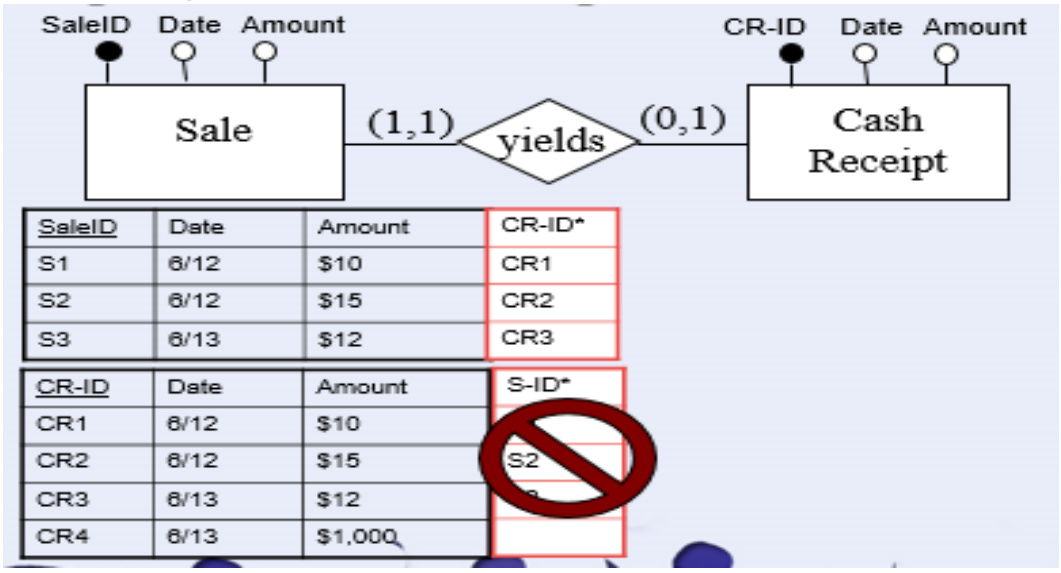
Relationship Conversion

- Step 4: For remaining relationships that have (1,1) participation by one entity set, post the related entity's primary key into the (1,1) entity's table as a foreign key
  - I.e., for the following participation cardinality patterns
    (0,N)-(1,1) (1,N)-(1,1) (1,1)-(0,N) (1,1)-(1,N) (0,1)-(1,1) (1,1)-(0,1)
    - Do NOT make a separate table
    - Post a foreign key INTO the (1,1) entity's table from the other entity's table
    - Redundancy is avoided and load is not an issue if you follow this instruction
    - If you post the opposite direction, either redundancy [for N maximums] OR load [for 0 minimums] will be a problem

Example 1: Posting into a (1,1)



Example 2: Posting into a (1,1)



SaleID	Date	Amount	CR-ID*
S1	6/12	$10	CR1
S2	6/12	$15	CR2
S3	6/13	$12	CR3

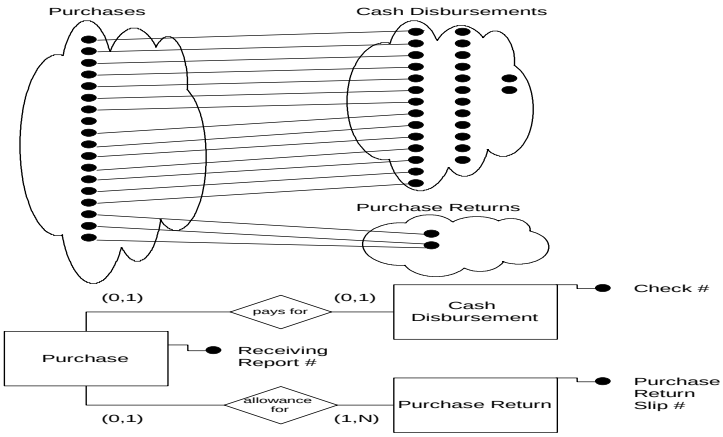
CR-ID	Date	Amount	S-ID*
CR1	6/12	$10	
CR2	6/12	$15	S2
CR3	6/13	$12	
CR4	6/13	$1,000	

Relationship Conversion

- Step 5: For remaining relationships that have (0,1) participation by one or both of the entities, consider load I.e., for the following participation cardinality patterns (0,N)-(0,1) (1,N)-(0,1) (0,1)-(0,N) (0,1)-(1,N) (0,1)-(0,1)
  - The rule for maximum cards requires posting into a (0,1) or making a separate table; you CANNOT post into the (0,N) or (1,N)
  - The rule for minimum cards says you really shouldn't post into the (0,1) because it will create null values that waste valuable space in the database
    - However, if a separate table would waste more space, then it is better to follow the maximum rule and break the minimum rule
  - 5A: Post the related entity's primary key into the (0,1) entity's table as a foreign key for any relationships for which that results in a high load
  - 5B: Create a separate table for any relationships for which posting a foreign key results in low load
    - Note: For (0,1)-(0,1), step 5A, post whichever direction results in highest load; if neither direction yields high load, then follow step 5B

Example: Load Considerations

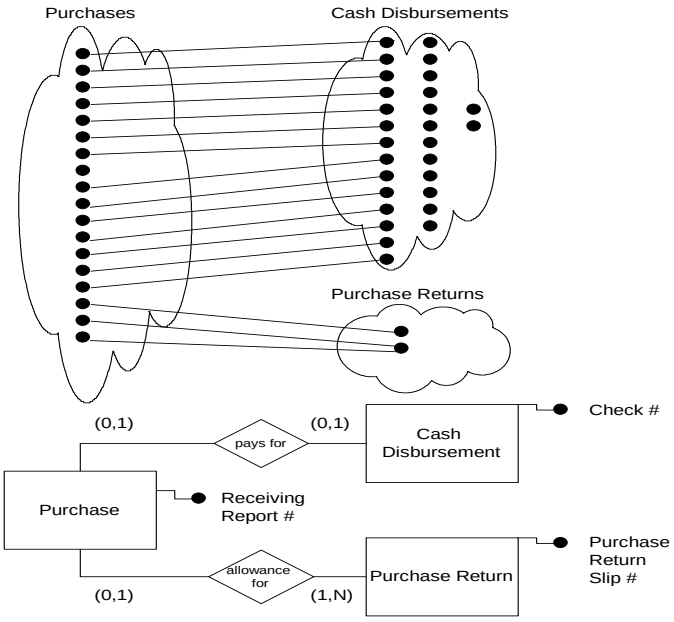
- Some cash disbursements (13/26) pay for purchases
  - If we post Receiving Report# into Cash Disbursement, 13 out of 26 will be non-null
  - This is a medium load
  - Might be worth breaking minimum rule
  - Consider other posting option
- Most purchases (14/18) result in cash disbursements
  - If we post Check# into Purchase, 14 out of 18 will be non-null
  - This is a high load
  - Worth breaking the minimum rule



Conclusion: post Check# into Purchase table to represent the "pays for" relationship

Example: Load considerations

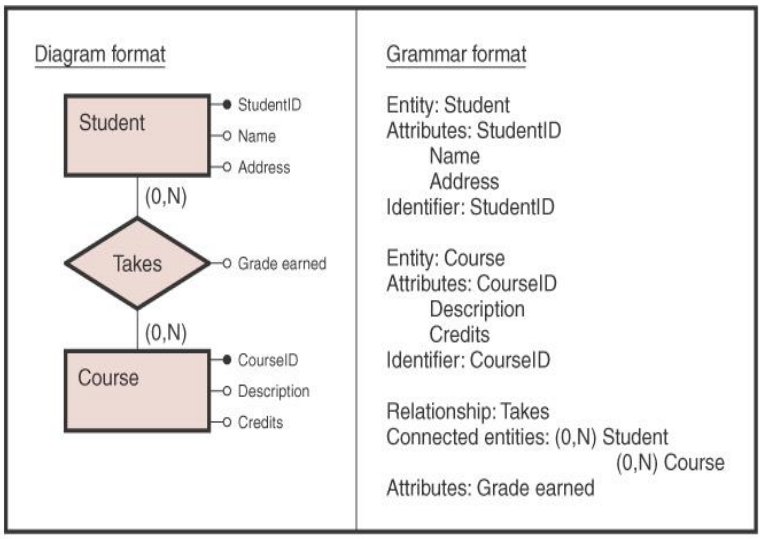
- Few purchases (3/18) result in purchase returns
  - If we post Purchase Return Slip# into Purchase, only 3 out of 18 will be non-null
  - This is low load
  - Must either make a separate table or consider posting the other direction
- Can't post receiving report# into purchase return because one purchase return slip # can be associated with multiple purchases



Conclusion: Make a separate table to represent the "allowance for" relationship

Relationship Attribute Placement

- If relationship becomes a separate table, then relationship attributes are placed in that table
- If relationship can be represented by a posted foreign key, relationship attribute is posted alongside the foreign key



Student

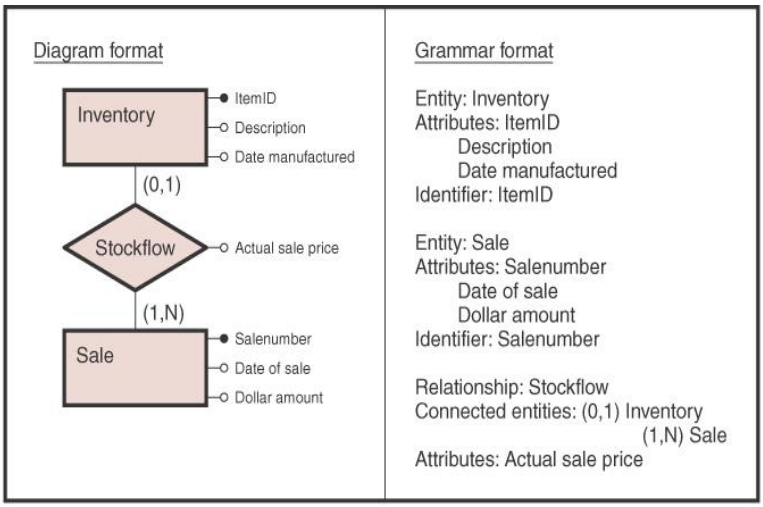
StudentID	Name	Address
999888	Mildred	123 Almanac St.
888777	Kent	456 Market Dr.
777666	Candace	789 Harriet Ave.

Course

CourseID	Description	Credits
ACG611	Advanced AIS	3
FIN642	Financial Markets	3
MIS650	IT Management	3

Takes

StudentID	CourseID	Grade Earned
999888	ACG611	B
999888	MIS650	A–
888777	MIS650	B+



Inventory

ItemID	Description	Date Manufactured	Salenumber	Actual Sale Price
I1	Big blue item	9/24/05	1	$450
I2	Triangle green item	9/25/05	1	$375
I3	Small square item	9/26/05		
I4	Medium pink item	9/27/05	2	$500

Sale

Salenumber	Date	Dollar Amount
S1	10/12/05	$825
S2	10/15/05	$500

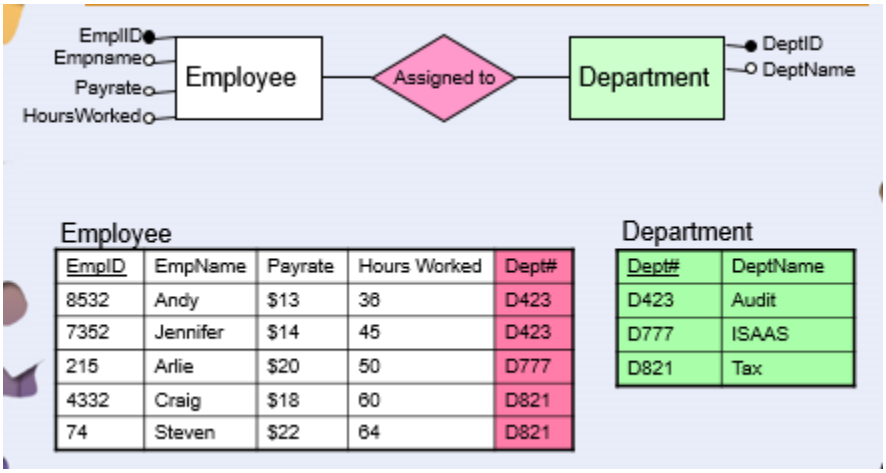
Fixing One Fact Multiple Places

Employee

EmpID	EmpName	Payrate	Hours Worked	Dept#	DeptName
8532	Andy	$13	36	D423	Audit
7352	Jennifer	$14	45	D423	Audit
215	Arlie	$20	50	D777	ISAAS
4332	Craig	$18	60	D821	Tax
74	Steven	$22	64	D821	Tax

- What facts are in multiple places in this table?
- Reverse engineer to get the ER model that this table must represent
- Is the ER model that results in this table correct?
- What SHOULD the ER model have been instead?
- What is the correct relational model?

Fixing One Fact Multiple Places



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EmpID	EmpName	Payrate	Hours Worked	Dept#
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7352	Jennifer	$14	45	D423
215	Arlie	$20	50	D777
4332	Craig	$18	60	D821
74	Steven	$22	64	D821

Department

Dept#	DeptName
D423	Audit
D777	ISAAS
D821	Tax

Fixing Multiple Facts in One Place

Warehouse

Warehouse#	Address	QOH
W1	123 Oak	2,14,784
W2	456 Pine	4,23,873

Inventory

Product#	Description	StdCost	QOH
AB12	Granddaddy	$5,000	2,4
BC445	Mama	$3,000	14,23
DD2	Littlebabe	$100	784,873

InventoryInWarehouse

Warehouse#	Product#
W1	AB12
W1	BC445
W1	DD2
W2	AB12
W2	BC445
W2	DD2

- What facts are in multiple places?
- How could this be avoided?

Warehouse

Warehouse#	Address
W1	123 Oak
W2	456 Pine

Inventory

Product#	Description	StdCost
AB12	Granddaddy	$5,000
BC445	Mama	$3,000
DD2	Littlebabe	$100

InventoryInWarehouse

Warehouse#	Product#	QOH
W1	AB12	2
W1	BC445	14
W1	DD2	784
W2	AB12	4
W2	BC445	23
W2	DD2	873

GOOD LUCK ;)