1.6 Exercises

1.6.1 Organisational Information Systems

Consider the example of a large supermarket chain such as Pick ‘n Pay.

- Identify a typical activity that would be recorded using the Transaction Processing System. How often would such an activity occur, and what member of staff would be responsible for recording it ?

- Operational management is responsible for monitoring routine daily activities. Suggest a regular weekly report that might be produced by the MIS, which includes information based on the activity you have just identified. Can you think of a situation in which this activity might be included in an exception report, in order to draw attention to a potential problem ?

- Tactical management are responsible for forward planning, based on a combination of MIS reporting and forecasting with the aid of a DSS. What sort of decision about future business operations might incorporate information about the activity you originally defined ?

- Strategic management make use of external as well as internal data in developing long term business strategies. What examples of external data might be relevant to the strategic planning of a supermarket chain ?

1.6.2 Using Corporate Information

Make a list of all the different organisations that are likely to have recorded your personal details (UCT, sports club, cellphone company, hospital, school, church etc).

- In what ways could this information have been useful in monitoring the (past) activities of the organisation?

- In what ways could this information be used for future planning?

2. Transforming Data into Information

In everyday speech, we do not always draw a clear distinction between the terms “data” and “information”, but the difference between the two is vital to the understanding of what IS is all about. Data is a collection of raw facts, each one of them insignificant when viewed in isolation. The purpose of an information system is to process that collection of raw facts in some way, so as to produce information that is useful to somebody.

For example, if the telephone directory contained a random assortment of names, addresses and telephone numbers, in no particular order, and with no logical association between names and phone numbers, it would be of no use to anybody. The facts (data) might all be present, but the information value of such a directory would be worthless. By associating each phone number with the name of the corresponding subscriber, and by sorting the list in alphabetical order of surname, information is produced. This helps to illustrate the inherent complexity of any information system – first you need to define what purpose it is going to serve (i.e. what information you want to produce), then you need to identify what data will be required in order to generate that information, work out how the data will be captured, how it will be stored, how it should be processed to get the desired result, and how the resulting information should be communicated to the person needing it.

Viewed in this way, we can see that data and information have very different characteristics.

2.1 Data

Since facts are *about something,* data *refers to* some outside object, event or concept. Data does not necessarily have to refer to a *physical* object: it can be about concepts (I think therefore I am a thinker; my bank balance is R4321.01 in debit), relationships between objects (I live in Oubordvolwater), etc. but it does pertain to an objective real world “out there” which the information system seeks to describe or model. Often the data model is an incomplete model since we are usually just interested in certain aspects of the real world. Alternatively, a complete model may consume too many resources or not be practical.

It follows logically that facts or data have a ***truth-value.*** They are *true* if they reflect the state of the outside world accurately. Of course, they can also be *false,* as is the case in the last two statements. Sometimes, it may not be possible to check the truth-value; in this case, the truth-value of the data element may be ambiguous.

Also, data has to be *represented* somehow. This representation can take one of many forms, all of which boil down to some particular structuring (pattern) of matter or energy. You have one example in front of you: this sentence consists of shapes made up of black ink particles on a white sheet of paper! (It can also be dark grey on light grey, depending on the print and paper quality.) We will discuss the representation issue in more detail later.

The fact that data is represented in a matter or energy form leads to another characteristic of data: it is *encoded* using a specific symbolism and the data can be understood only if one knows how to *decode* it. The symbolism can be a certain language and its written alphabet, a digital (numerical) representation of sound frequency (compact discs), the colour and shape of flags (ship-to-ship visual signalling) or any other agreed code. Often many different options exist depending on need: an English message could be spoken or “signed” in sign language, written using the “normal” alphabet or in shorthand, in Braille, in Morse code, in bar code etc.

A final characteristic of data is that it can often be *structured* quite easily into a standard format and grouped into large sets of similar data items, especially in organisational contexts: address lists, customer records, inventory details, personnel records.

2.1.1 Representing Data

Data can exist only if it is encoded using some form of structured matter or energy. The actual physical encapsulation (in matter or energy form) of the data is its ***storage medium***. The following are just some examples of how data can be represented.

- Ink particles on a piece of paper or other material (book, packaging, T-shirt logo, graffiti)
- Polystyrene lettering or logos on a promotional in-store display board
- Needle pins on a city map (indicating e.g. locations of recent robberies)
- Magnetic polarisation of suitable materials (music tapes, floppy diskettes)
- Light pulses through air or glass fibre (flashing lighthouse, laser light in optical fibre)
- Electronic pulses through copper, etc.

The way that data is represented within a computer system, is dictated by the fact that the basic electronic circuit inside a computer can usually manage only two different states: ON or OFF, i.e. either electricity is flowing or it is not; or, depending on which circuit we are discussing, it either holds an electrical charge or it does not. This is why computers are called binary: they can work only with two values (“bi” means two as in bicycle: two wheels). The ON and OFF state can represent, depending on convention, a “Yes” or a “No”; a “True” or a “False”; a “0” or a “1”. Or, in fact, anything else that could be coded using only two discrete values: positive/negative (numbers), white/black (printing), open/closed (switch), in/out of stock, registered or not, pass/fail etc. In this sense it can be said that computers can count only... one ... two!

Anything that can be encoded using only a single one of these simplistic “On/Off” electronic circuits is said to consist of **one *bit* of information**. The word *bit* is allegedly derived by contracting the term “binary digit” because computer scientists usually represent these two states by means of the two digits 0 and 1.

A bit is the smallest unit of information, everything less than a bit is nothing! Unfortunately, most data is far more complex than “Yes/No”. But, amazingly, even the most complex information can be represented using these simplistic binary circuits.

2.1.1.1 How Computers Store Numbers

We are all familiar with the decimal numbering system, based on the number 10. In this system, the available digits are 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9, i.e. for every number position, there are 10 possible options. Numbers consisting of multiple digits are computed based on powers of 10. For example, consider the number 4075. The value of this number is computed in the following way (from right to left):

5x1 + 7x10 + 0x100 + 4x1000 = 4075

Since computers are inherently based on the idea that their components are either on or off, this is usually represented in terms of binary numbers, where all digits are either 1 or 0. This means that for every number position there are only two options, 0 or 1. Numbers consisting of multiple digits are computed based on powers of 2 (since there are only two possible options for each position). For example, consider the number 11001. The value of this binary number in decimal terms would be computed in the following way (from right to left):

1x1 + 0x2 + 0x4 + 1x8 + 1x16 = 25

In decimal numbers, each "column" is 10 times the column to its right, so from right to left we have units, 10s, 100s, 1000s, etc. With binary numbers, each column is 2 times the column to its right (because a column can hold only two possible values, 0 or 1), so instead we have units, 2s, 4s, 8s, 16s, 32s, etc.

Thus to translate a decimal number into binary format, so that it can be stored and processed by a computer, we need to determine how many 32s, 16s, 8s, 4s, 2s and 1s the decimal number contains, and indicate the presence or absence of each of these by using a 1 or 0 in the correct column position. For example, the decimal number 43 consists of a 32, no 16, an 8, no 4, a 2 and a 1 (32+8+2+1=43), and would be represented in binary as 101011. In practice, numbers are usually represented in groups of at least 8 bits; and more commonly, 32 bits are used to allow for the storage of extremely large numbers.

2.1.1.2 How Computers Store Text

Much of the data in which people are interested does not consist of numbers but rather of text e.g. names, addresses, descriptions and sentences such as "The Bulls have won the match!" Any piece of text is composed of a collection of *alphanumeric* symbols: letters, punctuation marks and spaces. Our roman alphabet letters (both upper and lower case), the digits 0 to 9, the punctuation symbols as well as a number of "special symbols" which are commonly used in text such as the $ or the %, together add up to about 100 different *characters*. Since we already have a way of storing numbers in binary form, it is a simple matter to just assign a number to each of the characters we wish to represent. There are indeed a number of international standards for this: EBCDIC and ASCII are the two most common ones. Text is therefore commonly represented in a computer using bit sequences, which represent the numbers of the various characters which make up the text, according to some standard list of character codes. Although 7 bits would be sufficient to store up to 256 different binary codes, for technical reasons it turns out that it is easier to use groups of 8 rather than 7 bits; so text is usually stored in computers by encoding each character of the message in "clumps" of 8 bits. These sets of 8 bits are called ***bytes.*** Our "The Bulls have won the match!" sentence therefore would be represented by a sequence of 29 bytes.

Two notes to round off this section:

- As computers are being used in many countries that do not use Roman characters, the standard set or list of characters is being enlarged to include many more characters. This means that more bits are required to code each character (e.g. 2 or 4 bytes or 16/32 bits in Unicode). Do you understand why?
- Some of you may by now have realised that there is another method of storing numbers. Since a number can be written out in decimal form (as in "12876"), it is possible to encode each digit separately and store the number as a sequence of "text" characters. E.g. instead of calculating the binary equivalent of the number, you could store the it as a sequence of five characters, "1", followed by a "2", "8", "7" and "6". This method is not quite as efficient as the first method since it requires more space. (As an exercise, you should check how many bits or bytes would be needed to represent 12876 using its equivalent binary number and using text representation.) Also, computers are much better at doing number arithmetic in their native binary number representation.

32	65 A	97 a
33 !	66 B	98 b
34 "	67 C	99 c
35 #	68 D	100 d
36 $	69 E	101 e
37 %	70 F	102 f
38 &	71 G	103 g
39 '	72 H	104 h
...	...	...

Table 2.1. Decimal equivalents of some ASCII codes

2.1.1.3 How Computers Store Sound

The same principle applies here as with storing text: we need to find some way of translating sound into a sequence of numbers. This process is called ***digitisation***. It has been discovered that voices, music and any other sound signals are completely defined by the shape of their sound waves: their frequency. (We ignore the loudness or amplitude here for simplicity.) To make an almost perfect recording of any sound signal, all one needs to do is to check or *sample* the sound signal many thousands of times a second and record the frequency of the signal at each interval. This frequency can be represented as a number, typically below 20 000 (Hertz). One second of sound can therefore be represented as a long (say many thousands) sequence of numbers, each number corresponding to the frequency of the sound at each fractional part of a second (a *real* split-second!). If this seems like a lot of data for a short time of music, you're right! As you may have guessed, this is the way music or sound is recorded on compact disc, digital audio tape or sent between digital cellular telephones.

This discussion should explain why there is a trade-off between the amount of data and the quality. You can increase the accuracy of the sound by using larger numbers to represent the frequencies (a popular choice is between 8 or 16 bits). And you can increase the sampling rate (how many times per second the frequency gets "checked" or converted into a number, or in how many parts you split the second). Doing so will increase the fidelity of your data i.e. the quality of your digital recording. But: you also increase the total number of bits you require!

It should also be said that there are many alternative ways of representing sound in digital format, often vastly more efficient but typically less universal. For instance, the different notes of sheet music can easily be converted directly to numbers, without having to convert them first into frequencies. This is the principle behind MIDI-based music. This method would require less than one-thousandth of the number of bits generated by a sampling method!

2.1.1.4 How Computers Store Graphics

How can a computer store a picture of, say a mountain? Again, we need to find a way of converting the picture into a set of numbers. This is done in a manner very analogous to digitising music. Basically a picture is divided into many tiny squares or dots ("*raster-ised*"). If you look closely, you can still make out these dots on a television tube, newspaper photograph print or the printout of a low-quality computer dot-matrix printer. Each dot represents a tiny fraction of the overall picture and is therefore called a *picture element* or ***pixel***, which is then converted into a number. For a black-and-white picture this number will indicate how light or dark the pixel is, using a *grey-scale* of say 0 to 100, with 0 representing very white and 100 very black. (A real grey-scale will again use a "funny" number based on a round power of two – usually 256, which equals 2x2x2x2x2x2x2x2 and takes exactly one byte!) Colours can also be coded although not quite as straightforwardly. Colour coding is based on the fact that all colours are basically a combination of three primary colours. Three numbers representing the percentage of each primary colour to be used will uniquely reflect any colour of the dot. As with sound, the more accurate the numbers (more bits!) for each colour and the finer the raster grid, the higher the quality of your picture but also the more data is required. A good quality picture could easily require many millions of numbers to encode.

2.1.1.5 Animation and Movies

To record animation or "moving pictures", we make again use of the "time slicing" technique. Anyone who knows some of the technicalities of film movies or television is aware that the human eye can easily be fooled into seeing movement if shown a series of still pictures in quick succession. A film is indeed nothing but a series of photos taken at intervals of about a thirtieth of a second, which are shown rapidly one after the other. This is also the way cartoon movies are made: several tens of slightly different drawings have to be made for each second of movement. So digitising movies involves nothing but storing many, many successive pictures, often together with one or more sound tracks! Needless to say, this involves huge quantities of numbers.

2.1.1.6 Limits to Computer-based Data Processing

From the previous discussion, you have hopefully developed a more general idea of how data gets stored on computers. We experience the real world as continuous: time and space can be divided into as small a piece as we want. Digitisation involves slicing and cutting a big chunk of information about an object into very small elements and somehow catching the essence of each of these elements in a number. Usually there is more than one way to do this and often incompatible competing "standards" exist.

The question naturally arises: *can all data be digitised?* This is still an unresolved question. The following are just some of the limits to our current computer technologies.

- Digitisation of sensual data such as smell or taste is currently at a very primitive stage, although some success has already been achieved.

- Another problem area is accuracy: digitisation of real world objects is always an imperfect approximation of reality; sometimes we encounter limits to the precision that can be obtained. For many purposes, e.g. converting currencies or calculating taxes, this limit is of theoretical concern only. But for other purposes, such as weather prediction, fluid dynamics modelling etc., these are very real concerns.

Only time will tell whether these limits are only temporary shortcomings of the technology or reflect *real* limits of digital information processing.

2.1.2 Measuring Data

Once you have a basic understanding of how data is stored, it is relatively straightforward to tackle the question of how data can be measured. The simplest measure of data is its quantity or *size*: how *much* data is there? If we take our previous sample of text: "The Bulls have won the match!", then it is fairly easily to work out that it contains 29 characters (spaces and punctuation included). Thus, if each character requires 8 bits (which is one byte) to encode, then our sentence is 29 bytes long.

Just to get some feel for data quantities, some examples follow to indicate *typical byte* sizes.

- **One page of typewritten text**. A typical page contains around three thousand characters (about 50 lines of text of 12 words of 5 letters each), so it would be about 3000 bytes. How far is Cape Town from Simon's Town? You're likely to reply using *kilo*metres (40) rather than metres (40000). So whenever we refer to many thousands of bytes, we will also use the abbreviation *kilobytes* (or *KB* for short). A typed page with text holds a couple of kilobytes of information.

- **A paperback novel**. A typical novel consists of a few hundred of pages, say two hundred and fifty. Two hundred and fifty times three kilobytes is close to one million bytes. Most novels are between one half and two million bytes. Again, we try to avoid large numbers and one million bytes, or one thousand kilobytes, is called a *megabyte* (usually abbreviated to MB).

- **Two hours (a double CD) of high-fidelity music**. This calculation is a bit technical and it is really the end-result in which we are interested. But for those of you who *are* interested, here goes. Frequencies are encoded as two-byte (or 16-bit) numbers and the frequency is sampled about 40000 times each second. There are two stereo channels so for each second of music we need 2 x 40000 x 2 = 160 000 bytes or 160 KB. Two hours of music is 2 x 3600 seconds i.e. 7200 seconds x 160 KB per second = 1152000 KB = 1152 MB. One thousand megabytes is called a *gigabyte* (*GB* for short).

- **Photographic data sent back from a space exploration vessel**. On its mission, a planetary explorer could send back to earth medium resolution colour pictures of 10 megabytes each, at a rate of about 100 per day. Each day mission control receives therefore 100 x 10 megabytes = 1000 MB = 1 gigabyte. If the space voyage lasts three years (a typical trip to the outer planets) we have about 1000 days' worth of data i.e. 1000 gigabytes. You've guessed it: 1000 gigabytes also has a special name, a *terabyte.* A full-motion video would (uncompressed) also contain about a terabyte of (uncompressed) data!

From the above, you can see that digitising visual and audio signals requires a lot more data than text. A picture is worth a lot more than a thousand words, in fact it is more like a million words! And actions speak much, much louder than words if a short movie scene requires the equivalent of many billions of text words to store digitally.

Trivial fact: The film Toy Story took over 800 000 hours of work on 300 computers to produce. Each minute of animation took about two days to create.

2.2 Information

When we compare data with information, the first obvious difference is that information must be seen in a *context* in which it makes sense. This context usually relates to an action or a decision to be taken. In the case of a credit manager, information about outstanding accounts might be needed to decide whether to pursue a tighter credit policy. A telephone directory provides useful information when you need to contact a friend. Sometimes a decision might be made that no action needs to be taken as a result of information being provided; after checking the results for the first class test, your lecturer may decide that additional revision exercises are not needed! To put it into other words: there must be a *useful purpose* before data becomes information. In an organisation, we will try to collect only the data that satisfies the informational needs of the system's users, since superfluous data costs time and money to collect and store.

The second characteristic is that there must be a *process* by which *data* gets transformed into *information,* as illustrated in figure 2-2. This process can be as simple as looking up and locating a single data element in a data set (e.g. one number in a telephone directory), counting or totalling data elements (accounts) or it can involve more advanced statistical processing and charting.

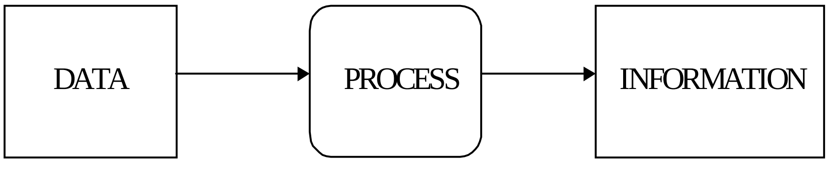

Figure 2-2: Transforming data into information

2.2.1 Qualities of Information

We live in a time where we are bombarded from all sides with information: the age of *information overload.* (Just ask any student!) It is becoming a vital survival skill to assess the quality of information. What distinguishes “good” from “bad” information? The following are just some of the *characteristics* or *attributes* of information. But note that these attributes are not always of equal importance - depending on the particular type of decision that needs to be made and the degree of risk attached to it, some attributes may be more critical than others.

- **Accuracy**. How accurate is the information or how much error does it contain? We do not always require perfect accuracy. Where a bank statement or invoice should be 100% accurate (although it may be rounded to the nearest cent or rand), “Errors & Omissions” of many millions of rands in the South African export statistics could be acceptable. If you want to drive a big lorry across a small bridge you need to know its weight to the nearest ton whereas if you wish to purchase diamonds you want a weight measurement which is significantly more accurate! If I, as production manager of a sweet factory, need to know how much stock of sugar we have available for the production of a particular sweet, I may not be satisfied with the answer “a lot” or “plenty”.
- **Reliability**. How dependable is the information? This is closely related to but not the same as accuracy. It is related to *how* the information was obtained, e.g. the quality of the source of the information. Take the example of the sweet factory. I ask the inventory manager how many tons of white sugar are remaining. She informs me “36200 kilograms” but obtained this figure by looking at the size of the pile of sugar and making a rough estimate or, even worse, checked the *brown* sugar instead. Despite the apparent accuracy, 36200 kg is not a very reliable figure.
- **Completeness**. Does it contain all the important facts? In the above sugar example, she could give the exact weight but fail to communicate that she is expecting another 200 tons of sugar to arrive later that day, or that they are about to use most of the sugar for the production of another type of sweet.
- **Verifiability**. Can the correctness of the information be checked? Is it possible to obtain another estimate for instance by using another source or another method? In the sweet factory, one might be able to use a computer-based inventory system to verify the answer given by the manager. On the other hand, if large quantities of sugar move in and out the warehouse all the time, it may be impossible to verify the figure.
- **Relevance**. How pertinent is the information to the question or decision? The course fees, the academic standard (pass rates!) and job opportunities are all factors which may have led you to choose to study Information Systems at UCT but some would have been more relevant than others. The Rand/Dollar exchange rate is more relevant to South African exporters than it is to Brazilian farmers.
- **Timeliness**. How up-to-date is the information? There is little use in having a computer program predict the next day’s weather with perfect accuracy if it takes 48 hours to produce the forecast!

- **Simplicity**. How complex or detailed is the information? To indicate the outstanding performance of students on the IS1 course, I could give standard deviations and other probability distribution characteristics of student marks over the last 10 years, full result lists or simply the pass rate of last year's students. A mere pass rate would probably be too simplistic while a complete list of results is too detailed. Best would be to give a bar chart showing the distribution of symbols.
- **Cost**. How much did it cost to produce the information? One should always compare the cost of producing the information with the value gained from it. There is no need to write a five-page report with many tables and charts to answer a simple question or indicate that performance is in line with expectations or budget.

2.2.2 Measuring Information

As you have already seen, it is not difficult to measure the size or quantity of data. The measurement of information is more complex. Consider the two statements "Bulls win" and "The Bulls team has shown its superiority by winning the match"; their information content is very similar, yet the second sentence contains almost eight times as much data as the first. Also, the amount of data in a message may change depending on the method used to encode it. A sentence coded in Morse code has about only about a quarter of the data of the same sentence in Unicode. But Unicode can also cope with Vietnamese text whereas Morse code cannot even distinguish between capitals and lower case Roman alphabet.

This has prompted communication theorists to look at another way of measuring information, which involves reducing it to the smallest expression that can still communicate the required content. For instance, the Bulls can either win or not, so the shortest way to send a message expressing the result of the match would be through a (previously agreed upon) binary code e.g. 1 = Win, 0 = No win. So the information content of "The Bulls have won the match!" can be reduced to one single bit.

Of course, we might require more detailed information about the result of the match, especially about the "no win" option. A perhaps more appropriate coding scheme would be 0= Bulls lose; 1= draw; 2= Bulls win; 3= match has been postponed. In this case we would have an information content of two bits. See whether you can work out a scheme for coding these four options using only two bits (i.e. in binary format).

An alternative concept for measuring information is based on its "surprise value", which calculates the number of options you have before you receive the information and measures how the information reduces these possibilities. *Information reduces uncertainty*. Drawing a playing card at random from a full deck has 52 possibilities, so the surprise value or information content of which card has been drawn is 1 in 52 or (slightly less than) 6 bits since 6 bits can encode 64 different options.

2.3 Knowledge and Wisdom

The concepts of data and information, which have been discussed in some detail, are actually the two lowest levels of a hierarchy (see Figure 2-3).

Knowledge is a much broader concept than information because knowledge consists of many pieces of related information, and has a structure or organisation whereby each piece of information is linked to others. In addition to a large number of data facts, knowledge often includes rules to validate new information, algorithms by which to obtain or derive information, frameworks that indicate what types of information are relevant in which context, information about the information and its structure (*meta-information*) etc. If information is data in the context of a question, then knowledge is what enables you to ask the right questions. Knowledge consists of knowing which action alternatives are available and what information is required before one can decide on a specific course of action.

A related concept is *expertise,* which consists of more detailed and validated (proven) knowledge in a selected area e.g. a car mechanic is supposed to have a lot of specific knowledge about the functioning of a motor car and its engine. Expertise has the connotation of being specific to a more restricted (often quite technical) domain, but also deeper or more detailed than knowledge.

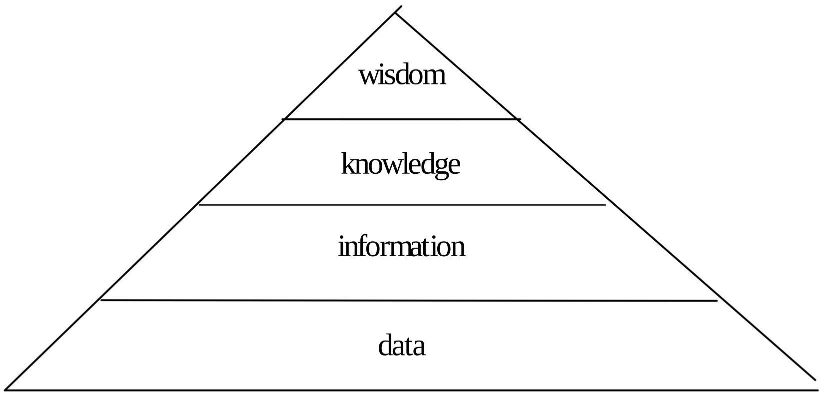

Figure 2-3: The hierarchy from data to wisdom

Finally, **wisdom** adds yet another dimension by combining knowledge with experience, critical reflection and judgement, such as when assessing the moral and ethical implications of a decision. The issue of representing higher levels of information e.g. knowledge, reasoning, expertise, experience, etc. is also still very much the subject of current research. No computer has (yet?) been able to generate original wisdom. But then, so have few humans!

2.4 Producing Business Information

The various characteristics of data and information that have been presented in this chapter, are directly relevant when developing systems that are intended to produce business information. In deciding what information is needed, it is important to consider how it will help to reduce uncertainty (surprise value) and how concisely it can be communicated (size). Not all of the attributes of information are equally important in every situation: in one case, early access to information may be more valuable than extreme accuracy, while in another case accuracy may be sufficiently vital to justify a time delay. If you are choosing a movie to watch this evening, you do not need to know all the details of the plot; if you are thinking of investing in a film production, a lot more information will be needed, even if it takes longer to acquire. A knowledgeable business manager will ensure that appropriate information is being provided to meet specific business requirements.

Careful analysis is needed to identify the data that will be used to produce this information. How well can its truth value be established? If you are not sure whether your facts are correct, then any business decision based on those facts is likely to be of dubious value – illustrated by the acronym GIGO (garbage in, garbage out). Sensible decisions need to be made about the types of data that will be stored, and the size implications: consider the difference between storing the sound of a spoken message, or its text equivalent.

Finally, all levels of the organisational structure must be catered for. Data accumulated through the TPS must be sufficient to generate the various types of MIS reports, to allow for forecasting using the DSS, and to explain trends over time which could influence strategic planning. As we commented earlier, there is more to an information system than simply buying a computer!

2.5 South African Perspective

The rapid growth of Nando's fast-food franchise created a need to manage its operations more effectively, particularly because until recently information from separate stores was only supplied to strategic management on a monthly basis. Information technology has now been used to collect operational data which provides managers with instant access to information about sales (at daily or even hourly level), profit margins, turnover, service problems and sales trends. Ten strategic Key Performance Indicators were identified that allow strategic management to monitor problem areas at individual store level and improve customer service while minimising operational costs. Errol Epstein, the MIS director at Nando's, comments that as a result of their new information system "we have an holistic view of our business and can manage our stores efficiently, cut down on wastage, and build our brand strategically".

2.6 Beyond the Basics

Knowledge is more complex than either data or information, and is more difficult to define and to store. **Knowledge management** systems attempt to capture organisational knowledge, including undocumented personal knowledge based on experience, so that it can be shared and applied effectively throughout the organisation. This requires the identification of valuable knowledge and where it is located, the extraction and encoding of the knowledge, storage, maintenance and retrieval processes for the knowledge base, and delivery of knowledge to recipients when needed. For example, BP has captured knowledge related to drilling malfunctions based on the practical experience of its technicians around the world, which can be used to provide solutions for problems that may occur in the future.

Grant Brewer of Ernst & Young believes that knowledge sharing should be a part of every organisation's information strategy (Intelligence magazine, November 2002). "Your information strategy should be to ensure that employees have ready access to current information. You then have to tackle the more difficult task of getting your employees to share their expertise, which most often comes in the form of experience rather than structured learning. The intellectual capital of your employees is possibly the most valuable asset in your organisation."

2.7 Exercises

2.7.1 Data encoding

A simple way to make a code is to think of a word or phrase and write it down, followed by the rest of the letters of the alphabet that you didn't use in the phrase, and then replace the original letters of your message with the code letters in corresponding positions. The reason you use a specific word or a phrase before the other letters is because that makes it easy for you and your correspondent to remember the key without having to write the code down, and risk having it discovered by the enemy. (If a letter is used more than once in your word or phrase, just leave it out after the first time you use it.)

- Try using your first name as the key for encoding the message "Data must be decoded to be understood".

2.7.2 Binary numbers

- What is the decimal equivalent of each of the following? 10011, 01110, 10101
- Write each of the following numbers in binary format: 13, 22, 9

2.7.3 Data vs Information

At the end of the year, assuming that your student fees have been paid, your exam results will be posted to your home address. The statement you receive will show your name and student number, your degree, and your final result for each course. It will also inform you whether you have been awarded any supplementary or deferred exams, and whether you have met the readmission requirements for your degree.

- In order to generate this document, what data would have been captured and when?
- What processing of the original raw data would have taken place?

2.7.4 Information attributes

Refer back to question 1.6.2 at the end of the previous chapter, in which you identified organisations that have recorded your personal details. How accurate is that data at the present date (i.e. have you changed address, phone number etc)? In what ways might incorrect data affect the usefulness of reports or cause inefficiency of business processes?

3. How Systems Function

An information system is, as its name implies, a special type of *system*. In this chapter we will introduce you to the basic systems concepts, and briefly explore some of the systems theories that are directly applicable to organisations. Along the way, we hope that you will master the practice of looking at your environment through “systems-coloured glasses” and applying these new principles to the world around you.

3.1 What is a System?

As a university student, you form part of the educational system, regardless of what subjects you are studying or how well you perform. Your body in turn is a highly complex biochemical system, as is the annoying mosquito buzzing around in your room or the more restful plant standing next to your window. You, as an individual, also form part of your family (social) system. The electrical light illuminating your room forms part of the electrical (energy) system, which, like the plumbing or air-conditioning system, is part of your house or hostel, which can also be seen as a (physical) system. The pen you are holding in your hand is a small, self-contained system, as is the whole earth (“*Gaia*”), which is in turn a sub-system of our solar system. Once you start looking for systems, they seem to crop up everywhere. But what, exactly, is a system? What have all of the above systems, despite their apparent diversity, in common?

3.1.1 Definition of a System

Since a system is a subjective concept, there is no unanimously accepted definition of a system. In order to study this phenomenon more closely, we will adopt the following definition:

- A **system** is an organised assembly of **components** with special relationships between the components.
- The system does something, i.e. it exhibits a type of **behaviour** unique to the system or has a specific objective or **purpose**.
- Each component contributes specifically towards the behaviour of the system and is affected by being in the system. If a component is removed, it will change the system behaviour.
- Someone has identified the system as being of special interest.

Not just any random collection of parts or elements constitutes a system. For example, a pile of rocks is *not* a system, just like a random collection of words does not make up a meaningful sentence. There needs to be a definite (perceived) structure that has some form of order, pattern and purpose. Sometimes the structure may be very tenuous, apparent only to few observers. At other times observers may agree on the fact that a given structure constitutes a system but there may be disagreement about what exactly is part of the system and what not i.e. its exact boundaries. An **information system** is a system that gathers and transforms data in order to produce information for its end-users. If it is to function successfully, then its developers and its users must agree on the purpose of the system, its components and the relationships between them.

Another essential element of the definition involves the subjective aspect: a system is not an objective "thing" out there that exists on its own but it is something attributed to a set of interrelated components by an observer.

3.1.2 The Systems View and Systems Thinking

The definition of a system is, however, somewhat of an academic exercise. The real essence of systems theory is being able to look at the world from a different perspective. The **systems view** involves adopting the reference framework and the terminology of systems theory, trying to apply various analogies with other systems and checking which of the systems laws and theories hold for the system of interest. **Systems thinking** is just a whole new way of thinking about the world in which you live. Being able to adopt this approach is quite an eye-opener for many, a pleasant and novel experience in fact, and much more important than merely being able to explain all the various concepts that will be introduced in this chapter.

Why is this systems view so important? Can we not just learn about the technology of information systems and dispense with more philosophical matters? The problem with the purely technical approach is that it often fails to take into account the inter-relation of problems and proposed solutions, which is incorporated in the systems view. The study of information systems is about solving an organisation's problems with respect to its information needs. Installing a computer is often a quick fix but may turn out to be a very sub-optimal solution, not taking into account many of the human and organisational factors. Some authors go even further and claim that most of today's complex problems, such as crime, drugs, poverty, war, suicides, breakdown of family structures, unbridled materialism, global warming and more, are a result of the short term and technicist vision of society's decision makers who fail to adopt a holistic systems view when addressing problems.

3.2 Elements of a System

3.2.1 Environment and Boundary

As soon as we identify a system, we define a **boundary**: what is inside the boundary belongs to the system, everything outside the boundary is not part of the system. However, most systems do not exist in isolation. Systems, or their components, inter-act with the world outside their boundary. The part of the outside world with which the system interacts is called the system's **environment**. What about the boundary itself: do you think that it belongs to the system itself, or is it part of the environment?

3.2.2 Inputs, Transformation Process and Outputs

The interactions of a system with its environment can take the form of inputs or outputs**.** **Inputs** take the form of material objects, energy and/or information flowing from the environment into the system. **Outputs** are released or sent from the system back into its environment. This output can either be useful (to some outside system) or waste. Within the system, the inputs usually undergo some kind of **transformation process** so that the outputs are different from the inputs. Often, inputs and outputs undergo further specific transformations *at* the system boundary; the system components responsible for these transformations are called the **interfaces**.

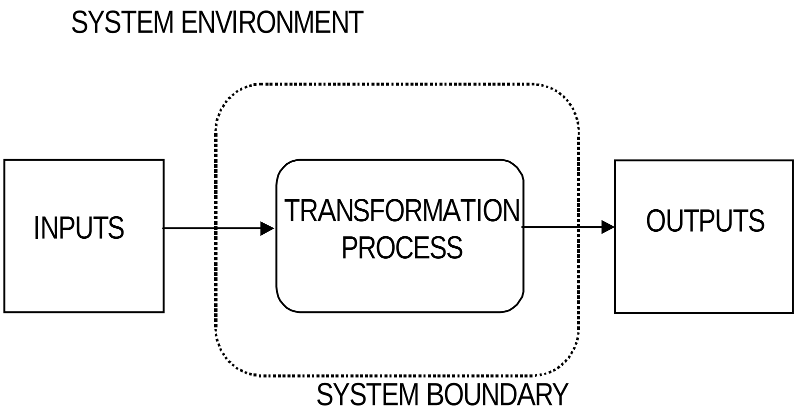

Figure 3-1: The basic elements of a system

Some systems perform very simple energy or matter transformations. Other, more complex systems, such as our human mind, perform quite intricate and sometimes even incomprehensible transformation processes (as evidenced by some student examination answers!) A motor car, for instance, turns petrol and oxygen into motion, heat and a variety of waste gases (exhaust fumes). It also takes its occupants from one physical location to a hopefully different location.

Information systems Error! Bookmark not defined. accept data as input, via an interface such as a computer keyboard or barcode scanner. Transformations may be trivial (counting or adding a set of numbers, copying a set of data), slightly more complex (e.g. drawing a map from co-ordinate data) or extremely complex (making a medical diagnosis based on symptoms and signs, deciding whether to launch a new product range, translating a poem). The information outputs of the system will finally be presented to end users, via an interface such as a computer screen or a printer.

3.2.3 Components and Subsystems

A system consists of various **components** which, taken together, make up the system. The interaction between the system components is responsible for processing the inputs into outputs. Although components can also interact directly with elements from the environment i.e. across the system boundary, most of their interactions will be with other components within the same system.

Often, components themselves can be viewed as smaller systems on their own: they are **sub-systems** of the system under consideration. The motor car mentioned above, for instance, has an electrical sub-system and an air-conditioning sub-system.

In the case of an **information system**, the basic components that interact are

- the hardware or physical equipment used to process and store data
- the software and procedures used to transform and extract information

- the data that represents the activities of the business
- the network that permits the sharing of resources between computers
- the people who develop, maintain and use the system.

Each of these components will be discussed in more detail in later sections of this book. At the same time, don't lose sight of the fact that the information system in turn is merely one component of the organisation, and must interact with other departments and business activities.

To understand the workings of a system, it is often useful not to take into account all the details of each of the subsystems. The level of detail with which you study a given system is called the **granularity**. If you want only to drive a car, you may be satisfied with a fairly coarse granularity i.e. you need to know about such things like the ignition and petrol tank but not about the condenser or the differential. However, if you are a car fanatic or repair mechanic (or if the car does not want to start), you need a much more detailed understanding of the subsystems within the car i.e. you need to study the system at a much finer granularity.

The coarsest possible description of a system is called the **black box** view of the system: you just describe the inputs and outputs but make no attempt at understanding what actually goes on *inside* the system. When first analysing or discussing a system, it often makes sense to view its subsystems as black boxes. The telephone communication system is, for most of us, very much like a black box: we dial a number and, if all is well, we hear a familiar voice in our handset. Luckily, we do not need to know how the various telephonic exchanges managed to establish our connection or how our voice signal got transmitted. Our scientific pocket calculator is another example: when we want to calculate the cosine of a certain angle, we enter a number, press on the *cosine* function and it displays a result without us being aware of how in fact it arrived at this result. If a black box hides *all* internal system details, what do you think is meant by a **white box**? A **grey box**?

Trivial fact: The biggest machine in the world is the telephone system. The vast network of cables and satellites links together over a billion different telephones, fax machines and modems that connect a third of our world.

3.2.4 Objectives, Control and Feedback Loops

Systems have a **function**, **goal** or **purpose**. This goal can be internalised e.g. the desired room temperature for a central heating thermostat device or the profit motive in a commercial business enterprise. This purpose can also be imposed from the outside e.g. when we use a motor car to drive from our home to the shop. In order for the system to achieve its goal(s), it needs to be able to modify its behaviour. **Control** is the mechanism whereby special **control signals** or, when coming from outside the system, **control inputs**, modify the processes and activities which occur within the system.

The **controller** is the component or (sub-)system which exercises the control and can be part of or outside the system under consideration. The controller observes the behaviour of the system, typically by looking at certain system outputs and compares them to the desired state or objective. In the case of a deviation, the controller would adjust certain (input) controls to modify the system's processes. This 'round trip' of using output signals and using them to modify input signals is called a **feedback loop**, and the whole process is one of **feedback control**. There is always a slight delay before the output can be "interpreted", the consequent control changes are effected and the system behaviour is adjusted. This delay is called the (time) **lag.** Lags can vary from the milliseconds it takes an ABS car braking system to release the brakes of a locked wheel to the many years it may take to vote an unpopular government out of office in a country's democratic political governance system. In the case of a business, output from the MIS will be used to provide feedback regarding routine business transactions, so that managers can monitor operational activities and introduce changes if necessary.

System feedback can be **positive** or **negative**. If the system behaviour needs to be altered (reversed) in order for its output to move closer to the desired state, then we have a ***negative feedback loop***. Two examples are the way a singer adjusts the tone of her voice so that it is in harmony with the orchestral instruments or the correction that we apply to the steering wheel if the car moves slightly out of its lane. However, if the feedback loop reinforces the current behaviour of the system, then we speak of ***positive feedback***, such as when a student achieves good marks after studying hard for a test. Consider a small boy throwing a tantrum: his mother could discipline him by sending him to his bedroom, or could pacify him by giving him a sweet. Which of these would be positive and negative feedback, and why?

The study of how systems can be controlled, with a particular focus on automatic or self-controlling systems, is called **cybernetics**. Although it initially arose from engineering, it is now considered to be a sub-discipline of general systems theory.

3.3 Systems Concepts

When analysing systems and their interaction with the environment, a number of useful concepts should be borne in mind.

3.3.1 Open vs Closed Systems

Any system that interacts with its environment is called an **open system.** There is in reality no such thing as a **closed system,** which would have no inputs or outputs and therefore, in a sense, no environment. Nevertheless, some systems are mainly self-sufficient whilst other, more open systems have a much greater degree of interaction with their environment. It is important to cater for this interaction with the environment when planning any system – there would be no point in starting a business that manufactures top quality goods, if you have no way of delivering them to your potential customers, or if you do not have access to the raw materials that you need!

3.3.2 Dynamic vs Static Systems

A **dynamic system** is a system that has at least one (and usually many) activity or process; as opposed to a **static system**, which has no activity, whatsoever. Again, there are very few completely static systems and we typically use these concepts in a relative sense: we refer to one system as being more dynamic than another, more static system. The more dynamic a system, the more flexibility must be built into the inter-relationship of components, allowing them to function in different ways as activities change – especially important in a modern business environment.

3.3.3 Continuous vs Discrete Systems

A **continuous system** is a system where inputs (and outputs) can be varied by extremely small amounts or quantities. **Discrete systems** are systems where the inputs or outputs can take on only certain discrete or distinct values. A traffic light (*robot*) is a discrete traffic signalling system because its three lights (green, amber or red) are either on or off. It remains discrete, even if we extend the number of signals e.g. some lights can be switched on simultaneously (as in England where a simultaneous amber and red light indicate an imminent change to green) or allow for flashing lights (to indicate malfunction or during night-time operation). A mercury-based thermometer, like many physical systems, is a continuous system as the level of mercury rises or falls gradually along with imperceptible fluctuations in the environment's temperature. Many electronic systems are a combination of both e.g. a digital thermometer has a sensor that records temperature as a continuous input but displays a temperature reading which has been rounded to the nearest degree.

Discrete systems have clearly identifiable **states.** The traffic light is either green or not when you cross the intersection; there is little use in arguing with the traffic officer that it was still a little bit green! A continuous input or output is often converted or approximated to a nearly continuous but actually discrete measure, such as when we measure a temperature to the nearest tenth of a degree or time the finish of an athlete to the nearest hundredth of a second. This enables us to model the real, physical world with electronic equipment such as computers, which can work only with finite precision (i.e. discrete) numbers. A good example of how well this conversion process can work is the Compact Audio Disc recording system which samples the music many thousands of times a second and converts the frequency of the sound signal at each time point into an integer number between 1 and 60000.

3.3.4 Structure and Hierarchy

The interactions between the various sub-systems and components of a system display some pattern or regularity. In this sense the observer can identify certain relationships, which contribute to the overall behaviour of the system. The entire set of relationships is referred to as the **structure** of the system. In a purely physical system, the physical location of the components and the connections between them will account for most of the structure e.g. the way the various parts of a car are joined together would account for its structure. In systems that involve informational and conceptual components, the structure will be much less tangible and involve some level of abstraction e.g. when you try to identify the social structure of an extended family unit.

Often, components of a system can be regarded as smaller systems in their own right. These are called **sub-systems** of the system under consideration and the latter probably constitutes most of their environment. These smaller sub-systems are thus embedded within the system, which in turn may be a sub-system of yet another, larger system: the **supra-system**. This nesting of systems within systems within systems is referred to as a **system hierarchy**. A common example is the physical universe (the ultimate physical supra-system), which is made up of galaxies (our Milky Way is one), which in turn consist of solar systems (e.g. ours with the familiar sun at the centre), which contain planets (including the planet Earth with its moon). Our planet Earth consists of a biosphere which contains all living things, including human society, which is in turn made up of social sub-systems or cultures, made up of humans (biological systems), made up of cells, in turn consisting of complex molecules etc. all the way down to the basic building blocks of matter (currently quarks). Another example is a large multinational organisation (one system, whose super-system is the international political economy) which may consist of various national companies, who in turn have regional branches or establishments, which may consist of various departments or project groups etc.

3.3.5 Holism and Emergent Properties

The chemical behaviour of one molecule of water (H_2O) is very different from the behaviour of large amounts of them when they make up an ocean. The inorganic chemist will have little to share with the wave surfer, art photographer or scuba diver about the properties of water. We are also familiar with the fact that the actions of a large mob or crowd may be very different from the behaviour of any individuals making up the mob. And of course the psychological and emotional behaviour of an individual can not be understood from the perspective of (or reduced to) his biological make-up i.e. his cell structure.

The perspective from which claims that many aspects of a system can be understood only in terms of its entirety, and not necessarily be reduced to the characteristics of its components, is called **holism** (the opposite of *reductionism*)**.** This is often expressed in the popular saying that a system is *more than the sum of its parts.* Holism also implies that it is important to be aware of the inter-relation between the various components of a system: *everything is related to everything.* When a person is ill, traditional medicine will look at the symptoms of the patient, diagnose the illness and prescribe some medication which will cure the patient by relying on some type of biochemical reaction within the body of the patient. The holistic approach will look at the lifestyle of the person, her emotional well-being and any psychological factors which may have contributed to the illness, i.e. a much wider perspective is taken, and illnesses are viewed in the context of the individual as a social, psychological *and* biological system.

The holistic systems view implies that a system has certain properties, qualities or attributes which cannot be reduced to or understood from its components alone. These properties are called the **emergent properties** of a system. Examples of emergent properties are the corporate culture of an organisation, the consciousness of a living individual, the feel of a car, the atmosphere or vibe of a pub, the cultural identity of a social group.

3.3.6 Entropy

An important measure of a system is the amount of order (in the case of matter or information) or potential energy it contains. The measure for disorder or energy degradation is **entropy**: the higher the level of disorder, the higher the entropy level. All systems change over time and, unless a system can draw on resources from the environment, it will tend to become more disorderly or lose energy (“run down”) i.e. entropy increases. This is one of the

