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Developing High Quality Data Models

Abstract:
This document describes how to develop data models so they are stable, flexible to changing business practices, and extensible to changing business needs.

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Author: Matthew West
Editor: Julian Fowler

Further copies are available from:

Matthew West
Shell International Limited
ISCL/4, Shell Centre, London, SE1 7NA, UK

Fax: +44 171 934 6786

E-mail: m.r.west@profs.iscl4.silon.simis.com

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Issue 1.0 - Draft	8-Dec-95	First cut taken from "Developing High Quality Data Models" - for comment
Issue 2.0	18-Mar-96	Restructured to bring in material from Managing Data Quality, Managing Shared Data, and Reviewing and Improving Data Models.
Issue 3.0	27-Aug-96	All diagrams changed from Oracle*CASE notation to EXPRESS-G, captions and cross-references corrected.

Editor's note

It is proposed that this next release will also be available as a fully searchable HTML document for placement on the EPISTLE web site maintained by the University of Newcastle.

Acknowledgement

This document is based on work first undertaken for Shell International. Permission to use and extend this work is gratefully acknowledged. I would also like to acknowledge the contribution made by members of EPISTLE to the development of this work.

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1. Executive Summary

To manage information, information systems must:

- know what information they have, and what it is about,
- extract portions of the information base suitable for a particular purpose,
- exchange data between organisations and systems,
- integrate information from different sources, resolving what is about things they already have information about, and what is about new things,
- share the same data between applications and users with different views, and
- manage the data, including history, for life.

This means that we need standards so that data has the same meaning in different organisations and systems. The current lack of standards means that systems and interfaces often cost more than they should, to build, operate, and maintain. They may also constrain the business rather than support it. A major cause is that the quality of the data models implemented in systems and interfaces is poor.

- Business rules, specific to how things are done in a particular place, are often fixed in the structure of a data model. This means that small changes in the way business is conducted lead to large changes in computer systems and interfaces.
- Entity types are often not identified, or incorrectly identified. This can lead to replication of data, data structure, and functionality, together with the attendant costs of that duplication in development and maintenance.
- Data models for different systems are arbitrarily different. The result of this is that complex interfaces are required between systems that share data. These interfaces can account for between 25-70% of the cost of current systems.
- Data cannot be shared electronically with customers and suppliers, because the structure and meaning of data has not been standardised. For example, engineering design data and drawings for process plant are still sometimes exchanged on paper.

The membership of EPISTLE have been involved in the development of a significant number of data models, and have had the opportunity to review a large number of other data models. The need has been recognised to establish good practice in the development of data models.

This document presents the following principles whose application will help in developing high quality data models.

1. *Candidate attributes should be treated as representing relationships to other entity types.*
2. *Entities should have a local identifier within a database or exchange file. These should be artificial and managed to be unique. Relationships should not be used as part of the local identifier.*
3. *Activities, associations and event-effects should be represented by entity types (not relationships or attributes).*
4. *Relationships (in the entity/relationship sense) should only be used to express the involvement of entity types with activities or associations.*
5. *Entity types should represent, and be named after, the underlying nature of an object, not the role it plays in a particular context.*
6. *Entity types should be part of a subtype/ super type hierarchy of generic entity types in order to define a universal context for the model.*

2. Introduction

2.1 Purpose

A data model defines the structure and meaning of data. This document is primarily concerned with data models that enable the reuse of data by different applications, either by integrating and sharing data within a single database, or exchanging data by some other means such as a file transfer.

This document aims to provide a practical guide to developing high quality data models. After reading and understanding this guide, those who create data models should know the principles to apply in order to develop data models that will:

- √ meet the data requirement,
- √ be clear and unambiguous to all (not just the authors),
- √ be stable in the face of changing data requirements,
- √ be flexible in the face of changing business practices,
- √ be reusable by others,
- √ be consistent with other models covering the same scope (if they were developed following these principles), and
- √ be able to integrate data from different data models.

In addition, they should be able to develop data models faster.

2.2 Target Audience

This document is addressed to those involved in the preparation and review of data models.

2.3 Prerequisites

A basic knowledge of entity relationship modelling is an advantage when reading this document. A recommended text is "Oracle CASE*Method - Entity Relationship Modelling", by Richard Barker, Addison-Wesley ISBN 0-201-41696-4.

2.4 Structure

This document:

- presents the background that gives rise to the need to establish good practice in data model development,
- identifies principles which contribute to the development of high quality data models,
- answers common questions that arise, and
- presents some techniques that can help preparing and documenting data models.

2.5 Relationship to Previous Work

This document draws on and develops work originally undertaken for and published by Shell International - Information Services in a number of booklets including:

1. "Managing Data Quality", IC92-124, Matthew West, November 1993.
2. "Managing Shared Data", IC91-078, Matthew West, Malcolm McEwan February 1992.

3. "Reviewing and Improving Data Models", IC91-077 T3, Bruce Ottmann, Matthew West, Sandy Fyfe, December 1992.
4. "Developing High Quality Data Models Volume 1: Principles and Techniques", IC94-033, Matthew West, March 1994.
5. "Developing High Quality Data Models Volume 2: The Generic Entity Framework, Version 1.0", IC94-034, Matthew West, March 1994.
6. "Developing High Quality Data Models Volume 3: Data Model Templates", IC94-035, Matthew West, March 1994.
7. "The Database Design Process", IC91-077 T1, Fre van der Werff, December 1991.
8. "Flexibility in Database Design", IC91-077 T2, Fre van der Werff, March 1993.
9. "Entity Type and Relationship Naming Standards", IC94-036, Matthew West, April 1994.
10. "Logical Attribute Naming Standard - Volume 1: The Standard", IC91-077 S2, Matthew West, June 1993.
11. "Logical Attribute Naming Standard - Volume 2: Word Lists", IC91-077 S2, Matthew West, June 1993.

This document brings much of this work together, and aims to present it in a way that makes this difficult subject as accessible as possible. It also develops the ideas in these original documents based on the experience gained since they were originally published, especially in the EPISTLE forum.

3. A Business Perspective of Information

3.1 The Role of Information

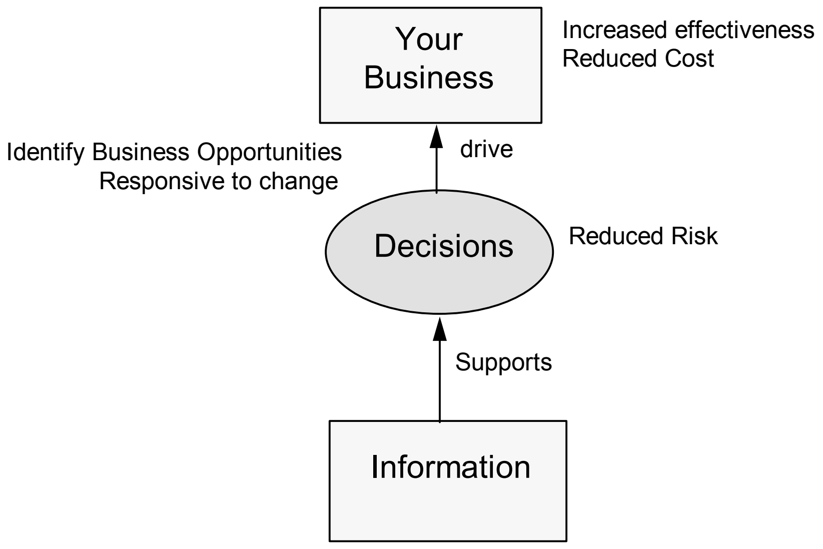


Figure 3-1: How information adds value to business

Information is involved in every business activity. Indeed, information is sometimes the only or main output of an activity. For instance, product design is conducted solely to create the information to be able to manufacture a product. The value of information in business comes from its use in contributing to sound decisions. (The only other use I know of for information is as entertainment.) If you can't rely on your information then the result can be missed opportunities, or higher costs.

As a consequence of this information is shared as part of the interaction and integration of business activities. At the technical level, data is shared when it is created and used by different computer systems, people, or organisations.

3.2 Key Requirements for Information

Almost every business activity results in new data being created. The use of this data is not restricted to the activity that creates it; often it is used in other activities.

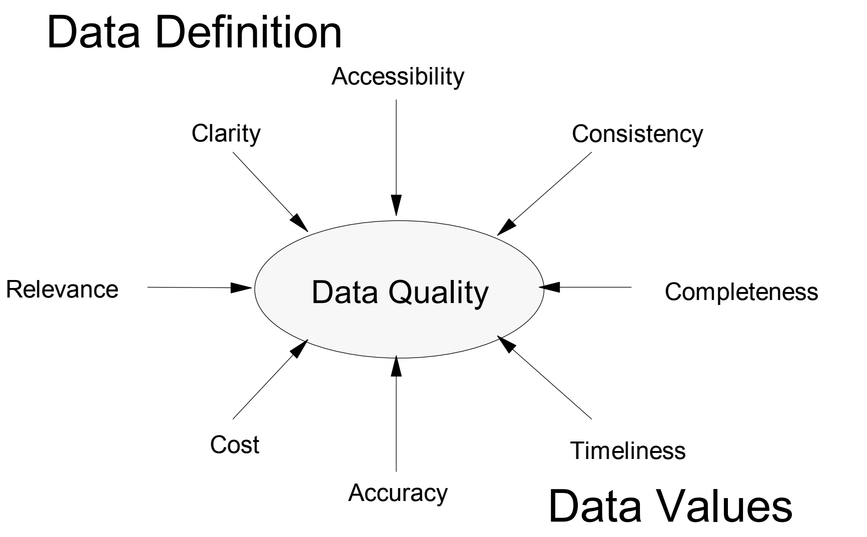


Figure 3-2: Some important properties of data

Some important properties of data for which requirements need to be met are:

definition related properties

relevance:	the usefulness of the data in the context of your business.
clarity:	the availability of a clear and shared definition for the data.
consistency:	the compatibility of the same type of data from different sources.

content related properties

timeliness:	the availability of data at the time required and how up to date that data is.
accuracy:	how close to the truth the data is.

finally related to both are:

completeness:	how much of the required data is available.
accessibility:	where, how, and to whom the data is available or not available (e.g. security).
cost:	the cost incurred in obtaining the data, and making it available for use.

Data Models address the properties related to the definition of data.

3.3 The Promise of Computer Based Information

	Image	Symbolic	Syntactic	Semantic
Meaning	In the Content →			In the Structure
Example	Bit Map Ink on Paper	Characters Vector Graphics	Hypertext Linked Files	"Intelligent" CAD
Computer Support	Touch Up	Spell Check Scale Drawing	Human Navigable Links	Computer Navigable Links
Standards	FAX TIFF	ASCII CGM DXF	OLE CDA SGML	STEP POSC

Figure 3-3: The changing shape of information

The way that we hold and manage information has been changing in recent years. Twenty years ago almost all our information was held on paper. Today most of it is held electronically either as electronic documents, or as data in databases. Even here the trend is to hold information as data because this enables increased computer support, for example "intelligent" drawing packages. The intelligence comes because having information in a structured form means the computer can have knowledge of what the information is about, and can therefore act to support the user based on that knowledge.

3.4 Key Requirements for Information Systems

To manage information, information systems must:

- know what information they have, and what it is about,
- extract portions of the information base suitable for a particular purpose,
- exchange data between organisations and systems,
- integrate information from different sources, resolving what is about things they already have information about, and what is about new things,
- share the same data between applications and users with different views, and
- manage the data, including history, for life.

This means that we need standards so that data has the same meaning in different organisations and systems.

3.5 The Reality of Computer Based Information

A number of problems are found as a result of the way data is held in information systems:

- Arbitrary or inappropriate restrictions are placed on the data that can be held.
- History data cannot be held.
- Fudge or false data may be introduced to overcome restrictions.
- Uncontrolled redundancy of data requiring reconciliation of different versions.
- difficulty in integrating data from different sources because of incompatibility in definitions and format.
- The same data structures may be replicated.
- The same functionality may be replicated.

All of these problems either restrict the way a company does business, or add to the cost of doing business. Here are some financial and time penalties incurred when these problems are encountered:

- Translating data is expensive. The cost of interfaces to translate the meaning of data can account for 25-70% of the total cost of a system development project.
- The need to translate data means that users of different systems can often only share data sequentially, and not concurrently. This can extend the time required for critical business processes.
- There is a slower response to the need for change in systems. Interfaces cost time as well as money.
- Quality suffers. Duplication of data is inefficient and invites errors, which may lead to inferior business decisions.
- Staff time is wasted trying to locate and reconcile data.

3.6 The Role of Data Models

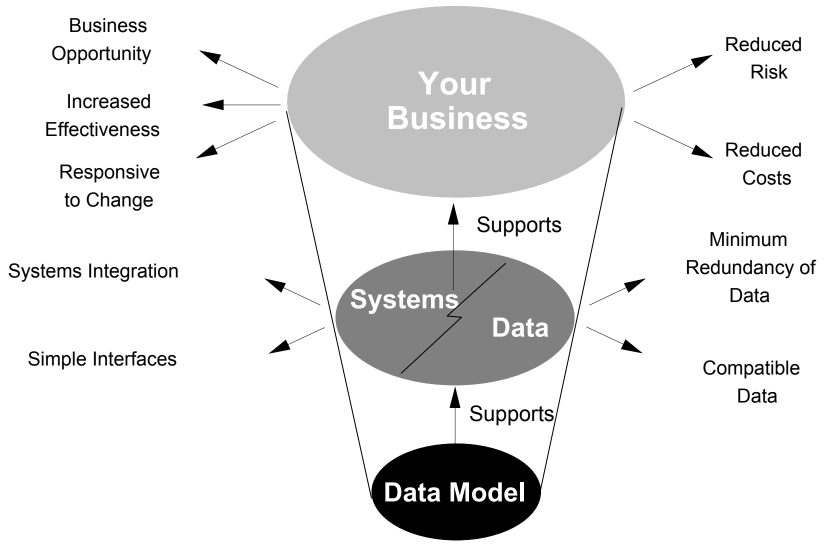


Figure 3-4: how data models deliver benefit

Data models support data and computer systems by providing the definition and format of data. If this is done consistently across systems then compatibility of data can be achieved. If the same data structures are used to store and access data then different applications can share data. The results of this are indicated above.

However, systems and interfaces often cost more than they should, to build, operate, and maintain. They may also constrain the business rather than support it. A major cause is that the quality of the data models implemented in systems and interfaces is poor.

- Business rules, specific to how things are done in a particular place, are often fixed in the structure of a data model. This means that small changes in the way business is conducted lead to large changes in computer systems and interfaces.
- Entity types are often not identified, or incorrectly identified. This can lead to replication of data, data structure, and functionality, together with the attendant costs of that duplication in development and maintenance.
- Data models for different systems are arbitrarily different. The result of this is that complex interfaces are required between systems that share data. These interfaces can account for between 25-70% of the cost of current systems.

- Data cannot be shared electronically with customers and suppliers, because the structure and meaning of data has not been standardised. For example, engineering design data and drawings for process plant are still sometimes exchanged on paper.

The reason for these problems is a lack of standards that will ensure that data models will both meet business needs and be consistent.

4. The Need for Standards

4.1 Background

Before going further it is worth remembering that all models are a limited representation of something else, as illustrated in Figure 4-1. The representation will have a particular purpose in mind, and will focus on representing those aspects that are important to that purpose.

A data model defines the structure and meaning of data. This document is primarily concerned with data models that enable the reuse of data by different applications, either by integrating and sharing data within a single database, or exchanging data by some other means such as a file transfer.

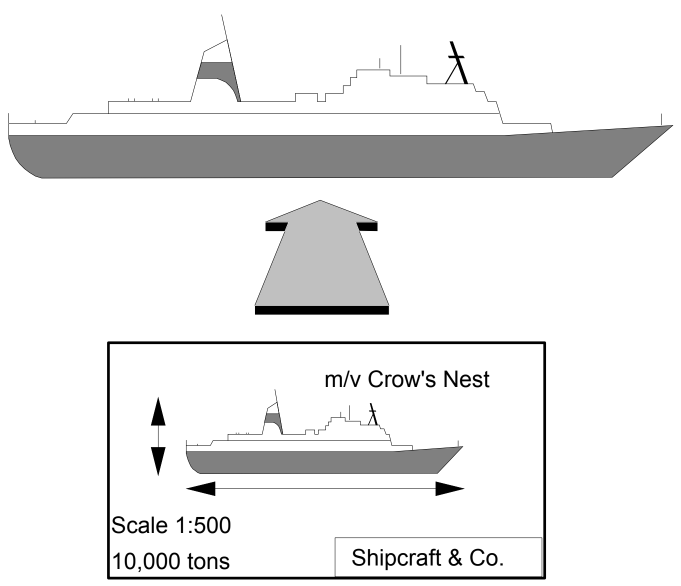


Figure 4-1: A model is a limited representation of some important aspects of something used for a purpose

4.2 The ANSI/SPARC Architecture

The technique of data modelling can be used for many purposes. This is illustrated in Figure 4-2 below following the architecture developed by the Standards Planning and Requirements Committee (SPARC) of the American National Standards Institute (ANSI) on Computers and Information Processing (ANSI/X3) and first published in 1975. This shows that a data model can be an external model (or view), a conceptual model, or a physical model. This is not the only way to look at data models, but it is a useful way, particularly when comparing models.

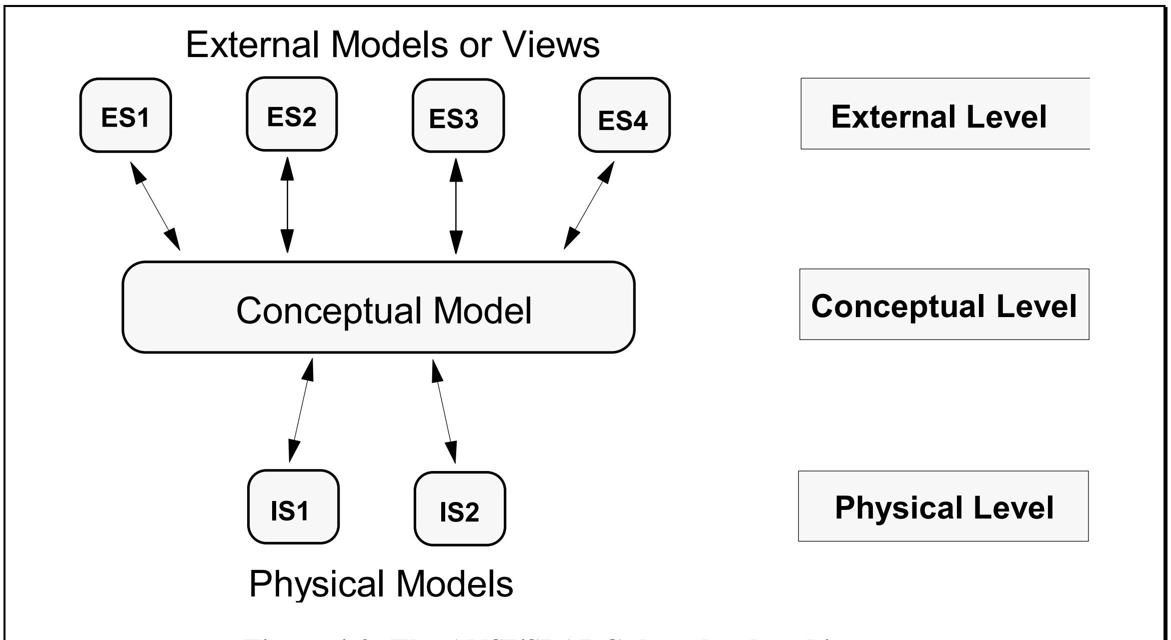


Figure 4-2: The ANSI/SPARC three level architecture.

An external model (or view) looks at the world from a particular perspective, for a particular purpose. There are many possible external views of the world: they may overlap, and do not have to be compatible. In particular, external views are an appropriate place to hold the data requirements for a particular business context and the rules that apply to it. The data models of most applications today take a view of the world from the perspective of that application, and so are external models.

A conceptual model is an underlying or neutral model that is capable of supporting any valid (and perhaps changing) external view that falls within its scope. As a result, a conceptual data model is not an appropriate place to hold rules that may change. A corporate data model should be an example of a conceptual model. To be able to integrate data from different sources, a data model must be conceptual relative to the source data models.

A physical model represents a way in which data is physically stored. There may be many valid physical models for a conceptual model. The requirement is that a physical model must be able to support the conceptual model.

Data models at each of these levels are useful and important, and can be represented using the entity relationship modelling technique. However, because they can all be represented in the same way it is important to distinguish at which level a model is.

The most important level of model for tackling the problems of data sharing and exchange is the conceptual model. This is the level that is the basis for sharing between different parties and is the level primarily addressed in this document.

4.3 Requirements for Data Models

From the business requirements outlined above the following requirements for data models are derived. They should:

√ meet the data requirement,

√ be clear and unambiguous to all (not just the authors),

√ be stable in the face of changing data requirements,

√ be flexible in the face of changing business practices,

√ be reusable by others,

√ be consistent with other models covering the same scope, and

√ be able to reconcile conflicting data models.

In addition, it should be possible to develop data models quickly.

4.4 Data Modelling Today

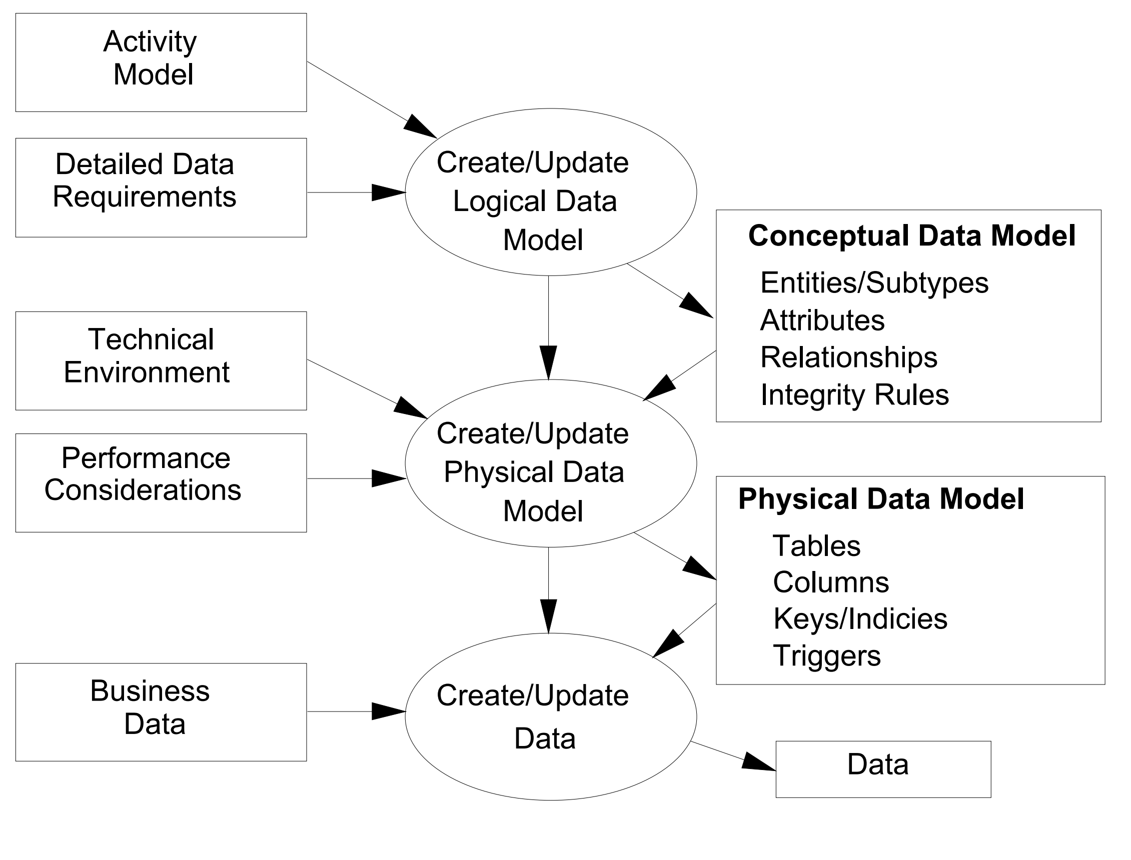


Figure 4-3: Data Modelling Today.

Figure 4-3 illustrates the way data models are developed and used today. A conceptual data model is developed based on the data requirements for the application that is being developed, perhaps in the context of an activity model. The data model will normally consist of entity types, attributes, relationships, integrity rules, and the definitions of those objects. This is then used as the start point for interface or database design.

This use of data models has proved successful when looking at the original development of a single system in isolation. However, when you take a broader, or longer term view, some issues arise.

4.5 Some Issues for Data Models

Systems sometimes cost more than they should. Some of the reasons for this are attributable to how data modelling is done (or the lack of it) and these are illustrated in Figure 4-4 below.

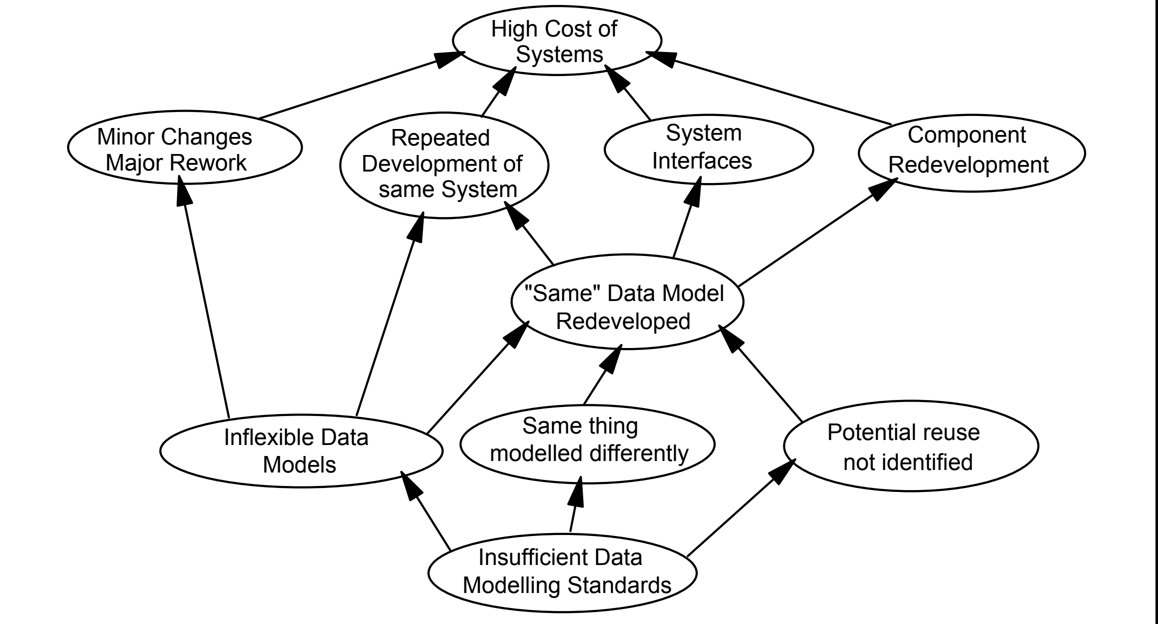

High Cost of Systems
Minor Changes Major Rework
Repeated Development of same System
System Interfaces
Component Redevelopment
"Same" Data Model Redeveloped
Inflexible Data Models
Same thing modelled differently
Potential reuse not identified
Insufficient Data Modelling Standards

Figure 4-4: Some Issues for Data Models.

Sometimes apparently small enhancements to a system cause major rework in the system or interfaces. This points to inflexibility in the original data models.

This is also a major cause of the repeated development of essentially the same system. If "how things are at some time and place" is built into a system, then any restrictions imposed by the system must be accepted by anyone wishing to use it. Otherwise the system will be rejected. This is the challenge faced by those who build packages.

System interfaces account for 25% to 70% of the development and support costs of current systems. The primary reason for this cost is that these systems do not share a common data model. If data models are developed on a system by system basis, then not only is the same analysis repeated in overlapping areas, but further analysis must be performed to create the interfaces between them.

Most systems contain the same basic components, redeveloped for a specific purpose. For instance the following can use the same basic classification model as a component:

- Materials Catalogue,
- Product and Brand Specifications,
- Equipment specifications.

The same components are redeveloped because we have no way of telling they are the same thing.

A lot of the inconsistency that arises between data models is because of the different ways in which real world objects are represented in entity-relationship diagrams. Figure 4-5 below shows some of the representations we have found in models we have reviewed.

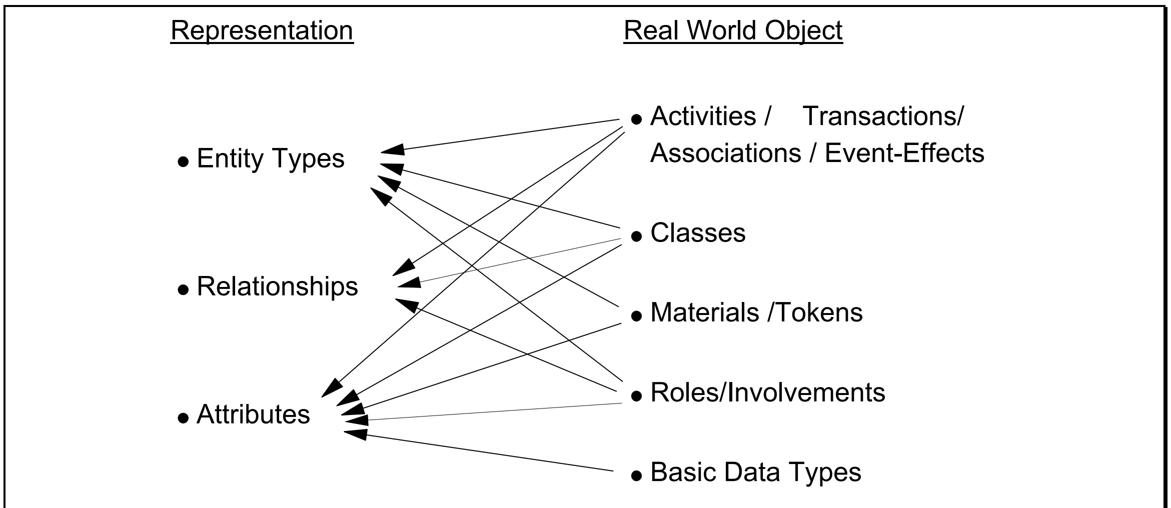


Figure 4-5: Some mappings of real world objects to entity-relationship concepts today.

If the same concepts are modelled in different ways, then there is no way that you can expect that different models of the same thing will look the same.

The differences between how things get modelled is caused by building models that have a specific viewpoint, or specific rules and constraints built in. Since others may have different rules or a different view point, these are things that we know we don't want in a conceptual data model. Thus we have to understand how to represent the world in a neutral way so the resulting models are flexible and stable.

4.6 Required Standards

The underlying reason for these problems is a lack of data modelling standards.

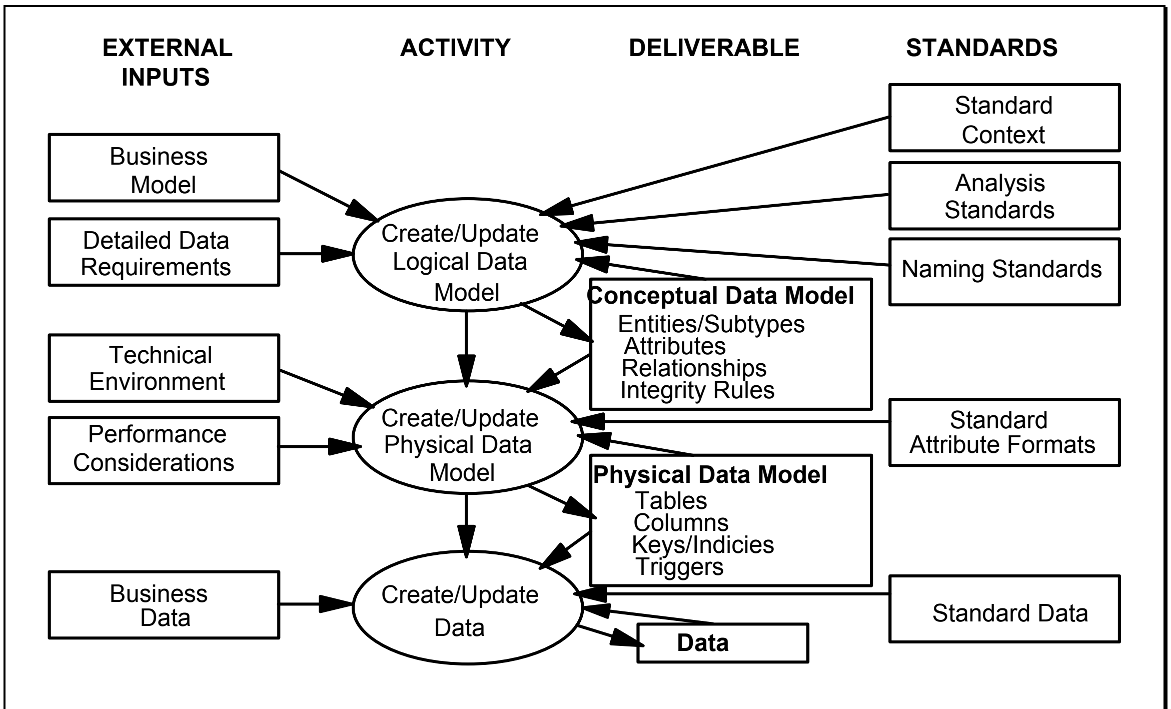


Figure 4-6: Standards required for high quality data models.

Figure 4-6 identifies standards that are needed so that data and data models can be shared rather than redeveloped. This document presents the second of these, analysis standards.

4.7 Principles for Conceptual Data Models

The principles presented here have been discovered, not invented, as supporting the development of data models that meet the requirements in section 4.3. Other requirements might give rise to other principles. They represent good data modelling practice, which can be applied to a wide range of entity relationship or object oriented modelling approaches (e.g. diagramming conventions).

5. Principles for Attributes

Data modelling practitioners have traditionally aimed at a third normal form (3NF) model within the context of the data requirement for the current application. This leaves many attributes representing relationships to real world objects that should be recognised as entity types. We call entity types with attributes that hide other entity types *complex entity types*.

5.1 An Example - Sales Product

Figure 5-1 gives an example of a complex entity type[1].

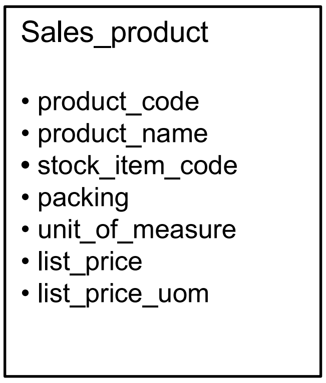


Figure 5-1: A complex entity type.

The clue to look for is a relatively large number of attributes, or unexpected attributes. This means that a particular business view is being modelled rather than the underlying nature of the problem.

The process that is followed in resolving a complex entity type is to examine each attribute in turn, discover what it means, and determine whether it is really an attribute *of* the entity type in question. The key question is does the attribute directly describe the entity type, or does it represent a relationship to another entity type which is perhaps unrecognised.

First look at the entity type. What is it about? Sales Product is a classification of the products, materials, and possibly services we sell.

The first attribute is Product Code. This appears to be the identifier for the Sales Product and is appropriate. Likewise the Product Name/Brand appears to be a textual description of the Sales Product and is also appropriate.

However, this is not the case for Stock Item Code. "Code" is a word which is usually used in Attributes that are entity type identifiers. So if Product Code is the identifier for Sales Product, then what is Stock Item Code the identifier for?

If you are familiar with Sales and Stock systems you will understand that there are two different views of product that are important. One is the view of what is stocked or made, the other is the view of what is sold. This is necessary because the same product is sometimes sold under different names into different markets, or the same Sales Product is supplied from Products with different specifications. Now the Sales Product entity type is clearly the view of what is being sold, however,

[1] All data model diagram examples use the EXPRESS-G notation. EXPRESS-G is defined in ISO 10303-11. A brief tutorial on EXPRESS-G diagrams is given in section 10 of this document. In some cases, the "verbosity" of the EXPRESS-G notation for attributes makes it easier to list attributes within the box that represents the entity data type. This has been done in this example.

the Stock Item Code attribute is referring to the view of what is held as stock. This is illustrated in Figure 5-2 below.

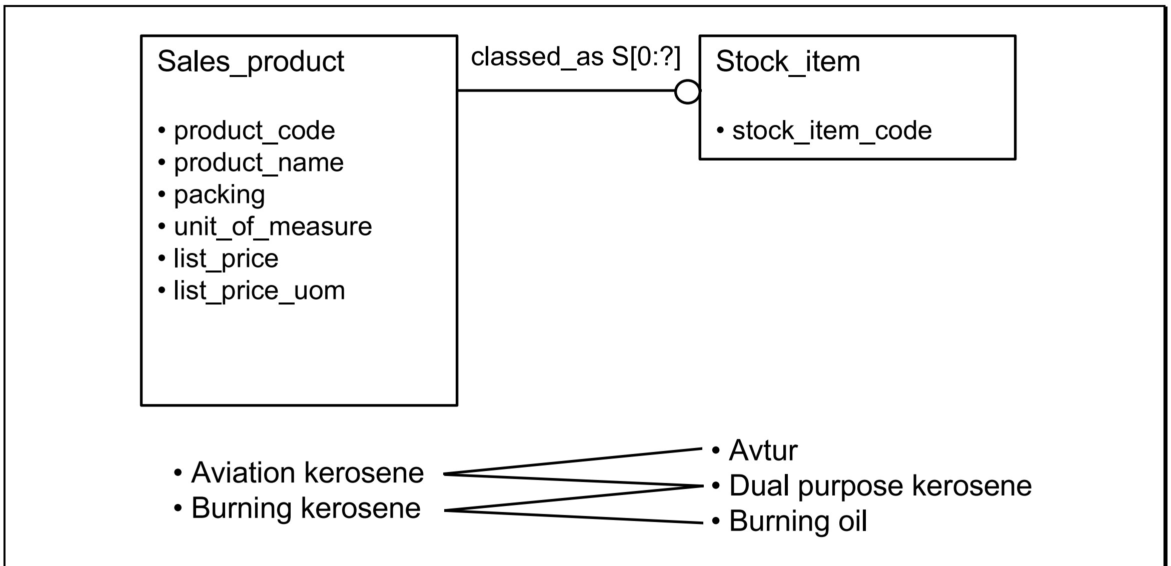


Figure 5-2: Identifying the different views of Product.

Note that the relationship is many-to-many, as illustrated by the example of the different types of Kerosene held and sold. The original model could not have catered for Aviation Kerosene possibly being supplied from either Avtur or Dual Purpose Kerosene, or Burning Kerosene being supplied from either Burning Oil or Dual Purpose Kerosene.

Let us consider the Packing attribute next. This refers to the type of material used to pack the Sales Product. Again this is really representing a hidden entity type, this time, those materials which are used to pack other materials. Again a new entity type is created with a relationship to Sales Product. The cardinality of the relationship is unclear. It is assumed here that if the same Sales Product is sold in a different Packing then it is deemed to be a different Sales Product. Figure 5-3 shows the resulting model.

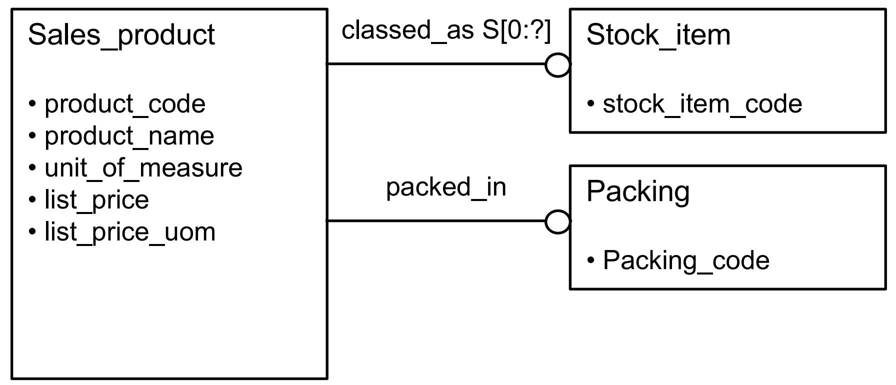


Figure 5-3: Identifying Packing as a separate entity type.

The next attribute to consider is List Price. The List Price can change over time, and it is not unusual to have several List Prices at the same time when selling into different markets. The current model means that only one List Price at a time is allowed and that the history of what the List Price has been cannot be held. Thus the List Price should be represented as a separate entity type, with a one-to-many relationship, as illustrated below in Figure 5-4.

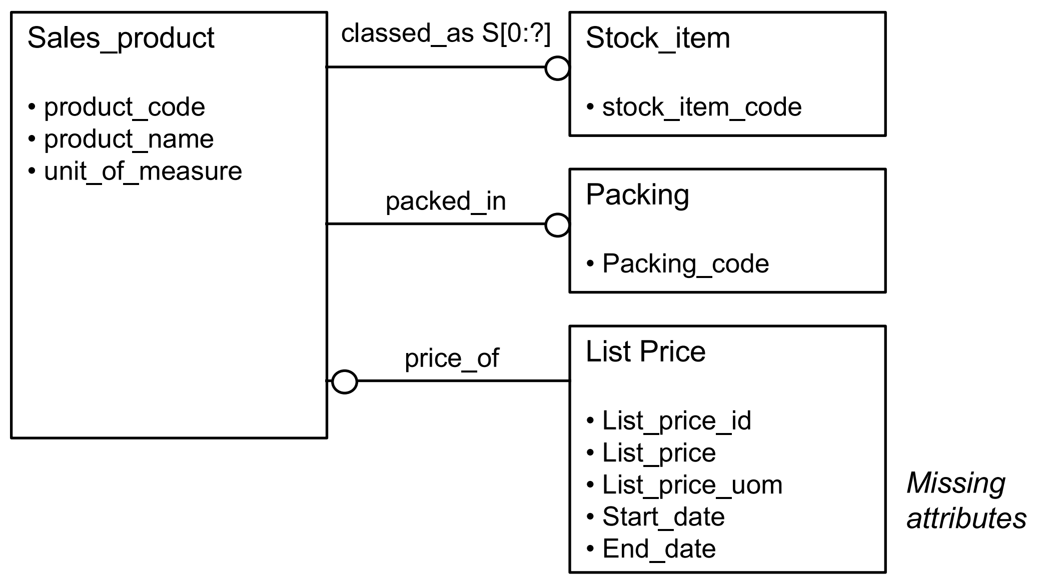


Figure 5-4: Identifying the List Price entity type and it's attributes.

You will notice that some additional attributes are appropriate to indicate the period over which a List Price is valid, and to allow for prices to be quoted in different currencies.

An apparent disadvantage here is that the number of entity types has increased. This is a temporary phenomenon. As the model grows in size, these simpler entity types get reused in different contexts. An example that starts to illustrates that is given below.

5.2 An Example - Personnel and Security

The entity types in Figure 5-5 came from three different systems. As you can see from the attributes in bold, much of the data is repeated between the systems. Further each of the entity types is complex.

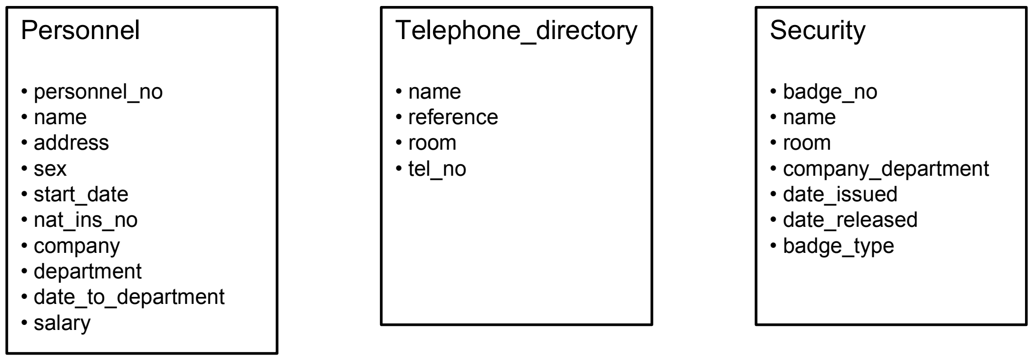


Figure 5-5: Entity Types from three different systems.

There were many problems caused by these systems. First, when people joined the company or worked on contract, they had to provide the same data several times. Any changes to the data also required multiple updates, with a high chance that one of the systems would get out of date. In addition there were three different systems created and maintained to manage the same data.

Figure 5-6 below shows the partial analysis of the Telephone Directory entity type, as a complex entity type.

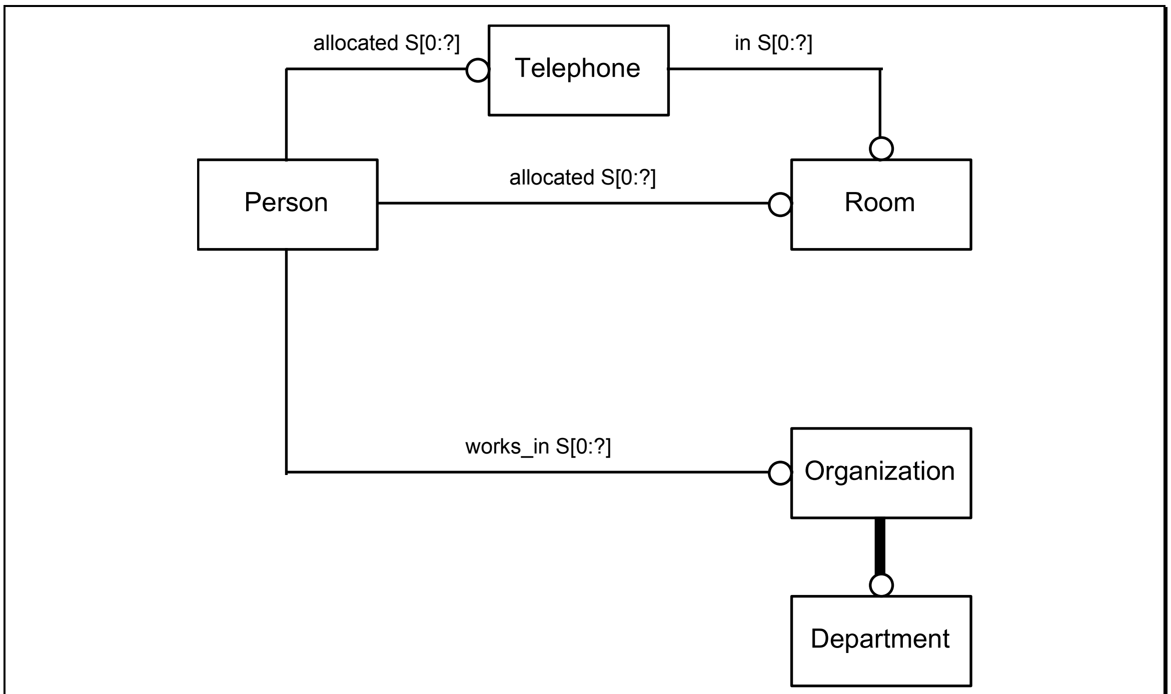


Figure 5-6: Resolution of the Telephone Directory entity type.

Figure 5-7 shows the partial analysis of Personnel as a complex entity type where it overlaps with the Telephone Directory and Security entity types, as a complex entity type.

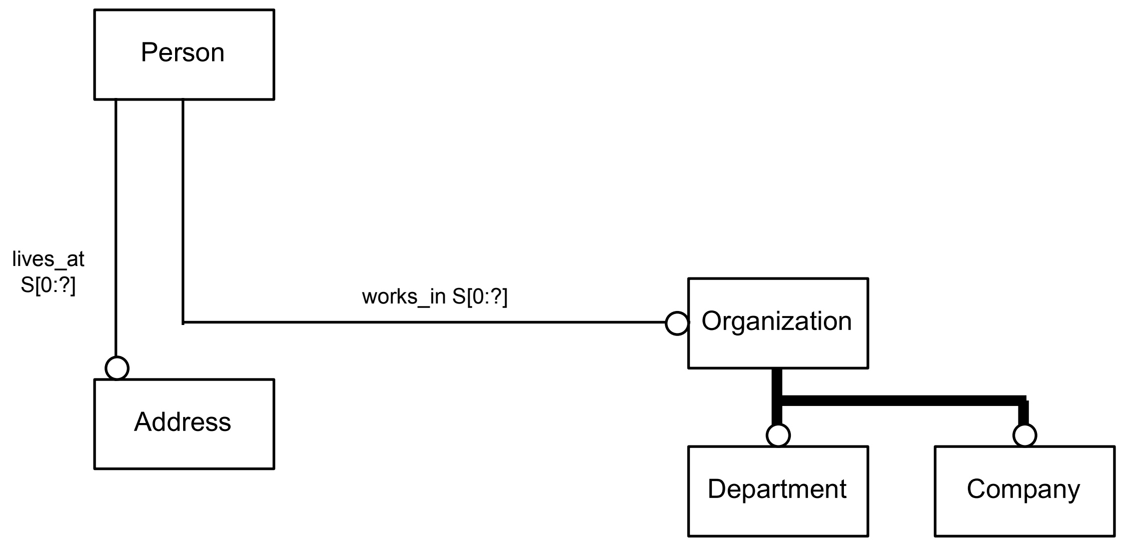


Figure 5-7: Partial resolution of the Personnel entity type.

Figure 5-8 below shows the partial resolution of the Security entity type, as a complex entity type.

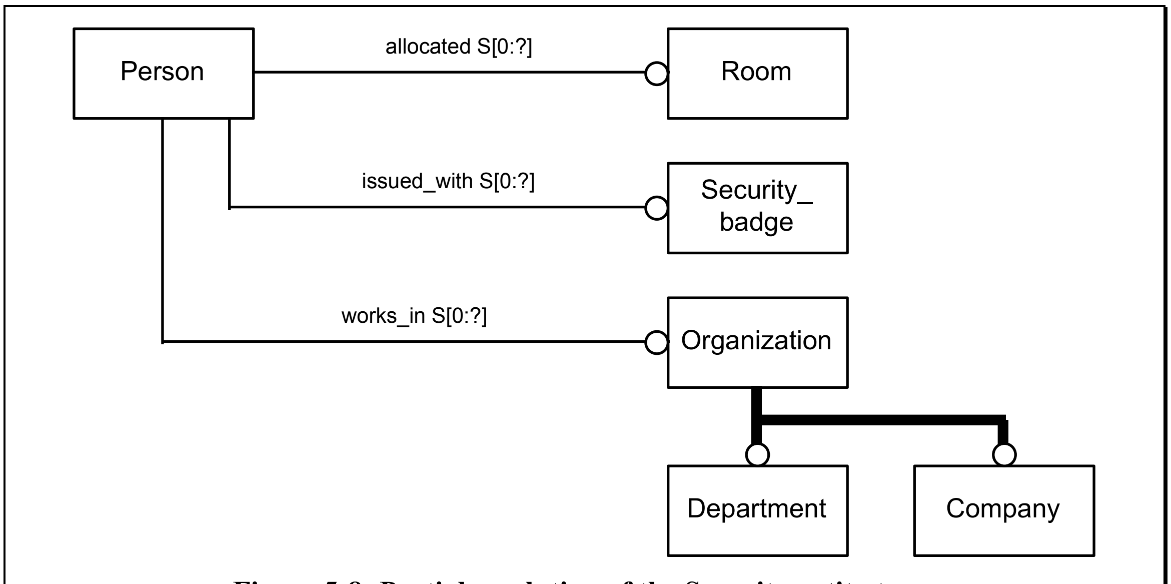


Figure 5-8: Partial resolution of the Security entity type.

Now that these original entity types have been analysed in more detail, it is easy to see how they fit together without interfaces or data duplication. Figure 5-9 shows the result.

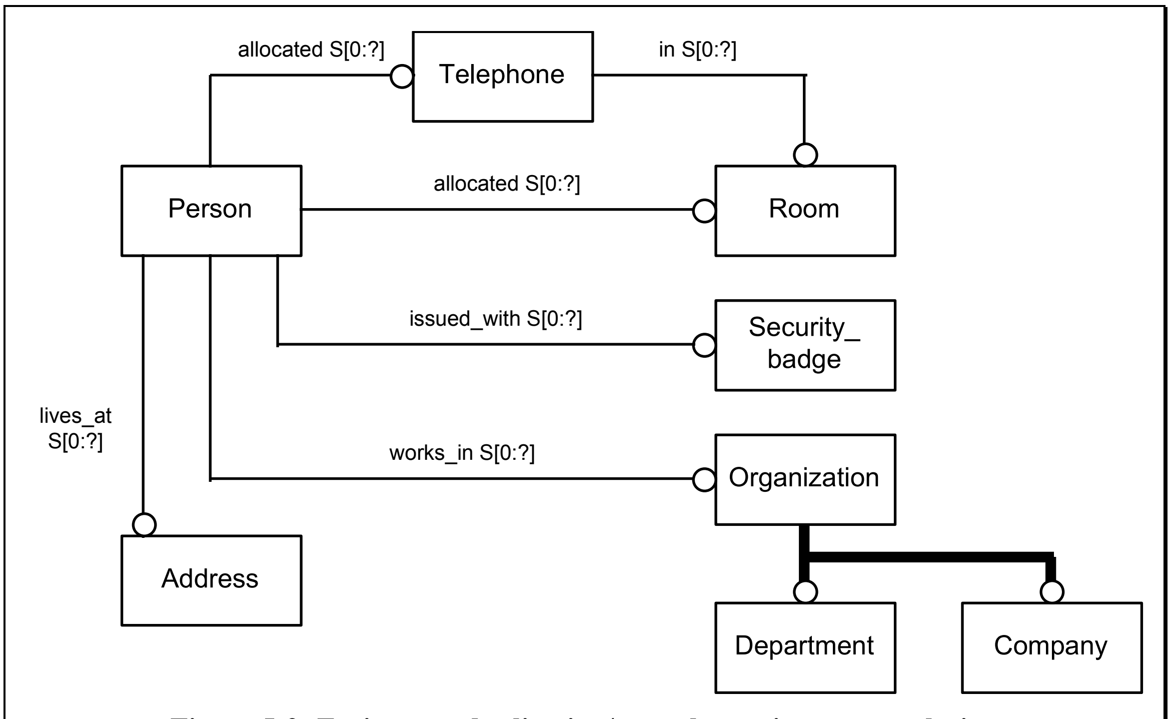


Figure 5-9: Entity type duplication/ complex entity type resolution

You will notice that there are two more entity types, and still a number of many-to-many relationships to resolve. This is due to the three initial entity types being complex as in Section 5.1. Most of the attributes will map onto the entity types shown. Some dates await resolution of the many-to-many relationships.

5.3 Principle 1

Thus we get Principle 1:

1. *Candidate attributes should be treated as representing relationships to other entity types.*

5.4 Identification

There are two levels at which identification of things is important:

1. internal, within a file or database, and
2. external, across a number of independently managed files, databases, or organisations.

5.5 Internal Identification

The purpose of an internal identifier is for the efficient and effective management of data about something by computer systems. Within a database or file it is important that each object represented has a surrogate, so that information about the object can be grouped together. In a database this might be provided by an attribute. In a STEP Part 21 file, this is provided automatically.

Relationships should not be used as part of the internal identifier because this makes the existence of the object dependent on the relationship, and hence it makes existence of information about the object dependent on knowledge of information about the object it is related to. Even where there is real world dependence, it is unusual for it to translate into data dependence, e.g. because I must have two parents does not mean that you must know who my parents are to know me.

5.6 The Trap - Inappropriate Choice of Unique Identifier.

In the real world things don't necessarily come with a convenient number stamped on them for identification. Sometimes we do gives things an identifier, but often we refer to things indirectly "the one I ordered last week" and rely on the context. There is a temptation to carry over this indirect identification of objects through the relationships or attributes they have into data models where it can cause problems.

Consequences

Imposing restrictions through the data structure means:

- *Arbitrary or inappropriate restrictions are placed on the data that can be held.*
- *Fudge or false data may be introduced to overcome the restrictions in the data structure. This may have to be programmed around.*
- *The entity type will only work within the context defined. A change in business rules may require a change in the database structure.*
- *The resultant system is harder to share.*

Failing to correctly recognise entity types means:

- *The same data structures may be replicated.*

5.7 An Example - Ship

Figure 5-10 shows an example of this. It is in fact the same example as above.

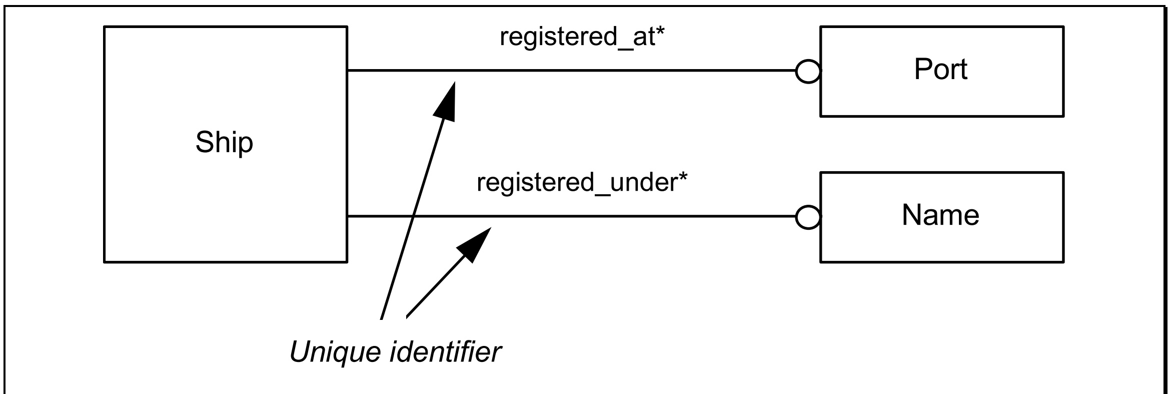


Figure 5-10: Inappropriate choice of Unique Identifier.

The entity type Ship has as its primary unique identifier two relationships, Port, and Name. This depends on the context for ships that ships are normally registered at a port under a name. However, this gives no way of identifying a Ship before it is registered. Either fudge data or another entity type would be required to show this information.

In addition, using the relationships to Port and Name as the unique identifier means that those relationships have to be mandatory, and unchanging. This means that using the relationships as the unique identifier places restrictions on the business.

This problem arises from modelling the data, rather than what the data is about. The temptation is to think that you are restricted in your choice of unique identifier to the attributes and relationships which the user is interested in.

The solution is disarmingly simple. If there is not a single attribute which never changes over the life of an entity, then create one, to act as a surrogate for and to identify instances of the entity type. If they are important enough to hold information about, they deserve being given their own identifier. It is further worth noting that the values should not be changeable by the user, and indeed do not necessarily ever have to be seen by the user.

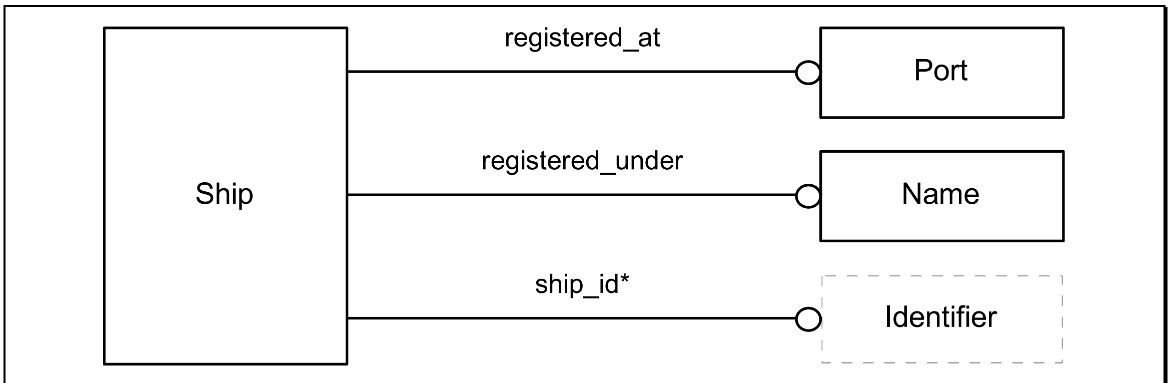


Figure 5-11: Getting the unique identifier right.

In this case an attribute Ship_ID could be added. The entity type with its new identifier is shown in Figure. A ship is always a ship!

5.8 Another Example - Packed Product

Figure 5-12 shows an example based on packed products. A Product Item is identified as being a Physical Product in a Package. Because the relationships are to be used as the unique identifier they must be mandatory.

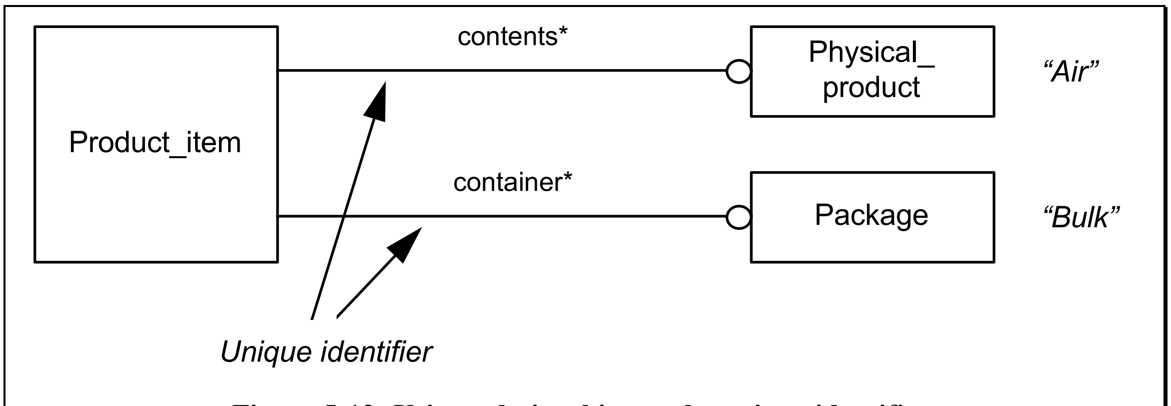


Figure 5-12: Using relationships as the unique identifier.

The problems caused by this choice of unique identifier are those that result from the restrictions the necessary cardinality places on the business. In this case fudge and false data need to be introduced.

This arises because in the description of the entity types it is explained that sometimes a Physical Product is sold in bulk form, without a package, and sometimes Packages are moved or sold without any contents. To get round this a Physical Product of Air was introduced, and a Package of Bulk. This works around the fact that the cardinalities of the two relationship are incorrect. They have been made mandatory, when they should be optional.

Introducing the fudge data to overcome the incorrect cardinalities can have expensive consequences. Because Air is not really a Physical Product it can become necessary to introduce into code that uses the table things like "for all the Physical Products .. except Air ..". This is expensive to design, build, check and maintain. It is also unnecessary.

The solution is to create an attribute specifically to be the identifier of a Product Item. This then means that you do not have to make the relationships mandatory when they are not. The result is shown in Figure 5-13.

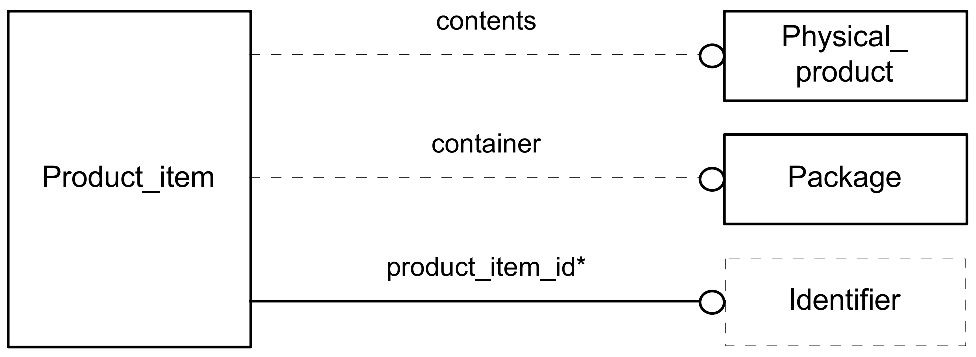


Figure 5-13: Using a special attribute as the unique identifier.

5.9 Principle 2

2. *Entities and records should have an internal identifier within a database or exchange file. These should be artificial and managed to be unique.*

   Relationships should not be used as part of the internal identifier.

Artificial means that the identifier has no meaning to the user, and is arbitrary (e.g. the next number in a list). It also means that no program would be able to analyse the identifier and make some judgement on what sort of thing it represented.

5.10 External Identification

The purpose of external identification is so that computer systems, people, and organisations can know what information is about in a broader context than the local computer system or organisation. This is particularly important for the integration of data from different systems. Take for example the unit of measure kg. If one system calls it "kg", and another "kilograms", then they will not be able to exchange data. A weight of 30 kg in the first system would be meaningless to the second system.

The first thing to understand about external identifiers is that there can be many of them. For example, I have an employee number, a driving licence no, a National Insurance number, a National Health Number etc. The next thing is to understand that each of these identifiers is issued by an authority, which manages them so that an identifier is only issued for one person, and that a person only has one identifier (at a time).

The consequence of this is that external identification is best dealt with as part of the overall data model, and so is not dealt with further here.

5.11 Record Identifiers

We sometimes forget that records are things too, which we may wish to manage, or authorise for a particular use. Some DBMS's give each record a record identifier, which is not seen by the user. This identifies a particular record (within the DBMS instance) and is not a surrogate for the object itself. Both are needed for proper management of data.

5.12 Expected Attributes

The following are attributes that would be expected.

Record Identifier:	an artificial identifier that can be used as a reference to the record. It is a local identifier that is only required to be unique within the database or file. Sometimes this is provided by the management system, as with an Oracle row id.
Local Object Identifier:	a local identifier or surrogate for an object being represented. Sometimes this is provided by the management system, such as in a STEP Part 21 file.

All other information should be held through associations, to other objects, or to *information content*, subtypes of which give numeric and text values, as well as geometric and other representations. These would most likely be implemented through specific tables for a particular data type, e.g. text, binary, numeric.

6. Principles for Relationships

6.1 Relationships and Associations

In order to clarify the discussion, I would like to start by distinguishing between how I will use the terms "relationship" and "association". I shall use the term "association" to represent what one thing has to do with another. On the other hand, in the context of entity-relationship modelling, a relationship is the line that links one entity type to another. It can be used to *represent* a concept, such as an association.

6.2 A Bad Example - Batch and Product Type

Understanding how to represent the world is best done by looking at an example. In Figure 6-1 below I have reproduced the model used to explain the EXPRESS-G notation for entity-relationship diagrams.

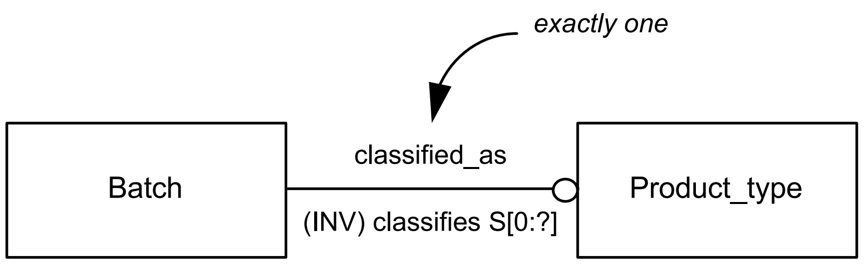


Figure 6-1: An example of a relationship.

This model is already better than many you will see. Often relationships are not named, or are given meaningless names like "has" and "for". The key thing to notice is that the entity types at both ends of the relationship are independent entity types. That is, they exist independently of the things around them. A *batch* is some stuff in a tank, and a *product type* is a specification to which we try to make product, e.g. unleaded mogas. Inherently, we can have stuff sitting in tanks without knowing what type of thing it is, and we can have types of thing we would like to have, without actually having any.

The data model in Figure 4.9 tells a different story. It says that I can't have a *batch* unless it is classified. It also says that a *batch* can only be classified as one *product type*, and it says that the classification can never change (or I lose the history of how it was classified if I do). None of these things are generally true, even if they are appropriate in some special circumstances. Thus this model can restrict the business, and lose history. This is generally true for all relationships between independent entity types.

Representing activities or associations as relationships may mean that restrictions are placed on users as to what data can be held. This is inappropriate in a conceptual model. The fact is that associations are passive links between entity types, and as such are things of potential interest in their own right. In particular they have attributes, such as the date the association was created, and the date it was terminated. Associations are caused and terminated by activities. Similarly, an activity is something happening, and has attributes such as the start date/time and end date/time of the activity, and relationships such as who or what did it.

6.3 A Second Example - Packed Products

The model in Figure 6-2 shows Product Item as the types of things sold. The cardinalities in the model say that a Product Item *must* consist of a Physical Product *and* a Package.

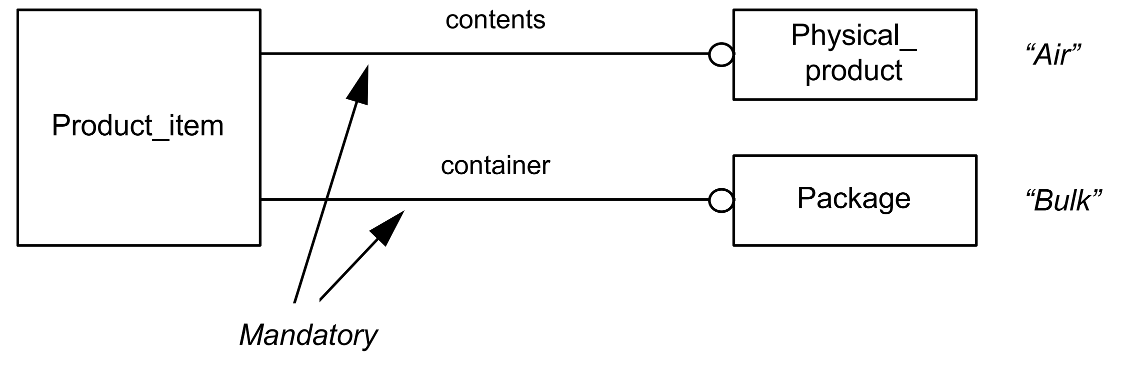


Figure 6-2: Inappropriate Cardinalities.

The problems this causes were explained above.

Figure 6-3 shows an improved model with the cardinalities corrected and made optional.

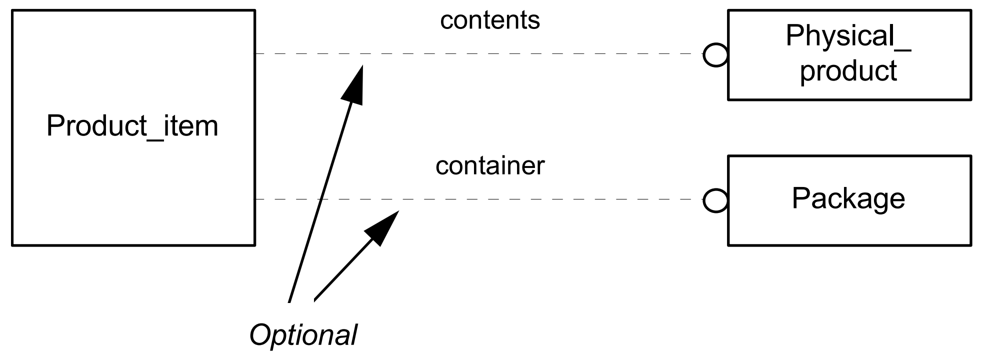


Figure 6-3: Getting the basic cardinalities right.

Again, the correct cardinalities arise from modelling the underlying nature of the problem, rather than the perception of the problem.

6.4 The Trap

Sometimes cardinalities are set to one-to-many, meaning one at a time, when the cardinalities are really many-to-many over time because the relationship is transferable.

Consequences

Imposing restrictions through the data structure means:

- *Arbitrary or inappropriate restrictions are placed on the data that can be held.*
- *History data about a relationship cannot be held.*
- *The entity type will only work within the context defined. A change in business rules may require a change in the database structure.*
- *The resultant system is harder to share.*

6.5 An Example - Ship

Figure 6-4 shows that a Ship is registered at one Port and only one Port, under one name and only one name.

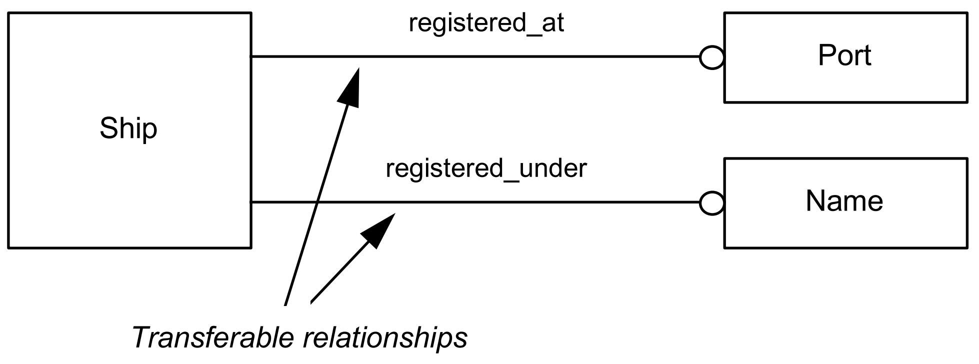


Figure 6-4: Transferable relationships

However, what happens if you re-register a Ship? How do you know what it was previously sailing as? The same applies to the Name. If it changes you do not know that it refers to a vessel that you had blacklisted, or was an old friend.

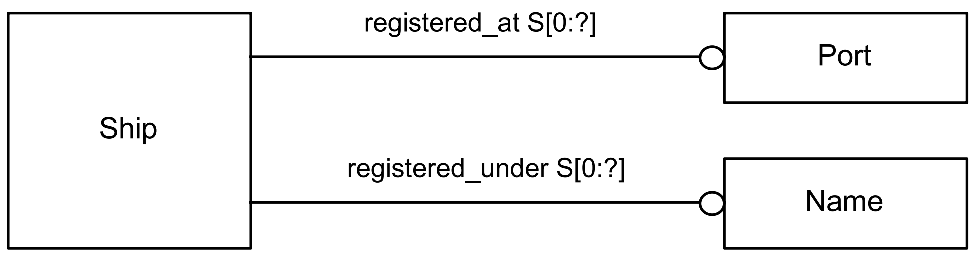


Figure 6-5: Correct cardinalities for transferable relationships.

Figure 6-5 shows the correct relationship cardinalities as many-to-many, which recognises that a one-at-a-time relationship is potentially many-to-many over time. The problem was caused by modelling a business perspective, that we normally refer to a ship by its name and port of registration, rather than looking for what underlies that view.

Resolving the many-to-many relationships into entity types leads to a model as illustrated in Figure 6-6.

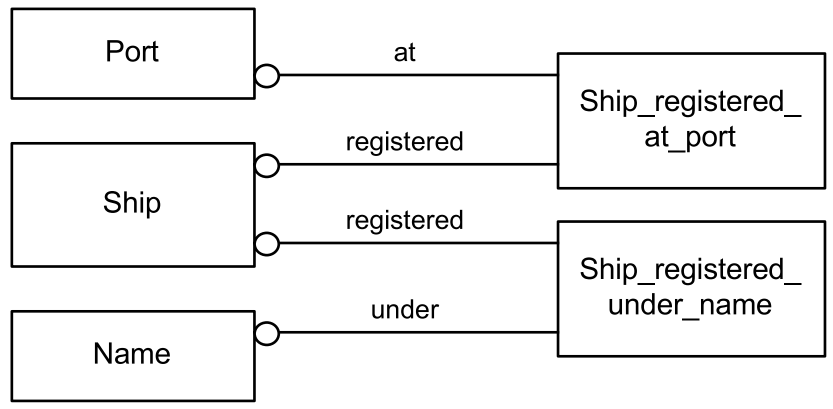


Figure 6-6: Resolution of many-to-many relationships.

However, in this case the activity for both these relationships is Registration, and if this is recognised, then we can have one instead of two entity types representing the registration as shown in Figure 6-7 below.

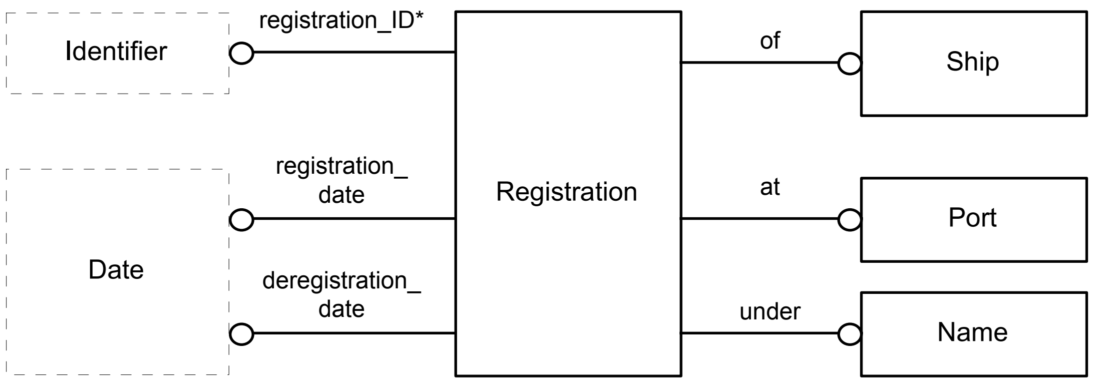


Figure 6-7: Understanding that Activities cause Relationships

Notice that the Registration entity does not use the relationships as its unique identifier, but has its own Registration ID. The relationships to the other entity types are one-to-many, and are now named in terms of the involvement of the entity type in the activity.

6.6 A Good Example - Transfer and Storage

In Figure 6-8 below, *storage (of material)* is an association between a *material* and a *facility* that is caused by a *transfer* of the *material* into the *facility*, and is terminated by another *transfer* of the *material* out of the *facility*. Each *transfer* may create one *storage (of material)* and terminate one *storage (of material)*. In between, nothing happens, but an association of interest exists.

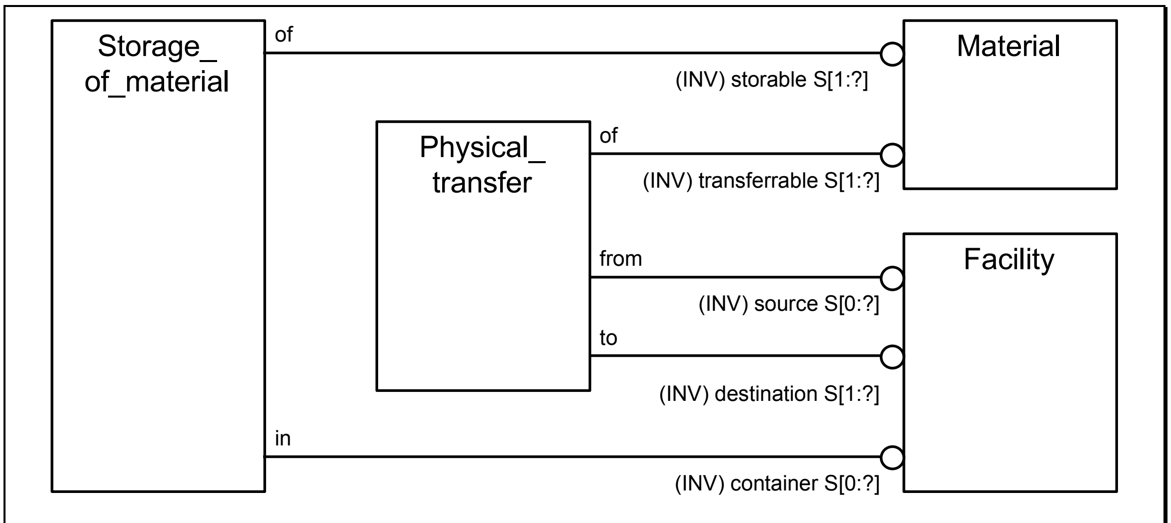


Figure 6-8: Transfer and Storage of Material.

Notice that the sticks on the "lolly-pops" only occur on entity types representing activities (*physical transfer*) or associations (*storage of material*) and that an activity or association is at one end of *all* the relationships.

6.7 Principle 3

Thus we get as our third principle:

3. *Activities and associations should be represented by entity types (not relationships or attributes).*

Occasionally you may feel that the relationship between an activity and an object should be many-to-many. If this is the case then you should look either at decomposing the activity, or aggregating the object that is involved in the activity.

For example, you might be transferring 4 pumps together. You could recognise the "togetherness" by creating a *material* that represented the 4 pumps, which would be composed of the 4 individual pumps. The aggregate object can then be transferred.

6.8 Principle 4

If associations and activities are represented by entity types, what then is represented by relationships? Again Figure 6-8 provides examples. Each relationship is now between an independent entity type and an activity or association. Thus each relationship represents what an independent entity type has to do with an activity or association. We call this an *involvement*, and the name of the involvement represents the *role* played by the independent entity type in the activity or association (not always easy to do). Thus we get the fourth principle:

4. *Relationships (in the entity/relationship sense) should only be used to express the involvement of entity types with activities or associations.*

7. Principles for Entity Types

One of the biggest problems in managing data is identifying what is being talked about. That is, what is a sound basis for identifying and naming entity types? In order to be able to hold data about something we need to identify what *it* is. In order to be able to share data about something, we need to have a consistent view of what *it* is about, independent of the context for a particular use.

When data is context dependent, then it means that the data could mean something else in another context. In order to make such data independent of its context, the context must be made an explicit part of the data, rather than something assumed.

Two ways in which things can go wrong are given below.

7.1 An Example - Combined Entity Types

Figure 7-1 shows a data model using the 'Merise' notation that focuses on the entity type *site*. When you look at the relationships that *site* has to other entity types it becomes clear that it represents many things.

First, *site* can be decomposed into a number of *plants* which in turn can be decomposed into a number of *groups of units*, which can be decomposed into *units*. This is the concept known as *facility*, which is about the purpose and service provided by something.

Secondly *site* presents a *safety and security plan*. Clearly, this is about the *organisation* responsible for the *facility*, rather than the *facility* itself.

Finally, there are *traffic & flows* with *outside*. This suggests that *location* is also wrapped up in *site*.

This combination of concepts was possible because in the place where this model came from there was a 1:1:1 relationship between these concepts that allowed them to be modelled together, and the word *site* was sufficiently ambiguous that it could be used in the context of each of them. Combining these concepts gives a model which others may not be able to use, and which may not apply given changing circumstances.

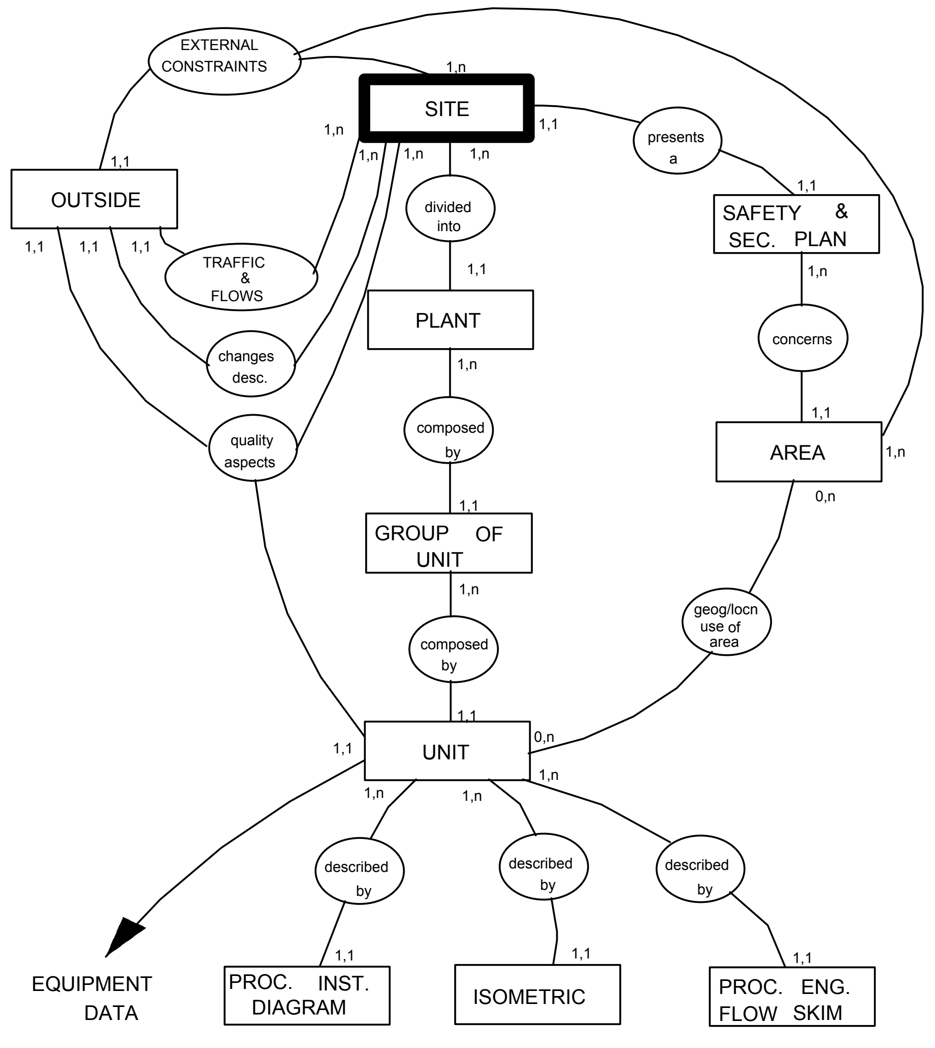


Figure 7-1: SITE - a complex entity type.

7.2 An Example - Stock

Entity types can get named inappropriately. This sometimes happens because of the indirect way in which we often describe things. Then when we describe the same object from a different perspective, we can be fooled into thinking it is something different.

Figure 7-2 shows an example where this has happened.

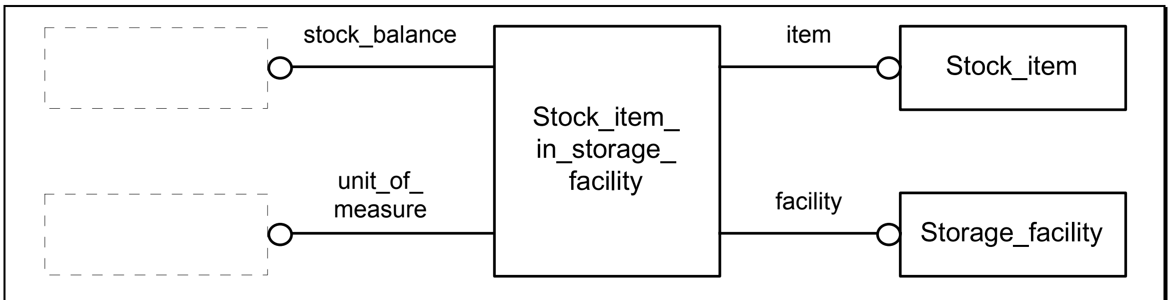


Figure 7-2: Misunderstood Entity Types.

Here, a Stock Item is a type of thing which is held in stock, the Storage Facility is where the Stock Item is held, and Stock Item in Storage Facility indicates the amounts of the Stock Item held in the Storage Facility.

The misunderstood entity type is Stock Item in Storage Facility. If you examine the name literally it suggests that some Stock Items are in a Storage Facility. Now Stock Items are classes of material, so at best putting Stock Items into a Storage Facility might mean putting specification sheets into a tank. This is clearly not what is intended, so we have to look for the missing words. Common sense and the attributes tell us that the entity type is about the Stock of material which is in a Storage Facility and is classed as being of a Stock Item. A more appropriate name for the entity type then is simply Stock, because we know about the Stock Item and Storage Facility through the relationships. This is illustrated below in Figure 7-3.

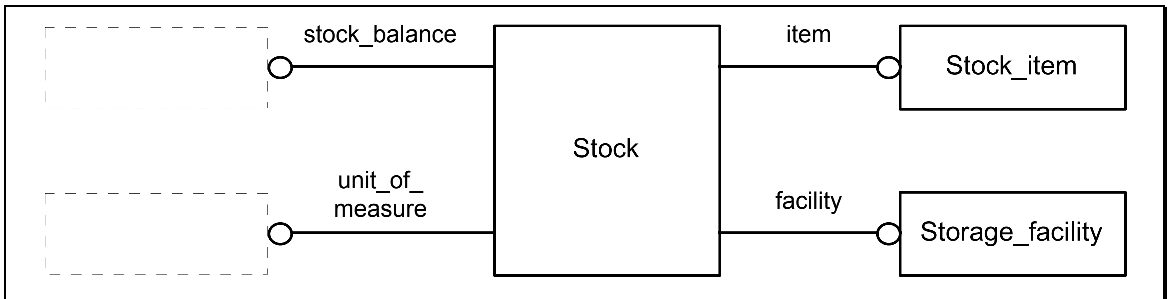
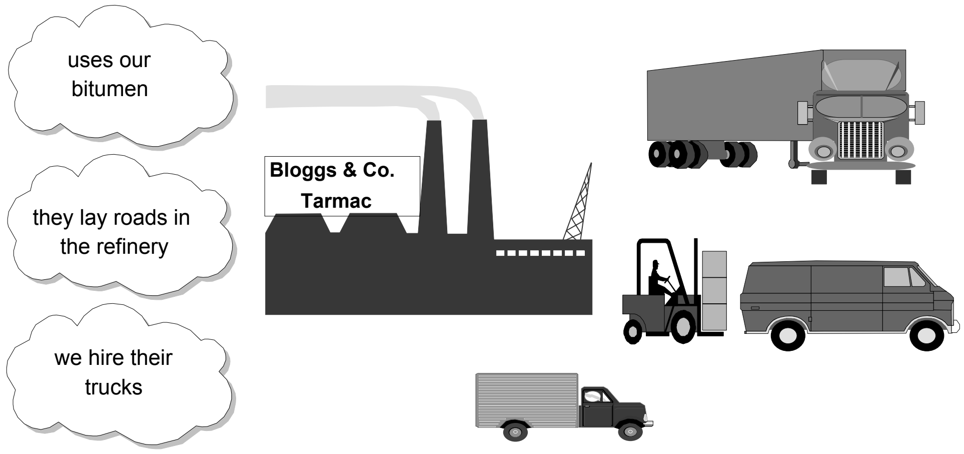


Figure 7-3: A more appropriate name for the entity type.

There are other problems with this model, but they are not dealt with here.

7.3 Naming Entity Types

The way we see things is often determined by the role something plays in a particular business context. This is illustrated in Figure 7-4 below.



Any one Company can do any, one or none of the above.

Figure 7-4: Different roles played by the same company.

Sometimes these roles get turned into entity types, like *customer*, *supplier*, or *agent*. However, the same *organisation* can play each of these roles, so we need to be able to recognise that a customer may also be a supplier or agent. A similar way that roles get turned into entity types is when an entity type is subtyped based on the ones that have a particular relationship (i.e. play a particular role).

7.4 The Trap - Fixed Hierarchies.

Sometimes a number of entity types are linked by one-to-many relationships showing a hierarchy of detail. However, this construct can cause considerable difficulty to the business because it allows only one hierarchy to be represented. This does not reflect the real world, and as a result can cause unnecessary and inappropriate restrictions on the business. In fact it is the combination of entity type partitioning and restrictive cardinalities.

Consequences

Imposing restrictions through the data structure means:

- *Arbitrary or inappropriate restrictions are placed on the data that can be held.*
- *Fudge or false data may be introduced to overcome the restrictions in the data structure. This may have to be programmed around.*
- *Data may be replicated to overcome the restrictions in the data structure. The different versions must be reconciled.*
- *The entity type will only work within the context defined. A change in business rules may require a change in the database structure.*
- *The resultant system is harder to share.*

Failing to correctly recognise entity types means:

- *The same data structures may be replicated.*
- *The same functionality may be replicated.*

7.5 An Example - Stock Classification

An example is given in Figure 7-5.

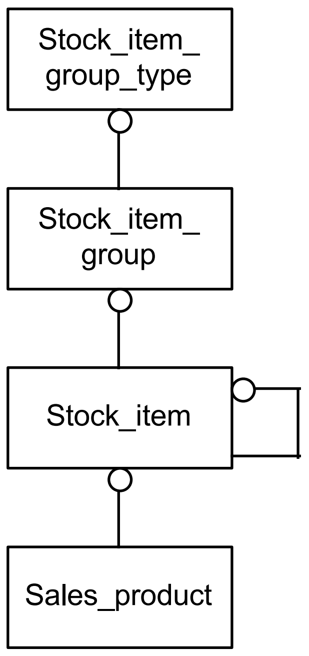


Figure 7-5: A fixed hierarchy.

All Stock Items *must* belong to one and only one Stock Item Group which *must* belong to one and only one Stock Item Group Type. An example of the kind of restriction this can place is that you might have Naphtha as a Stock Item, and you might have Feedstock, Intermediate, and Finished Product as Stock Item Groups. This model restricts you to allowing Naphtha to be only classed as one of those, even though it can be all three.

The first step is to check that the entity types are of the same type. By comparing each of the entity types it can be seen that all the entity types are Classes of Stock or Material, so the entity type Class is a supertype to them all as shown in Figure 7-6.

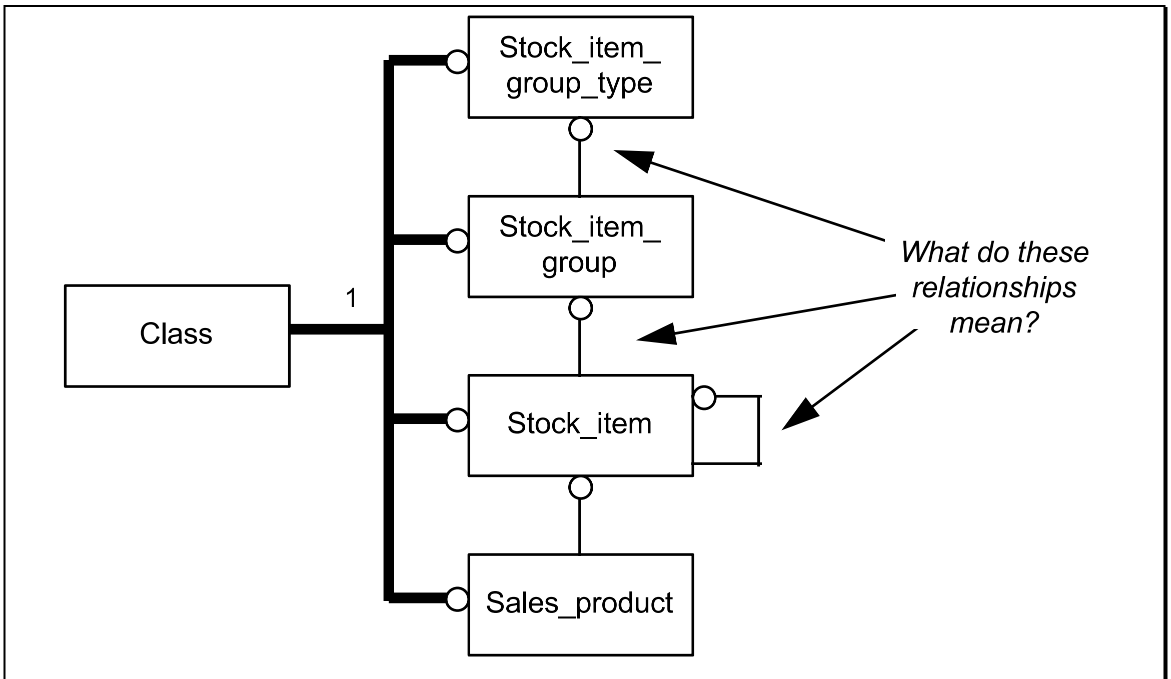


Figure 7-6: Recognising Subtypes.

The next thing is to check that all the relationships are the same. In our case the three relationships indicated in Figure 7-6 are of the same type, indicating that the entity type at the one end is a generalisation of the entity type at the many end. On the other hand the relationship between Stock Item and Sales Product is indicating that one is sold as the other, which is a different type of relationship. This being the case we can simplify the model and add flexibility at the same time by introducing a supertype to Stock Item, Stock Item Group, and Stock Item Group Type of say Stock Class and move the one-to-many relationship to the supertype. This gives the situation in Figure 7-7.

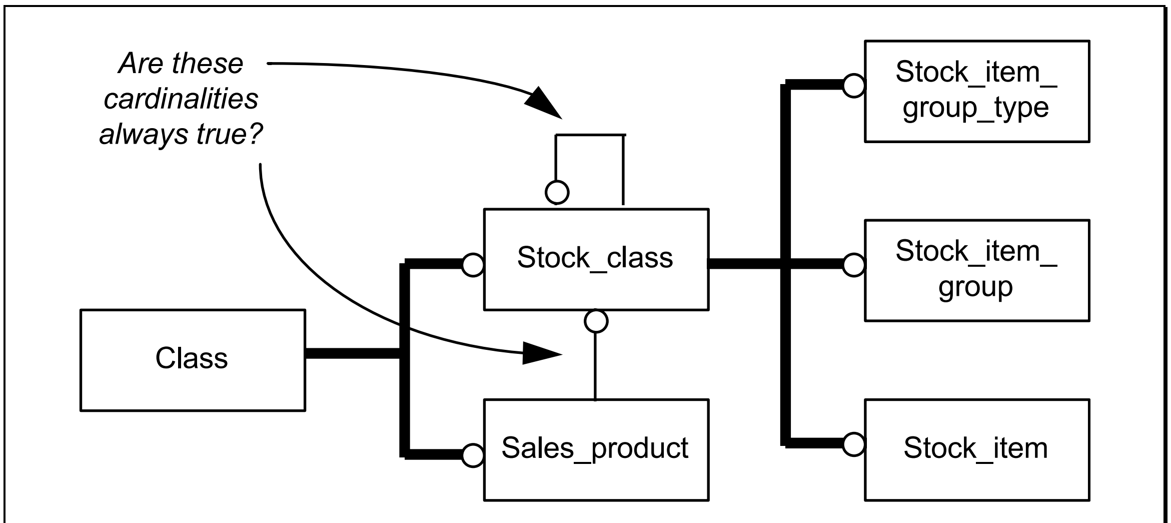


Figure 7-7: Removing some restrictions.

At this stage the three subtypes are illustrative rather than restrictive. However, we have still to consider the cardinality of the relationships. The cardinality of the relationship between Sales Product and Stock Item was dealt with in the previous example, and should be many-to-many. From the example used in the first paragraph of this example it is also clear that the relationship on Stock Class should also be a many-to-many. This leads to the situation in Figure 7-8 below.

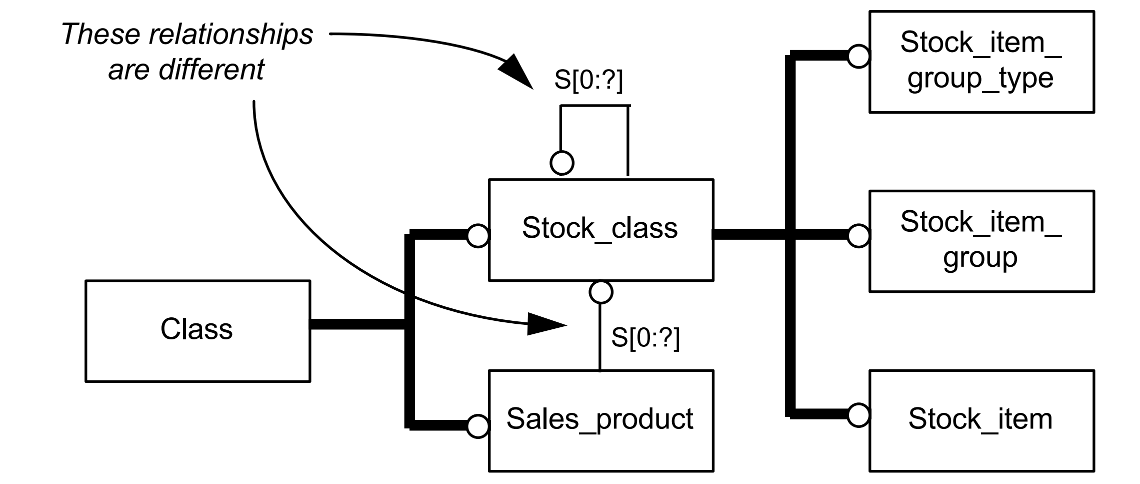


Figure 7-8: Removing more restrictions.

Finally, the Class supertype can be discarded, if you wish, to give the model below in Figure 7-9. The many-to-many relationships should of course be resolved into entity types.

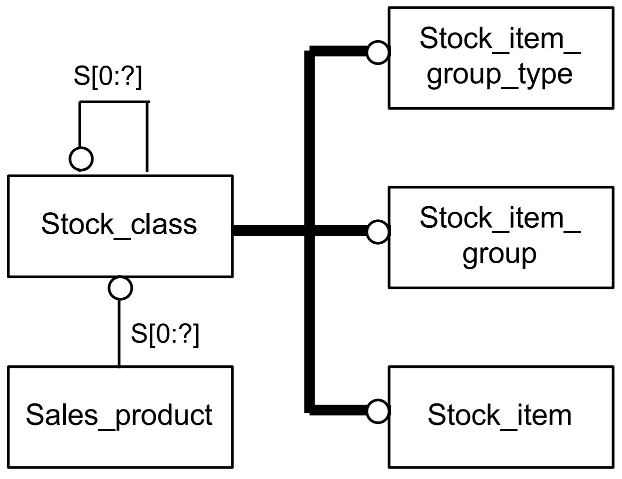


Figure 7-9: The final resolution.

7.6 Principle 5

Representing the roles that objects play, can be quite appropriate in an external model (or view), but it is not appropriate for a conceptual model since the same object can play many roles and we wish to have a single and enduring view of all objects. Thus we get the following principle for entity types used in conceptual data models.

5. *Entity types should represent, and be named after, the underlying nature of an object, not the role it plays in a particular context.*

Thus as a result of this principle, any occurrence of an entity type will belong to it from the time it is created to the time it is destroyed, not just whilst it is of interest. This is important when managing the underlying data, rather than the views on it used by applications. We call entity types that conform to this principle *generic entity types*.

However, subtypes representing roles can be useful to illustrate a business context, and so are allowed provided they have no attributes or relationships that are not inherited from the super type. One way of doing this is illustrated in Figure 7-10 below.

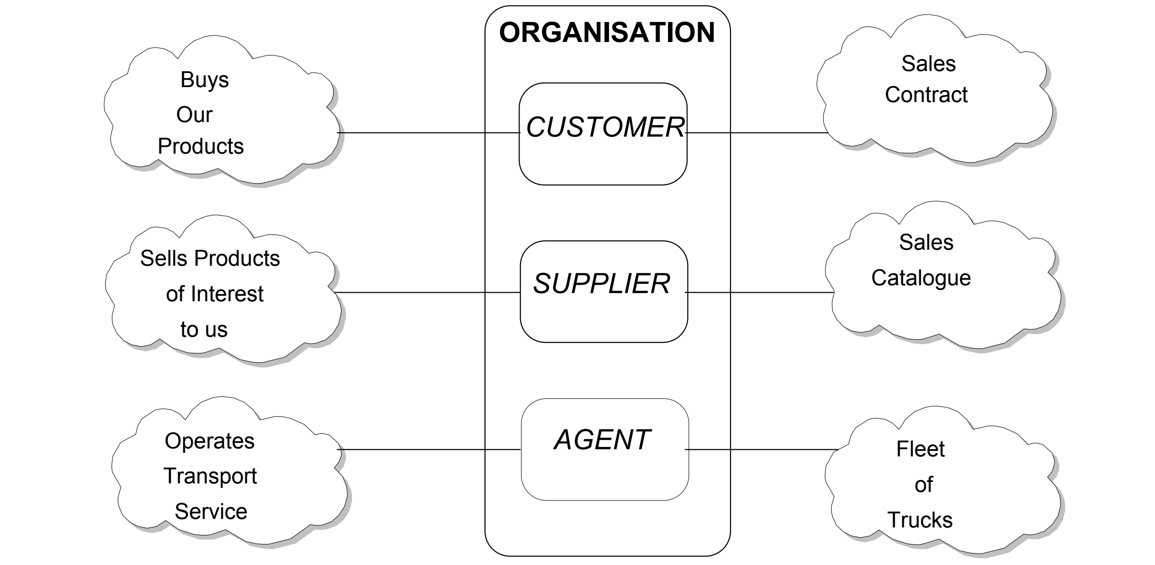


Figure 7-10: Entity types should only represent the underlying nature.

The entity type representing the underlying nature is shown as a super type. The entity types representing the roles played are shown as subtypes. These entity types are given a number of names, overlapping subtypes, populations, or business views. We use the term *population*.

7.7 Context and Scope

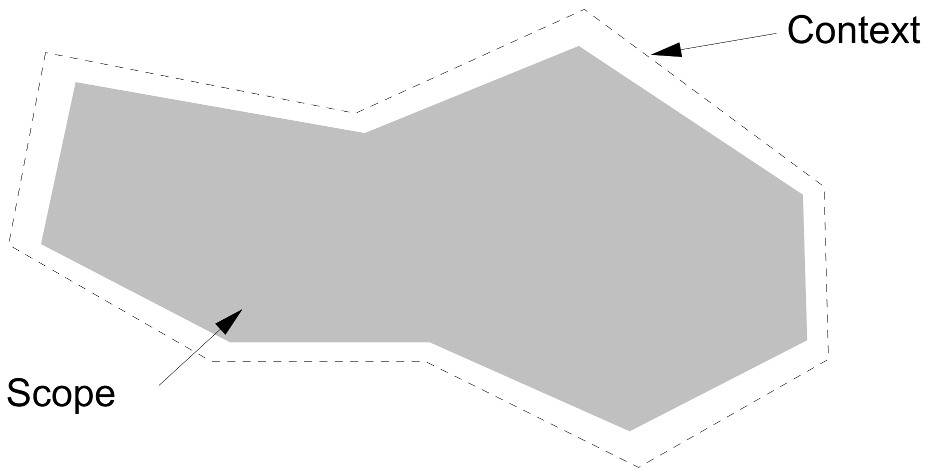


Figure 7-11: The scope must fit within the context for internal consistency

All data models have a context and scope, although they may not be formally defined. The context of a data model is the range within which it is valid, whilst the scope of a model is what it contains. This is illustrated in Figure 7-11 above. Note that the scope of a model is the same as or less than the context (otherwise the model will not be internally consistent). Thus a model might have a context of "sales", but a scope of only "order taking" in this case. It would be possible to expand the model to cover all of "sales" without changing what had already been modelled. A problem that often arises is that when there is a change in business requirements, the addition in scope to the model takes it outside the original context. This is illustrated in Figure 7-12 below.

The result is that the model will have to be redeveloped to change or enlarge the context so that the new scope will fit. Similar problems arise when bringing together models developed independently with different contexts and overlapping scopes.

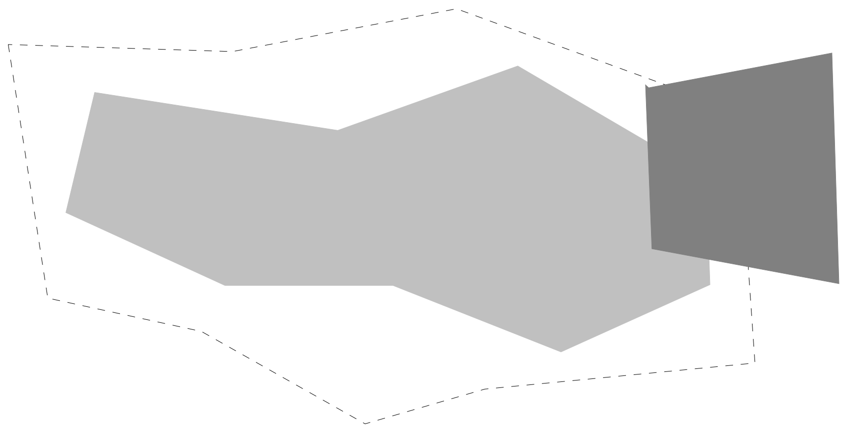


Figure 7-12: Models that are developed in different contexts will be incompatible.

The desirable state is illustrated in Figure 7-13 below. Here, each model is developed within the same context. As a result they fit together, being consistent where they overlap.

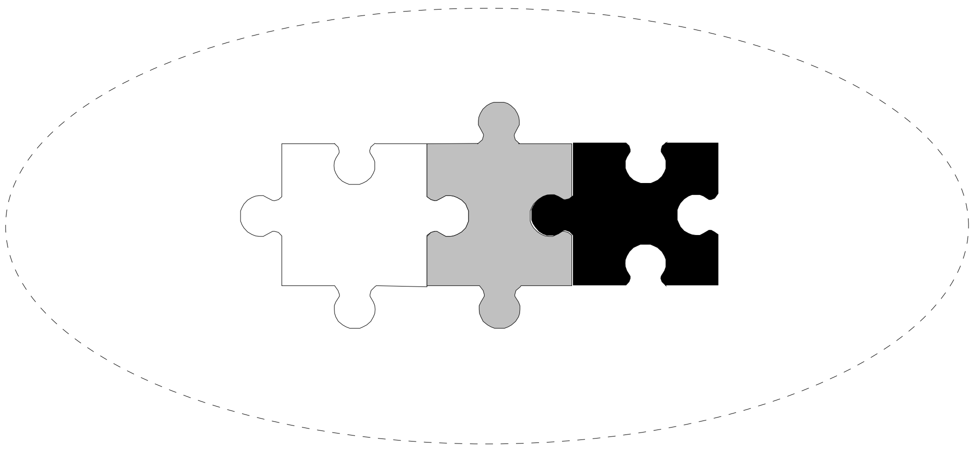


Figure 7-13: Data Models that share the same context, fit together.

The question is, how can you define a common context for data models?

7.8 Principle 6

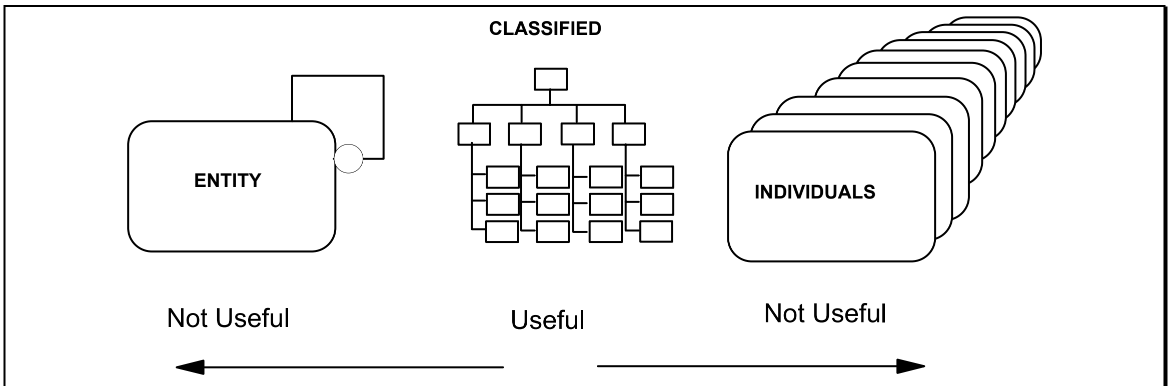


Figure 7-14: A subtype/super type hierarchy must be at the right level to be useful.

An answer lies in a subtype/ super type hierarchy of entity types. This hierarchy must be universal in its context, which is guaranteed if it consists only of generic entity types, even if it is not complete. Figure 7-14 above shows that some care must be taken to ensure that subtyping is taken to an appropriate level. Too high a level of subtyping means that entity types could mean almost anything. Too low a level of subtyping means that you get lost in the detail.

6. *Entity types should be part of a sub-type/super-type hierarchy of generic entity types in order to define a universal context for the model, and to avoid duplication of concepts and data.*

A framework of generic entity types has been developed by EPISTLE, and is presented in "The EPISTLE Framework V2.0".

There are two tests that must be applied when considering a new subtype of a generic entity type: validity, and usefulness. The first is that the proposed sub-type is valid (i.e. it is a generic entity type). This is covered above by principle 1. Usefulness is harder to determine, but the question is really what has been gained in data management terms by making the distinction.

Take for example the two candidate subtypes of *material; artefact* and *natural material*. The distinction between them is that one is man-made, and the other is not. Because the distinction is known at the creation of the objects, and nothing man-made can become not man-made, the subtypes can be considered valid. However, what is gained by making the distinction? Artefacts and natural materials can be bought and sold, moved about, used as raw materials and so on. For this reason, the distinction is not useful.

7.9 Impact of Using the Principles

The result of using the principles is that we now have a straightforward mapping of real world objects to their representation. This is illustrated below in Figure 7-15.

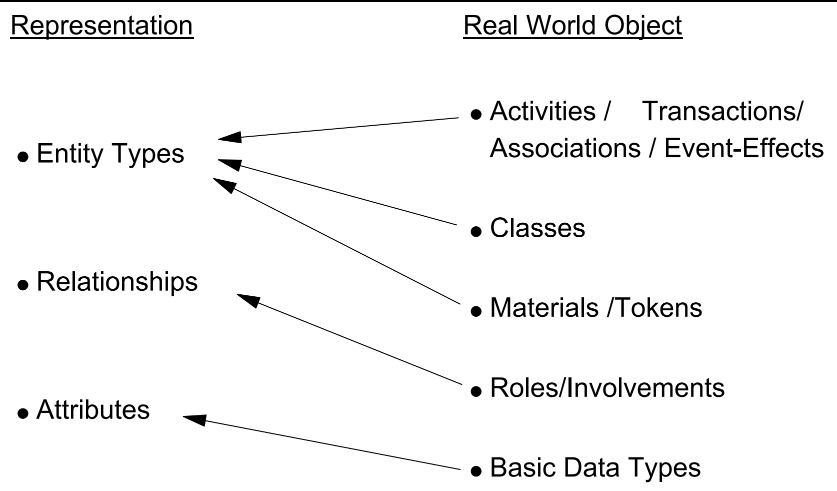


Figure 7-15: Standardised representation of real world objects

The result of applying these principles is that models developed using them can be used for many purposes. This can be illustrated by the following example using a map in place of a data model.

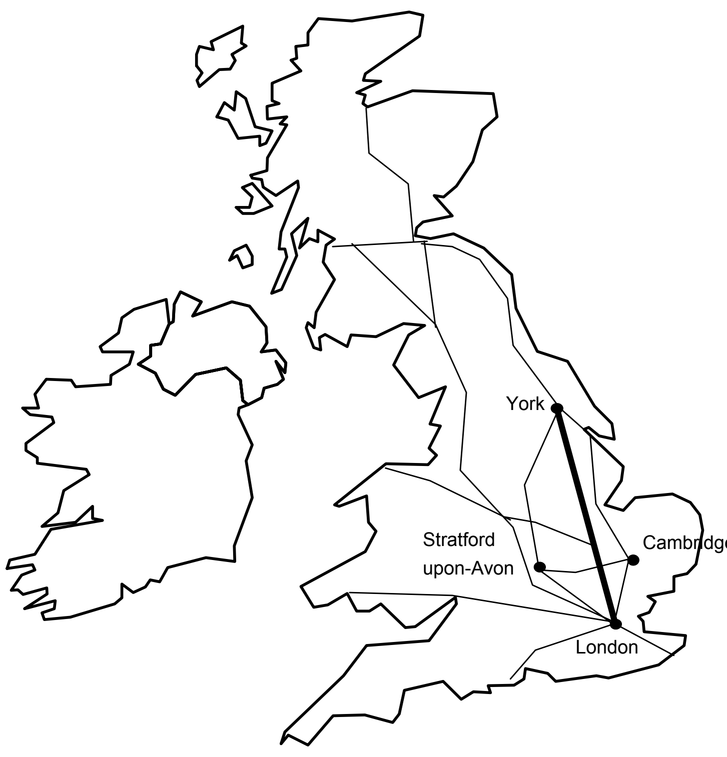


Figure 7-16: Different uses can be made of the same model when it is neutral.

The map illustrated in Figure 7-16 shows some of the roads in the United Kingdom. However, it can be used for many purposes. For example, if you were travelling from London to York on business, you could look at the map and see that the quickest way was to go up the motorway.

However, you might also want to visit York for a holiday. It is a historic town with Roman walls and many beautiful buildings. In which case you might want to take in the sights on the way. You might decide to go via Cambridge, which is a beautiful university town, and perhaps via Stratford-upon-Avon, the birthplace of the famous playwright, Shakespeare.

These different uses can be made of the map because it is neutral to the journey that is taken, or the purpose of the journey. A neutral data model can be used in the same way.

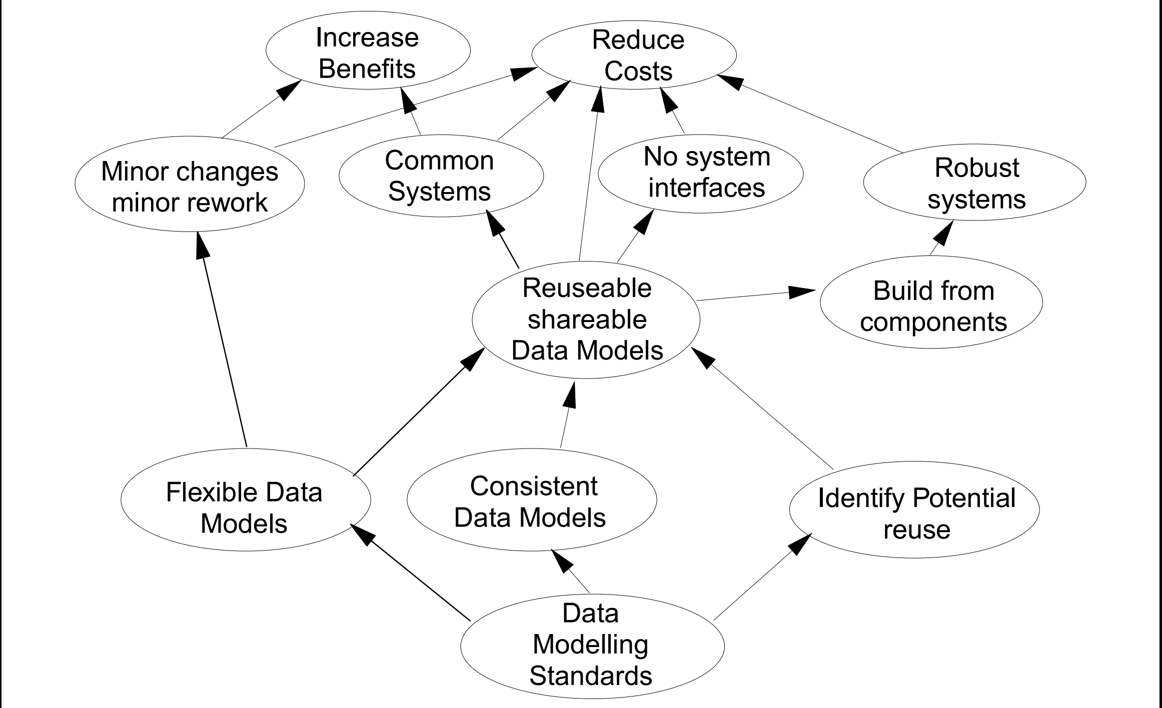


Figure 7-17: The objectives of Data Modelling Standards.

How this works for data models is illustrated in Figure 7-17. This shows that using the principles as a standard helps to develop data models that are:

- flexible,
- consistent,
- enable potential for reuse to be identified,
- reduce the cost of maintenance,
- make developing systems easier,
- reduce the cost of system interfaces, and
- make systems more robust, through using components that have already been tested through use.

8. Ah But ...

There are a number of questions that are frequently asked about the principles in the previous chapter. In this chapter we try to answer some of these questions.

8.1 But What About Performance?

When it comes to implementing systems based on conceptual models that follow the principles outlined here, the default database design can look rather different from a traditional database design. This gives the database a different performance profile, i.e. it does some things better, and some things worse. On balance there is a performance penalty; you don't get something for nothing.

There was a time when performance was an absolute issue. There were physical performance constraints from the hardware that you had to work within. For most cases this no longer applies. If you have a performance problem, you can solve it by throwing more hardware at it. If your application is processor bound, throw more processors at it (2, 10, 20 processors). If your application is I/O bound, strip the data over more disks. There is a cost to this, but then there are benefits too, and a normal business case can be made (or not) based on the lifetime cost of the system (not just project development and implementation costs).

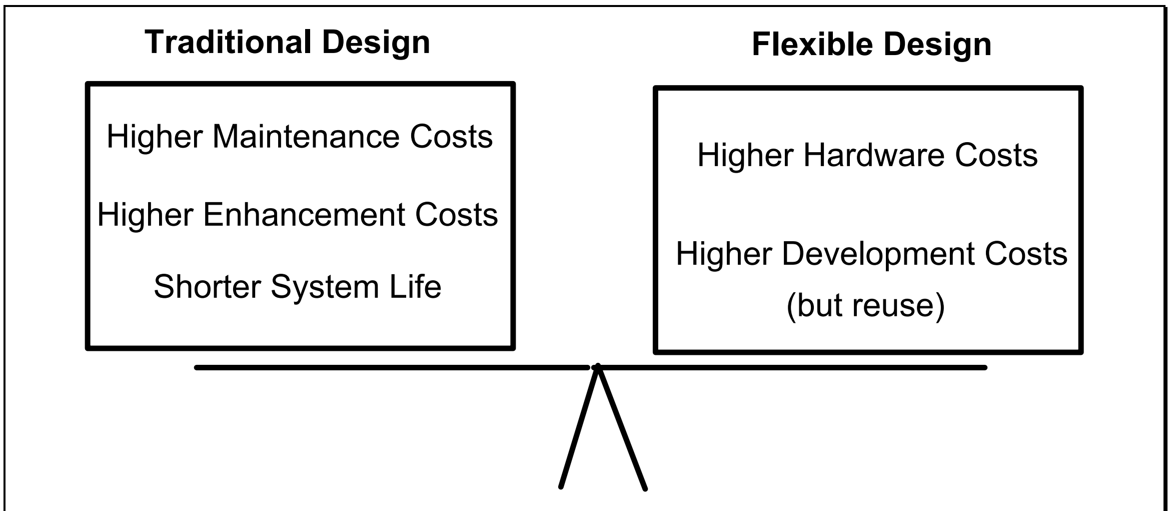


Figure 8-1: The Cost Balance for Flexible Design.

The balance of costs is shown in Figure 8-1. Traditional designs tend to optimise the initial development and implementation cost of a single system, at the expense of higher maintenance costs, higher enhancement costs, and in the end a shorter system life. On the other hand flexible designs require more powerful hardware to achieve the same performance, and have higher initial costs in development (although this will be offset because flexible components can be shared by or reused in several systems).

The relatively static cost of software development versus the plummeting cost of hardware means that the balance will become more and more one sided, in favour of flexible design.

8.2 0.1. But How Do I Implement the Rules?

There is a school of data modelling which is almost completely at odds with the principles we have presented here. They would say that business rules should be enforced through the data model, and implemented in the structure of the data, e.g. an employee can have one and only one manager, implemented by having the manager as a column on the employee table. Only one manager can ever be held.

First, business rules are important. They do need to be held and enforced.

Second, only some business rules can be expressed in the data model, even if that is what you wish to do. There is a prize waiting for the person who can enforce the following rule in the structure of a single data model. "For a car to be allocated to an employee, the car must be owned by the department the employee works for".

The question then is not whether business rules should be expressed, but how. There are a number of good ways in which rules can be implemented in relational databases without affecting flexibility. They are using:

- *indices* to enforce uniqueness constraints,
- *views* to maintain data in pre-defined combinations,
- *referential integrity constraints* to maintain mandatory relationships,
- *stored procedures* to enforce complex business rules on data storage and access, and
- *common modules* to enforce business rules at the application level.

Thus insisting on the structure of your data being flexible places some restrictions on how business rules are expressed and enforced. It does not mean that they can't or shouldn't be held or enforced.

8.3 But I Want a Data Model I Can Show My Users

Data models that enable the sharing and exchange of data are not good for communicating a particular business perspective on the data, but this is often what people need to do, not least to ensure you have understood the requirement correctly!

Traditional entity-relationship diagrams have sometimes been found confusing by users. I was therefore very pleased to discover a set of diagramming conventions that leant themselves to being understood. These were defined by the developers of the CASE Data Interchange Format (CDIF) and have been adapted slightly here. An example model is given below in Figure 8-2.

The conventions are that the boxes are entity types and the arrows are relationships. The relationship is named in terms of the activity which causes the relationship between the entity types. The secret is that the direction of the arrow tells you how to read the relationship. Thus the first relationship is read as "Method contains Phase". People understand how arrows work. In fact you don't even need to tell your users it is an entity relationship model (why frighten them).

It is relatively straightforward to translate between this style of informal data model into a formal data model. Each relationship shown here maps to an entity type which represented the association or activity from the relationships.

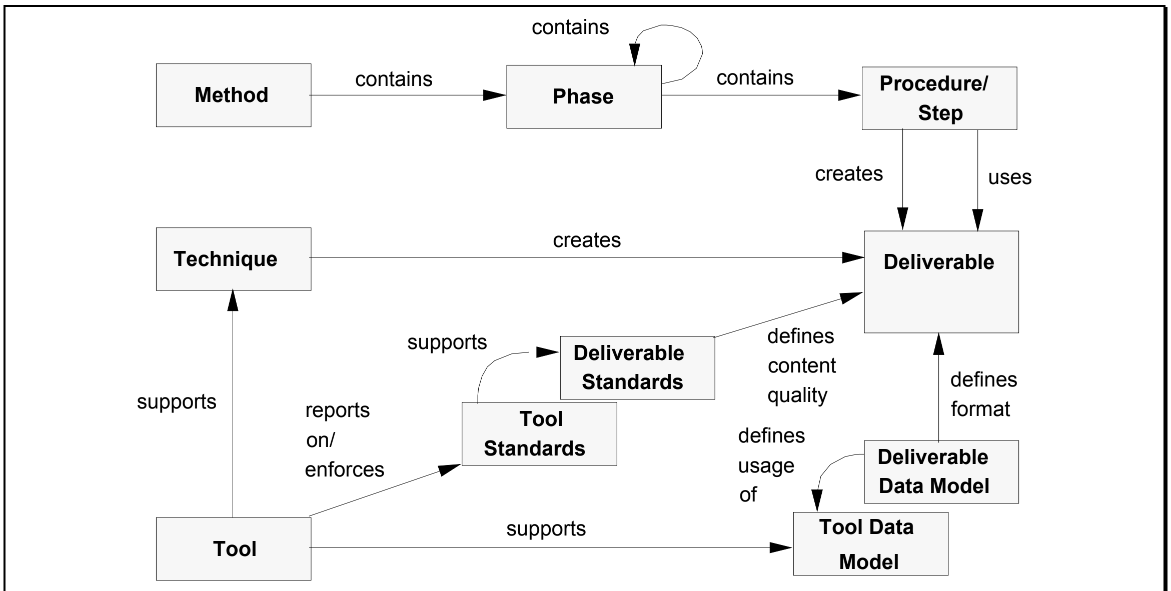


Figure 8-2: A data model using the CDIF notation

8.4 But Won't I Have To Redevelop All My Applications?

From the early days of Information Engineering there was an appreciation that data needed to be shared across the business. The approach then was to create a single Corporate Data Model of all a business's data, and then build systems based on that data model. Several years later, the end of the data modelling phase would not be in sight, and parts of the model would already be changing to reflect changes in the business. Most took a pragmatic stance when they appreciated this inevitability, and restricted the scope of the effort, so that the outcome was the redevelopment of some of an enterprise's systems, effectively producing larger islands of data. The main problem was that the whole enterprise had to be modelled in one go to ensure consistency.

With generic entity modelling this is no longer necessary. Because the standards identified here help to ensure stability and flexibility in data models, small pieces of the problem can be dealt with at a time, building up to a complete solution that fits together. The way this works is illustrated in Figure 8-3 below.

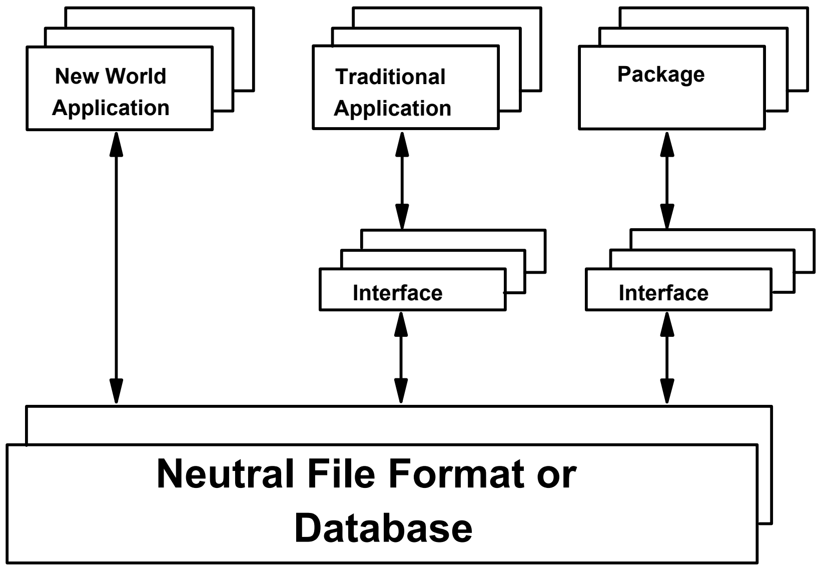


Figure 8-3: The practicalities of sharing and exchanging data between systems and organisations.

Initially, a neutral data model might be developed as the basis for the exchange of data between systems using a flat file. This would have the advantage that only one interface would have to be built for each system, rather than one per system pair. Packages could be interfaced using this approach.

In the second phase the neutral data model might be implemented as a database to act as a buffer between existing systems. New systems could then use this database directly to share data, and extend it with their new requirements.

In addition, existing systems could be migrated to the neutral database as business requirements for concurrent access to data justified the cost.

8.5 But what about Object Orientation?

Here are two questions that get asked about object orientation.

- Is generic entity modelling object oriented?
- Will generic entity modelling be made obsolete by object oriented methods?

Perhaps surprisingly, the answer to both is no. There is a great deal of hype about object orientation that suggests it is fundamentally different. This is not true, as becomes clear when you translate the object oriented words into Information Engineering terms. Take the Object Modelling Technique, proposed by Rumbaugh et al, which is generally regarded as the most complete of the current crop of methods. The basic methods employed are:

- data flow modelling,
- state transition modelling, and
- extended entity relationship modelling.

You may be familiar with all these. They are all well established techniques. The new bits are the extensions to entity-relationship modelling. These allow for multiple inheritance (multiple super-types) and methods in particular.

The hype suggests that these new features are a technology fix which will ensure that reusable components result from the development process. Unfortunately, this is not true. Whilst these new features do *enable* reusable components to be developed, it is not sufficient. It is better to think of the extensions as some more rope lying around the place with which you might hang yourself, particularly in the case of multiple inheritance.

More than ever, understanding the principles of how to develop good models will be important if the benefits promised by object orientation are to be delivered. Fortunately, the principles presented here apply as much to object oriented models as they do to entity relationship models. We expect to add to these principles over time as best practice in using the new features of object orientation emerges.

8.6 But Why Stop Here?

One of the questions we are sometimes asked is "why stop here?" Why not analyse further and make the models more generic?

The answer is that we have done. The next level of analysis takes the current relationships, which represent involvements, and represents them as entity types. This is followed by recognising that associations are derived entity types, and thus only hold data about the activities that cause and terminate associations. Finally, all attributes are represented as relationships to something else, except for the object identifier.

8.6.1 Really Generic!

At about this point you reach a very pure form of theoretical data model known as a *binary relational* model. In a binary relational model no entity type has more than two attributes (including the many end of a relationship). Fortunately, it is not possible to analyse beyond this point. Unfortunately, the data model that results is almost impossible to understand.

8.6.2 Flexible and Stable

The question is "why would you want a data model that generic?" The objective is to have models that are flexible and stable, not models that are generic. It happens that achieving models that are stable and flexible results in models that are more generic than is commonly the case today. Thus the standards presented here ensure that models are generic only where this contributes to stability and flexibility.

8.7 But Won't it Take Longer to Develop Data Models?

If you consider what happens currently, then what you see is that the same requirements are constantly being remodelled. Therefore, developing "better" data models does not necessarily mean it has to take longer because you can reuse existing models for part or all of your requirements. There is already enough work done for this almost always to be the case.

9. Techniques for Creating Data Models

This section contains a collection of techniques we have come across or developed that have proved useful in creating and validating data models. They are offered here as a tool kit for you to use, rather than as a rigid method to be followed.

9.1 Source Material

9.1.1 Activity models, Interviews, and Forms

The ideal situation for creating a data model is to have an accurate, written description of the business area to be modelled, and access to a group of people from the business who can be asked questions when clarification is required, and who can validate the model that is created.

At least some source material will come from interviews: the scope of the business area for instance. However, today it is relatively common to have a good written description of information requirements from activity models, and this should be at least one source for your analysis.

It is also worth mentioning that those who have not been involved with data modelling before often find it difficult to express themselves in data modelling terms. There are two approaches that can be taken. One is to teach them how to understand data models. The other is to model their requirements in a way they are familiar with, e.g. as an activity model, simplified data model, or as forms. The approach to take will depend on those involved. For users assigned to the project it is certainly worth ensuring they understand data models. For requirements gathering from the user community it is perhaps not necessary, and collecting the general data requirements in their terms may be more appropriate.

9.1.2 Existing Systems

One of the more common problems when developing data models for new systems is that whilst they represent what the old system didn't do well, they sometimes don't cover what the old system did do well, because everyone took it for granted, and forgot to mention it as a requirement. It is therefore important to check through the old system(s) (be they manual or automated) to ensure you model all the things that need to be modelled. Discarding functionality and data should be a conscious decision.

9.2 Workshops

One of the most powerful ways to get a data model that stakeholders are committed to is to involve them in its creation. Creating the model in a workshop is an effective way of doing this. It brings stakeholders together, ensuring that they see other stakeholders' perspective on what is being modelled, and enables conflicts to be more readily identified and resolved.

A workshop session should involve between 4 and 6 people to be effective. One member of the team should be expert in the modelling techniques and act as facilitator. For large modelling exercises, modelling sessions can be held in parallel with the results fed back to the whole group in plenary.

9.2.1 Mapping to the Generic Entity Framework

Ideally you will be starting from an agreed text describing the area to be modelled, often an activity model. The approach to take is to identify (underline) the key words (nouns and verbs) in the description.

The next task is to map these words to the Generic Entity Framework. Often it will be necessary to ask additional questions to clarify what is meant in order to be able to place the word in the framework. This is an important part of the analysis process. The following are the minimum set of questions that should be asked.

- Is this a particular thing, or a type of thing (differentiates between *instance* and *class*)?
- What Subject (*activity, association, material,* etc.) does it fall under?
- What Qualifier (*actual, planned,* etc.) does it fall under?

Often you will find that the same word falls in more than one place. This is quite normal and can be for a number of reasons.

- The word represents a complex concept.
- The word is a homonym (has more than one meaning).
- The discussion brings related concepts to light.

When this happens all the mappings should be considered valid, at least initially. Additional mappings should be created and added in the relevant place, perhaps with a qualifying word or number to differentiate them.

Using these templates small pieces of model (fragments) can be developed and put together to realise models that are both large and consistent.

9.2.2 Selecting and Using Templates

Applying the principles identified here makes it relatively easy to develop data models by starting from the key activities and associations, and then identify what other things are involved in them. This is one reason why activity models make such a good source of material for developing a data model.

Starting with the activity or association, look through the templates in the "EPISTLE Framework" to see if any of them applies. Remember that many business activities can be decomposed into simpler activities.

If a template can be found, then the next step is to identify what plays the various roles identified in the template for your situation.

If you cannot find an existing template, then you need to create one by identifying the different things that are involved in the activity or association.

9.2.3 Use of Populations to Illustrate Usage

The formal entity types in the model are the generic entity types from the framework, because they will be the basis for consistency and sharing across models. However, it is desirable to make the current usage of these entity types clearer. This can be done by adding populations to the data model.

Populations are illustrative sub-types of the generic entity types. They illustrate a particular context, and are allowed to overlap with each other. For example, whilst *customer* and *supplier* do not pass the test as generic entity types, they are quite acceptable as populations.

The key rule about populations is that they do not have relationships or attributes, except those which they inherit from the generic entity type they belong to.

9.2.4 Using Examples To Check The Model

Once the model fragment around an activity or association has been created, check it out with example data. This helps to ensure the model does what you think, and also helps to clarify what the model represents.

9.2.5 Resolving Conflicts

Conflicts are common when developing data models. Hard debate is one of the best ways to discover the truth. However, it is important to remember that it is the merits of ideas that are being debated, not the merits of people. One of the most important things to realise for a facilitator, is that in cases of conflict the challenge is to find out how it is both sides are right.

Arguments are most often over words and what they mean. It is important to understand that for the model it is the meaning rather than the word that represents it that is important. One way to separate the word from the meaning is given below.

"Call it a duck" is the battle cry, and then get each of the protagonists to describe what their "duck" is. Usually, you will discover that two different things are being discussed, described by the same word (homonym). Afterwards names can be chosen to distinguish the two different concepts.

Another common problem is that people want different names for the same thing (synonyms). That's OK. You don't have to choose. Just concatenate them. Then everyone is happy. Eventually, a natural selection process takes place, and one of the names, or a new one emerges. We once had an entity type called *characteristic/ property/ specification*!

When the discussion is about relationships, you may find people trying to enforce business rules through the cardinality. "But we never have more than one manager for an employee". Point out that it isn't necessarily always true for everyone. Try to think of when it is not the case, "We might want to keep the history of whom an employee has been managed by" might work in this case. Point out that the model does not prevent them from having only one manager per employee. It just doesn't enforce it for others. Capture the rule in some other way, e.g. in the definition of the employee population.

Sometimes users or system developers will not like the model you produce because it doesn't reflect how they see things. Remember, it isn't supposed to reflect a particular view point, so this may happen quite often. However, the model is supposed to meet the data requirement, so you should ask the objector to identify data that the model does not hold (remember data, not rules). Examples should be required to justify any complaint. If you cannot demonstrate how the example data can be held, you need to extend your model, (this is the only sound basis for objection).

Sometimes an issue may have been discussed, and you have gone round in circles a couple of times without reaching a resolution. The most likely reason for this is that you are missing the information needed to resolve the issue. Log the issue and move on. Something usually turns up later to resolve it that is unknown or unclear now.

9.3 Documenting Data Models for Others

Data models are often documented in a way that is unclear or ambiguous, so that readers will have a number of questions about the intention of the model. This is not to say that the originator of the model did not know what the model was supposed to represent, but that it had not been communicated. Too often data model documentation is only useful to the author(s) of the data model. This is a severe curb on obtaining useful comment on the model, or in getting it used by others.

9.3.1 Subject Areas - Size and Layout

The first point is that entity relationship diagrams should be kept small. Preferably not more than 10 or so entity types. This means that most data models will have to be split up into a number of diagrams or subject areas.

The reason for limiting the size of a subject area is so that the data model can be seen and understood with a particular focus. A single diagram with perhaps several hundred entity types leaves you wondering where to start, and what is relevant in your circumstances. Using subject areas shows you what is relevant for your situation, and gives you a place to start.

You will notice that the data model diagrams in this document have a distinctive style which we recommend because it both helps to lay out and read the diagrams. Relationships are horizontal, and thus so are the relationship names. You can then read the diagram from left to right, rather than round corners.

9.3.2 Subject Area Descriptions

Accompanying the diagram there should be a description of the diagram in plain language. The objective should be both to explain what the diagram means to those who cannot read the model, and to provide a cross check for those who are reviewing the model of what it is supposed to represent. It is useful to document key concepts, how you have modelled these, and any unresolved issues here too, since these will help others to understand what you have done.

9.3.3 Examples

Adding examples to the subject area diagram is a great aid to explaining what a model means. The examples of each entity type should be from one or more consistent examples, and the example should be talked through in the subject area description.

9.3.4 Entity Type Definitions

Unfortunately, entity type definitions are often ambiguous or unclear. We recommend the following general structure for a definition:

> A *(reference to supertype)* that *(distinguishing features)*.

For example, the definition for *process plant* might read:

> A *facility* that is used to transform feedstocks into products.

Referring to a generic entity type clearly identifies the type of thing that is being referred to, whilst the distinguishing features will tell what makes these different from others of the same generic entity type.

For association entity types the form of the definition should be:

> An association that indicates an *(entity type name from one relationship)* is *(nature of association)* for an *(entity type name from other relationship)*.

For example, the definition for the entity type *storage (of material)* might read:

> An association that indicates a *material* is stored in a *facility*.

Notice that the formal definition is clear, concise, and unambiguous (i.e. you could look at something and say whether or not it belonged to the entity type). Definitions with words like 'and', 'or', or 'where' in them should be viewed with suspicion.

As well as the formal definition, additional notes may be added as to the interest in the entity type and how it may be used. Special restrictions and business rules may also be added here.

Finally, examples should be included to confirm the meaning.

9.3.5 Entity Type to Subject Area Cross Reference

It is important to understand the usage of different entity types. You should therefore create an entity type to subject area cross reference that shows the subject areas an entity type appears in (the cross reference the other way is best found by looking at the subject area diagrams). This can be generated from most CASE tools, and can be conveniently documented with the entity type definition.

9.3.6 Estimating Guidelines for Documentation

Documenting data models (as opposed to developing them) to this standard does not come free. Our experience is that it takes about one man month to document 100 entity types to the standards identified here.

10. EXPRESS-G Notation

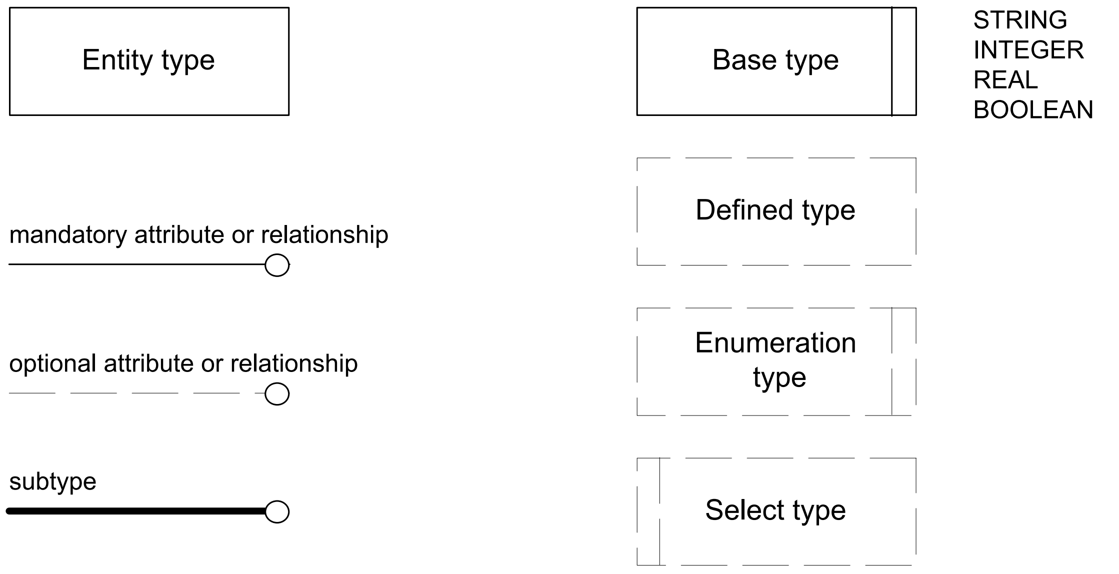
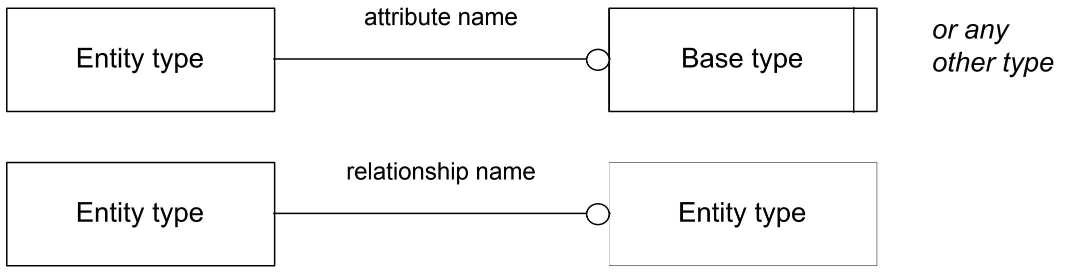
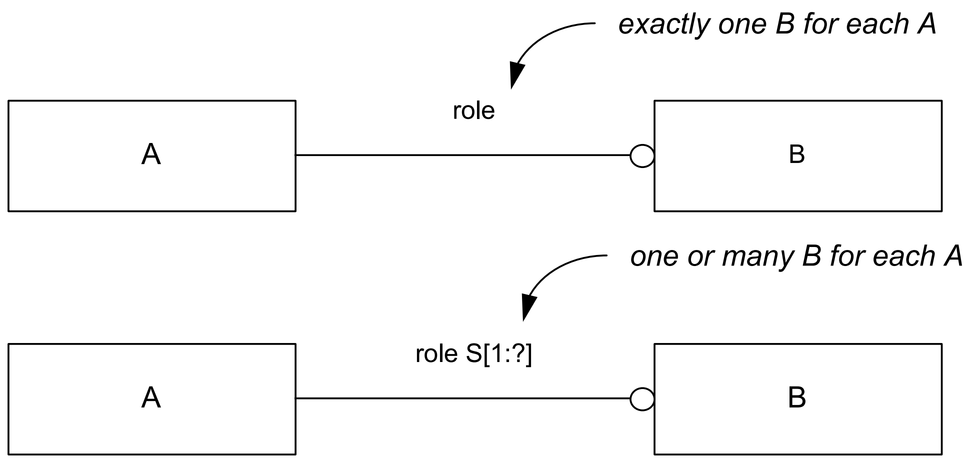


Figure 10-1: Data Model notation.



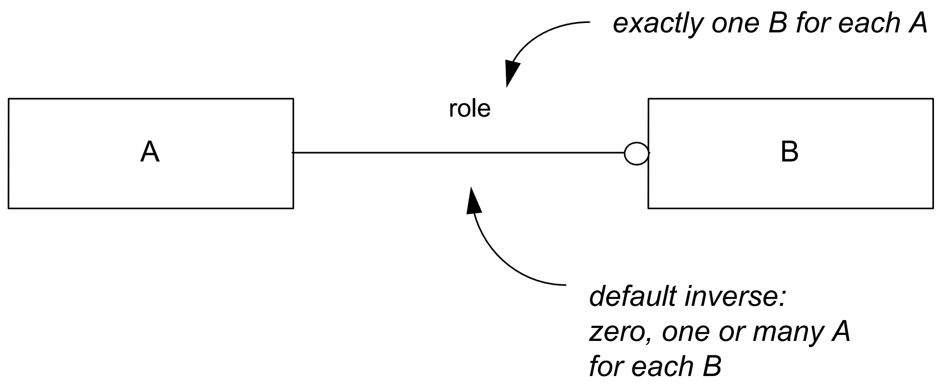
- ☐ An attribute specifies the role played by a base type (or an enumeration, select, or defined type) in the definition of an entity type.
- ☐ A relationship specifies the role played by an entity type in the definition of another entity type.

Figure 10-2: Attributes and relationships.



- ☐ EXPRESS-G specifies the cardinality of an attribute relationship in terms of an aggregation (SET, BAG, ARRAY, LIST).
- ☐ In this course we are mainly interested in cardinalities, so we assume that all aggregates are SETs.

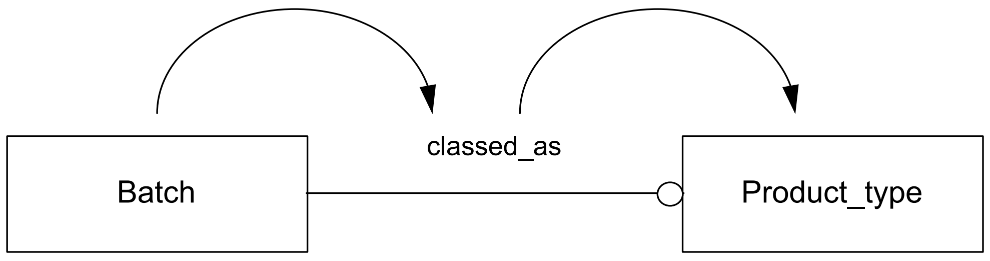
Figure 10-3: Cardinalities.



- ☐ Every relationship has an inverse.
- ☐ Default is that the inverse relationship is not named, and that the cardinality is zero, one or many.
- ☐ Naming the inverse allows this to be constrained.

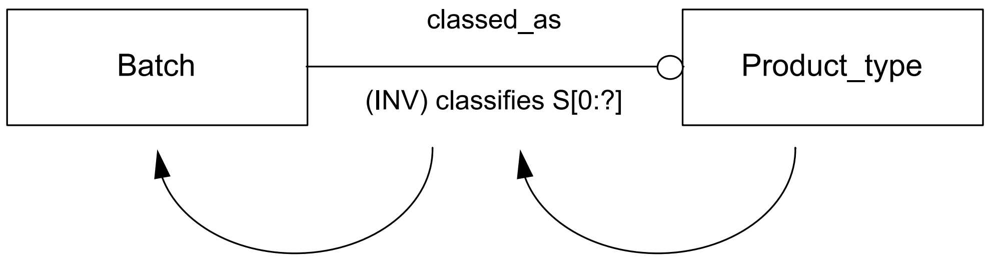
Figure 10-4: Inverse Relationships.

The boxes represent entity types and the lines between them relationships. Figure 10-2 to Figure 10-4 above show the meaning of the symbols used for relationships. The relationship between two entity types can be read in either direction as indicated in Figure 10-5 and Figure 10-6 below.



- Read in the direction of the "lolly-pop".
- **Batch** - classed as - **Product type**.

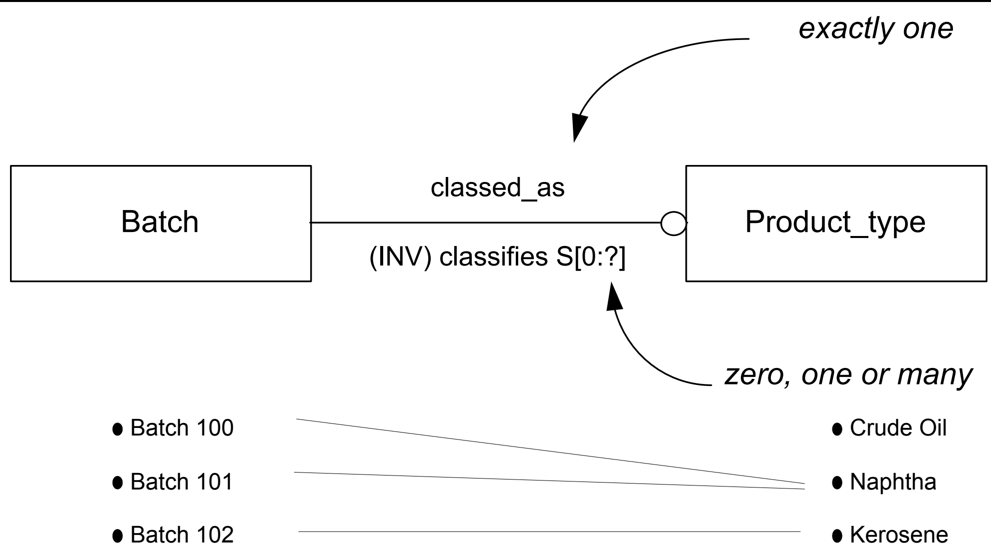
Figure 10-5: Reading the relationship from Batch to Product Type.



- Read the inverse in the opposite direction.
- **Product_type** - classifies - **Batch**.

Figure 10-6: Reading the relationship from Product Type to Batch.

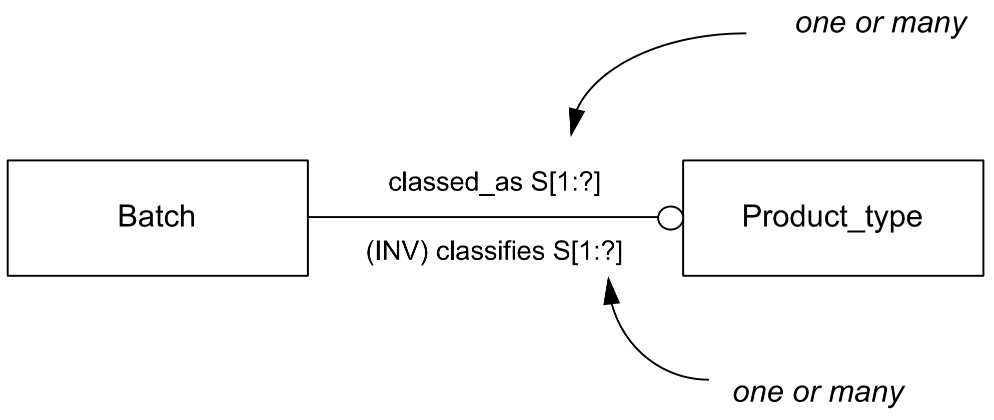
This is often as much as required for business use, however, the diagrams do say more about the number of entities (instances) at one end of a relationship that may or must be involved with an instance at the other end. This is referred to as the cardinality of a relationship. The meaning is explained in Figure 10-7 and Figure 10-8.



☐ **Batch** - classed as one - **Product type**.

☐ **Product type** - related to zero, one or many - **Batch**

Figure 10-7: Default maximum cardinalities.

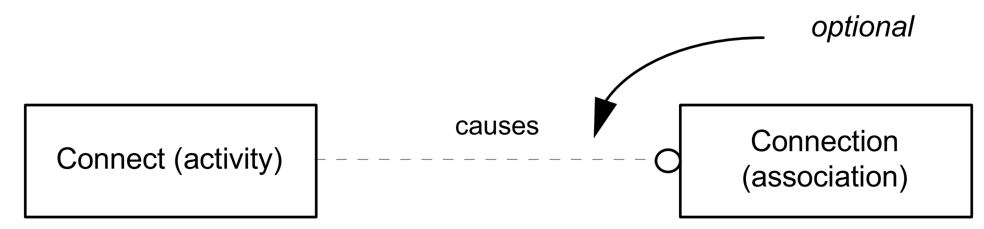


☐ **Batch** - classed as one or many - **Product type**.

☐ **Product type** - related to one or many - **Batch**

Figure 10-8: Reading the diagram with maximum cardinalities.

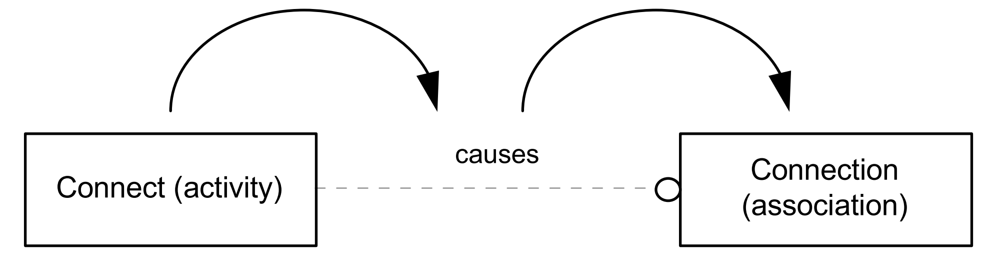
Optional relationships are drawn with a dashed line as shown in .



- ☐ In EXPRESS, OPTIONAL means "this attribute/relationship exists, but it is not necessary to hold data about it"

Figure 10-9: Optional relationships

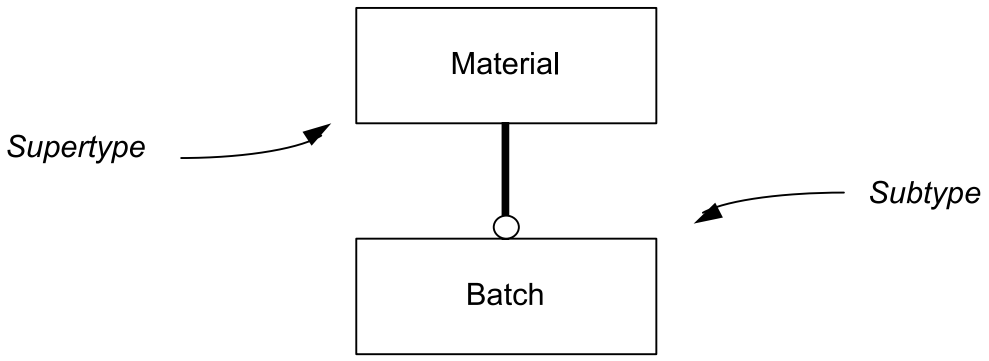
Optional relationships are read as illustrated in Figure 10-10.



- ☐ A connect activity may cause exactly one connection (causes zero or one connection)

Figure 10-10: Reading minimum cardinalities on an optional relationship.

Subtypes are shown linked to the supertype by a thick line with a lolly-pop at the subtype end, see Figure 10-11. Thus *batch* is a subtype of *material*.



- ☐ A **Batch** is a type of **Material**.
- ☐ All **Batches** are **Materials**.
- ☐ Some **Materials** are **Batches**.

Figure 10-11: Subtypes and Supertypes.

Additional conventions that are observed here are that the set of subtypes does not necessarily completely cover the membership of the super-type. Also, overlapping subtypes, or *populations* are represented as subtypes, but with the name in italics.

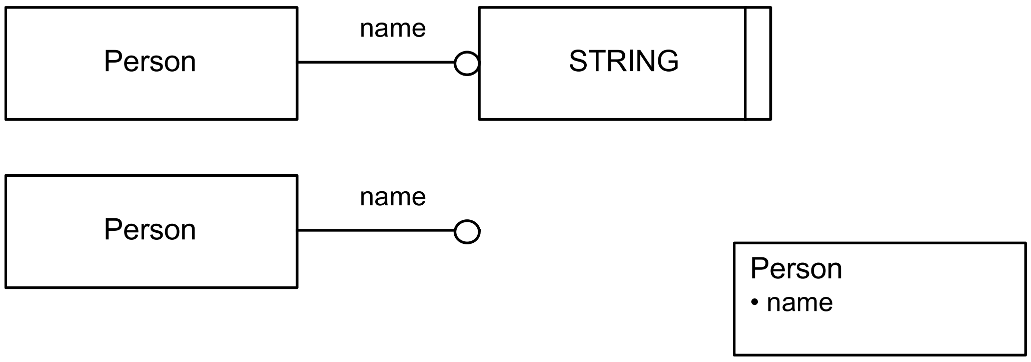


Figure 10-12: Attributes

Finally, attributes are depicted as shown in Figure 10-12; in order to save space in diagrams, EXPRESS-G allows the base type or defined type symbol for an attribute to be omitted (the case where just the “lollipop” is shown). However, even this form can lead to cluttered and potentially confusing diagrams. Therefore, we sometimes use the third option shown: this *not* standard EXPRESS-G, but borrows from IFEF1X, Oracle*CASE and other entity-relationship notations in listing the attributes by name within the box that represents the entity data type.