

# **CIM Modeling: IDEF0 and IDEF1x**

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## **Understanding the Process**

“...the lack of understanding results in incorrect, inconsistent and unclear requirements for a system which in turn results in a faulty system design.”

- *Bravoco and Yadav (1986)*

- A systematic methodology is needed to provide understanding and analysis of a complex system
- Structural Analysis and Design Technique (SADT)

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## Structural Analysis and Design Technique

- SADT is based on three concepts borrowed from software engineering approach
  - A top-down modeling approach
  - A graphical approach that highlights specific sections in a hierarchy
  - Distinguishing between data, people, devices and activities which clearly shows what is performed and how

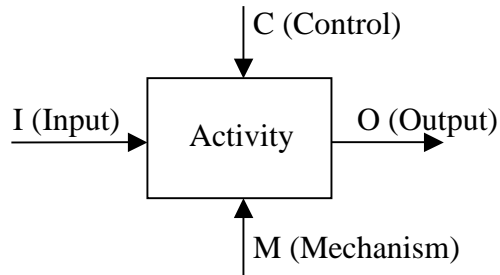
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## ICAM Project and its Missions

- US Airforce, Integrated Computer-Aided Manufacturing (ICAM) Project
  - To specify a *complete system* with which an *architecture for manufacturing* could be defined.
- IDEF (ICAM DEFinition method)
  - IDEF0: a structured functional analysis method
  - IDEF1: an information modeling method
  - IDEF2: a dynamic model methodology
  - IDEF3: a process and simulation model

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## IDEF0 : Structured Functional Analysis

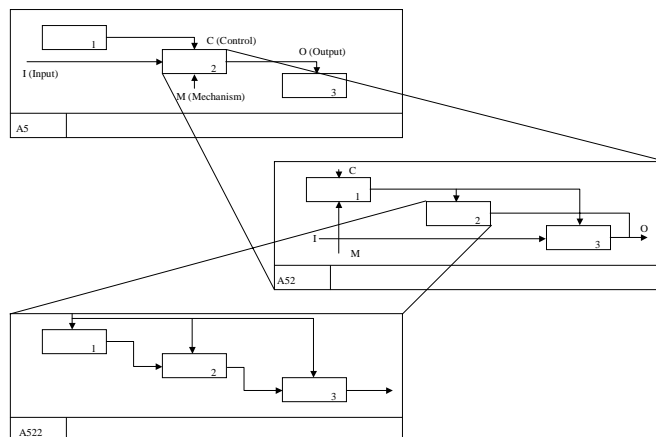


- An ***input***, an object, information or data, is transformed by an ***activity*** to produce an ***output***
- A ***control*** constrains how the activity is carried out
- A ***mechanism***, a person, system or device, performs and carries out the activity

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## Decomposition of Activities in IDEF0

- A hierarchical way of decomposing a complex subject into its constituent parts or sub-activities



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## Types of IDEF0 Models

- Different IDEF0 models serves different purposes for analyzing, modeling, designing or automating a process or system
- Three types of models
  - *Generic* IDEF0 model
  - ‘*As is*’ IDEF0 model
  - ‘*As should be*’ IDEF0 model

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## Generic IDEF0 Models

- A *generic* IDEF0 model
  - represents the generally accepted or intrinsic activities for a defined process or system
  - serves as a reference or standard model
  - can be universally useful in understanding a process or system which has generally accepted definitions of activities
  - can be used to evaluate an ‘as is’ model

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## **'As is' IDEF0 models**

- An '*as is*' IDEF0 model
  - describes the existing practice of a system
  - is the first step to understanding or modifying a system
  - is a basic step to system design
  - is a necessary step to system automation
  - can be evaluated by the generic model

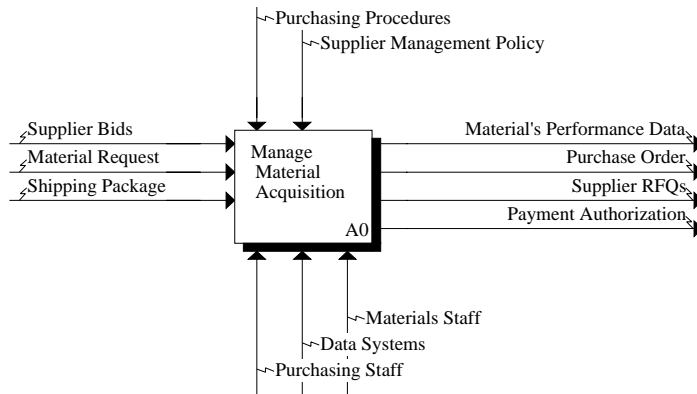
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## **'As should be' IDEF0 model**

- '*As is*' and/or *generic* models
  - evaluate how a modification in an activity may impact on other activities to influence the performance of the overall system
- An '*As should be*' IDEF0 model
  - is developed from *generic* and/or '*as is*' models
  - defines a strategy for process improvement
  - defines a process model for automation
  - defines a company long-term goal

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# An Example - Material Acquisition Process



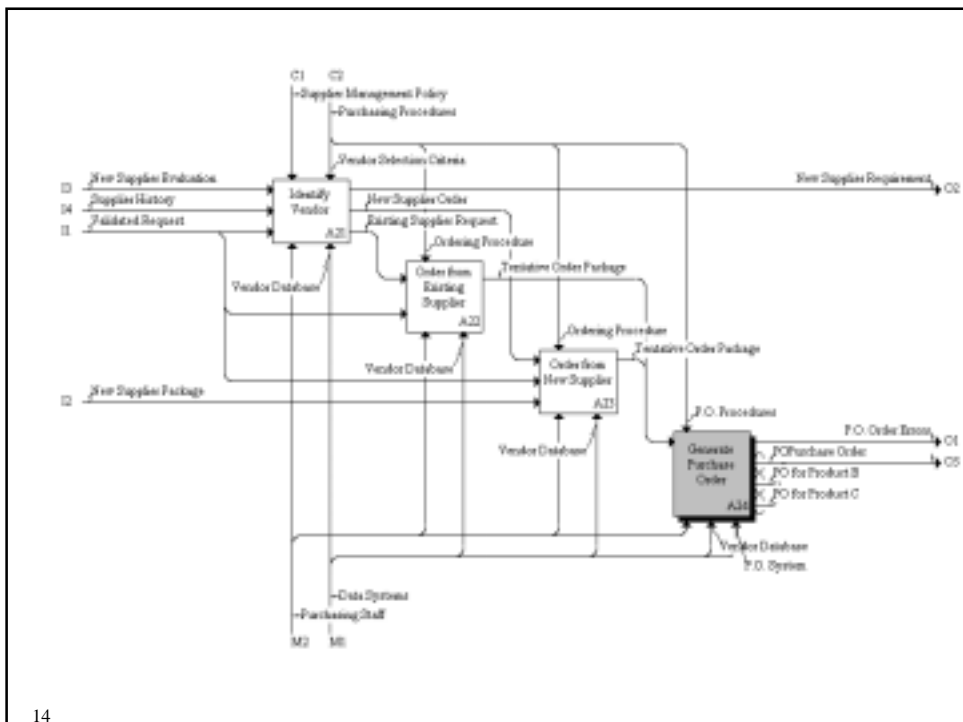
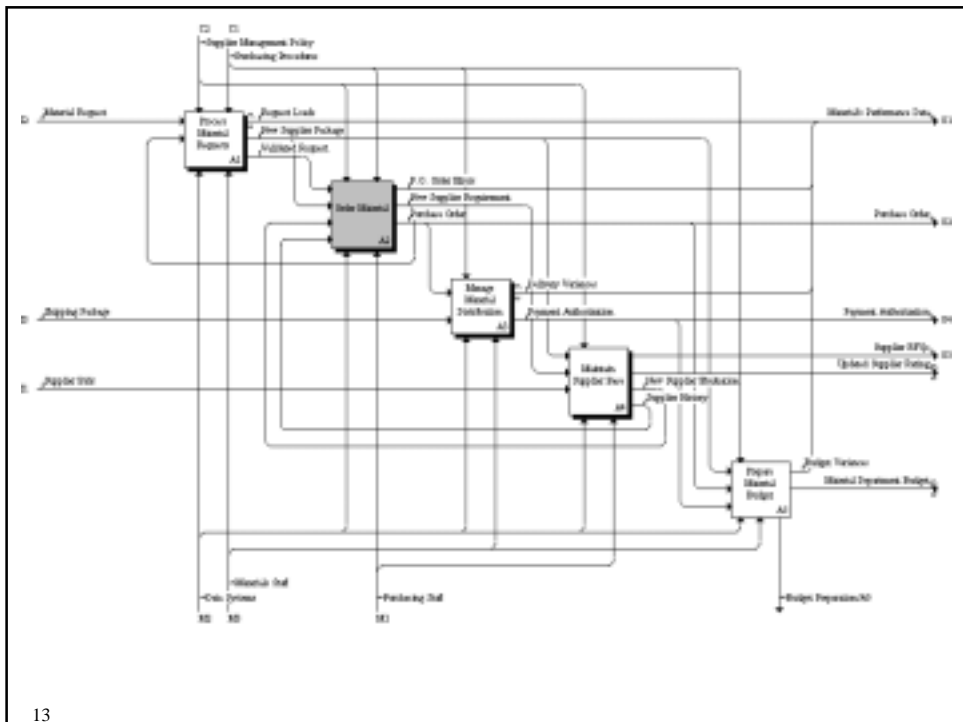
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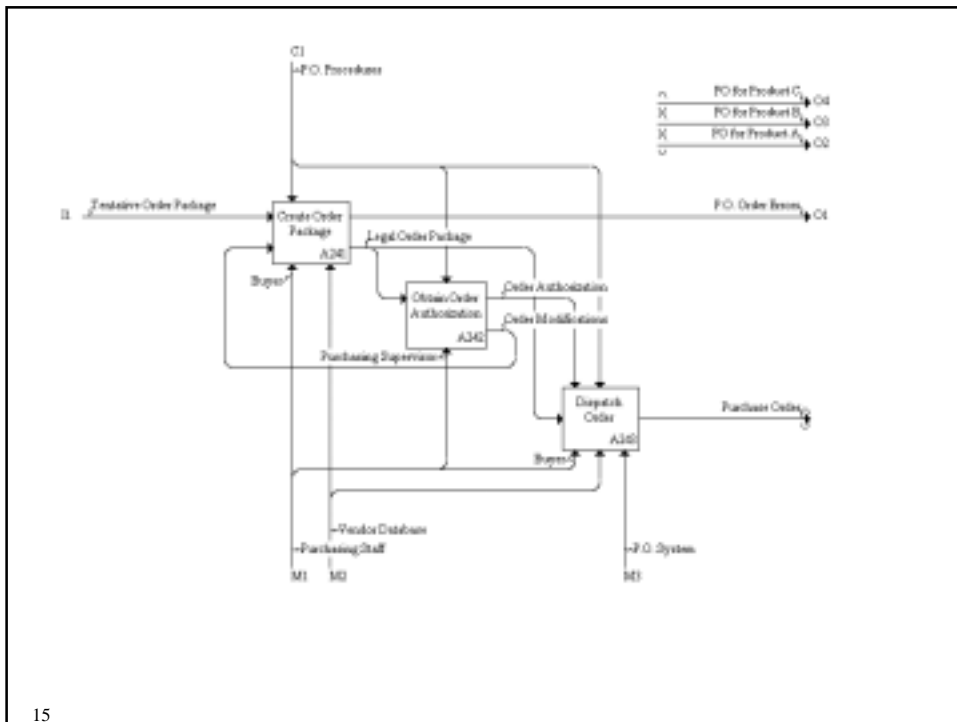
## Material Acquisition Node Tree

```

    A0: Manage Material Acquisition
      Decomposition A0: Manage Material Acquisition
        A1: Process Material Requests
          Decomposition A1: Process Material Requests
            A11: Log Material Request
            A12: Validate Material Request
            A13: Resolve Request Problems
            A14: Develop New Supplier Specifications
        A2: Order Material
          Decomposition A2: Order Material
            A21: Identify Vendor
            A22: Order from Existing Supplier
            A23: Order from New Supplier
            A24: Generate Purchase Order
          Decomposition A24: Generate Purchase Order
            A241: Create Order Package
            A242: Obtain Order Authorization
            A243: Dispatch Order
        A3: Manage Material Distribution
          Decomposition A3: Manage Material Distribution
            A31: Receive Material
            A32: Deliver Material
            A33: Process Payment Authorizations
        A4: Maintain Supplier Base
          Decomposition A4: Maintain Supplier Base
            A41: Monitor Existing Suppliers
            A42: Resolve Supplier Issues
            A43: Evaluate Prospective Supplier
          Decomposition A43: Evaluate Prospective Supplier
            A431: Evaluate Supplier Pricing
          Decomposition A431: Evaluate Supplier Pricing
            A4311: Request Bids
            A4312: Receive Bids
            A4313: Evaluate Bids
            A432: Evaluate Material Quality
            A433: Evaluate Service Record
            A44: Maintain Supplier Database
        A5: Prepare Material Budget
  
```

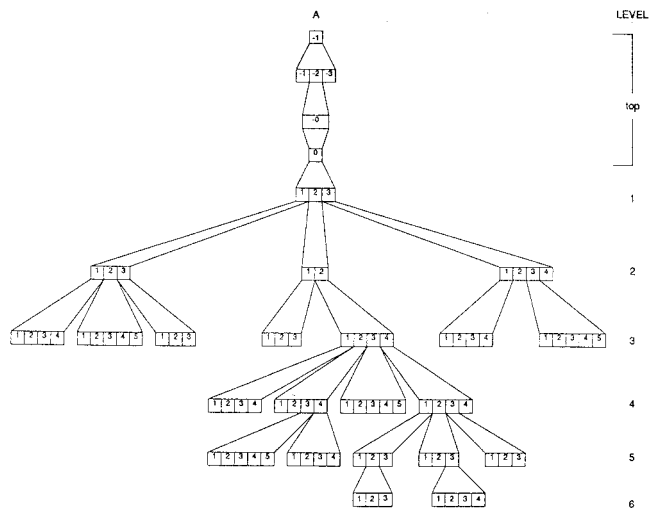
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## A Generic Model of Manufacturing Plan



Overview of the generic model

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# Activity Nodes of Manufacturing Plan

A-1	Produce New Product	A22	Plan Component Manufacture	A22413	Update Operation Data
A-11	Market & Manage Product	A221	Analyse Component	A2242	Generate Programs
A-12	Plan Manufacturing	A2211	Retrieve Component Analysis	A22421	Establish Cutter Path Requirements
A-13	Execute Manufacturing Program	A2212	Separate Features	A22422	Produce Machine Movement Data
A-0	Plan Manufacturing	A2213	Derive Feature Dependant Geometry	A22423	Produce Part Programs
A0	Plan Manufacturing	A2214	Determine Geometric Component Elements	A224231	Establish System Requirements
A1	Design Product	A222	Derive Manufacturing Method	A224232	Post Process
A11	Establish Design Concept	A2221	Determine Rqwg Material Form	A224233	Update Part Program Data
A111	Produce Design Ideas	A2222	Select Process Options	A224234	Prove Part Programs
A112	Select Design Principle	A2223	Select Process	A2243	Derive Operation Times
A113	Evaluate Design	A2224	Select Process Sequences	A22431	Derive Machining Times
A114	Formalise Design	A22241	Select Machine	A22432	Retrieve Synthetic Times
A12	Carry Out Functional Design	A22242	Derive Process Sequence Options	A22433	Produce Operation Times
A121	Identify major Assemblies	A22243	Derive Capacity Requirement	A2244	Format Information
A122	Retrieve Assembly Design	A22244	Assign Sequence Priority	A3	Plan When to Manufacture
A123	Establish Critical Design Features	A223	Establish Auxiliary Requirements	A31	Produce Aggregate Production Schedule
A124	Design Assemblies	A2231	Select Tools	A311	Derive Production Levels
A125	Finalise Product Design	A2232	Retrieve Tool Information	A312	Assess Resource Capability
A13	Carry Out Detail Design	A2233	Select Auxiliary Tooling	A313	Establish Resource Requirement
A131	Identify Component Form	A2234	Establish Workholding Requirement	A314	Establish Production Plan
A132	Retrieve Existing/ Similar	A2235	Retrieve Workholding Information	A32	Establish Master Production Schedule
A2	Plan How to Manufacture	A224	Establish Operation Information	A33	Establish Manufacturing & Resource Plan
A21	Plan Product Assembly Methods	A2241	Establish Operation Details	A331	Establish Component Demand
A211	Analyse Product	A22411	Retrieve Operation Data	A332	Establish Purchase Requirement
A212	Establish Assembly Technique	A22412	Analyse Operation	A333	Derive Manufacturing Requirement
A213	Establish Assembly Requirement	A224121	Establish Component Criteria	A334	Assess Capacity
		A224122	Derive Machining Parameters	A335	Establish Manufacturing Program
		A224123	Establish Operation Characteristics	A34	Schedule Resource & Manufacturing

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## IDEF1x - Information Modeling

- System integration and automation
  - transparent information
  - exchangeable information
  - easily accessible information
  - integrated, effective database management system (DBMS)
- IDEF1x Data modeling
  - Semantic data modeling
  - Entity-Relational (ER) approach

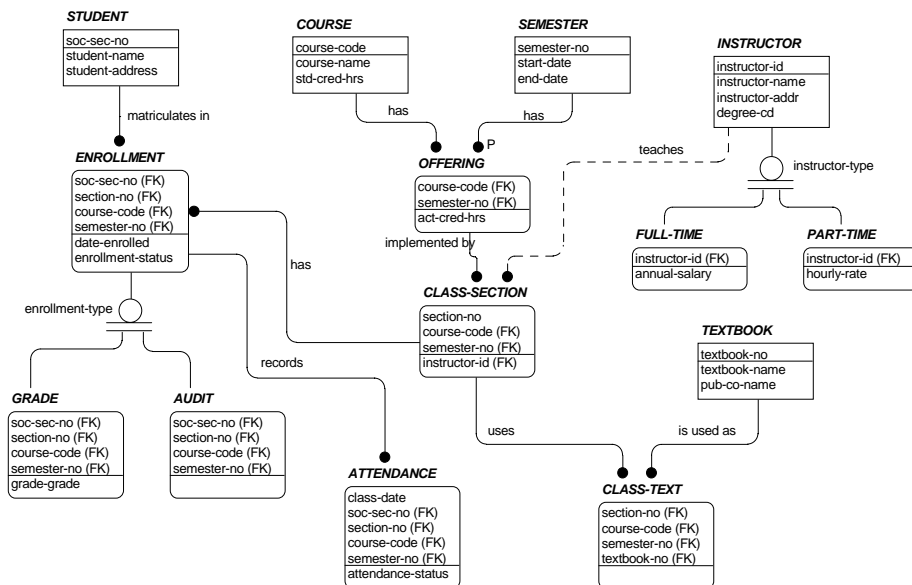
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# Semantic Entity-Relational Approach

- Entities:
  - objects about which data can be stored
  - e.g. people, places, machines, concepts, etc
- Attributes:
  - quantifiable characteristics of the entities
  - e.g. age, occupation, phone #, address, etc
- Relationship between entities:
  - e.g. “machine *produces* parts
  - “student *matriculates* in courses”

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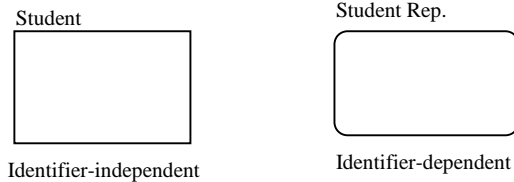
## An example - A Class Enrollment System



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## Entities

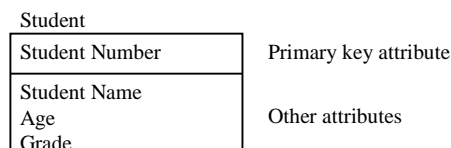
- An *entity* is a class of real or abstract objects that share common characteristics - e.g. student
- An individual member of the class is called an *entity instance* - e.g. John Doe is a student
- Identifier-independent and identifier-dependent entities:



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## Attributes

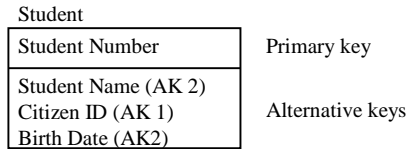
- An *entity* is characterized by a set of *attributes* - e.g. student number, name, age, grade, etc.
- An *attribute instance* is a specific value of the attribute for an entity instance - e.g. b2701234 is the student number of John Doe
- *Primary key* attribute is the attribute used to identify a unique entity instance - e.g. student number



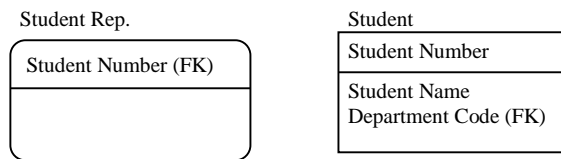
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# Keys

- *Alternative keys (AK)* are attributes *can be but are not used* to identify an entity instance

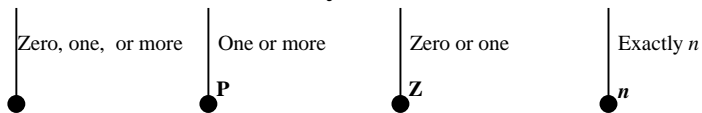


- Foreign keys (FK):

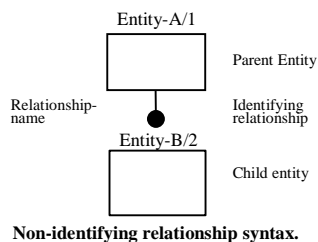
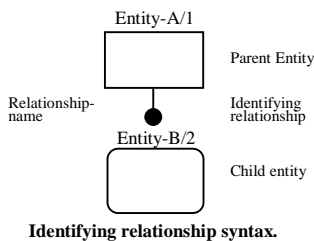


# Parent-Child Relationships

- Relational cardinality

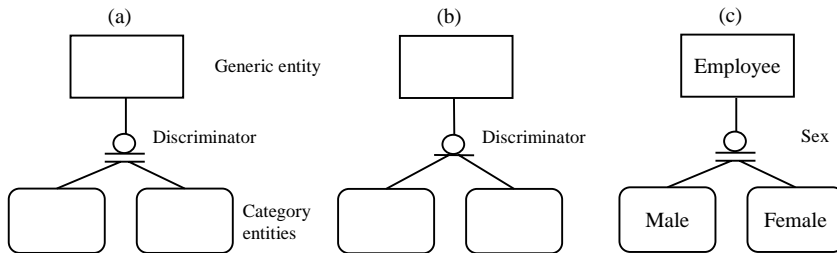


- Identifying relationship (e.g. student-enrollment)
- Non-identifying relationship (e.g. instructor-class section)



## Categorization Relationships

- Complete categorization: e.g. Students are categorized into male and female
- Incomplete categorization: e.g. students are categorized by the clubs they join

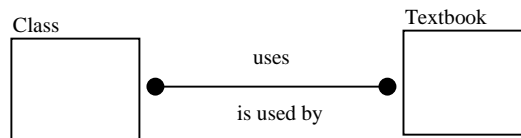


Complete (a), (c) versus incomplete (b) categorization.

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## Non-specific Relationships

- Non-specific (many-to-many) relationships are not allowed in a fully defined IDEF1x model
- They are used during development stage and are then *refined* into specific relationships - e.g. class-textbook relationship



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## Model Construction

- **Phase 0:** objectives, scope, and plan
- **Phase 1:** determining entities
- **Phase 2:** identification & definition of relationship
- **Phase 3:**  
relationships refinement, keys definitions,  
relationships/keys validation
- **Phase 4:**  
non-key attributes definition, further refinement of  
data structure

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## Phase 0

- Objectives:
  - project definition and scope - e.g. registration
  - source materials - e.g. forms, historical cases
  - author conventions - e.g. jargon, terminology
- Modeling plan:
  - project planning
  - data collection
  - model construction
  - model validation
  - acceptance review

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## Phase 0 (continued)

- Team
  - project manager
  - modelers
  - sources of information
  - subject matter experts
  - acceptance review committee

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## Phase 1

- Choosing entities from a pool of “nouns”:
  - Can it be described? i.e. does it have attributes?
  - Are there several instances?
  - Can instances be differentiated?
- Entity name
  - Does it refer to or describe something? (if yes, not an entity)
- Definition (Example: machine shop)

Entity name	Entity synonyms	Entity definition
Part	None	A part is a component of an assembly. Parts are indexed in the Part Manual
Machine	None	A machine is a device used to reduce or finish materials by turning, planing, shaping or milling. In this shop, machine types include milling machines, drill presses, and lathes
Tool	Machine Tools	Tools are used in conjunction with machines to cut or shape material. Tools include drill bits, cutting inserts, and milling cutters. They are able to be removed from the machine for storage purposes
Product	None	An item manufactured within the shop meant to be sold. It is assumed that entities within Products are general products, not each specific item produced

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## Phase 2

- Identification of related entities:

	Machine	Tool	Part	Product
Machine		X ~	X ~	
Tool	X ~		X	
Part	X ~	X ~		X
Product			X ~	

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## Phase 2 (continued)

- Relationship definition

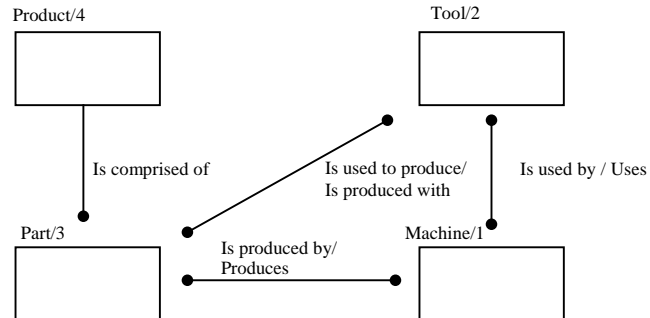
Entity	Specific/ Non-specific	Relationship name	Relationship definition
Product/Part	S	Is comprised of	Products are comprised of one or more parts that have been assembled in some way. Each kind of part is used in the production of only one type of product
Machine/Part	N	Produces/Is Produced by	A Particular machine or a type of machine can be used to produce or machine a particular part. Parts may be produced by any one of a number of machines (this is especially true if the part is machined on a machining centre).
Machine/Tool	N	Uses/Is used by	A machine uses one or more interchangeable tools. These tools may be used by one or more machines.
Tool/Part	N	Is used to produce/ Is produced with	Specific tools are required for machining specific types of parts. A part is produced by a particular machine / tool pair.

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## Phase 2 (continued)

- Entity level diagram construction

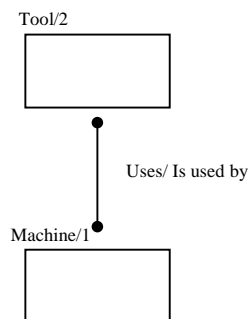


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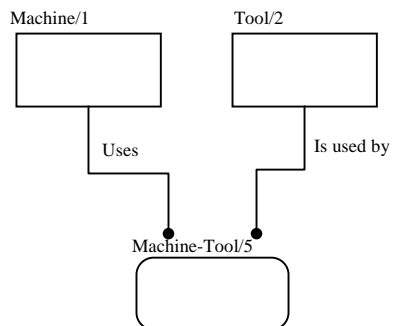
## Phase 3

- Non-specific relationship resolution - use of *associative entity*

This....



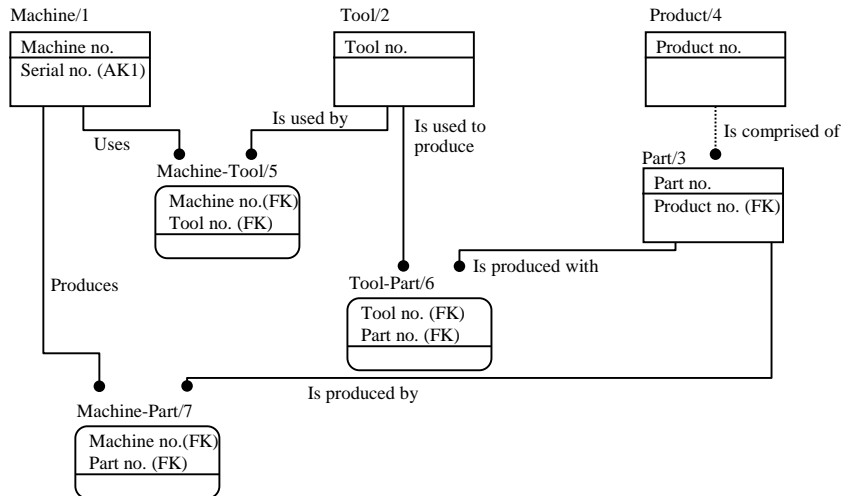
Resolves to ...



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## Phase 3 (continued)

- Key attribute identification and key migration



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## Phase 3 (continued)

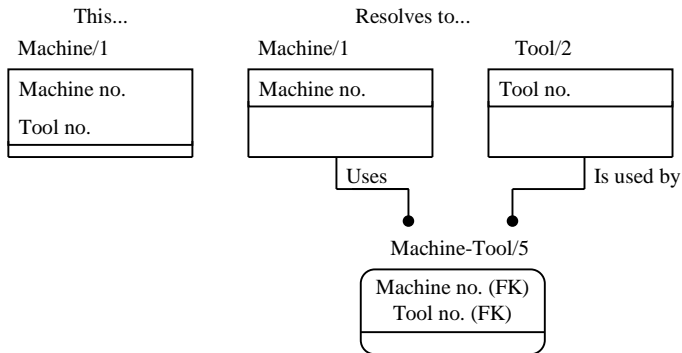
- Key and relationship validation

- non-specific relationship is prohibited
- key migration must occur between parent (or generic) entities and child (or category) entities
- the use of an attribute that might have more than one value at a time for a given entity instance is prohibited (no-repeat rule)
- the use of an attribute that could be null in an instance is prohibited (no-null rule)
- entities with compound keys should be smallest set possible for identifying an instance (smallest-key rule)
- Assertions are required for *dual* relationship paths between entities
  - Equal dual path
  - Unequal dual path
  - indeterminate dual path

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## Phase 3 (continued)

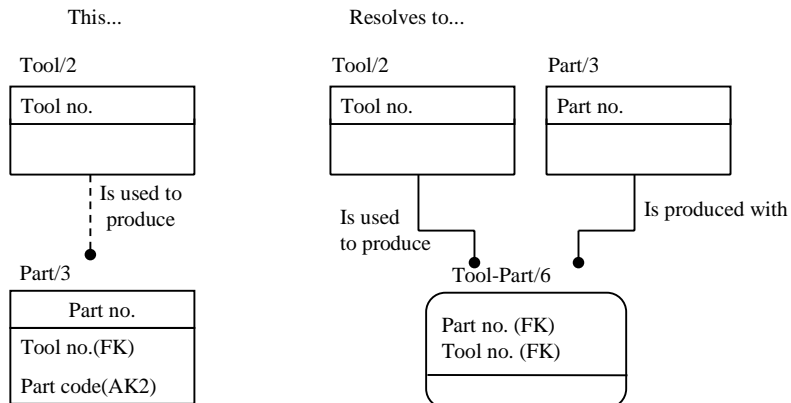
- Example of no-repeat rule



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## Phase 3 (continued)

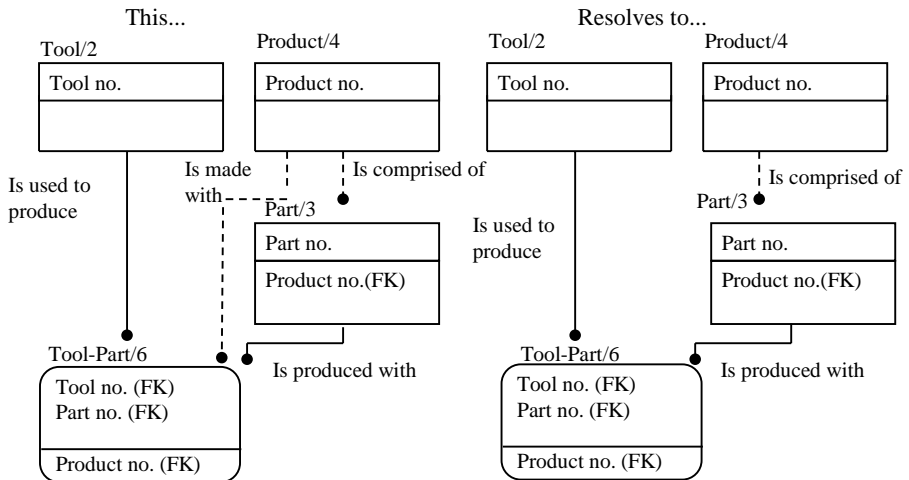
- Example of no-null refinement



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## Phase 3 (continued)

- Example of redundant dual relationship path



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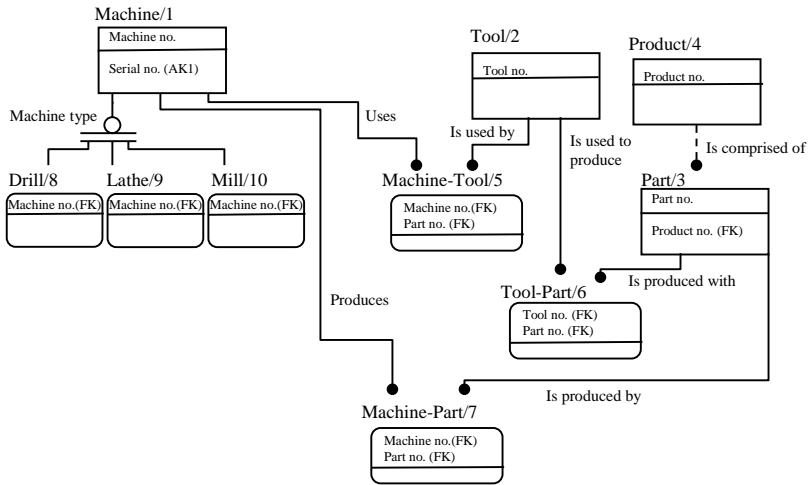
## Phase 3 (continued)

- Key attribute definition: name , synonyms and definition
- Entity/Attribute matrix

Entity/Attribute	Machine no.	Tool no.	Part no.	Product no.	Serial no.
Machine	OK				O
Tool		OK			
Part			OK	I	
Product				OK	
Machine-Tool	IK	IK	I		
Tool-Part		IK	IK		
Machine-Part	IK		IK		

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## Results of Phase 3 -Machine Shop Example



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## Phase 4

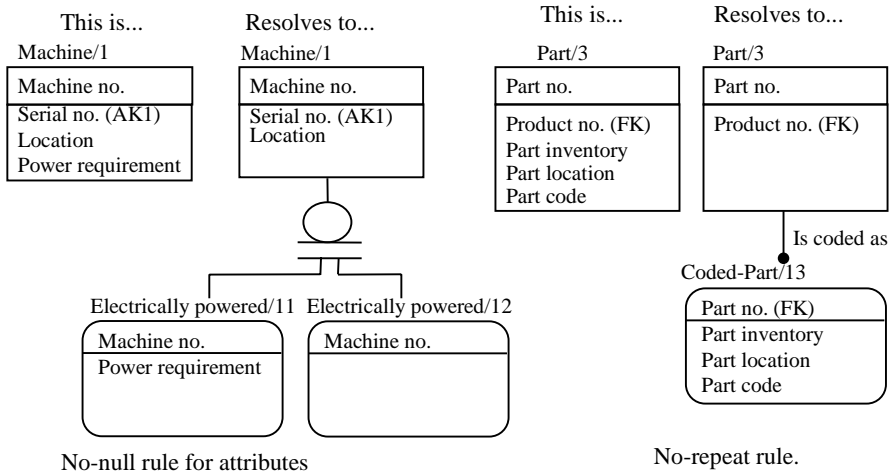
- Non-key attribute identification and definition

Number	Attribute name	Source data number
1	Product cost	3
2	Product inventory	3
3	Product location	4
4	Machine location	13
5	Machine power req.	14
6	Tool location	17
7	Tool material	15,17
8	Tool life	15
9	Part inventory	3
10	Part location	3
11	Manufacture time	19
12	Manufacture cost	19

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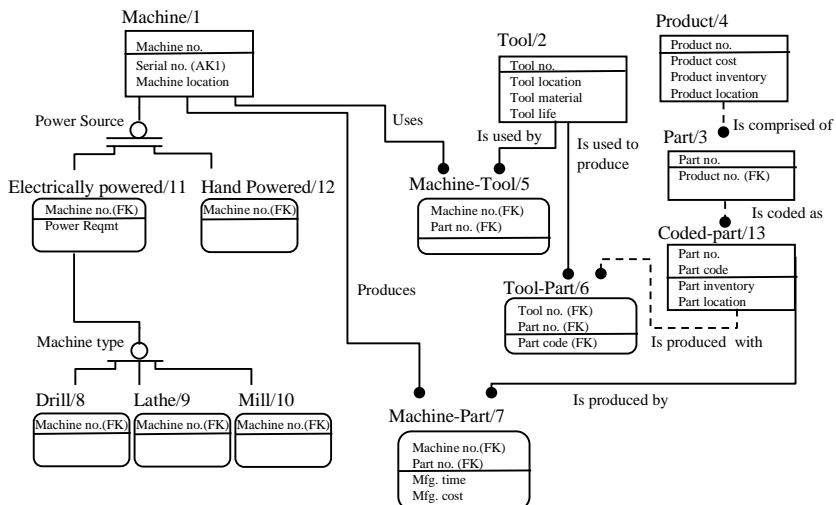
## Phase 4 (continued)

- Model refinement



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## Results of Phase 4 -Machine Shop Example



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## **Computerized Analysis and Design Tools**

- IDEFs are used to analyze and model a complex system in order to plan, reengineer or automate the process
- The analysis and modeling are themselves to be integrated with design and implementation - Computer-Aided Software Engineering (CASE)
  - integration between IDEF0 and IDEF1x
  - database generation by IDEF1x model