BOOK 1 OF 2

VERTICAL TRANSPORTATION PLANNING IN BUILDINGS

A Portfolio Thesis for the Degree of Doctor of Engineering in Environmental Technology

by

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February 1998

ABSTRACT

This thesis is submitted for the degree of Doctor of Engineering in Environmental Technology. The degree is awarded for industrially relevant research, based in industry, and supported by a programme of development courses.

This project aims to contribute to a reduction in the environmental burdens of vertical transportation systems. The author has carried out an environmental assessment showing that the dominating environmental burdens of vertical transportation systems arise from their use of electricity while in operation in buildings.

An assessment of traffic demand has concluded that we are probably over-sizing lifts, and are therefore installing systems that consume more energy than necessary. Traffic planning techniques for single and double deck lifts have been reviewed and developed.

The kinematics (motion) of lifts has been studied. New formulae have been derived that allow us to plot travel profiles for any input of journey distance, maximum velocity, maximum acceleration and maximum jerk. Taking these journey profiles as inputs, a mathematical model of a DC Static Converter Drive has been developed. The model can be used to calculate the energy consumption of any individual lift trip.

A lift simulation program has been developed. The program uses the research in traffic, kinematics and motor modelling as a basis for developing energy saving lift control strategies.

DECLARATION

This portfolio thesis is the result of my own work and, except where explicitly stated in the text, includes nothing which is the outcome of work done in collaboration. No part of this thesis has been or is currently being submitted for a degree, diploma, or any other qualification at any other university.

ACKNOWLEDGEMENTS

The author would like to thank his supervisors, Dr Pratap Mehta of Brunel University and Mr John Haddon of Ove Arup & Partners for supervising this work. The author is also grateful to colleagues at Brunel University, Ove Arup & Partners and the CIBSE Lifts Group for sharing their knowledge and experience which have provided an excellent basis for the research.

The author gratefully acknowledges financial support of this research from the Engineering and Physical Sciences Research Council, The Ove Arup Partnership, and the Chartered Institution of Building Services Engineers.

CONTENTS BOOK 1

EXECUTIVE SUMMARY

0.1 INTRODUCTION

The Engineering Doctorate is a 4 year research degree, awarded for industrially relevant research, based in industry and supported by a programme of development courses. The combined Brunel and Surrey Programme is unique in that it has the specific theme of "Environmental Technology".

This project aims to contribute to a reduction in the environmental burdens of vertical transportation systems. The most widely used vertical transportation system is the lift or elevator. It was originally assumed, and subsequently demonstrated that the predominant environmental burdens of lift systems are due to their energy consumption while in use in buildings. Reduction of the energy consumption of lift systems has therefore been the main project objective.

0.2 GREEN LIFTS?

Is there such as thing as a "green" lift? Can we design a lift system that delivers good passenger service at an acceptable cost while incurring minimum environmental impact?

To assess the environmental impact of vertical transportation systems, we first need to have some measure of environmental burdens. The science of assessing environmental impact is still in its infancy. However, increasingly companies are quoting and applying Life Cycle Analysis (or Assessment), known as LCA. LCA attempts to quantify the environmental burdens of a product or process during its entire life cycle. It considers components such as

- resource extraction of materials for manufacture
- manufacture and installation
- use of product

- re-cycling and re-use
- waste
- transportation at all stages

Consider a hypothetical eight floor, four lift system manufactured and installed in the United Kingdom, whose life cycle could be represented in a diagram as shown in Figure 0.1

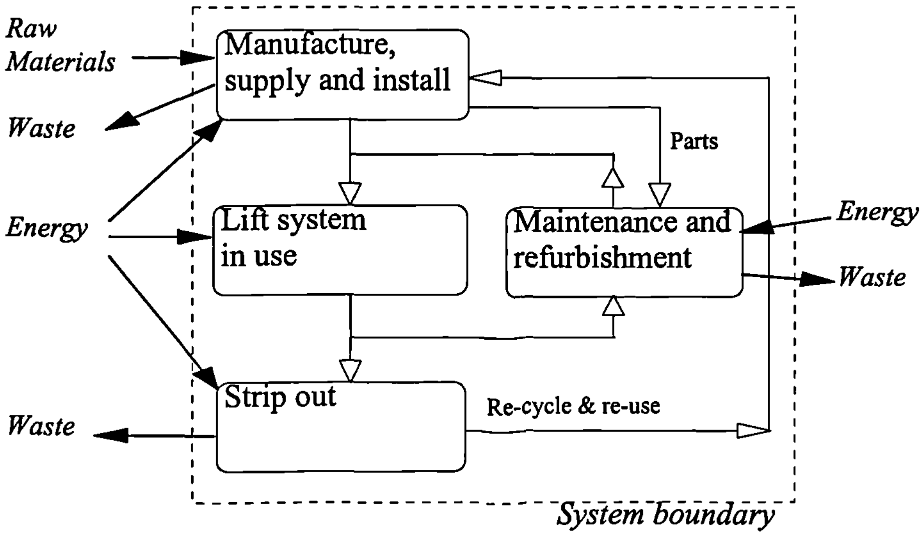


Figure 0.1 Hypothetical lift system Life Cycle Assessment

A computer database from the PEMS(2.2) Life Cycle Analysis program has been used to analyse this lift configuration. A summary of the results from the PEMS analysis is given in Figure 0.2. This shows that the dominating environmental burdens in the life of this hypothetical lift system are the non-renewable resources depleted, the waste created and the emissions generated through the production of electricity for operation of the lifts while in use. The environmental burdens associated with other stages in the life cycle are relatively small.

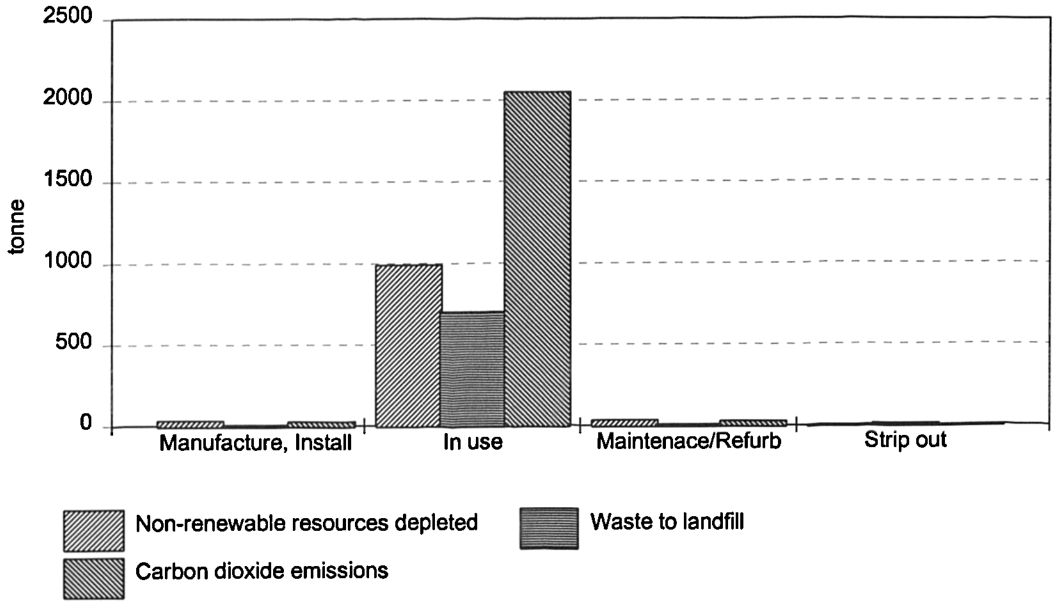


Figure 0.2 Lift Life Cycle Assessment results - impact over entire life cycle

The results are for lift systems, but the findings can be generalised to all vertical transportation systems, all of which have a high energy usage and a long design life.

Use of renewable resources in manufacture, recycling and re-use, efficient transport, disposal/spillage of hydraulic oil, etc. are all important, but secondary issues. Alone they cannot be the basis of claims for a green lift installation.

Where they are installed, lifts and escalators are a significant proportion of the building load; the draft CIBSE Energy Efficiency Guide(2.3) suggests 4 to 7%. Kone sales documentation suggests 5 to 10%. The importance of energy efficient Heating, Ventilation, Air Conditioning (HVAC) and lighting systems is generally accepted; the wealth of related research and development in both these fields reflects this. The author suggests that vertical transportation systems should be among the next in line for "greening".

The use of electricity at current levels is unsustainable, and damaging to our environment. As responsible stewards of the earth, we should be reducing our energy consumption and seeking to develop sustainable energy sources.

There are a number of "basic" principles for green lifts that should be considered by designers before adopting advanced strategies. These include:

- selection of energy efficient lift drives
- minimising inertia and other resisting forces
- efficient lift car lighting
- accessible stairs

Some manufactures promote their products as green because they include energy efficient drives; others promote their use of re-cycled packaging. This project should put these, and other environmental claims in context. For maximum effect in reducing the environmental burdens of lifts, we should concentrate on researching ways of reducing their energy consumption. Although they are not the largest energy user in a building, the potential savings are worthwhile.

0.3 ASSESSMENT OF TRAFFIC DEMAND

Assessment of performance is a crucial element in lift design. If lifts are too small, slow, or insufficient in number, passengers have to wait for excessive periods for a lift to arrive in response to landing calls. On the other hand, the luxury of an over-lifted building is an expensive one - floor area that could be let to tenants is lost to additional or larger lift lobbies and shafts; capital, maintenance and energy costs of the installation are higher.

The need to specify appropriate numbers of lifts, their capacity and speed, etc. has led to the study of lift traffic analysis. But lift performance results from lift traffic analysis are of no better quality than the estimated passenger traffic patterns that are used in the calculations or simulations.

A typical traffic flow for an office building is given by Barney and dos Santos(3.1), reproduced in Figure 0.3. Conventional procedure is to base the design of the lift systems on the morning up peak traffic situation.

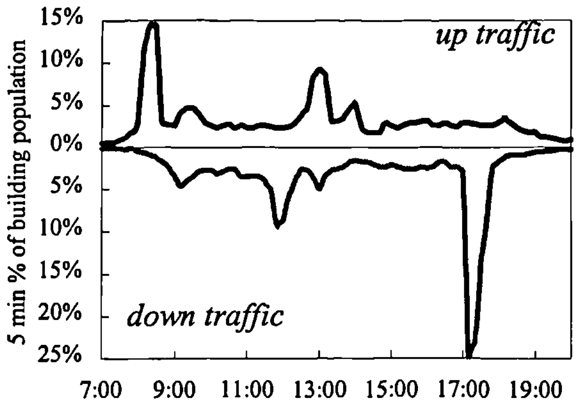


Figure 0.3 Typical office traffic, Barney(3.1)

Passenger traffic surveys have been carried out by the author at a range of buildings. A typical result is given in Figure 0.4.

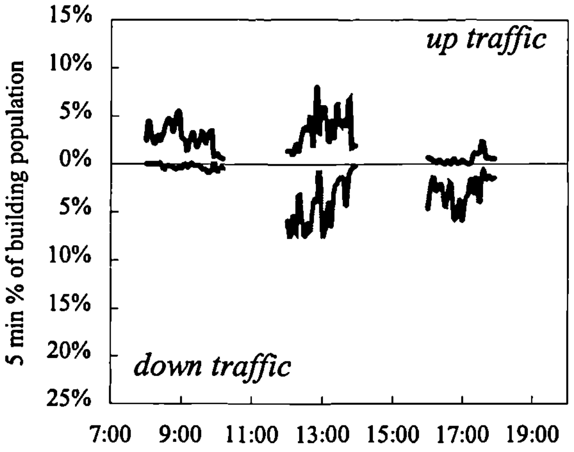


Figure 0.4 Typical office traffic survey

The traffic survey results suggest that the morning traffic peaks are less marked in buildings than they were when traditional up peak design criteria were formulated. In work-related buildings occupied during the day, the busiest time appears to be over the lunch period.

If the traffic studies of commercial buildings made during this research are representative, designers are allowing too much handling capacity during the morning up peak, and not giving enough attention to the waiting times for passengers during the lunch peak.

It would be dangerous to disregard established up peak design criteria without a wider study of building traffic flow peaks; more data must be collected. Thus means of representing and collecting traffic data have been reviewed and developed. The author favours an infra-red beam counting system as the best available technology for data collection.

The research suggests that we need to revise our design criteria. This is unlikely to result in fewer lifts, but would reduce car sizes, and therefore lead to energy savings.

0.4 TRAFFIC ANALYSIS

To realise any savings made through revising our design criteria, we need the appropriate traffic analysis tools. In this thesis we look at analytical traffic techniques, which are currently the most popular and widely applied.

Most lift designs are based on up peak calculations. The up peak is not always the most appropriate choice of peak period for the analysis. Nevertheless, the up peak calculation is important as an industry standard benchmark calculation, and a good starting point for assessing the handling capacity of a lift system.

The up peak lift calculation is based on estimating the time taken for a lift to make a single "round trip" of the building. The calculation assumes that people load the lift at the lowest floor, and get dropped off as the lift stops off at upper floors. The lift then expresses back to the ground floor. The round trip time is calculated for a single lift, so results for two of more lifts are extrapolated accordingly.

Improvements to the "standard" up peak calculation have been proposed. These include:

i. Introduction of formulae for the calculation of flight times. These formulae can be used for any travel distance and lift dynamics; the original calculation is based on a look up table which fixed the floor height and limited the choice of speeds, etc.

ii. Formulation of adjustments made for lifts which do not reach rated speed in a single floor jump.

A sensitivity analysis on the adjustments made for (ii) has demonstrated that the variation between the original and "corrected" results are relatively small (less than 2%).

A computer program has been written to implement the up peak calculation. This program will be given away with CIBSE Guide D *Transportation Systems in Buildings.*

The standard up peak calculation is a valuable tool, but has a number of limitations. These include:

- the calculation only considers up peak traffic; as previously discussed, this is not believed to be the most onerous traffic flow in buildings
- in some instances up peak calculations are inappropriate, e.g. in shopping centres, car parks, airports or hospitals
- it is difficult to adjust the calculation to analyse up peaks for buildings with basements which are occupied

Prior to joining the EngD programme, the author developed an new lift traffic analysis calculation which overcame these limitations. The *General* calculation allows us to carry out a round trip time calculation analysing any peak passenger traffic flow for any practical configuration of conventional lifts. The calculations are implemented in the Oasys (Ove Arup Computer Systems) LIFT program.

To avoid the inefficiencies of over-design, we need improved selection and analysis techniques. The tools developed will help in realising the savings achievable by improving our assessment of traffic demand.

0.5 DOUBLE DECK LIFT TRAFFIC ANALYSIS

Double deck lifts have two separate cabs built into a single unit so that the upper and lower cabs serve adjacent floors simultaneously. During peak periods maximum operating efficiency is achieved by restricting the lower cabs to serving odd numbered floors, and the upper cabs to serving even numbered floors.

Double deck lifts provide greater handling capacity per shaft than conventional lifts. This is particularly attractive for high rise buildings. The sacrifice is that double deck lifts are less convenient for passengers.

The General analysis approach has been applied to double deck lifts. The research carried out allows us to analyse any practical configuration of double deck lifts and any peak traffic flow. The calculations are based on considering the probable number of stops and average reversal floors of a lift during its round trip. The arrival of passengers at a lift landing station is assumed to be approximated by a Poisson process.

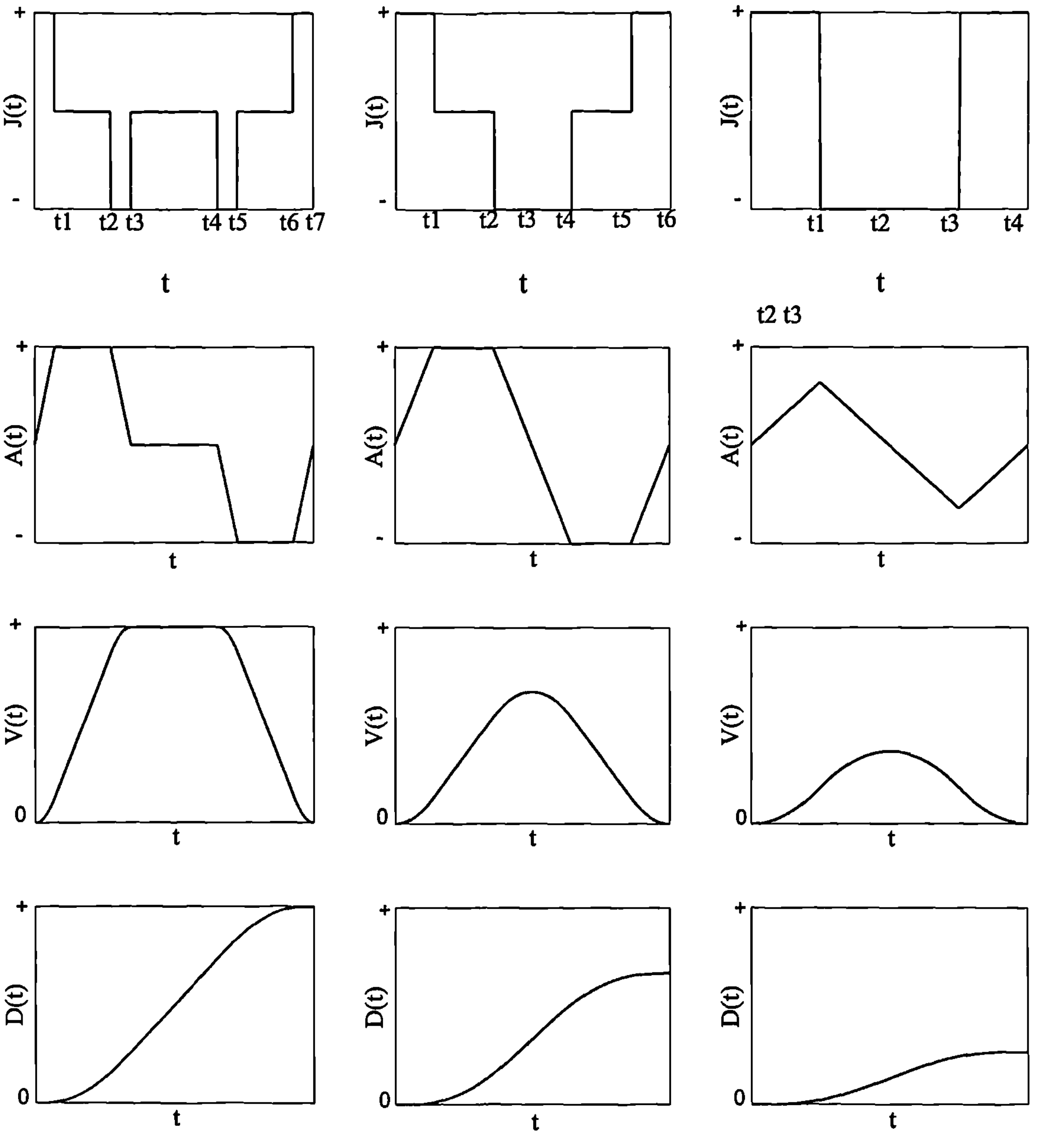
The formulae have been implemented by the author in the Oasys LIFT program, and are being used at Arup in the design of high rise developments.

This section of the research arose primarily from the commercial need to analyse high rise buildings. Dependant on loading, double deck lifts may or may not be a "green" vertical transportation system.

0.6 LIFT KINEMATICS

Lift kinematics is the study of the motion of a lift car in a shaft without reference to mass or force. The maximum acceleration and jerk (rate of change of acceleration) which can be withstood by human beings without discomfort limits this motion. Ideal lift kinematics are the optimum velocity, acceleration and jerk profiles that can be obtained given human constraints.

For this research project, equations have been derived which allow ideal lift kinematics to be plotted as continuous functions for any value of journey distance, speed, acceleration and jerk. Supplementary results include journey time formulae for use in lift traffic analysis.



(A) (B) (C)

Figure 0.5 Ideal Lift Kinematics for: (A) lift reaches full speed; (B) lift reaches full acceleration, but not full speed; (C) lift does not reach full speed or acceleration

The derivation is divided into three major sections, corresponding to the journey conditions where: (A) the lift reaches full speed; (B) the lift reaches full acceleration, but not full speed; and (C) the lift does not reach full speed or acceleration. Conditions A to C are represented graphically in Figure 0.5 Each of the three conditions is divided into time slices, beginning and ending at each change in jerk or change in sign of acceleration.

Microprocessor controlled variable speed drives can be programmed to match reference speed profiles generated through the study of lift kinematics. The research undertaken for this project is programmed in software, so these profiles can be generated quickly and easily. In later sections we will discuss how, by varying the kinematics for each trip, we can save energy.

0.7 MOTOR MODELLING

The purpose of this section of the research is to derive a motor model so that it can be built into a lift simulation program. We can then calculate the total energy consumption of a lift system for a given passenger traffic profile and lift control system. This will allow us to investigate possible energy savings.

A motor model based on work by other researches was implemented and extended. The drive is a separately excited DC motor, fed from a fully controlled 6 pulse converter. The model now uses, as an input, the motion profiles generated from the kinematics research. Equations for load torque and load inertia have been developed.

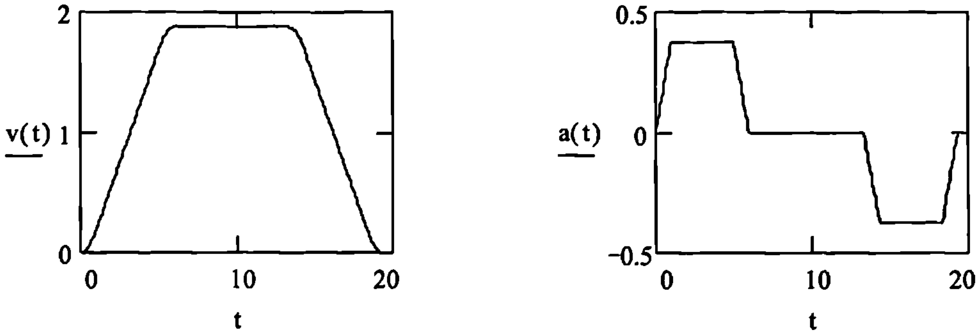


Figure 0.6 Velocity and acceleration profiles

Applying the ideal lift kinematics equations we can generate suitable velocity and acceleration plots, as shown in Figure 0.6.

Applying the motor model, we can calculate the power consumption and power factor during the trip, as plotted in Figure 0.7

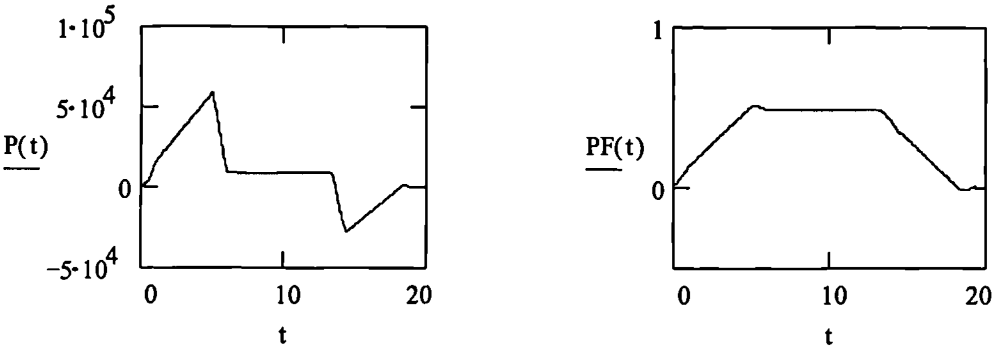


Figure 0.7 Power consumption and power factor during a lift trip

Results from the model are consistent with those presented by other researchers. Site tests suggest that the model is generating consistent power consumption profiles (some input variables could not be measures), and can at least not be rejected.

The motor model is an important component of the tools developed to test energy saving ideas. It has been implemented and applied in *Liftsim* as discussed in the following sections.

0.8 LIFT SIMULATION SOFTWARE

The lift simulation program, *Liftsim* has been written as development platform for "green" lift control systems. It will also have applications as an advanced lift traffic analysis tool.

The program has been written using Microsoft Visual C++ (for Windows 95 and Windows NT). C++ is a complex object oriented language, but it produces very fast programs, and easily reusable/portable code.

Liftsim has seven main simulation classes which define the behaviour of the system. These are:

- The *building* class defines the building in terms of number of stories and story heights.

- The *motion* class implements the ideal lift kinematics research carried out for this project. Programs using the class can specify the journey distance, rated velocity, etc. and output the current distance travelled, velocity, etc. at any time, t, since the journey began.

- The *lift* class defines a lift (rated speed, capacity, floors served, etc.) and its current status (position, speed, load, etc.). The *motion* class is applied to enable the lift to move according to the selected journey profile. The *lift* class includes algorithms to allow lifts to answer landing and car calls according to the principles of directional collective control.

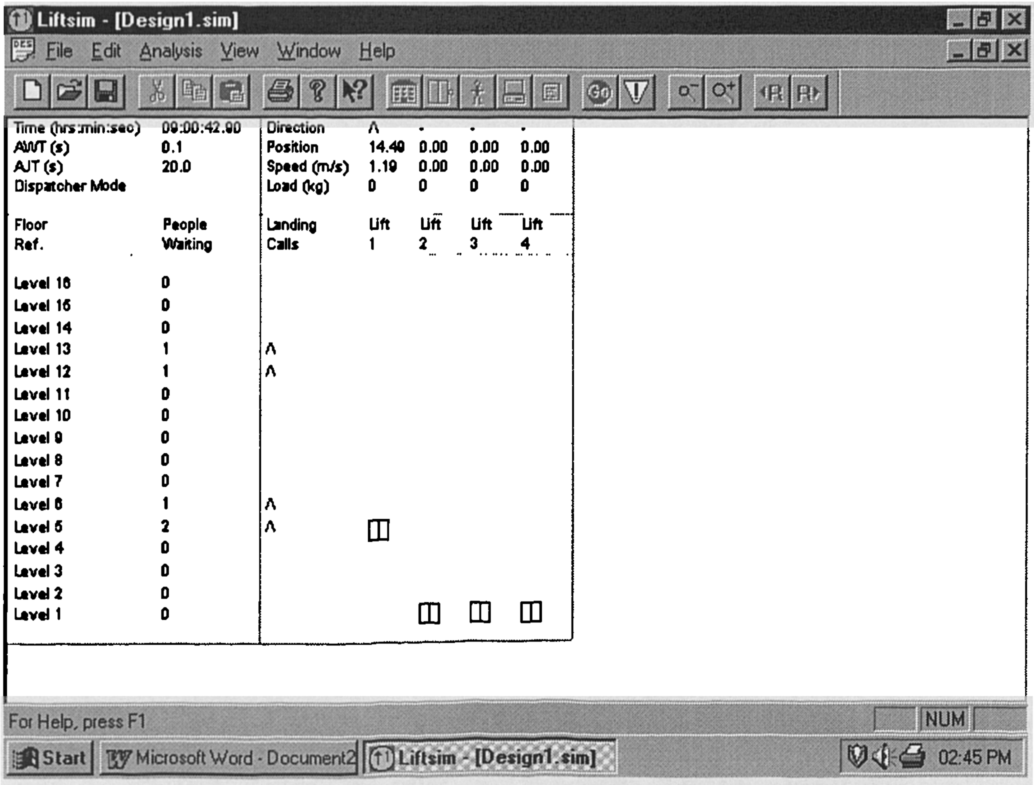
- The *dispatcher* class defines rules for allocating which lift serves which calls. The default dispatcher logic has been based on conventional group control with dynamic sectoring.

- The *person* class defines a person, what time he/she arrives at the landing station, where he/she wants to go, their mass, etc. Once the journey is complete, the class provides details about passenger waiting and journey times.

- The *traffic* class converts arrival rate and destination probability data into a corresponding set of person objects.

- The *motor* class defines the characteristics of the drive. The class calculates the energy consumption and other characteristics of a DC six pulse static converter drive.

The *Liftsim* interface is Windows based, and allows the user to edit all the system data in dialogue boxes containing standard Windows controls (radio buttons, drop downs, etc.) and a spreadsheet-like control for tabular data entry. The program uses a multi-document interface, so the user can be working on a number of different simulations at the same time. A screen shot of the program is given in Figure 0.8.



Time (hrs:min:sec)	09:00:42.90
AWT (s)	0.1
AJT (s)	20.0
Dispatcher Mode	

Direction	^	.	.	.
Position	14.40	0.00	0.00	0.00
Speed (m/s)	1.19	0.00	0.00	0.00
Load (kg)	0	0	0	0

Floor Ref.	People Waiting	Landing Calls	Lift 1	Lift 2	Lift 3	Lift 4
Level 16	0					
Level 15	0					
Level 14	0					
Level 13	1	^				
Level 12	1	^				
Level 11	0					
Level 10	0					
Level 9	0					
Level 8	0					
Level 7	0					
Level 6	1	^				
Level 5	2	^	◫			
Level 4	0					
Level 3	0					
Level 2	0					
Level 1	0			◫	◫	◫

Figure 0.8 Simulation display

The program is a time slice simulation; it calculates the status (position, speed, etc.) of the lifts, increments the time, re-calculate status, increments time, and so on. As Windows is a multitasking operating system, the program cannot take full control of the computer's resources and run in a continuous loop. It must wait for a processing "thread" to become available, run one cycle of the simulation, then wait for the next thread to become available. Provided that there are not too many other demands on the computer's processor, the simulation will run faster than real time on a Pentium PC using a time slice of 0.01 seconds.

Once the simulation is complete, the results print preview includes:

- the input data

- results for average waiting time, longest waiting time, and a plot of the waiting time distribution

- results for average transit time, longest transit time, and a plot of transit time distribution

- the total power consumption for each lift, and total number of motor starts

Liftsim provides us with a power tool to test energy saving ideas. It also has applications as an advanced lift traffic analysis tool.

0.9 GREEN LIFT CONTROL STRATEGIES

Barney and dos Santos(9.1) define a group supervisory control system as *a control mechanism to command a group of interconnected lift cars with the aim of improving lift system performance.* Conventionally this system performance has concerned maximising the handling capacity of the lift system, and minimising passenger waiting and transit times.

It would be counterproductive to ignore conventional system performance criteria as excessive waiting for lifts is very frustrating for passengers. So let us define a green lift control system as a *group control system that considers conventional measures of system performance, as well as means to reduce energy consumption.*

Three strategies that are appropriate to a green lift control system have been considered. The strategies have been implemented, and tested using *Liftsim.*

Green Strategy No.1 - Control of Kinematics

Conventionally lifts have the same maximum velocity, acceleration and jerk for every trip. If the system does allow any variation, this is generally pre-set by the lift service engineer or building owner.

Research by the author in ideal lift kinematics has allowed us to generate, quickly and easily, motion profiles for any input of journey distance, velocity, acceleration and jerk. This allows us to consider control systems that vary all these parameters on line in lift system controllers.

An algorithm has been developed that tests a range of velocity and acceleration options (ranging ± 20% from rated velocity and acceleration) before the start of each trip. In tests a 33.4% saving in energy consumption has been achieved. The average journey time has increased by just 1.3 seconds.

Green Strategy No.2 - Reducing the Number of Stops

The energy consumption of a motoring lift peaks during the acceleration phase, and is relatively low once the lift reaches full speed. There is regeneration during the deceleration phase, but this is less in total than the energy expended during the acceleration phase. Thus it is reasonable to assume that there will be energy savings if we can transport the same number of passengers, with less stops, but without an increase in the overall distance travelled by the lifts.

One way to achieve this is by forcing the dispatcher to allocate a landing call to a lift when it is:

- already due to stop at that floor for a passenger's car call, and
- travelling in the right direction to serve the landing call.

This condition for a "forced" allocation may not occur for some time, e.g. it is unlikely during solely up peak traffic, or during light inter-floor traffic. But most lift systems are likely to benefit from the strategy at some time during their daily cycle.

In tests the "green" algorithm implementing this strategy caused a 3.2% reduction in the number of motor starts, leading to a 6.2% reduction in the energy consumption. The waiting time distribution remains very similar, but there is a minor improvement in transit times.

Green Strategy No.3 - Selective Parking Policies

When a lift has answered all its calls and becomes free, it can be "parked" at the floor it last answered a call, or sent to another floor in anticipation of future calls. From the energy saving viewpoint, we should apply parking policies selectively.

A simulation was set up for a fifteen storey building with very light inter-floor traffic. The simulation was run with and without a parking policy that implements a parking strategy.

The parking strategy improved passenger waiting and journey times, but increased the energy consumption by 43%. The results demonstrate that parking policies improve performance, but are not always appropriate.

Green control systems should place parking calls selectively. This could be achieved by the dispatcher reviewing the potential contribution to system performance of parking calls before deciding whether or not they should be made.

Simulation has demonstrated that each of these strategies will allow green control systems to reduce energy consumption without a significant deterioration in passenger waiting and journey times. The results are for a DC static converter drive, but it would be reasonable to assume that there would be similar savings in applying these strategies with other regenerative drives.

0.10 CONCLUSIONS AND FURTHER WORK

0.10.1 Green lifts

This project aims to contribute to a reduction in the environmental burdens of vertical transportation systems, primarily lifts. It has been shown that energy consumption is by far the most important factor. Further work in this area should be focused on communicating these findings. The lift system will not normally be the largest energy user in a building, but potential energy saving are still worthwhile.

A number of basic principles for green lifts have been identified. The choice of drive, position of stairs, etc. all have a major effect on the energy consumption of the vertical transportation system.

0.10.2 Planning issues

Lift designers need to have a good understanding of passenger traffic demand, and analysis techniques to assess the performance of possible lift configurations. If both of these are not in place, then there is a high probability that installed systems will be either inadequate or over-designed. The first alternative is unacceptable to passengers. The second is unnecessarily expensive, and will consume more energy.

The up-peak seen in commercial buildings is less marked than when current design criteria were formulated. The lunch time peak is now the busiest period. Further surveys need to be carried out to confirm these results, but it is likely that designers are often installing more capacity than is required.

Traffic analysis techniques based on Round Trip Time calculations have been developed and extended. The up-peak calculation has been implemented in a computer program which, it is intended, will be issued with the revised version of CIBSE Guide D, *Transportation systems in buildings*.

As we believe the lunch period is not the most onerous time for the lifts, it is important to be able to assess this period with traffic calculations. We can do this using the General Analysis calculation technique, which the author derived prior to joining the EngD programme. This is a relatively complex technique to implement and to apply. Therefore further research to determine the equivalent lunch time handling capacity relative to a given up-peak handling capacity would be beneficial.

Revising our design criteria is unlikely to result in fewer lifts, but would reduce car sizes, say from 1250 kg to 1000 kg. And therefore lead to energy savings.

0.10.3 Traffic analysis for double deck lifts

Double deck lifts provide greater handling capacity per shaft than conventional lifts. This is particularly attractive for high rise buildings. Formulae have been derived and implemented that allow analysis of any peak traffic flow for any practical configuration of double deck lifts. The approach taken for double deck lifts could be extended to cover triple and quadruple deck lifts if required.

This section of research has arisen primarily from commercial pressures to analyse the performance of lift systems in high rise buildings. A study of the relative energy consumption of double versus single deck lifts for a range of lift installations would be useful further work.

0.10.4 Mathematical models of lift motion and drives

In order to develop strategies for energy saving, we need models to experiment and test our ideas.

The ideal kinematics equations derived allow continuous, optimum functions of jerk, acceleration, speed and distance travelled profiles to be plotted against time. The ability to plot profiles for any input of jerk, acceleration and travel distance gives additional flexibility in the design of lift controllers. This functionality has been applied in the design of green control strategies.

Although there is some guidance already, it would be useful to study more fully the relative levels of ride comfort as the acceleration and jerk are changed.

A motor model based on work by other researches has been implemented and extended. The model now uses, as an input, the motion profiles generated from the kinematics research. Equations for load torque and load inertia have been developed. We can now model the operation and power consumption of a lift trip for any journey, direction and loading. Further research into the modelling of this and other lift drives would be valuable.

0.10.5 Liftsim and green control strategies

The simulation program, *Liftsim* implements the kinematics and motor model research, so provides a development platform for "green" lift control systems. *Liftsim* is written in Microsoft Visual C++ using object oriented programming techniques.

Liftsim's passenger generator creates passengers, then the program performs a time slice simulation. The built in control system is based on conventional group control with dynamic sectoring. Additional control systems could be added, which would be worthwhile further work. Once the simulation is complete, *Liftsim* displays results on screen in a print preview format.

Three green lift control strategies have been developed and applied to the dynamic sectoring control algorithm:

(i) Control of kinematics
(ii) Reducing the number of stops
(iii) Selective parking policies

Simulation suggests that we can achieve an energy saving in excess of 30%. These results are for a DC static converter drive. It is reasonable to assume that there would be similar savings in applying these strategies with other regenerative drives. The development of additional drive models would enable us to confirm this assumption.

There is considerable scope for further development and testing of green lift control strategies using *Liftsim*. The performance of existing strategies needs to be tested across a wider range of installations and traffic flows. Other strategies are likely to arise as the simulation is applied and experimented with. It is envisaged that the research will ultimately lead to green lift control systems being implemented by control systems manufacturers.

The program also has applications as an advanced traffic analysis tool, and is being tested on some current Arup jobs.

Chapter 1

INTRODUCTION TO FINAL REPORT

1.1 ENGD REQUIREMENTS AND OBJECTIVES

The Engineering Doctorate (EngD) requirements and objectives are set out in the course handbook and regulations. In summary:

An EngD is a 4 year research degree, awarded for industrially relevant research, based in industry and supported by a programme of development courses.

The combined Brunel and Surrey Programme is unique in that it has the specific theme of "Environmental Technology". The overall Programme thesis is that the traditional practices of Industry are unsustainable. Its aim is to provide Engineering Doctors with the necessary skills to balance environmental risk along with all of the traditional variables of cost, quality, productivity, shareholder value, legislative compliance etc.

The EngD programme requires Research Engineers to submit course work assignments along with regular written evidence of progress on the research project. The research outcome needs to be at least to the same level as a PhD, i.e. the candidate has to make "a contribution to knowledge", as well as demonstrating competence in specified research and business skills.

1.2 BACKGROUND TO THIS PROJECT

The author joined Ove Arup & Partners as a graduate Electrical Engineer in 1987. In the following six years he completed the Arup graduate training programme, and went on to lead the design of electrical services for a number of major, national and international construction projects. His special interest in vertical transportation led to the publication of a number of research papers. With the backing of Ove Arup &

Partners, the author joined the Environmental Technology Engineering Doctorate programme in 1993. This has provided an opportunity for him to research, in greater depth, topics that have arisen out of previous industrial experience.

The project was awarded a grant from the Engineering and Physical Sciences Research Council. In addition to sponsorship from Ove Arup & Partners, the Chartered Institution of Building Services Engineers has contributed to the research financially, and taken an active interest in the project.

1.3 PROJECT OBJECTIVES AND BOUNDARIES

This project aims to contribute to a reduction in the environmental burdens of vertical transportation systems. The most widely used vertical transportation system is the lift or elevator. It was originally assumed, and subsequently demonstrated, that the predominant environmental burdens of lift systems are due to their energy consumption, while in use in buildings. Reduction of the energy consumption of lift systems has therefore been the main project objective. Some references will be made to other vertical transportation systems, e.g. escalators. The case for why it is important to consider "Green Lifts" is presented in Chapter 2 of this thesis.

The energy consumption of a lift system is the function of many variables, ranging from the design of the motor, through to planning issues such as the number, size and speed of lifts, passenger traffic levels, and the position of the stairs. Ove Arup & Partners are consultants who specify, as opposed to manufacture engineering systems. Thus the approach taken has been to concentrate mainly on factors that Arup can specify, or may influence industry research and development through published material. These are mainly planning issues, thus the title of this thesis, "Vertical Transportation Planning in Buildings".

1.4 OVERVIEW OF CONTRIBUTION TO KNOWLEDGE

The project has yielded a "contribution to knowledge" in a number of areas which will be outlined in this thesis. These include:

Environmental Assessment

- applying life cycle assessment to demonstrate that "energy in use" is the most significant cause of environmental burden for vertical transportation systems

Lift System Models

- improving our understanding of passenger traffic flows in buildings to provide the basis for improved planning of vertical transportation systems
- development of new and enhanced traffic analysis calculations for better planning
- derivation of formulae to plot ideal lift kinematics
- enhancements to lift motor modelling techniques
- application of object oriented paradigm to lift simulation

Green Control Strategies

- development of energy saving lift control strategies

To date the project has yielded six conference papers and two journal papers. A further journal paper has been accepted for publication. Many of these papers, and other articles have been widely published in the national and international vertical transportation trade press.

Chapter 2

GREEN LIFTS?

2.1 INTRODUCTION

Is there such as thing as a “green” lift? Can we design a lift system that delivers good passenger service at an acceptable cost while incurring minimum environmental impact?

In this chapter we will investigate the environmental impact of vertical transportation systems, and introduce ways of reducing that impact. The discussion begins with Life Cycle Analysis, which enables us to quantify the environmental burdens associated with a product or process.

2.2 QUANTIFYING ENVIRONMENTAL BURDENS

To assess the environmental impact of vertical transportation systems, we first need to have some measure of environmental burdens. The science of assessing environmental impact is still in its infancy. However, increasingly companies are quoting and applying Life Cycle Analysis (or Assessment), known as LCA. LCA attempts to quantify the environmental burdens of a product or process during its entire life cycle. It considers components such as

- resource extraction of materials for manufacture
- manufacture and installation
- use of product
- re-cycling and re-use
- waste
- transportation at all stages

The LCA approach is very good at identifying the key environmental burdens. For example, The Economist reported(2.1):

- In studies, one washing powder manufacturer has determined that 80% to 90% of the energy used in washing clothes is used once the powder has left the factory, in heating up water in the washing machine. A combination of washing powder and machine that used cold water could therefore be marketed as a truly green laundry product.

- It can be shown that the environmental burdens associated with transporting goods for re-cycling can sometimes outweigh the benefits of recycling the product in the first place. This type of evidence led the Danish government to lift its ban on non-refillable containers.

2.3 LIFT LIFE CYCLE ASSESSMENT

Consider a hypothetical eight floor, four lift system manufactured and installed in the United Kingdom, whose life cycle could be represented in a diagram as shown in Figure 2.1.

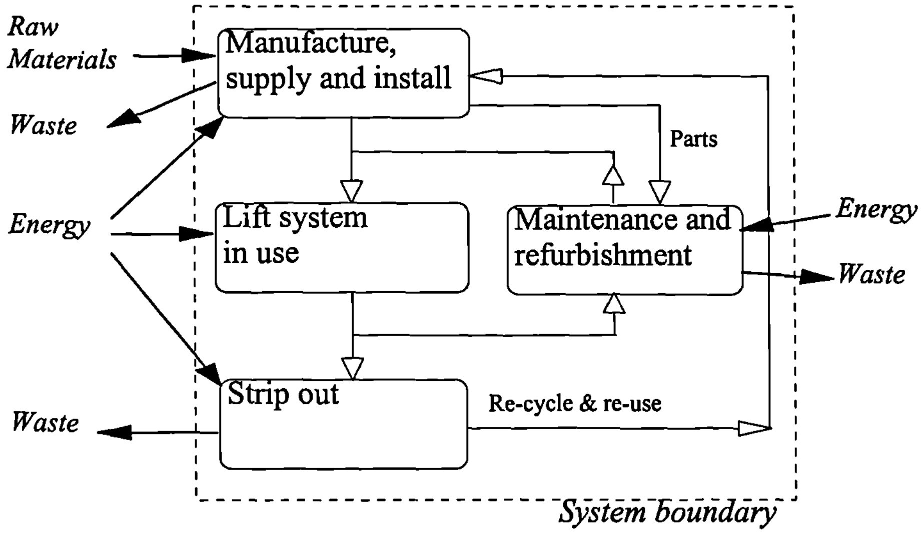


Figure 2.1 Hypothetical lift system Life Cycle Assessment

A computer database from the PEMS(2.2) Life Cycle Analysis program has been used to analyse this lift configuration, based on the following assumptions:

General assumptions

- Life cycle assessment flow diagram as in Figure 2.1
- UK manufactured lift system installed in London
- 4 No 1000kg lifts
- 30 year life with one major refurbishment at 15 years
- Use of PEMS database (The PEMS database is biased towards the packaging industry, so for instance, data for plastic is based on "plastic strap".)

Manufacture, supply & install

- Estimates of materials used (where PEMS data available): 120 kg glass, 400 kg plastic, 7000kg steel, 20kg wood
- Transport of materials to factory/site: total of 300km for 7000kg of steel, using <16t truck via motorway
- All other personnel/material transport assumed negligible
- Electrical power consumption for manufacture, supply and install, 10000kWh

In use

- Assume 300kWh consumption per working day for complete lift system over 30 years

Maintenance/refurbishment

- Assume over lifetime is equal to total supply, manufacture and install
- Stripped out materials re-cycled, but not credited to system (no waste to landfill)

Strip out

- Power used during strip out, 100kWh
- Land-fill (including transport) of 120kg glass, 400 kg plastic, 7000kg steel, 20kg wood

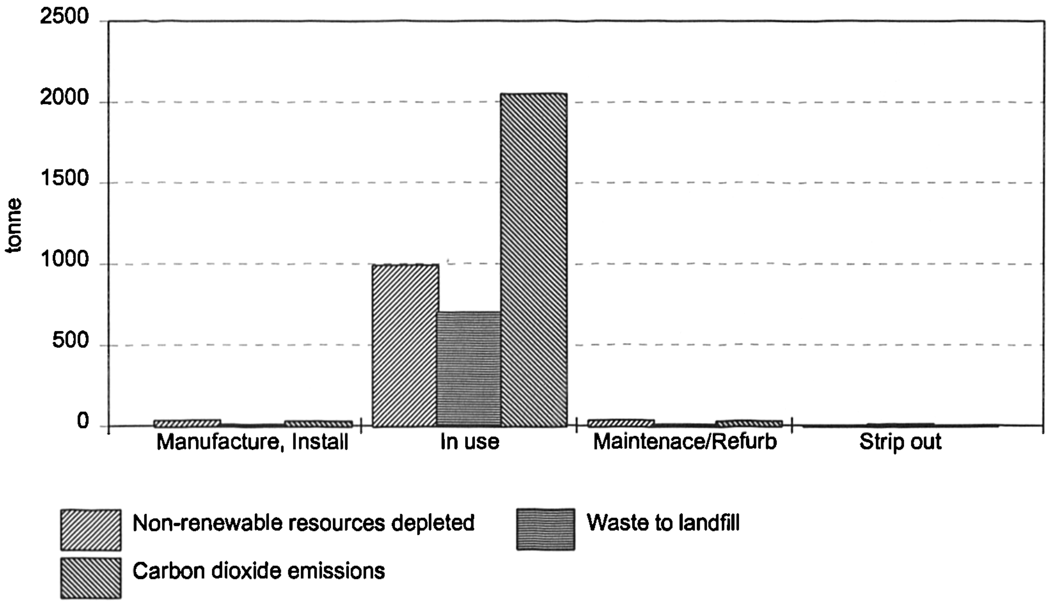


Figure 2.2 Lift Life Cycle Assessment results - impact over entire life cycle

A summary of the results from the PEMS analysis is given in Figure 2.2. This shows that the dominating environmental burdens in the life of this hypothetical lift system are the non-renewable resources depleted, the waste created and the emissions generated through the production of electricity for operation of the lifts while in use. The environmental burdens associated with other stages in the life cycle are relatively small.

The PEMS data for energy usage is not industry-specific. As this is by far the most dominant factor in the analysis, improvements in the (packaging biased) PEMS data for plastic, etc. would have minimal impact on the results.

The results are for lift systems, but the finding can be generalised to all vertical transportation systems, all of which have a high energy usage and a long design life.

Use of renewable resources in manufacture, recycling and re-use, efficient transport, disposal/spillage of hydraulic oil, etc. are all important, but secondary issues. Alone they cannot be the basis of claims for a green lift installation.

2.4 WHY IS ENERGY EFFICIENCY IMPORTANT?

2.4.1 Greenhouse effect

The greenhouse effect is caused by trace gases in the earth's atmosphere which absorb infra-red radiation emitted by the Earth's surface, causing a warming of the atmosphere. This natural effect is responsible for maintaining the temperature at the earth's surface which enables life. Man is upsetting the earth's natural balance by creating additional greenhouse gases. There is evidence to suggest that this is, and will cause global environmental effects such as droughts and floods.

The most important greenhouse gas is carbon dioxide, steadily increasing due to the burning of fossil fuels for energy generation and vehicles. Others include chlorofluorocarbons (CFCs). Half the carbon dioxide emitted in the UK results from the use of energy in buildings.

2.4.2 Pollution

Burning fossil fuels for energy generation produces nitrous oxide and sulphur dioxide which dissolves in the atmosphere creating acid rain. This is believed to have caused damage to lakes, plants, buildings, forests and fisheries. Nuclear electricity generation creates radioactive waste for which there is no satisfactory means of disposal.

2.4.3 Renewable resources and sustainable resources

If a resource can be regenerated it is said to be renewable, e.g. hardwood. If a renewable resource can be regenerated at a rate that matches the demand for it, it is said to be sustainable, e.g. softwood.

The use of fossil fuels for electricity generation is not sustainable. Sustainable energy sources such as wind, solar and hydroelectric do not, at this time, provide sufficient electrical power at a low enough cost to displace our dependence on non-sustainable sources.

2.4.4 Comment

The use of electricity at current levels is unsustainable, and damaging to our environment. As responsible stewards of the earth, we should be reducing our energy consumption and seeking to develop sustainable energy sources.

2.5 ARE LIFTS SIGNIFICANT ENERGY USERS?

Where they are installed, lifts and escalators are a significant proportion of the building load; the draft CIBSE Energy Efficiency Guide(2.3) suggests 4 to 7%. Kone sales documentation suggests 5 to 10%. The importance of energy efficient Heating, Ventilation, Air Conditioning (HVAC) and lighting systems is generally accepted; the wealth of related research and development in both these fields reflects this. The author suggests that vertical transportation systems should be among the next in line for "greening". Apart from environmental concerns, the financial cost of the electricity used by lifts is a major incentive for adopting energy saving designs. A 20% saving on a system using 300 kWh per working day would save in excess of £1000 per year at 1997 electricity prices.

2.6 GREEN LIFT BASICS

2.6.1 General

There are a number of "basic" principles for green lifts that should be considered by designers before adopting advanced strategies. These are summarised as follows.

2.6.2 Lift drives

Hydraulic lifts are energy inefficient in comparison with electric lifts. In his site measurements, Doorlaard(2.4) concluded that *the energy consumption of hydraulic lifts travelling at the same nominal speed is over two times the consumption of conventional two-speed lifts*. Hydraulic lifts do have benefits (e.g. low structural building load, flexible motor room position, low capital cost). But they are not green.

Lift manufacturers offer a wide range of electric lift drives ranging from single speed AC machines to variable speed AC and DC machines. A summary of these drives and their applications is given in[2.5]. Their energy efficiencies vary significantly. The most efficient electric lift drives are the modern fully controlled static converter DC and variable voltage variable frequency AC drives (including vector control drives); the AC drives provide better power factor control.

Green lift drives should be regenerative, i.e. return power to the mains when delivering negative torque (braking). The alternative, dissipating the energy in resistors can be doubly wasteful, as the waste heat introduces an additional cooling load in an air conditioned building. Installation of regenerative systems should be co-ordinated with the electrical building services design engineer as additional protection and harmonic filtering may be required.

2.6.3 Other installation issues

The torque, and therefore the energy, required of a motor to accelerate a lift can be reduced if we minimise inertia and other resisting forces. All rotating components (gear, brake, sheaths, etc.) and travelling components (lift car, counterweight, finishes, ropes, etc.) contribute to the inertia and to resisting forces in the system. Compared with the conventional worm gear, significant reduction in inertia and higher efficiencies have been demonstrated for by Zinke[2.6] for planetary gears, and by Stawinoga[2.7] for V-belt drives.

Lift car lighting should use efficient sources and be switched off automatically if a lift is not in use for long periods.

2.6.4 Planning issues

The total energy consumption of the installation is also dependant on planning issues. If stairs are accessible, attractive and adjacent to the lifts, there is likely to be a reduction in the use of lifts for short trips. It is also good to avoid over-sizing of lifts, as larger lifts result in greater inertia, larger motors and more energy use. While it is important to design spare handling capacity into a lift installation, over-sizing can be the result of:

- poor knowledge of probable traffic flows, leading to "safe" overestimates of required handling capacity.

- where traffic analysis suggests small lifts are acceptable, it is common to up-size the lifts selected. For instance, in a new office development where six, eight person lifts meet handling capacity and interval design criteria, ten or thirteen person lifts might be selected as larger lifts are perceived as prestigious.

2.7 OVERVIEW OF FOLLOWING CHAPTERS

In Chapter 3, the author reviews lift passenger traffic demand and data collection techniques. It is suggested that current lift design criteria need to be updated due to changes in working practices; and that these criteria result in the installation of excessive handling capacity. Having estimated prospective lift traffic, it is necessary to have analysis techniques to determine the number, size and speed of lifts required. In Chapters 4 and 5 traffic analysis techniques based on round trip time equations are reviewed and developed.

The developments in Chapters 3 to 5 are beneficial in the pursuit of improved design practice. From the environmental perspective, the benefit is that improved design criteria and analysis techniques will help avoid the over sizing of lift cars. Moving large, heavy lift cars up and down buildings when they are only partly loaded at peak times is not energy efficient.

In Chapters 6 and 7 tools are developed to model lift movement and corresponding energy consumption. These tools are implemented in a lift simulation program which is discussed in Chapter 8. The program is used to develop strategies for energy saving control systems which are discussed in Chapter 9.

Assuming that an installation has been designed with energy saving in mind, the developments in Chapters 6 to 9 provide a means by which we can reduce energy consumption further.

2.8 DISCUSSION

In this chapter we have used Life Cycle Analysis to identify the environmental burdens of lift systems. As was expected intuitively, the main burdens are caused by generating electricity to power the lifts while they are in use transporting passengers in buildings. Other environmental burdens are relatively minor. Thus, for maximum effect in reducing the environmental burdens of lifts, we should concentrate on researching ways of reducing their energy consumption.

Reducing energy consumption is important because of the environmental damage caused by the generation of electricity. The use of electricity at current levels is unsustainable. We need to reduce our current energy consumption as well as developing sustainable sources for the future.

The lift system will not normally be the largest energy user in a building. Other systems have higher loads and can offer greater energy savings. Nevertheless, there is correspondingly more research in environmental friendly HVAC, lighting, etc. systems. Energy saving lifts should not be disregarded as the potential savings are still worthwhile.

A number of basic principles for green lifts have been identified. The choice of drive, position of stairs, etc. all have a major effect on the energy consumption of the vertical transportation system. As a starting point, these choices should be made with energy saving in mind. We can then go on to consider more advanced strategies.

In the following chapters we will explore and develop these advanced strategies. We will show that savings can be made by improving the planning of vertical transportation systems using improved estimates of passenger demand. Furthermore, strategies for energy saving control systems will be developed through the application of motor and lift simulation models.

Some lift manufactures promote their products as being green because they include energy efficient drives; others promote their use of re-cycled packaging. Further work in defining green lifts should be focused on putting manufacturers' claims into context. This is primarily an exercise in communication, which has already begun through the publications arising from this project.

REFERENCES

2.1 *Life ever after*, The Economist, (9 October 1994), pp107.

2.2 *Life cycle inventory analysis computer model (PEMS)*, Pira International, Leatherhead, Surrey, England.

2.3 *CIBSE Energy Efficiency Guide*, (26 January 1994 draft), section 3.9, 1.

2.4 Doolaard D A *Energy Consumption by Different Types of Drive System* Elevator Technology 4, Proceedings of ELEVCON'92 (The International Association of Elevator Engineers)(1992)

2.5 Peters R D *Mathematical Modelling of Lift Drive Motion and Energy Consumption* Proceedings of CIBSE National Conference 1995 (The Chartered Institution of Building Services Engineers)(1995)

2.6 Zinke W *Planetary Gear and Frequency Inverter Set New Standards in Lift Drive Efficiency* Elevator World (January 1996)

2.7 Stawinoga R *New Mechanical Solutions for High Efficiency Gears* Elevator Technology 5, Proceedings of ELEVCON'93 (The International Association of Elevator Engineers)(1993)

Chapter 3

ASSESSMENT OF TRAFFIC DEMAND

3.1 INTRODUCTION

Assessment of performance is a crucial element in lift design. If lifts are too small, slow, or insufficient in number, passengers have to wait for excessive periods for a lift to arrive in response to landing calls. Furthermore, passengers travelling more than a few floors in under-lifted installations often endure long journey times - the result of the lifts having to stop to answer other calls at most of the intermediate floors. On the other hand, the luxury of an over-lifted building is an expensive one - floor area that could be let to tenants is lost to additional or larger lift lobbies and shafts; capital, maintenance and energy costs of the installation are higher.

The need to specify appropriate numbers of lifts, their capacity and speed, etc. has led to the study of lift traffic analysis. Lift traffic analysis allows us to assess the performance of a proposed lift installation based on estimates of building passenger traffic patterns. Lift traffic analysis techniques ranging from up peak calculations(3.1)(3.2) to general analytical formulae(3.3) and simulation techniques(3.4) are widely applied. But lift performance results from lift traffic analysis are of no better quality than the estimated passenger traffic patterns that are used in the calculations or simulations.

In this chapter the author summarises current, published knowledge of lift passenger traffic patterns and compares this with survey results. Current design guidelines are questioned, and means of improving our knowledge of lift passenger traffic patterns are discussed.

3.2 CURRENT KNOWLEDGE OF TRAFFIC PATTERNS

3.2.1 General approach

In estimating prospective passenger traffic patterns, a designer might consult:

- Elevator Traffic Analysis Design and Control(3.1)
- Vertical Transportation, Elevators and Escalators(3.2)
- CIBSE Guide D, Transportation Systems in Buildings(3.5)
- Standards, e.g. in the UK, BS 5655 Part 6(3.6)

There are other sources of information, including manufacturers' planning guides, but these tend to re-iterate the recommendations of above. Barney, dos Santos(3.1) and Strakosch(3.2) present example diagrams of passenger traffic in a commercial, office building. These diagrams have been re-drawn in Figures 3.1 and 3.2.

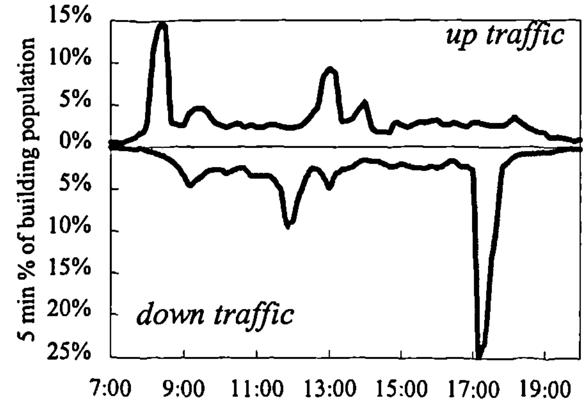


Figure 3.1 Typical office traffic, Barney(3.1)

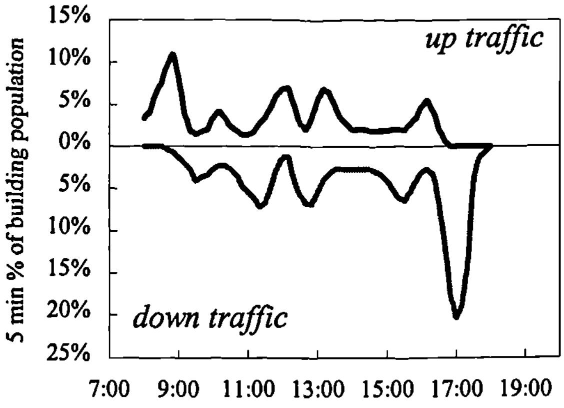


Figure 3.2 Typical office traffic, Strakosch(3.2)

According to Barney and dos Santos(3.1), conventional design procedure is to determine the performance of lift systems for the morning up peak traffic situation. This is consistent with the author's experience from reviewing consultants' and manufacturers' calculations. The common approach is probably because:

- the up peak traffic condition is relatively simple to analyse
- it is widely accepted that, if a lift system can cope efficiently with the morning up

peak, then it will cope with other periods in the day

- most traffic flow design recommendations are for up peak handling capacity

CIBSE Guide D(3.5) suggests the following up peak traffic flows for design purposes:

Building Type	*Arrival rate (% in 5 minutes)*	*Building Type*	*Arrival rate (% in 5 minutes)*
Hotel	10-15	Flats	5-7
Hospital	8-10	School	15-25
Office (multiple tenancy)	11-15 regular, 17 prestige	Office (single tenancy)	15 regular, 17-25 prestige

Table 3.1 CIBSE Guide D guidance on peak arrival rates

Strakosch(3.2) places most emphasis on the incoming up peak traffic, but also proposes two-way and outgoing traffic criteria. BS 5655 Part 6(3.6) offers only up peak design criteria.

3.2.2 Published lift traffic surveys

Detailed lift traffic surveys carried out by researchers, consultants and manufacturers are rarely published. One exception is *A survey of passenger traffic in two office buildings*(3.7) published by BRE in 1974. Results are summarised in Table 3.2.

Building	*Traffic period*	*Peak 5 min % building population using lifts*
Southbridge House	morning up peak	12.2
	evening down peak	8
Sanctuary Buildings	morning up peak	7.8
	evening down peak	6.7

Table 3.2 Summary of BRE traffic survey results

The BRE survey also concluded that lunch time traffic amounts to 12% of building population in both buildings, but this includes stair traffic.

3.3 TRAFFIC SURVEYS

Passenger traffic surveys have been carried out by the author at a range of buildings. Results are summarised in Figures 3.3 to 3.7 which record the traffic to and from the main terminal floor(s), except for Building E where the predominant traffic flow was inter-floor. Traffic was measured only during peak periods (normally morning, lunch and evening; morning and evening for the hotel).

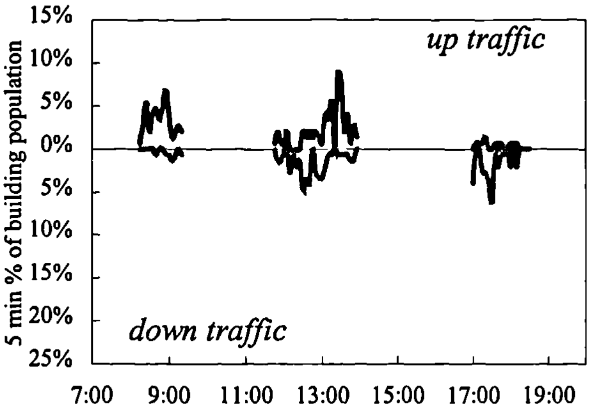


Figure 3.3 Building A traffic survey results for single tenancy office, engineering

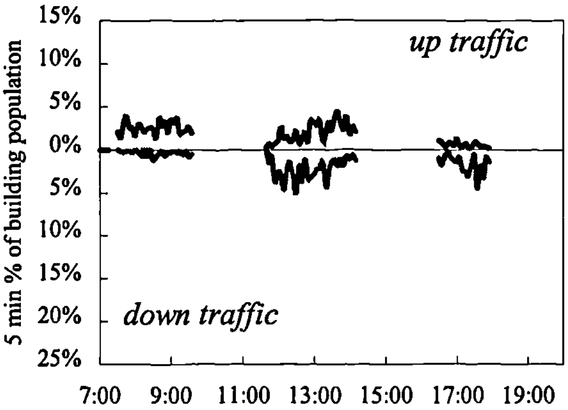


Figure 3.4 Building B traffic survey results for single tenancy office, banking/dealers (results based on nominal population of 1 person/10m^2 as actual occupancy not available)

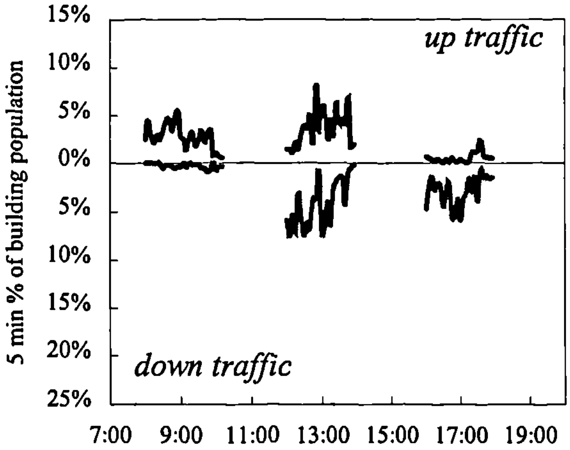


Figure 3.5 Building C traffic survey results for single tenancy office, general

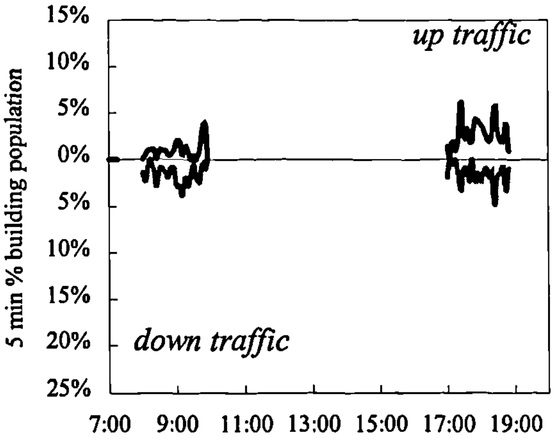


Figure 3.6 Building D traffic survey results for prestigious traditional hotel

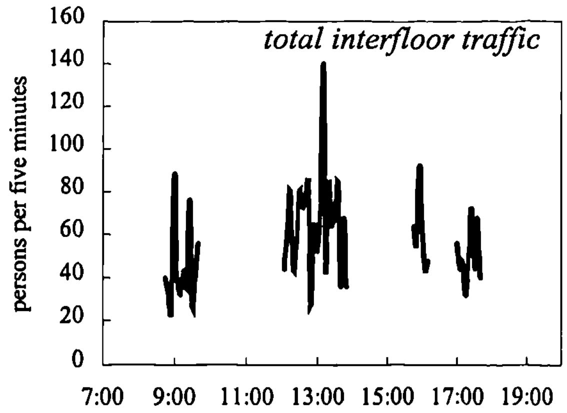


Figure 3.7 Building E traffic survey results for major high rise hospital

(results not shown as % as only one of two passenger lift banks available for survey)

3.4 REVIEW OF RESULTS

The traffic survey results suggest that the morning traffic peaks are less marked in buildings than they were when traditional up peak design criteria were formulated. In work-related buildings occupied during the day, the busiest period appears to be over the lunch period. Lunch traffic is a combination of up and down peak traffic to the main terminals, but often includes an element of inter-floor traffic. This inter-floor traffic is especially significant in buildings with restaurants, meeting rooms, etc.

A lift system has a greater passenger handling capacity during lunch time traffic than during a morning up peak. This is because during an up peak all the passengers are loaded at the ground floor. During lunch peaks, the lifts are loaded in both directions, and may carry up to twice as many passengers in a single round trip.

However, if the same total handling capacity is assumed, people wait longer for a lift at lunch time than they do during a morning up peak. This is because the combination of passengers travelling up and down the building results in more stops per round trip.

If the traffic studies of commercial buildings made during this research are typical, designers are allowing too much handling capacity during the morning up peak, and not giving enough attention to the waiting times for passengers during the lunch peak.

In testing these findings on Arup designs, it is apparent that revising our design criteria is unlikely to result in fewer lifts, but would reduce car capacities, say from 1250 kg to 1000 kg. And therefore lead to energy savings.

It would be dangerous to disregard established up peak design criteria without a wider study of building traffic flow peaks; more data must be collected. Thus the remainder of this chapter discusses means of representing and collecting traffic data so that, in due course, updated design criteria can be formulated for a wide range of buildings.

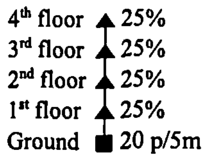
3.5 REPRESENTING LIFT TRAFFIC FLOWS

Traditionally lift traffic flows have been defined in terms of the percentage of the building population transported upwards and downwards in five minutes, as used in Figures 3.1-3.6. For more complex flows such as lunch peaks we need a more comprehensive way of describing lift traffic. The author presented an approach in his paper on *General Analysis Lift Calculations*(3.3) that allows us to describe traffic flow completely. Two terms are required:

μ_i the passenger arrival rate at floor i (defined for each floor at which passengers may arrive

d_{ij} the probability of the destination floor of passengers from floor i being the jth floor (defined for all possible i and j)

Using these terms, a simple up peak traffic flow in an office block could be represented as in Figure 3.8. And a more complex traffic flow could be represented as in Figure 3.9.



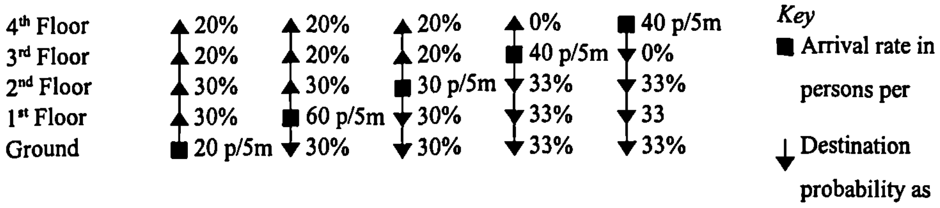


Figure 3.8 **Figure 3.9**

Future design criteria should enable the designer to estimate peak traffic flows in these terms from a knowledge of the office building population, number of hotel rooms, etc. dependant on the building type.

3.6 CARRYING OUT LIFT SURVEYS

3.6.1 Alternative survey techniques

The are a number of alternative approaches to collecting data on lift passenger traffic patterns. Those considered by the author are discussed in the following subsections. Other and new technologies may yield alternative approaches.

3.6.2 Manual surveys using observers

In manual surveys observers count passengers in and out of the lifts. Manual surveys are normally based on one of two approaches:

i. survey from the main terminal(s), where observers count passengers in and out of the lifts as they arrive/depart from the main terminal floor(s). Traffic between other floors is assumed to be negligible. Survey results given in Figures 3.3 to 3.6 where collected using this approach.

ii. the in-car survey, where observers are situated in the lift car, and count the passengers in and out at every floor the lift stops at. Survey results given in Figure 3.7 were collected using this approach.

Manual surveys are discussed in detail in (3.1) and (3.8). The new generation of cheap, miniature video cameras (used with a video recorder) can be used to make observation unobtrusive; the recorded video is played back off site for counting.

The survey techniques do not allow us to describe traffic flow completely as:

- (i) only measures arrival rate at the main terminal floor(s) and requires assumptions to be made about arrival rates and destinations probabilities on other floors. These assumptions are generally based on the building floor populations.

- (ii) measures arrival rates at all floors, so provides superior data to (i). Overall destinations probabilities (averaged over all arrival floors) can be approximated from the count of passengers as they leave the lift. Collecting data to enable traffic to be described completely is impractical for the human observer unless traffic is light - to achieve a full data set of destination probabilities, the observer would have to track every passenger, e.g. passenger 53 entered the lift at floor 3 and alighted at floor 6; passenger 54 entered the lift at floor 4 and alighted at floor 10, etc.

3.6.3 Control system and traffic analyser surveys

Conventional systems

Traffic analysers are linked to the lift control system, and record the time every landing and car call is made and cleared. They analyse this data and provide a range of performance results and graphs. Modern control systems incorporate similar functionality.

A range of traffic and performance measures can be determined, for example:

- average response time to landing calls by time of day
- distribution of response times
- distribution of car calls by floor

Traffic analysers give a good indication of a lift system's performance, but very limited information about the actual passenger traffic flow. This is because they have no means of determining the number of people transported on each trip, e.g. a landing call at floor five and corresponding car call to floor seven could equally be a single person, or a group of people travelling together. The use of accurate weighing devices would provide a guide to passenger load. But ambiguities occur if people are loading and unloading at the same floor, e.g. five people loading and three people unloading would provide the same weight differential as two people loading.

Therefore, on its own, traffic analyser data does not give us the information we require.

Inverse S-P method

Al-Sharif suggested a means of interpreting data that is available to traffic analysers. The Inverse S-P method(3.9) applies conventional up peak traffic analysis formulae "backwards" to estimate the number of passengers using a lift from the number of car calls and lift movements. The Inverse S-P method is effective, yet applies only to up and to down peak traffic.

Estimation of complete traffic flow

The author reported having derived a method for extrapolating (complete) traffic flow from control systems data in(3.10). The development of this method has been halted after successful preliminary tests as further work is impractical without taking data directly from lift system controllers. Manufacturers have proved unable or unwilling to provide access to the necessary data for research purposes. The proposed method is outlined as follows:

- The passenger arrival rate, μ_i, is a function of [the average time between a lift leaving floor i travelling up and the up landing call being pressed by the next passengers arriving at the landing station] and [the average time between a lift leaving floor i travelling down and the down landing call being pressed by the next passengers arriving at the landing station].

- This function can be derived by applying the assumption that the arrival of passengers at a lift landing is reasonably modelled by a Poisson process. (This assumption has previously been applied in lift traffic analysis(3.1)(3.3).)

- Destination probabilities can be estimated by analysis of car calls registered as the lift leaves each landing. Not every passenger will register a car call (as other passengers will have pressed the button first). But over time the relative frequency of unregistered car calls being pressed will provide a good indication of the average destination probabilities from each floor.

Figure 3.10 records some results from the preliminary tests where control system data was collected "manually" by observation.

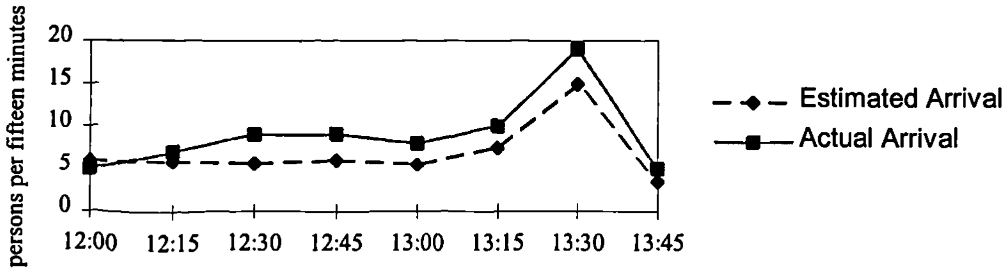


Figure 3.10 Poisson based estimate of traffic flow

3.6.4 Computer vision

Researchers(3.11)(3.12) have applied image processing techniques to video pictures of lift lobbies to determine the number of people waiting for the lifts. This lobby count aids the control system by enabling it to prioritise calls from busy floors.

A spin off from the lobby count system developed at Brunel University was a prototype "traffic surveyor" to count the passengers as they loaded and alighted the lifts. The system applies similar image processing techniques to the lobby count system, but compares each video frame in sequence to track people across the scene. If people join or leave the scene from the areas defined as the lift doors, they are counted as having loaded or alighted the lifts. In tests the system was found to be 80-85% accurate, errors being due mainly to a tendency to miss-track people from one image to the next.

This Brunel University research project has now concluded, so no further development is envisaged. But image processing is an active research area and improved pedestrian tracking systems are likely to be developed in the future, probably initially for security applications. In due course, we are likely to be able to purchase general purpose pedestrian tracking systems that will provide us with the basis for complete measurements of traffic flow.

3.6.5 Infra-red

Infra-red technology is widely applied, particularly in the security industry. Traffic surveys using photocells or infra-red beams were suggested in (3.13)(3.14). The approach requires a minimum of two horizontal beams to count people passing through the detection field in single file. The sequence of beam states enables direction to be determined. If people are walking side by side, horizontal beams will detect only a single person. This can be overcome by mounting beams vertically - a system believed to be using this approach is installed in a London department store monitoring escalator traffic.

Initial lab and site tests suggest that, although system logic can be fooled, in practice the overall counting accuracy of infra-red counting systems is high. The infra-red detectors effectively replace observers in manual surveys, so the data collected does not describe traffic flow completely (as in 3.6.2 ii we can only calculate average destination probabilities). But infra-red technology is available and relatively inexpensive to implement.

3.6.6 Written surveys

Written surveys, where people record the times of lift trips on a form, have been found to be unreliable(3.7); this was confirmed from the results of a written survey at Building A (Figure 3.3). This is probably due to a tendency for people to record their arrival and departure times as the fixed working hours of a company.

3.6.7 Security systems

Various security systems are applied to control access in buildings, some of which are integrated with the lift systems. Systems that use swipe cards to call the lift, or a key pad to control access to specific floors, do not yield useful traffic flow data. Where they are installed, systems that identify passengers individually as they arrive and depart lift lobbies, will enable traffic flow to be monitored completely.

3.7 OTHER ISSUES

3.7.1 Use of stairs

In planning lift installations, some designers make allowance for the use of stairs. The author's survey experience suggests:

- the number of people using the stairs in lieu of the lifts drops off sharply as the journey travel increases
- people are less likely to walk up than down
- an attractive staircase sited adjacent to the lifts is far more likely to be used than a back staircase

In the Building C (Figure 3.5) survey, use of the staircase was virtually nil in spite of the lifts being heavily loaded and long passenger waiting times; the main staircase was an unattractive fire escape sited well away from the lift lobby. Figure 3.11 shows the associated stair usage for the BRE(7) and Building A (Figure 3.3) surveys.

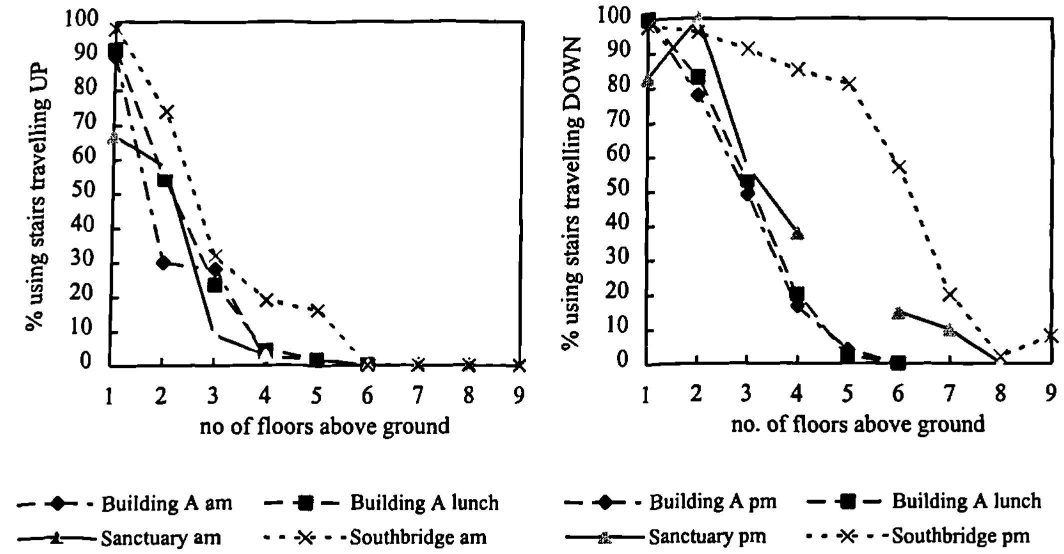


Figure 3.11 Example stair usage for up and down travel

In lift traffic surveys we need to *assess stair usage*, *otherwise* generalised recommendations will be inappropriate to:

- high rise buildings where the relative use of stairs is far less significant
- buildings where stair access is poor

3.7.2 Occupancy

If the results of traffic surveys are to be applied in the design of other buildings, it is important that traffic is recorded relative to the actual building population - plotting survey results of a partly occupied building relative to nominal building population can suggest misleadingly low traffic flows.

3.8 DISCUSSION

It is important for lift designers to have a good understanding of passenger traffic demand. A poor knowledge of demand will often result in either an inadequate or an over-designed system. The first alternative is unacceptable to passengers. The second is unnecessarily expensive, and will consume more energy.

Most lift installations in commercial buildings are designed on the basis that the morning up peak is the most onerous traffic condition for the lifts. Surveys carried out for this research project suggest that this is not the case, and that the lunch time is now the busiest period. Further surveys need to be carried out to confirm these results. However, they are consistent across the office buildings surveyed by the author, and with anecdotal evidence from designers to whom this work has been presented.

The findings on passenger traffic demand are important as a lift installation has a greater total handling capacity at lunch time than it does in the morning. This is because, during a lunch time peak, passengers are being transported during both the up and down journey of the round trip. During an up peak, the lift is normally empty during the down trip.

Thus revising our design criteria to take these findings into account is unlikely to result in fewer lifts, but would reduce car sizes, and therefore lead to energy savings.

It is recognised that large lifts are often associated with prestige. And that in order to improve environmental performance, we need to forego this luxury. As for many other products and processes, consumers will have to accept some changes if they want to support green issues.

In carrying out further surveys, researchers should use automated people counting techniques as it is very time consuming to collect large amounts of data manually. A range of surveying techniques has been reviewed. Currently the author favours an infra-red beam system as the best available technology, although further research in passenger counting techniques would be beneficial. The author continues to collect data, and has been encouraging others to publish their results so that improved design criteria can be established.

In planning new lift installations, it would be dangerous to disregard conventional up peak design criteria completely until a wider study of other traffic flow peaks is complete.

Major elements of the research discussed in this chapter were presented at the International Elevator Technology Conference, ELEVCON '96 and again at an IAEE London Lift Seminar.

REFERENCES

3.1 Barney G C, dos Santos S M *Elevator Traffic Analysis Design and Control* 2nd edn. (London: Peter Peregrinus) (1985)

3.2 Strakosch G R *Vertical Transportation: Elevators and Escalators* 2nd edn. (New York: J Wiley & Sons Inc.)(1983)

3.3 Peters R D *The Theory and Practice of General Analysis Lift Calculations* Elevator Technology 4, Proceedings of ELEVCON '92 (The International Association of Elevator Engineers)(1992)

3.4 Jenkins K *Elevator Simulation Techniques* Elevator Technology 4, Proceedings of ELEVCON '92 (The International Association of Elevator Engineers)(1992)

3.5 Various Authors *CIBSE Guide D, Transportation Systems in Buildings* (The Chartered Institution of Building Services Engineers)(1993) ISBN 0 900953 57 8

3.6 BS 5655 Part 6: Lifts and service lifts: Part 6: Code of practice for selection and installation (London: British Standards Institution)(1990)

3.7 Courtney R G, Davidson P J *A survey of passenger traffic in two office buildings* (Watford: Building Research Establishment)(June 1994)

3.8 Various Authors *Elevator World's Guide to Elevatoring* (Elevator World)(1992)

3.9 Al-Sharif L *New Concepts in Lift Traffic Analysis: The Inverse S-P method* Elevator Technology 4, Proceedings of ELEVCON '92 (The International Association of Elevator Engineers)(1992)

3.10 Peters R D *Green Lifts?* Proceedings of CIBSE National Conference 1994 (The Chartered Institution of Building Services Engineers)(1994)

3.11 So A T P, Kuok S K *A Computer Vision Based Group Supervisory Control*

System Elevator Technology 4, Proceedings of ELEVCON '92 (The International Association of Elevator Engineers)(1992)

3.12 Schofield A J, Stonham T J, Mehta P A *A machine vision system for counting people* Proceedings of Intelligent Buildings Congress '95 (Israel: The Stier Group Ltd)(1995)

3.13 Kaakinen M, Roschier N R *Integrated Elevator Planning System* Elevator World (March 1991)

3.14 Siikonen M L *Simulation - A Tool for Enhanced Elevator Bank Design* Elevator World (April 1991)

3.15 Peters R D, Mehta P, Haddon J *Lift Passenger Traffic Patterns: Applications, Current Knowledge, and Measurement* Elevator Technology 7, Proceedings of ELEVCON'96 (The International Association of Elevator Engineers) (1996) (also presented at IAEE London Lift Seminar May 1997)

Chapter 4

TRAFFIC ANALYSIS

List of symbols

a	acceleration (m/s/s)
CC	car (rated) capacity (persons)
CF	capacity factor (%)
d_f	average inter-floor height (m)
df_n	height floor n (m)
d_H	distance to reach reversal floor H excluding express zone (m)
d_X	total height of un-served floors in express zone (m)
H	average highest reversal floor
j	jerk (m/s/s/s)
L	number of lifts
$LOSS$	round trip time losses (%)
N	number of floors above main terminal
P	average number of passengers
S	average number of stops
T	cycle time (s)
t_a	advanced door opening time (s)
t_c	door closing time (s)
$t_{fd}(d)$	flight time for travel distance d (s)
t_{fl}	single floor flight time (s)
t_l	passenger loading time per person (s)
t_o	door opening time (s)

t_p	average passenger transfer time (s)
t_u	passenger unloading time per person (s)
t_v	time to travel between two adjacent floors at rated speed (s)
t_s	time consumed when making a stop (s)
t_{start}	allowance for motor start delay (s)
P	average number of passengers in car
%POP	5 minute up-peak handling capacity (% population)
RTT	round trip time (s)
U_{eff}	effective building population (persons)
U_i	population of floor i (persons)
UPPHC	up-peak handling capacity (persons/5 min)
UPPINT	average up-peak interval (s)
v	contract (rated) speed (m/s)

4.1 INTRODUCTION

Having reviewed a probable peak traffic demand, the next lift design stage is traffic analysis. In this chapter we will look at analytical traffic analysis techniques based on Round Trip Time calculations. These techniques are currently the most popular and widely applied.

4.2 STANDARD UP-PEAK CALCULATION

4.2.1 General

Most lift designs are based on up peak calculations. As discussed in Chapter 3 of this thesis, the up peak is not always the most appropriate choice of peak period for the analysis. Nevertheless, the up peak calculation is important as an industry standard benchmark calculation, and a good starting point for assessing the handling capacity of a lift system.

The up peak lift calculation is based on estimating the time taken for a lift to make a single "round trip" of the building. The calculation assumes people load the lift at the lowest floor, and get dropped off as the lift stops off at upper floors. The lift then expresses back to the ground floor (some designers include an allowance for additional stops made by the lift on its return journey). The round trip time is calculated for a single lift, so results for two of more lifts are extrapolated accordingly.

The up peak calculation has evolved over a number of years. Jones(4.1) determined results for the probable number of stops made by the elevator during its round trip. Schroeder(4.2) determined formulae for highest reversal floor. Barney and dos Santos(4.3) formalised the method with formulae that are now generally accepted by the Lift Industry. A summary of these formulae follow.

4.2.2 Up peak formulae

The average number of passenger assumed to load into a car during up peak traffic is

$$P = \frac{CF}{100} \cdot CC \qquad (4.1)$$

The effective building population of the buildings is

$$U_{eff} = \sum_{i=1}^{N} U_i \qquad (4.2)$$

The average highest reversal floor is

$$H := N - \sum_{j=1}^{N-1} \left(\sum_{i=1}^{j} \frac{U_i}{U_{eff}} \right)^P \qquad (4.3)$$

The average number of stops made by the lift during its round trip is

$$S := N - \sum_{i=1}^{N} \left(1 - \frac{U_i}{U_{eff}} \right)^P \qquad (4.4)$$

The average time taken for a single person to load or unload the lift is

$$t_p = \frac{t_l + t_u}{2} \tag{4.5}$$

The time taken for the lift to travel between two adjacent floors at rated speed is

$$t_v = \frac{d_f}{v} \tag{4.6}$$

The single floor flight time, t_{fl} is taken from a table, as re-produced in Table 4.1

Contract Speed (m/s)	Acceleration (m/s^2)	Single Floor Flight Time, 3.3m floor height (s)
1.00	0.4-0.7	7.0
1.50	0.7-0.8	6.0
2.50	0.8-0.9	4.8
3.50	1.0	3.7-4.0
5.00	1.2-1.5	3.7-4.0

Table 4.1 Typical flight times

The cycle time is the time to travel a single floor, and open/close the doors

$$T := t_{fl} + t_c + t_o \tag{4.7}$$

So the delay or "time consumed" by making a single stop is

$$t_s = T - t_v \tag{4.8}$$

The Round Trip Time is the time taken for the travel to/from the highest reversal floor at contract speed, plus the delay for each stop, plus the time for the passengers to load/unload. Thus,

$$RTT := \left[2 \cdot H \cdot t_v + (S + 1) \cdot t_s + 2 \cdot P \cdot t_p\right] \tag{4.9}$$

Some designers add 5-10% to the Round Trip Time for "losses" associated with controller inefficiencies, passengers holding the doors, and so on.

The up peak interval is calculated by dividing the round trip time by the number of lifts.

$$\text{UPPINT} = \frac{\text{RTT}}{\text{L}} \tag{4.10}$$

The interval is the average time between successive lift arrivals at the main terminal floor. It is not the average waiting time, which Strakosch states is about 55 to 60% of the interval, dependant on the control system(4.4).

The up peak handling capacity is the number of passengers transported in a five minute period. This is calculated as

$$\text{UPPHC} = \frac{300 \cdot \text{P} \cdot \text{L}}{\text{RTT}} \tag{4.11}$$

The handling capacity, expressed as a percentage of the building population transported in five minutes is

$$\%\text{POP} = \frac{\text{UPPHC} \cdot 100}{\text{U}_{\text{eff}}} \tag{4.12}$$

4.3 IMPROVEMENTS TO UP-PEAK CALCULATION

4.3.1 Flight time calculation

Determining flight time from Table 4.1 is limited as the inter-floor heights are assumed to be 3.3 m, and only "standard" speeds and accelerations are considered. The author's research in ideal lift kinematics has yielded general formulae to determine flight time for any travel distance and lift dynamics.

$$\textit{if} \quad d \geq \frac{a^2 \cdot v + v^2 \cdot j}{j \cdot a} \quad \textit{then} \quad t_{fd}(d) := \frac{d}{v} + \frac{a}{j} + \frac{v}{a} + t_{start} \tag{4.13}$$

$$\textit{if} \quad \frac{2 \cdot a^3}{j^2} \leq d < \frac{a^2 \cdot v + v^2 \cdot j}{j \cdot a} \quad \textit{then} \quad t_{fd}(d) = \frac{a}{j} + \frac{\sqrt{a^3 + 4 \cdot d \cdot j^2}}{\sqrt{a \cdot j}} + t_{start} \tag{4.14}$$

$$\textit{if} \quad d < \frac{2 \cdot a^3}{j^2} \quad \textit{then} \quad t_{fd}(d) := \left(32 \cdot \frac{d}{j}\right)^{\frac{1}{3}} + t_{start} \tag{4.15}$$

These formulae are consistent with results provided by Molz[(4.5)], but are in a simpler form.

Applying the $t_{fd}(d)$ function, the single floor flight time is

$$t_{fl} := t_{fd}(d_f) \tag{4.16}$$

Research in ideal lift kinematics is discussed in detail in Chapter 6 of this thesis. These travel time formulae are included in the draft revision of the new CIBSE Guide D, *Transportation Systems in Buildings*[(4.6)].

4.3.2 Lifts not reaching full speed in single floor jump and non-equal inter-floor heights

The conventional Round Trip Time equations assume that the lift reaches rated speed in the distance of a single floor jump; and that there are no irregularities in floor heights. This is not always the case, and the current CIBSE Guide D proposes a procedure for making "corrections" to the conventional RTT formulae. The author has formulated these corrections as follows:

Determine the distance d_H to reach reversal floor H, which can be written as

$$d_H = \left(\sum_{i=0}^{\mathrm{floor}(H)-1} df_i \right) + (H - \mathrm{floor}(H)) \cdot df_{\mathrm{floor}(H)} \tag{4.17}$$

(floor(x) is a function which returns the greatest integer less than or equal to x)

The average distance between stops is then

$$\frac{d_H}{S}$$

and the flight time to travel this distance is

$$t_{fd}\left(\frac{d_H}{S}\right)$$

The difference between this and the assumed time can be substituted into an enhanced equation for t_s which becomes

$$t_s = \left(t_{fd}\left(\frac{d_H}{S}\right) - \frac{d_H}{S \cdot v}\right) + t_c + t_o - t_a \qquad (4.18)$$

(Advanced door opening time (s) has been added to this formulae at the suggestion a member of the Guide D Revision Committee. Some designers take advanced door opening off the door opening time, but it is clearer to identify it separately.)

The $2 \cdot H \cdot t_v$ term in the RTT equation also needs to be revised to $2 \cdot \frac{d_H}{v}$ to take into account the new approach. The round trip time equation now becomes

$$RTT = \left[2 \cdot \frac{d_H}{v} + (S + 1) \cdot t_s + 2 \cdot P \cdot t_p\right] \qquad (4.19)$$

Equations for UPPINT and UPPHC remain the same.

A sensitivity analysis has been carried out to establish the "correction" due to adopting these "enhanced" equations. Data and results are given in Tables 4.2 to 4.7.

a	$0.8\ m/s^2$	t_c	2.9 s
CC	16 persons	t_l	1.2 s
CF	80%	t_o	1.2 s
df_0 to df_7	3.6 m	t_u	1.2 s
j	$1.6\ m/s^3$	t_{start}	0.5 s
L	4	U1 to U8	80 persons/floor
N	8	v	$2.5\ m/s^2$
t_a	0.5 s		

Table 4.2 Default analysis data

Speed	Acceleration	Jerk	% variation RTT
1	0.5	1	0
1.6	0.7	1.4	-0.11
2.5	0.8	1.6	0.72
3.5	1	1.6	1.01
5	1.3	1.6	1.14
6	1.5	1.6	1.15

Table 4.3 Variations in Speed

N	% variation RTT
4	0.08
6	0.36
8	0.72
10	1.08
12	1.38
14	1.6

Table 4.4 Variations in N

CC	% variation RTT
6	2.03
8	1.74
10	1.43
13	1.02
21	0.4
26	0.22
33	0.1

Table 4.5 Variations in CC

d_f	% variation RTT
3.2	0.8
3.4	0.76
3.6	0.72
3.8	0.68
4	0.64
4.2	0.6

Table 4.6 Variations in d_f

df_n	% variation RTT
all 3.6m	0.72
just df_0 5m	0.72
just df_4 5m	0.72
just df_7 5m	0.48
df_0 and df_4 5m	0.71
df_4 and df_7 5m	0.48
df_0 and df_7 5m	0.48
df_0, df_4 and df_7 5m	0.48

Table 4.7 Variations in inter-floor distances

These variations are relatively small. On balance the author, and other colleagues on the CIBSE Guide D Steering Committee are proposing to include the revised calculation for t_s and RTT, but to simplify the calculation for d_H to use simply the average inter-floor height. So, equation 4.17 becomes:

$$d_H = d_f H \qquad (4.20)$$

where

$$d_f = \frac{\sum_{i=0}^{N-1} df_i}{N} \qquad (4.21)$$

4.3.3 Express Zones

In high rise buildings lifts are often zoned to reduce passenger travel times and to save core space by not having all the lifts serving the upper floors of the building. An example of a zoned building is represented by the diagram in Figure 4.1.

18					●	●	●	●
17					●	●	●	●
16					●	●	●	●
15					●	●	●	●
14					●	●	●	●
13					●	●	●	●
12					●	●	●	●
11					●	●	●	●
10					●	●	●	●
9	●	●	●	●	○	○	○	○
8	●	●	●	●	○	○	○	○
7	●	●	●	●	○	○	○	○
6	●	●	●	●	○	○	○	○
5	●	●	●	●	○	○	○	○
4	●	●	●	●	○	○	○	○
3	●	●	●	●	○	○	○	○
2	●	●	●	●	○	○	○	○
1	●	●	●	●	○	○	○	○
Ground	●	●	●	●	●	●	●	●
Lift No	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
	LOW RISE				*HIGH RISE*			

Key ● Lift serves floor ○ Lift expresses past floor without stopping

Figure 4.1 Zoned building

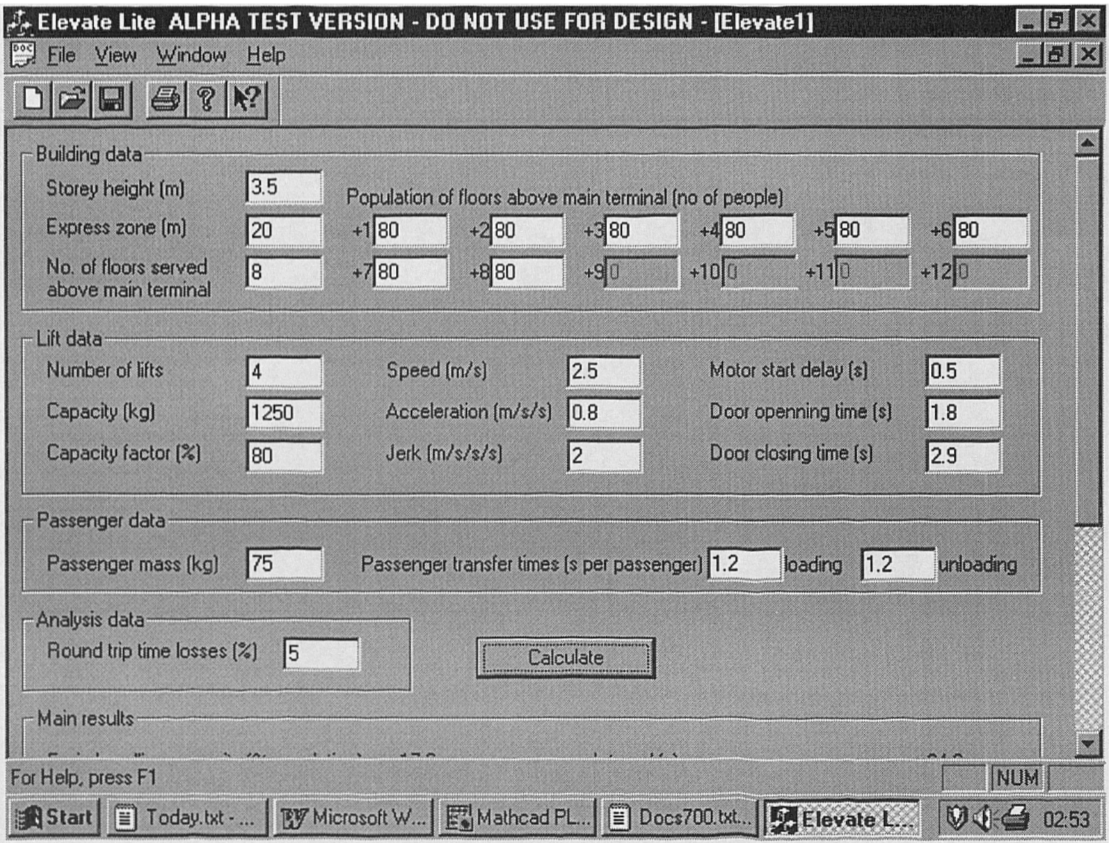
This express zone can be taken into account by revising the Round Trip Time Equation, 4.19 to

$$RTT = \left[2 \cdot \frac{d_H + d_X}{v} + (S+1) \cdot t_s + 2 \cdot P \cdot t_p \right] \qquad (4.22)$$

where d_X is the express zone; in this example, the sum of the floor heights of Levels 1 to 9.

4.3.4 Elevate Lite

The previous edition of CIBSE Guide D made extensive use of look-up tables to simplify the calculation procedure for designers. For this next version of the guide, the author has written a computer program to implement the up peak calculations given in sections 4.3.2 and 4.3.3. The program is written using Microsoft Visual C++ and runs under 32 bit Windows ('95 and NT). It will be given away with the revised CIBSE Guide.



Building data

Storey height (m) 3.5

Express zone (m) 20

No. of floors served above main terminal 8

Population of floors above main terminal (no of people)

+1	80	+2	80	+3	80	+4	80	+5	80	+6	80
+7	80	+8	80	+9	0	+10	0	+11	0	+12	0

Lift data

Number of lifts 4

Capacity (kg) 1250

Capacity factor (%) 80

Speed (m/s) 2.5

Acceleration (m/s/s) 0.8

Jerk (m/s/s/s) 2

Motor start delay (s) 0.5

Door openning time (s) 1.8

Door closing time (s) 2.9

Passenger data

Passenger mass (kg) 75

Passenger transfer times (s per passenger) 1.2 loading 1.2 unloading

Analysis data

Round trip time losses (%) 5

Figure 4.2 Screen shot of *Elevate Lite*

4.4 GENERAL CALCULATION

The standard up peak calculation is a valuable tool, but has a number of limitations. These include:

- the calculation only considers up peak traffic; as previously discussed, this is not believed to be the most onerous traffic flow in buildings
- in some instances up peak calculations are inappropriate, e.g. in shopping centres, car parks, airports or hospitals
- it is difficult to adjust the calculation to analyse up peaks in for buildings with basements which are occupied

Some of these limitations were overcome by Alexandris(4.7) who presented equations that allowed inter-floor traffic to be assessed. The limitation of this method is that passenger destinations are assumed to be the same from every floor, e.g. it is assumed that people travelling from floors x and y are both equally likely to want to go to floor

z. Consider the traffic in a multi-storey car park or office block with a restaurant floor to see the inconsistencies here.

Prior to joining the EngD programme, the author developed a new lift traffic analysis calculation which overcame these limitations. The *General* calculation allows us to carry out a round trip time calculation analysing any peak passenger traffic flow for any practical configuration of conventional lifts.

Details of the General calculation are widely published(4.8)(4.9). The calculations have been implemented (in Fortran) by the author in the Oasys (Ove Arup Computer Systems) LIFT program. This program, issued originally in 1989, has been applied extensively through the work of the Ove Arup Partnership.

4.5 DISCUSSION

Most lift designs are based on an up-peak analysis, which is an important industry standard benchmark. The up-peak analysis has been developed over a number of years with contributions from several authors.

The author of this research project has made two contributions. Firstly, to derive formulae to determine flight times for any travel distance and lift dynamics. This extends the standard method, which uses tabulated results.

Secondly, the author has implemented in formulae, "corrections" that were recommended for lifts not reaching full speed in a single floor jump, and for non-equal inter-floor heights. A sensitivity analysis on these corrections has demonstrated that the variations between original and corrected results are relatively small (less than 2%). It can be argued that this variation is too small to warrant changes to the standard up peak calculation procedure. In itself, this is an interesting and useful result.

The up-peak calculation has been implemented in a computer program which, it is intended, will be issued with the revised version of CIBSE Guide D, *Transportation* *systems in buildings.*

As discussed in Chapter 3, the lunch-peak is now believed to be the busiest period in a commercial building. Prior to joining the EngD programme, the author derived the *General Analysis* calculation technique that assesses a lift system's performance given any peak passenger demand, including lunch-time traffic. This is a relatively complex technique to implement and to apply. Therefore further research to determine the equivalent lunch time handling capacity relative to a given up-peak handling capacity would be beneficial. This would allow designers to assess lunch time performance while retaining well known and understood up-peak analysis techniques.

The work presented in this chapter is a contribution to the development of green lifts in that, to avoid the inefficiencies of over-design, we need improved lift selection and analysis tools. Without these tools, it is difficult to realise the savings which it has been suggested can be achieved by improving our assessment of traffic demand.

REFERENCES

4.1 Basset Jones *The probable number of stops made by an elevator* GE Review 26(8) 583-587 (1923)

4.2 Schroeder J *Personenaufzeuge* Foerden und Heben 1 44-50 (1955) (in German)

4.3 Barney G C, dos Santos S M *Elevator Traffic Analysis Design and Control* 2nd edn. (London: Peter Peregrinus) (1985)

4.4 Strakosch G R *Vertical Transportation: Elevators and Escalators* 2nd edn. (New York: J Wiley & Sons Inc.)(1983)

4.5 Motz H D *On the kinematics of the ideal motion of lifts* Forden und haben 26 (1) (1976) (in German)

4.6 Various Authors *CIBSE Guide D, Transportation Systems in Buildings* (The Chartered Institution of Building Services Engineers)(1993) ISBN 0 900953 57 8

4.7 Alexandris N A, Barney G C and Harris C J *Derivation of the mean highest reversal floor and expected number of stops in lift systems* Applied

Mathematical Modelling 3 275-279 (August 1979)

4.8 Peters R D *Lift Traffic Analysis: Formulae for the general case* Building Services Engineering Research and Technology, Volume 11 No 2 (1990)

4.9 Peters R D *The Theory and Practice of General Analysis Lift Calculations* Elevator Technology 4, Proceedings of ELEVCON'92 (The International Association of Elevator Engineers) (1992)

Chapter 5

DOUBLE DECK TRAFFIC ANALYSIS

List of Symbols

$d_{i,j}$	probability of the destination floor of a call from i being the jth floor (i and j must be both odd or both even for $d_{i,j} \neq 0$)
$DownJoin_i$	average number of passengers joining lift at ith floor on journey down
$DownLeave_i$	average number of passengers leaving lift at ith floor on journey down
FM	figure of merit for use of double deck lifts (%)
H_{rf}	average highest reversal floor of lower cab
INT(n)	interval (s)
INT(n)	interval, zone n (s)
JINT(i,j)	interval for journey from ith to the jth floor
L_{rf}	average lowest reversal floor of lower cab
N	number of floors ($N \geq 4$ and even)
$p_{i,j}$	probability of no calls from the ith to the jth floor in the time interval T
$pDS_{N-3} .. pDS_3$	probability that the lift will stop at intermediate floors on its journey down (subscript refers to floor lower cab stops at)
$pDSC_{N-3} .. pDSC_3$	probability that the lift will stop at intermediate floors on its journey down with stops coincident to both cabs
pH_n	probability of nth floor being the highest reversal floor (subscript refers to lower cab)
pL_n	probability of nth floor being the lowest reversal floor

	(subscript refers to lower cab)
$p(n)_{i,j}$	probability of n passengers travelling from the ith to the jth floor in the time interval T.
pS_1	probability that the lift will stop at the lowest floors (bottom cab floor 1, upper cab floor 2)
pS_{N-1}	probability that the lift will stop at the highest floor (bottom cab floor N-1, upper cab floor N)
pSC_1	probability that the lift will stop at the lowest floor with the stop coincident to both cabs
pSC_{N-1}	probability that the lift will stop at the highest floor with the stop coincident to both cabs
$pUS_3, pUS_5 .. pUS_{N-3}$	probability that the lift will stop at intermediate floors on its journey up (subscript refers to floor lower cab stops at)
$pUSC_3 .. pUSC_{N-3}$	probability that the lift will stop at intermediate floors on its journey up with stops coincident to both cabs
S'	probable number of stops including terminal floors
S_c	probable number of coincident stops
SPLIT(Q,i,j)	proportion of passengers travelling from the ith to the jth floor who are using lifts in zone Q
$UpJoin_i$	average number of passengers joining lift at ith floor on journey up
$UpLeave_i$	average number of passengers leaving lift at ith floor on journey up
μ_i	passenger arrival rate at floor i (persons s^{-1})

5.1 INTRODUCTION

Double deck lifts have two separate cabs built into a single unit so that the upper and lower cabs serve adjacent floors simultaneously. During peak periods maximum operating efficiency is achieved by restricting the lower cabs to serving odd numbered floors, and the upper cabs to serving even numbered floors.

Double deck lifts provide greater handling capacity per shaft than conventional lifts. This is particularly attractive for high rise buildings. The sacrifice is that double deck lifts are less convenient for passengers. Occupants of even numbered floors are required to use escalators to reach the upper lift cab on their way into the building. And again to reach the exit on their way out. Passengers have to walk one storey when an inter-floor trip from an odd to an even numbered floor, or vice-versa, is made. To alleviate this problem, double deck lift control systems can provide an odd-even floor service by operating in alternative modes out of peak times.

A more detailed discussion of the application of double deck lifts and their control systems is presented by Fortune in(5.1).

The value of double deck lifts in increasing the efficiency of lifting high rise buildings is recognised(5.1)(5.2), and calculations for their performance during the simple up peak traffic scenario have been defined(5.3). This chapter deals with the general case, allowing any practical configuration of double deck lifts and any peak traffic flow to be considered.

Similar general formulae have previously been presented by the author for conventional single deck lifts(5.4). It would be possible to extend these formulae for triple, quadruple, etc. deck lifts if required.

The calculations are based on calculating the probable number of stops and average reversal floors of a lift during its round trip. Lifts may be zoned to take into account the passenger split between different groups of lifts which may not be the same size, speed, etc., or which may not serve the same floors.

5.2 POISSON APPROXIMATION

It is generally accepted that the arrival of passengers at a lift landing station is reasonably approximated by a Poisson process. This gives the result:

$$p(n)_{i,j} = \frac{\left(\mu_i \cdot INT \cdot d_{i,j}\right)^n}{n!} \cdot \exp\left(-\mu_i \cdot INT \cdot d_{i,j}\right) \qquad (5.1)$$

When calculating probabilities, it is generally easier to calculate the probability of something not happening and then subtract this from 1 to arrive at the probability of the event happening. So, let

$$p_{i,j} = p(0)_{i,j}$$

which is the probability of no calls from the ith to the jth floor in the time interval INT. From (5.1),

$$p_{i,j} = \exp\left(-\mu_i \cdot INT \cdot d_{i,j}\right) \qquad (5.2)$$

5.3 PROBABLE NUMBER OF STOPS

When calculating the probable number of stops, it is necessary to consider both the up and the down journey of the lift, as the lift may stop at a floor twice during a single round trip.

For traffic analysis the designer is concerned with peak periods, so it is reasonable to assume that lifts are operating in their most efficient, double deck mode i.e. the lifts do not allow passengers to travel from odd to even floors or vice versa. This means that $d_{odd,even}$ and $d_{even,odd}$ must equal 0, which makes $p_{odd,even}$ and $p_{even,odd}$ equal to 1.

The probability of a lift stopping at a floor is one minus the probability that there are no calls to or from odd floors to the lower cab times the probability that there are no calls to or from the even floors to the upper cab. This gives the results:

$$pS_1 = 1 - \prod_{a=3}^{N} p_{a,1} \cdot p_{1,a} \cdot p_{a,2} \cdot p_{2,a} \qquad (5.3)$$

$$pUS_j := 1 - \left(\prod_{a=1}^{j-1} p_{a,j} \cdot p_{a,j+1} \cdot \prod_{b=j+2}^{N} p_{j,b} \cdot p_{j+1,b} \right) \qquad \text{for } j := 3,5..N-3 \qquad (5.4)$$

$$pS_{N-1} = 1 - \prod_{a=1}^{N-2} p_{N-1,a} \cdot p_{a,N-1} \cdot p_{N,a} \cdot p_{a,N} \qquad (5.5)$$

$$pDS_j = 1 - \left(\prod_{a=j+2}^{N} p_{a,j} \cdot p_{a,j+1} \cdot \prod_{b=1}^{j-1} p_{j,b} \cdot p_{j+1,b} \right) \qquad \text{for } j := 3,5..N-3 \qquad (5.6)$$

(Π is a mathematical symbol meaning multiply all the terms over this range.)

The total number of stops S' is calculated by adding together all the terms:

$$S' := pS_1 + \sum_{j} \left(pUS_j + pDS_j \right) + pS_{N-1} \qquad \text{for } j := 3,5..N-3 \qquad (5.7)$$

5.4 REVERSAL FLOORS

5.4.1 Reason for calculation

In an "average" journey, a lift may not reach the highest or lowest floor of a building. (This is less likely for double deck lifts than for conventional single deck lifts because double deck lifts carry more passengers, so are increasingly likely to have to stop at all floors.) Calculating the average highest and lowest reversal floors allows the possibility of this shortened round trip to be taken into account. In this derivation the highest and lowest reversal floors have been calculated with reference to the lower lift cab, i.e. the lowest possible floor is 1 and the highest possible floor is N-1.

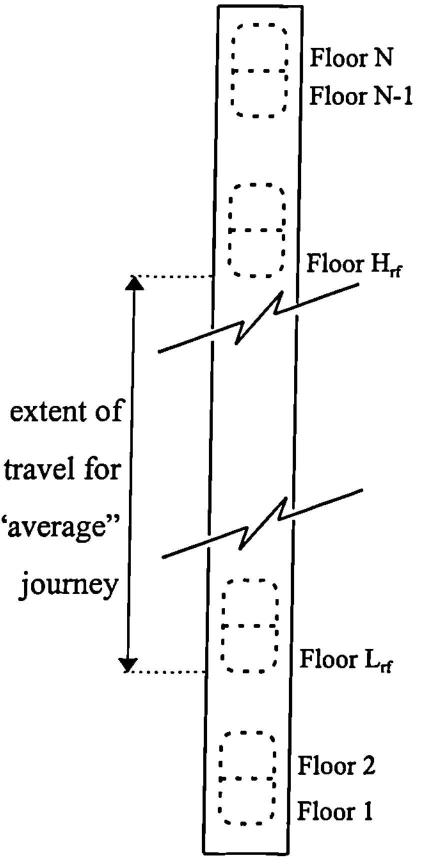


Figure 6.1 Highest and lowest reversal floors

5.4.2 Highest reversal floor

The probability of the jth floor being the highest reversal floor is the product of the probability that there is a call from a lower floor to either the jth or the (j+1)th floor and the probability that there are no calls to or from floors above j+1:

$$pH_1 := \prod_{a=1}^{N} \prod_{b=1}^{N} p_{a,b} \qquad (5.8)$$

$$pH_j = \left(1 - \prod_{a=1}^{j-1} p_{a,j} \cdot p_{j,a} \cdot p_{a,j+1} \cdot p_{j+1,a}\right) \cdot \prod_{a=1}^{N} \prod_{b=j+2}^{N} p_{a,b} \cdot \prod_{a=j+2}^{N} \prod_{b=1}^{j+1} p_{a,b} \quad (5.9)$$

for $j := 3,5..N-3$

$$pH_{N-1} := 1 - \prod_{a=1}^{N-2} p_{a,N-1} \cdot p_{N-1,a} \cdot p_{a,N} \cdot p_{N,a} \quad (5.10)$$

(A good check for this is that $\sum_j pH_j = 1$)

Given the probability of each floor being the highest reversal floor, the average highest reversal floor, H_{rf} is simply:

$$H_{rf} := \sum_j j \cdot pH_j \qquad \text{for } j := 1,3..N-1 \quad (5.11)$$

5.4.3 Lowest reversal floor

Similarly, calculate the probability of the jth floor being the lowest reversal floor, which is the product of the probability that there is a call from a higher floor to or from floors j or j+1 and the probability that there are no calls to or from floors below j:

$$pL_1 = 1 - \prod_{a=3}^{N} p_{a,1} \cdot p_{1,a} \cdot p_{a,2} \cdot p_{2,a} \quad (5.12)$$

$$pL_j := \left(1 - \prod_{a=j+2}^{N} p_{a,j} \cdot p_{j,a} \cdot p_{a,j+1} \cdot p_{j+1,a}\right) \cdot \prod_{a=1}^{N} \prod_{b=1}^{j-1} p_{a,b} \cdot \prod_{a=1}^{j-1} \prod_{b=j}^{N} p_{a,b} \quad (5.13)$$

for $j := 3,5..N-3$

$$pL_{N-1} := \prod_{a=1}^{N} \prod_{b=1}^{N} p_{a,b} \qquad (5.14)$$

(Again, a check for this is that $\sum_{j} pL_j = 1$)

Given the probability of each floor being the lowest reversal floor, the average lowest reversal floor, L_{rf} is simply:

$$L_{rf} = (N+1) - \sum_{j} pL_j \cdot ((N+1) - j) \qquad \text{for } j = 1,3..N-1 \qquad (5.15)$$

5.5 CAPACITY FACTOR

In a conventional up peak lift traffic calculation it is assumed that the lift is say 80% full at the beginning of its round trip. This approach cannot be taken for a general calculation as people may enter or leave the lift at any floor. One approach is to calculate the average number of people in the car when it leaves each floor. But first calculate the number of people entering and leaving the lift at each floor.

At the ith floor, going up, the number of passengers joining the car is

$$UpJoin_i := INT \cdot \mu_i \cdot \sum_{j=i+2}^{N} d_{i,j} \qquad \text{for } i := 1,2..N-2 \qquad (5.16)$$

No passengers join the lift at the top floors to go up, so $UpJoin_{N-1} := 0$ and $UpJoin_N := 0$.

At the ith floor, going up, the number of passengers leaving the car is

$$UpLeave_i = INT \cdot \sum_{j=1}^{i-2} \mu_j \cdot d_{j,i} \qquad \text{for } i = 3,4..N \qquad (5.17)$$

No passengers leave the lift at the bottom floors subsequent to an up journey, so $\mathrm{UpLeave}_1 := 0$ and $\mathrm{UpLeave}_2 := 0$.

At the ith floor, going down, the number of passengers joining the car is

$$\mathrm{DownJoin}_i := \mathrm{INT} \cdot \mu_i \cdot \sum_{j=1}^{i-2} d_{i,j} \qquad \text{for } i := N, N-1..3 \qquad (5.18)$$

No passengers join the lift at the bottom floors to travel down so $\mathrm{DownJoin}_1 := 0$ and $\mathrm{DownJoin}_2 := 0$.

At the ith floor, going down, the number of passengers leaving the car is

$$\mathrm{DownLeave}_i := \mathrm{INT} \cdot \sum_{j=i+2}^{N} \mu_j \cdot d_{j,i} \qquad \text{for } i := N-2, N-3..1 \qquad (5.19)$$

No passengers leave the lift at the top floors after a down journey so $\mathrm{DownLeave}_N := 0$ and $\mathrm{DownLeave}_{N-1} := 0$.

The above formulae allow you to calculated the average number of people joining and leaving the lift at each floor. From this, determine the average number of people in the car when it leaves each floor, travelling both up and down and the building. Dividing the maximum value by the lift capacity (in persons) gives the capacity factor, which is normally expressed as a percentage.

5.6 ROUND TRIP TIME

The round trip time for a single lift is the sum of the travel time from lowest to highest reversal floors, the number of stops times the delay time associated with a stop, and the time for people to load and unload the lift. An example of conventional round trip time formulae applied to double deck lift calculations can be found in (5.3). Having calculated the round trip time for a single lift, the interval, INT may be calculated as the round trip time divided by the number of lifts.

The calculations are iterative as the result, INT is required as an input to the calculations. INT must be estimated, then the calculations repeated until the input INT is equal to the result.

5.7 FIGURE OF MERIT

The figure of merit for use of double deck lifts is defined as being the percentage of stops that are coincident to both upper and lower cabs(5.3). A high figure of merit is preferable as it can be frustrating for passengers when the lift stops repeatedly and no one leaves or enters their lift cab.

The figure of merit is not required as an input to the iterative round trip time calculation, so only needs to be determined once a solution for INT has been found.

The probability of a stop at the jth and j+1th floors being coincident is the product of the probability of the lift needing to stop to serve a call to or from both j and j+1:

$$pSC_1 := \left(1 - \prod_{a=3}^{N} p_{a,1} \cdot p_{1,a}\right) \cdot \left(1 - \prod_{a=3}^{N} p_{a,2} \cdot p_{2,a}\right) \tag{5.20}$$

$$pUSC_j := \left[1 - \left(\prod_{a=1}^{j-1} p_{a,j} \cdot \prod_{a=j+2}^{N} p_{j,a}\right)\right] \cdot \left[1 - \left(\prod_{a=1}^{j-1} p_{a,j+1} \cdot \prod_{a=j+2}^{N} p_{j+1,a}\right)\right] \tag{5.21}$$

for $j := 3,5..N-3$

$$pSC_{N-1} := \left(1 - \prod_{a=1}^{N-2} p_{N-1,a} \cdot p_{a,N-1}\right) \cdot \left(1 - \prod_{a=1}^{N-2} p_{N,a} \cdot p_{a,N}\right) \tag{5.22}$$

$$pDSC_j := \left[1 - \left(\prod_{a=j+2}^{N} p_{a,j} \cdot \prod_{a=1}^{j-1} p_{j,a}\right)\right] \cdot \left[1 - \left(\prod_{a=j+2}^{N} p_{a,j+1} \cdot \prod_{a=1}^{j-1} p_{j+1,a}\right)\right] \qquad (5.23)$$

for $j := 3, 5 .. N - 3$

The total number of coincident stops S_c is calculated by adding together all the terms:

$$S_c := pSC_1 + \sum_j \left(pUSC_j + pDSC_j\right) + pSC_{N-1} \qquad \text{for } j := 3, 5 .. N - 3 \qquad (5.24)$$

giving figure of merit, expressed as a percentage:

$$FM := \frac{S_c}{S'} \cdot 100 \qquad (5.25)$$

5.8 OVERLAPPING ZONES

Lifts which serve the same floors and are of the same size, speed, capacity, etc. may be defined as being in a zone. If different zones do not serve the same floors, treat each as being independent, carrying out round trip time calculations for each zone separately. However, if a passenger could use lifts in either of two or more zones to make a journey, zones are "overlapping" and it is necessary to split up the passenger traffic between zones before carrying out the calculations. The results given for the single deck lifts in (5.4) also apply for double deck lifts:

$$JINT(i,j) := \sum_Z \left(\frac{1}{INT(Z)}\right)^{-1} \qquad (5.26)$$

where {Z}={all zones serving both the ith and the jth floor}

$$SPLIT(Q,i,j) := \frac{JINT(i,j)}{INT(Q)} \qquad (5.27)$$

5.9 EXAMPLES

5.9.1 Up peak analysis

Consider a 22 storey office building with 2000 m^2 net area per floor where the 5 minute up peak handling capacity required is 16%. Analyse the performance of 8 No 2.5 m/s, 1800 kg/1800 kg lifts. Assume the following additional parameters:

Population density	1 person per 15 m^2	Door operating times	1.8 s open,
Storey height	3.6 m		2.9 s close
Passenger weight	75 kg	Acceleration	0.8 m/s^2
Passenger transfer	1.2 s in, 1.2 s out	Jerk	2 m/s^3
Round Trip Time	5 % inefficiency	Motor start up delay	0.5 s

The passenger traffic can be represented as shown in Figure 5.2. Calculations are calculated according to the flow chart in Figure 5.3.

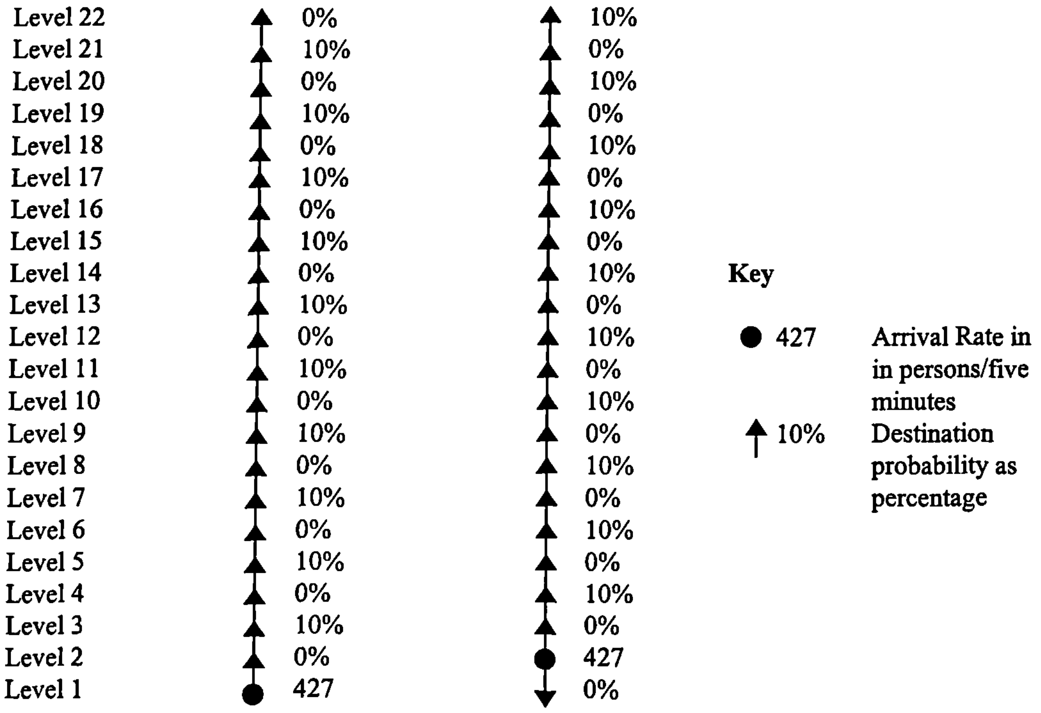


Figure 5.2 Example up peak traffic flow

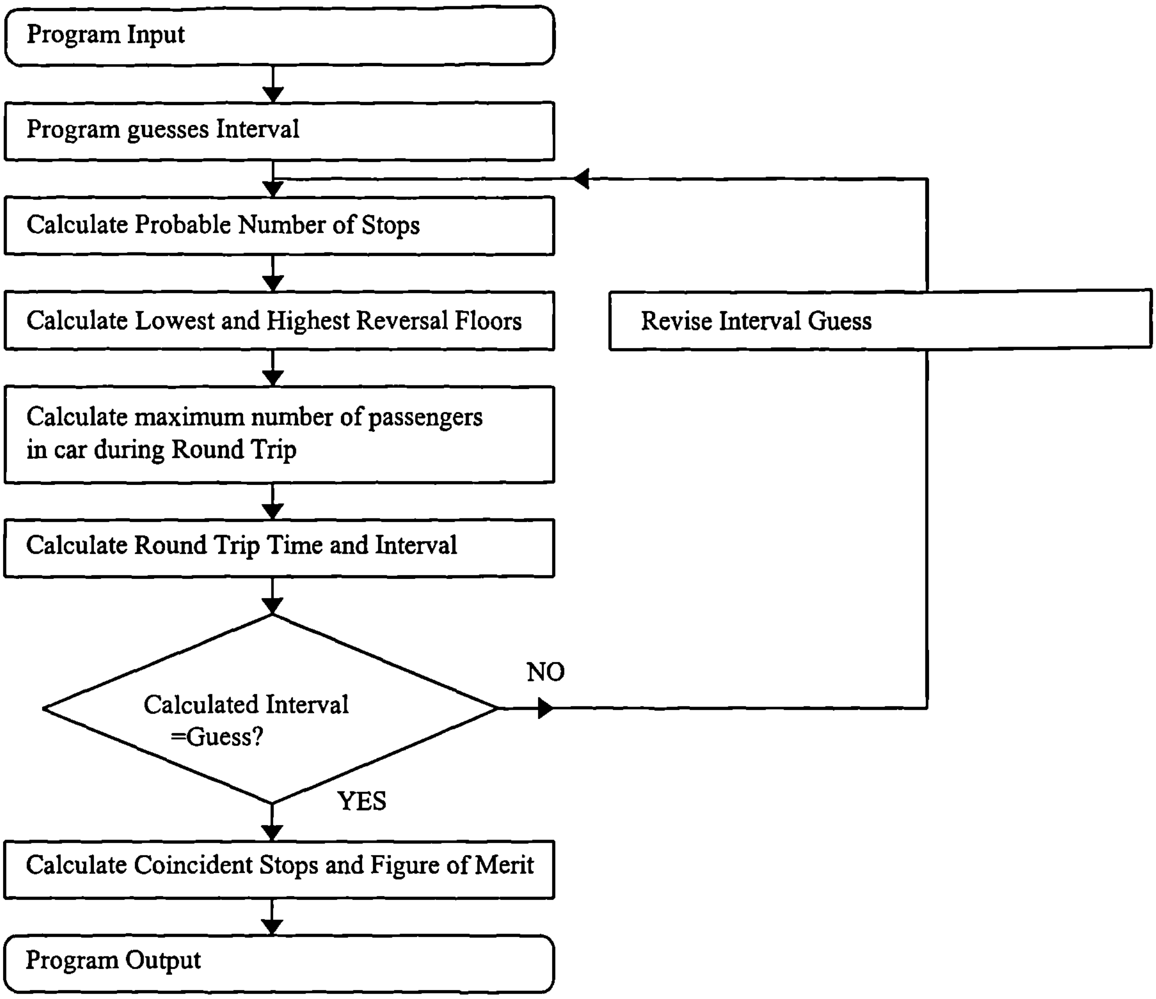


Figure 5.3 Calculation flow chart

Results from the Oasys LIFT program implementing the formulae are summarised as follows:

5 Min Handling Capacity	16%
Capacity Factor	76%
Probable Number of Stops	10.7 including main terminal
Highest Reversal Floor	Level 21 (to nearest floor lower cab reaches)
Interval	25.6 s
Figure of Merit	75 %

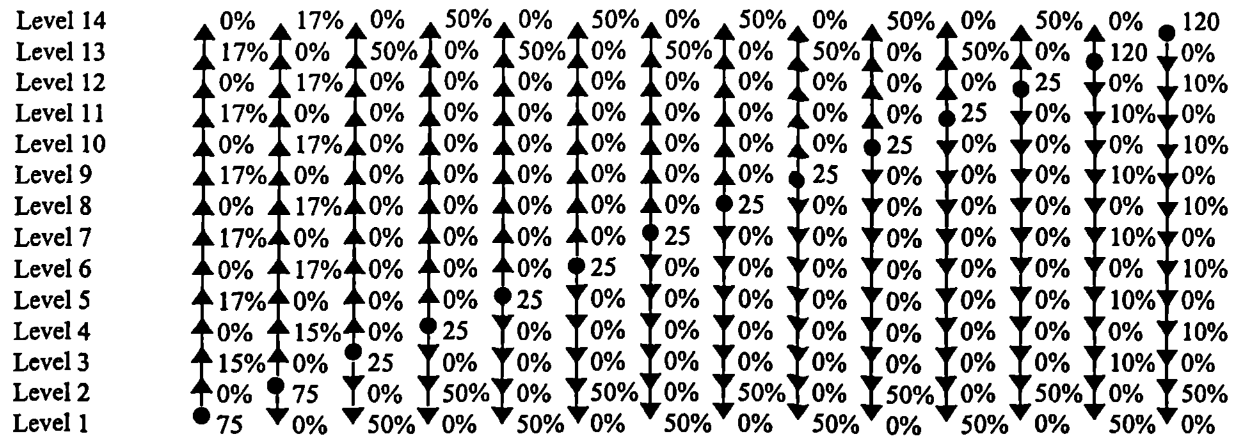
5.9.2 Lunch peak analysis

For a more complex example, consider the lunch peak scenario in an office building where there are double storey conference and restaurant facilities on the top two floors. Consider the scenario when a morning conference ends during the lunch time peak. Conference delegates are visitors to the building. The peak traffic is a combination of:

i. resident passengers travelling from their offices to the restaurant for lunch
ii. resident passengers travelling back to their offices after lunch
iii. resident passengers travelling to the ground floor to leave the building to buy sandwiches or eat out
iv. resident passengers returning from buying/eating lunch out

An example traffic flow is given in Figure 5.4. Assuming this traffic flow, analyse 8 No 2.5 m/s 1250 kg/1250 kg lifts and the following additional input parameters:

Storey height	3.6 m	Door operating times	1.8 s open, 2.9 s close
Acceleration	0.8 m/s^2	Passenger weight	75 kg
Jerk	2 m/s^3	Passenger transfer	1.2 s in, 1.2 s out
Motor start up delay	0.5 s	Round Trip Time	5 % inefficiency



Level 14	0%	17%	0%	50%	0%	50%	0%	50%	0%	50%	0%	50%	0%	120
Level 13	17%	0%	50%	0%	50%	0%	50%	0%	50%	0%	50%	0%	120	0%
Level 12	0%	17%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25	0%	10%
Level 11	17%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25	0%	10%	0%
Level 10	0%	17%	0%	0%	0%	0%	0%	0%	0%	25	0%	0%	0%	10%
Level 9	17%	0%	0%	0%	0%	0%	0%	0%	25	0%	0%	0%	10%	0%
Level 8	0%	17%	0%	0%	0%	0%	0%	25	0%	0%	0%	0%	0%	10%
Level 7	17%	0%	0%	0%	0%	0%	25	0%	0%	0%	0%	0%	10%	0%
Level 6	0%	17%	0%	0%	0%	25	0%	0%	0%	0%	0%	0%	0%	10%
Level 5	17%	0%	0%	0%	25	0%	0%	0%	0%	0%	0%	0%	10%	0%
Level 4	0%	15%	0%	25	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%
Level 3	15%	0%	25	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	0%
Level 2	0%	75	0%	50%	0%	50%	0%	50%	0%	50%	0%	50%	0%	50%
Level 1	75	0%	50%	0%	50%	0%	50%	0%	50%	0%	50%	0%	50%	0%

Figure 5.4 Complex traffic flow

Results from the Oasys LIFT program are summarised as follows:

Capacity Factor	68 %	Probable Number of Stops	11.9
Interval	26.7 s	Lowest Reversal Floor	1
Figure of Merit	83%	Highest Reversal Floor	13

5.10 DISCUSSION

Double deck lifts provide greater handling capacity per shaft than conventional lifts. This is particularly attractive for high rise buildings, where the core space taken by the lifts is a high percentage of the total floor area.

Kavounas(5.3) provided formulae to calculate the up-peak performance and handling capacity for double deck lifts. Formulae presented in this chapter allow analysis of any peak traffic flow for any practical configuration of double deck lifts. The approach taken for double deck lifts could be extended to cover triple and quadruple deck lifts if required.

The double deck formulae have been implemented by the author in the Oasys LIFT program, and are being used by Arup in the design of high rise developments.

This section of research has arisen primarily from commercial pressures to analyse the performance of lift systems in high rise buildings. This is a consequence of the EngD being based in industry rather than in academia. Nevertheless, it is a useful piece of research, allowing designers to consider lunch time and other peaks for double as well a single deck lifts.

It is possible to argue that double deck lifts are green; like double decker buses, they are an efficient means of transportation when fully loaded. However they are very inefficient if used for long periods while lightly loaded. A study of the relative energy consumption of double versus single deck lifts for a range of lift installations would be useful further work.

The General double deck lift traffic analysis technique was presented at the Elevator Technology Conference, ELEVCON'95(5.6). A more detailed paper was published in the CIBSE journal, Building Services Engineering Research and Technology(5.7).

REFERENCES

5.1 Fortune F J *Modern Double Deck Applications and Theory* Elevator Technology 6 Proceedings of ELEVCON '95 165-174 (Stockport: IAEE)(1995)

5.2 Strakosch G R *Double Deck Elevators: The Challenge to Utilize Space* Elevator World July 1990 50-53

5.3 Kavounas G T *Elevatoring Analysis with Double Deck Elevators* Elevator World November 1989 65-72

5.4 Peters R D *Lift Traffic Analysis: Formulae for the general case* Building Serv. Res. Technol. 11(2) 65-67 (1990)

5.6 Peters R D *General Analysis Double Deck Lift Calculations* Elevator Technology 6 Proceedings of ELEVCON '95 165-174 (Stockport: IAEE)(1995)

5.7 Peters R D, Mehta P, Haddon J *Lift Traffic Analysis: General formulae for double deck lifts case* Building Serv. Res. Technol. 11(4) (1996)

Chapter 6

LIFT KINEMATICS

List of Symbols

a	maximum acceleration/deceleration (m/s^2)
$A(t)$	acceleration at time t (m/s^2)
d	lift journey distance (m)
$D(t)$	distance travelled at time t (m)
j	maximum jerk (m/s^3)
$J(t)$	jerk at time t (m/s^3)
v	maximum velocity (m/s)
$V(t)$	velocity at time t (m/s)

6.1 INTRODUCTION

6.1.1 Lift kinematics

Lift kinematics is the study of the motion of a lift car in a shaft without reference to mass or force. The maximum acceleration and jerk (rate of change of acceleration) which can be withstood by human beings without discomfort limits this motion. Ideal lift kinematics are the optimum velocity, acceleration and jerk profiles that can be obtained given human constraints.

Microprocessor controlled variable speed drives can be programmed to match reference speed profiles generated through the study of lift kinematics. Examples of these speed reference curves, similar to those shown in Figure 6.1, are sometimes presented in lift manufactures' sales literature as a demonstration of the fast, comfortable and efficient lift transportation available for a particular drive system.

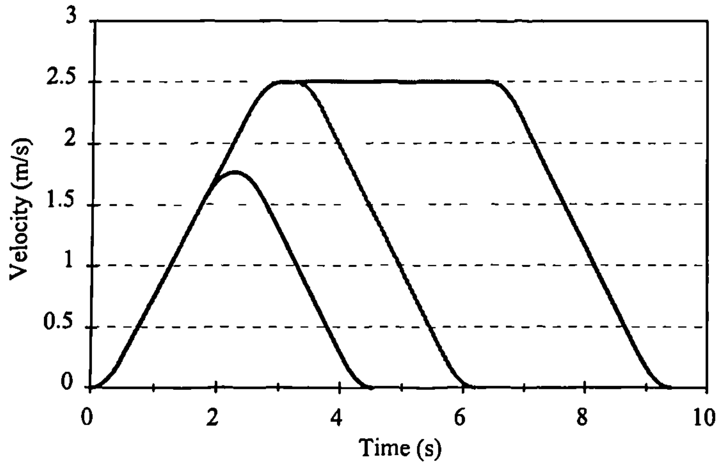


Figure 6.1 Example lift velocity-time profile for one, two and four floor runs

6.1.2 Previous work

P D Day and G C Barney provide references of previous published work in this field in section 11.4 of CIBSE Guide D, *Transportation Systems in Buildings* (6.1). In summary:

> H D Molz presented the first major work in this area in 1986. In his paper, *On the ideal kinematics of lifts* (6.2) (in German) he derives equations which enable minimum travel times to be calculated, taking to account maximum values of jerk, acceleration, and speed. If the lift trip is too short for the lift contract speed or acceleration to be obtained, the maximum speed and acceleration attained during the trip may be calculated. Some other points on the ideal kinematic curves are calculated. This paper was edited by G C Barney and re-published (6.3) by Elevatori in 1991 (in English and Italian).
>
> N R Roschier and M J Kaakinen apply Molz' formulae to provided summary tables of results for round trip time calculations (6.4).
>
> In *Elevator Trip Profiles* (6.5), J Schroeder presented a computer program that calculates the maximum speed, and minimum journey time that a lift can achieve for given flight distances if there is no speed limit. This produces interesting observations such as it would take a total trip of about 17 floors for

an 8 m/s lift to reach its full speed.

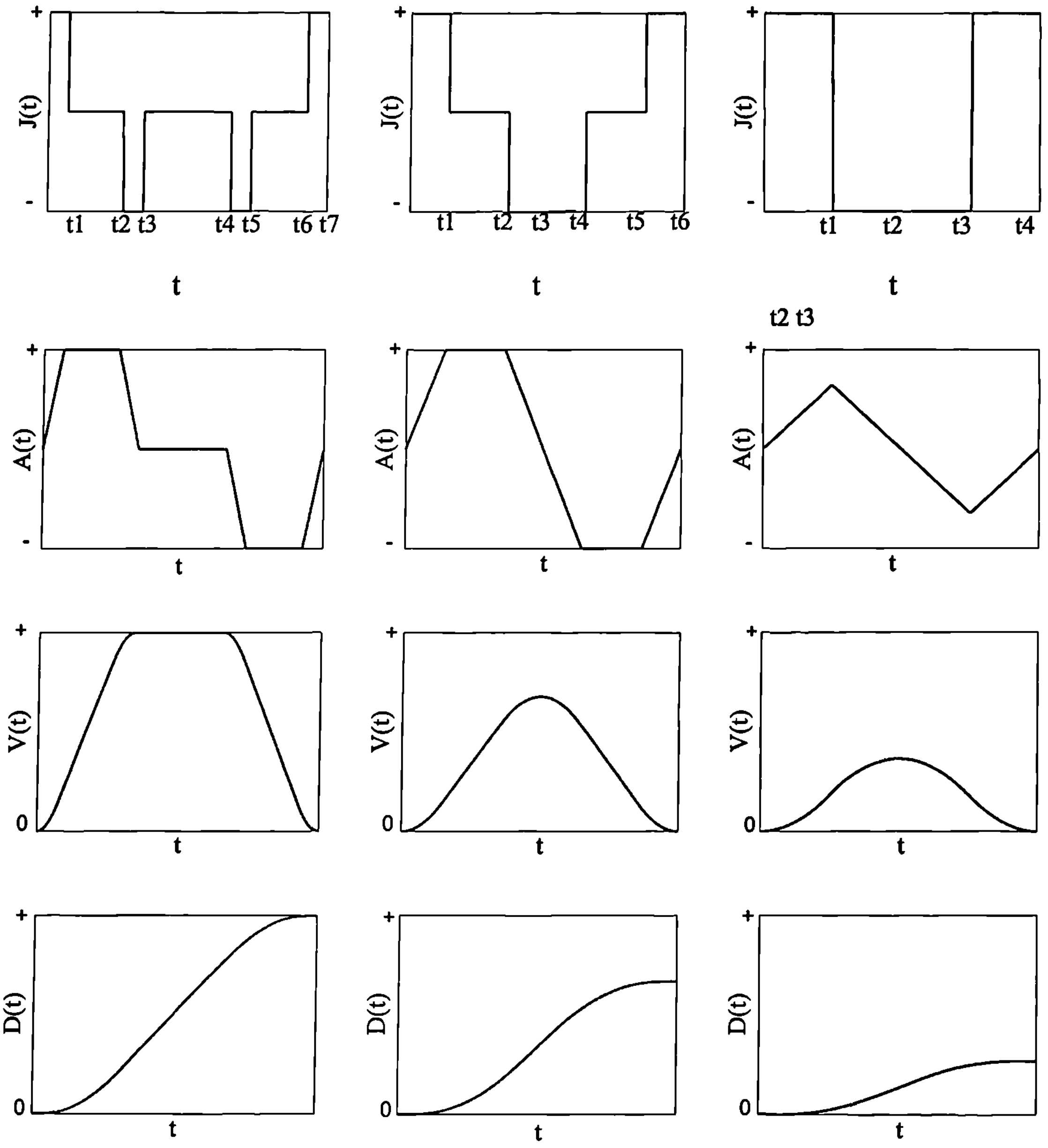
In *Elevator Electric Drives* (6.6) G C Barney and A G Loher suggest a computer program based on H D Molz' equations. This is reproduced in *CIBSE Guide D, Transportation Systems in Buildings* (6.1).

6.1.3 New developments

For this research project, equations have been derived which allow ideal lift kinematics to be plotted as continuous functions for any value of journey distance, speed, acceleration and jerk. Supplementary results include journey time formulae for use in lift traffic analysis. The remainder of this chapter is a summary of this research. Some or all of the results presented in this chapter (or equivalent software routines) may have been known to individual lift manufacturers; but, to the best of the author's knowledge, they have not been published.

6.1.4 Approach to derivation

The derivation is divided into three major sections, corresponding to the journey conditions where: (A) the lift reaches full speed; (B) the lift reaches full acceleration, but not full speed; and (C) the lift does not reach full speed or acceleration. The condition where full speed is reached before full acceleration is determined and excluded as this would be an illogical design. Conditions A to C are represented graphically in Figure 6.2. Each of the three conditions is divided into time slices, beginning and ending at each change in jerk or change in sign of acceleration.



(A) (B) (C)

Figure 6.2 Ideal lift kinematics for: (A) lift reaches full speed; (B) lift reaches full acceleration, but not full speed; (C) lift does not reach full speed or acceleration

6.2 DERIVATION FOR CONDITION A, LIFT REACHING FULL SPEED DURING JOURNEY

6.2.1 Calculation of t_n

Referring to Figure 6.2 (A) we can write down expressions for t_n as follows:

$$t_1 := \frac{a}{j} \quad (6.1) \qquad \frac{a}{2}\cdot t_1 + a\cdot(t_2 - t_1) + \frac{a}{2}\cdot(t_3 - t_2) := v \quad (6.2)$$

$$t_3 - t_2 = \frac{a}{j} \quad (6.3) \qquad t_5 - t_4 := \frac{a}{j} \quad (6.4)$$

$$\frac{a}{2}\cdot(t_5 - t_4) + a\cdot(t_6 \quad t_5) + \frac{a}{2}\cdot(t_7 - t_6) = v \quad (6.5)$$

$$t_7 - t_6 = \frac{a}{j} \quad (6.6)$$

Solving for t_n gives:

$$t_1 = \frac{a}{j} \quad (6.7) \qquad t_2 = \frac{v}{a} \quad (6.8)$$

$$t_3 := \frac{a}{j} + \frac{v}{a} \quad (6.9) \qquad t_5 := t_4 + \frac{a}{j} \quad (6.10)$$

$$t_6 := t_4 + \frac{v}{a} \quad (6.11) \qquad t_7 := t_4 + \frac{a}{j} + \frac{v}{a} \quad (6.12)$$

6.2.2 Motion during time period $0 \le t \le t_1$

Referring to Figure 6.2 (A) we can write down expressions for jerk and acceleration:

$$J(t) = j \quad (6.13) \qquad A(t) = j\cdot t \quad (6.14)$$

The velocity can be determined by integrating the acceleration:

$$V(t) := \int_0^t j\cdot T\,dT \quad \text{yields} \quad V(t) := \frac{j\cdot t^2}{2} \quad (6.15)$$

The distance travelled can be determined by integrating the velocity:

$$D(t) := \int_0^t \frac{j\cdot T^2}{2}\,dT \quad \text{yields} \quad D(t) := \frac{j\cdot t^3}{6} \quad (6.16)$$

6.2.3 Motion during time period $t_1 \le t \le t_2$

Referring to Figure 6.2 (A) we can write down expressions for jerk and acceleration:

$$J(t) = 0 \qquad (6.17) \qquad A(t) = a \qquad (6.18)$$

The velocity can be found by adding the velocity at the end of the previous time slice to the current acceleration, integrated:

$$V(t) := V(t_1) + \int_{t_1}^{t} a \, dT \quad \text{yields} \quad V(t) = \frac{-a^2}{2 \cdot j} + a \cdot t \qquad (6.19)$$

The distance travelled can be found by adding the distance travelled at the end of the previous time slice to the current velocity, integrated:

$$D(t) = D(t_1) + \int_{t_1}^{t} \frac{-a^2}{2 \cdot j} + a \cdot T \, dT \quad \text{yields} \quad D(t) := \frac{a^3}{6 \cdot j^2} - \frac{a^2 \cdot t}{2 \cdot j} + \frac{a \cdot t^2}{2} \qquad (6.20)$$

6.2.4 Motion during time period $t_2 \le t \le t_3$

Referring to Figure 6.2 (A) we can write down expressions for jerk and acceleration:

$$J(t) = -j \qquad (6.21)$$

$$A(t) = a - j \cdot (t - t_2) \quad \text{which by substitution yields} \quad A(t) := a - j \cdot t + \frac{v \cdot j}{a} \qquad (6.22)$$

The velocity can be found by adding the velocity at the end of the previous time slice to the current acceleration, integrated:

$$V(t) := V(t_2) + \int_{t_2}^{t} a - j \cdot T + \frac{v \cdot j}{a} \, dT \quad \text{yields} \quad V(t) := \frac{-a^2}{2 \cdot j} + a \cdot t - \frac{j \cdot t^2}{2} + \frac{t \cdot v \cdot j}{a} - \frac{v^2 \cdot j}{2 \cdot a^2} \qquad (6.23)$$

The distance travelled can be found by adding the distance travelled at the end of the previous time slice to the current velocity, integrated:

$$D(t) := D(t_2) + \int_{t_2}^{t} \frac{-a^2}{2 \cdot j} + a \cdot T - \frac{j \cdot T^2}{2} + \frac{T \cdot v \cdot j}{a} - \frac{v^2 \cdot j}{2 \cdot a^2} \, dT \quad \text{yields}$$

$$D(t) := \frac{a^3}{6 \cdot j^2} - \frac{t \cdot a^2}{2 \cdot j} - \frac{j \cdot t^3}{6} + \frac{a \cdot t^2}{2} + \frac{j \cdot v \cdot t^2}{2 \cdot a} - \frac{j \cdot v^2 \cdot t}{2 \cdot a^2} + \frac{v^3 \cdot j}{6 \cdot a^3} \qquad (6.24)$$

6.2.5 Motion during time period $t_3 \le t \le$ t4

Referring to Figure 6.2 (A) we can write down expressions for jerk, acceleration and velocity:

$J(t) := 0$ (6.25) $A(t) := 0$ (6.26)

$V(t) := v$ (6.27)

The distance travelled can be found by adding the distance travelled at the end of the previous time slice to the current velocity, integrated:

$$D(t) = D(t_3) + \int_{t_3}^{t} v\,dT \quad \text{yields} \quad D(t) = \frac{-a \cdot v}{2 \cdot j} - \frac{v^2}{2 \cdot a} + v \cdot t \qquad (6.28)$$

6.2.6 Simplification of t_4 to t_7

To complete solutions for t_n, refer to Figure 6.2 (A) to write down:

$$d = 2.D(t_3) + \int_{t_3}^{t_4} v\,dT \quad \text{yields} \quad t_4 = \frac{d}{v} \qquad (6.29)$$

By substitution, results for t_n become

$t_1 := \frac{a}{j}$ (6.30) $t_2 := \frac{v}{a}$ (6.31)

$t_3 = \frac{a}{j} + \frac{v}{a}$ (6.32) $t_4 = \frac{d}{v}$ (6.33)

$t_5 = \frac{d}{v} + \frac{a}{j}$ (6.34) $t_6 := \frac{d}{v} + \frac{v}{a}$ (6.35)

$t_7 := \frac{d}{v} + \frac{a}{j} + \frac{v}{a}$ (6.36)

6.2.7 Motion during time period $t_4 \le t \le t_5$

Referring to Figure 6.2 (A) we can write down expressions for jerk and acceleration:

$$J(t) := -j \qquad (6.37)$$

$$A(t) := -j \cdot (t - t_4) \quad \text{yields} \quad A(t) := \frac{j \cdot d}{v} - j \cdot t \qquad (6.38)$$

The velocity can be found by adding the velocity at the end of the previous time slice to the current acceleration, integrated:

$$V(t) := V\left(t_4\right) + \int_{t_4}^{t} \frac{j\cdot d}{v} - j\cdot T \, dT \qquad \text{yields} \qquad V(t) := v - \frac{j\cdot t^2}{2} + \frac{d\cdot j\cdot t}{v} - \frac{d^2\cdot j}{v^2\cdot 2} \qquad (6.39)$$

The distance travelled can be found by adding the distance travelled at the end of the previous time slice to the current velocity, integrated:

$$D(t) := D\left(t_4\right) + \int_{t_4}^{t} v - \frac{j\cdot T^2}{2} + \frac{d\cdot j\cdot T}{v} - \frac{d^2\cdot j}{v^2\cdot 2} \, dT \qquad \text{yields}$$

$$D(t) = \frac{-a\cdot v}{2\cdot j} - \frac{v^2}{2\cdot a} + v\cdot t + \frac{t^2\cdot j\cdot d}{2\cdot v} - \frac{t\cdot j\cdot d^2}{v^2\cdot 2} - \frac{t^3\cdot j}{6} + \frac{d^3\cdot j}{v^3\cdot 6} \qquad (6.40)$$

6.2.8 Motion during time period $t_5 \leq t \leq t_6$

Referring to Figure 6.2 (A) we can write down expressions for jerk and acceleration:

$J(t) = 0$ (6.41) $A(t) = -a$ (6.42)

The velocity can be found by adding the velocity at the end of the previous time slice to the current acceleration, integrated:

$$V(t) = V\left(t_5\right) + \int_{t_5}^{t} -a \, dT \qquad \text{yields} \qquad V(t) = v + \frac{a\cdot d}{v} + \frac{a^2}{2\cdot j} - a\cdot t \qquad (6.43)$$

The distance travelled can be found by adding the distance travelled at the end of the previous time slice to the current velocity, integrated:

$$D(t) = D\left(t_5\right) + \int_{t_5}^{t} v + \frac{a\cdot d}{v} + \frac{a^2}{2\cdot j} - a\cdot T \, dT \qquad \text{yields}$$

$$D(t) = \frac{-a\cdot v}{2\cdot j} - \frac{v^2}{2\cdot a} - \frac{d^2\cdot a}{v^2\cdot 2} - \frac{d\cdot a^2}{2\cdot j\cdot v} - \frac{a^3}{j^2\cdot 6} + v\cdot t + \frac{a\cdot d\cdot t}{v} + \frac{t\cdot a^2}{2\cdot j} - \frac{t^2\cdot a}{2} \qquad (6.44)$$

6.2.9 Motion during time period $t_6 \leq t \leq t_7$

Referring to Figure 6.2 (A) we can write down expressions for jerk and acceleration:

$$J(t) := j \qquad (6.45)$$

$$A(t) := -a + \left(t - t_6\right)\cdot j \quad \text{yields} \quad A(t) := -a - \frac{j\cdot d}{v} - \frac{j\cdot v}{a} + j\cdot t \tag{6.46}$$

The velocity can be found by adding the velocity at the end of the previous time slice to the current acceleration, integrated:

$$V(t) := V\left(t_6\right) + \int_{t_6}^{t} a - \frac{j\cdot d}{v} - \frac{j\cdot v}{a} + j\cdot T\, dT \quad \text{yields}$$

$$V(t) := v + \frac{a\cdot d}{v} + \frac{a^2}{j\cdot 2} - a\cdot t - \frac{j\cdot d\cdot t}{v} - \frac{j\cdot v\cdot t}{a} + \frac{j\cdot t^2}{2} + \frac{d^2\cdot j}{v^2\cdot 2} + \frac{j\cdot d}{a} + \frac{v^2\cdot j}{a^2\cdot 2} \tag{6.47}$$

The distance travelled can be found by adding the distance travelled at the end of the previous time slice to the current velocity, integrated:

$$D(t) := D\left(t_6\right) + \int_{t_6}^{t} v + \frac{a\cdot d}{v} + \frac{a^2}{j\cdot 2} - a\cdot T - \frac{j\cdot d\cdot T}{v} - \frac{j\cdot v\cdot T}{a} + \frac{j\cdot T^2}{2} + \frac{d^2\cdot j}{v^2\cdot 2} + \frac{j\cdot d}{a} + \frac{v^2\cdot j}{a^2\cdot 2}\, dT \quad \text{yields}$$

$$\begin{aligned} D(t) = {} & \frac{-v^2}{2\cdot a} + v\cdot t - \frac{j\cdot d\cdot v}{2\cdot a^2} \quad \frac{d^2\cdot j}{2\cdot v\cdot a} + \frac{t^3\cdot j}{6} - \frac{a\cdot v}{2\cdot j} - \frac{d^3\cdot j}{v^3\cdot 6} - \frac{t^2\cdot j\cdot d}{2\cdot v} + \frac{j\cdot d^2\cdot t}{2\cdot v^2} + \frac{a\cdot t\cdot d}{v} \ldots \\ & + \frac{t\cdot a^2}{2\cdot j} - \frac{t^2\cdot a}{2} - \frac{a^3}{j^2\cdot 6} \quad \frac{d^2\cdot a}{v^2\cdot 2} - \frac{d\cdot a^2}{2\cdot j\cdot v} + \frac{t\cdot d\cdot j}{a} + \frac{t\cdot v^2\cdot j}{2\cdot a^2} - \frac{t^2\cdot v\cdot j}{2\cdot a} - \frac{j\cdot v^3}{a^3\cdot 6} \end{aligned} \tag{6.48}$$

6.2.10 Verification of results at time t_7

From (6.36), we have $t_7 := \frac{d}{v} + \frac{a}{j} + \frac{v}{a}$ which by substitution into equation (6.47), yields $V\left(t_7\right) = 0$ and by substitution into equation (6.48), yields $D\left(t_7\right) := d$ which is correct.

6.2.11 Range over which results apply

Results for condition A apply if the lift reaches full speed during its trip, which occurs if:

$$\frac{d}{2} > D\left(t_3\right) \quad \text{yields} \quad \frac{a^2\cdot v + v^2\cdot j}{j\cdot a} \le d \tag{6.49}$$

6.3 CONDITION B, LIFT REACHING MAXIMUM ACCELERATION, BUT NOT FULL SPEED

The derivation for condition B is similar to that for condition A. For brevity, only results are given.

Results apply over the range $2\cdot\frac{a^3}{j^2} \le d < \frac{a^2\cdot v + v^2\cdot j}{j\cdot a}$ (6.50)

6.3.1 Values of t_n

$t_1 := \frac{a}{j}$ (6.51) $t_2 := \frac{-a}{2\cdot j} + \frac{\sqrt{a^3 + 4\cdot d\cdot j^2}}{2\cdot j\cdot\sqrt{a}}$ (6.52)

$t_3 = \frac{a}{2\cdot j} + \frac{\sqrt{a^3 + 4\cdot d\cdot j^2}}{2\cdot j\cdot\sqrt{a}}$ (6.53) $t_4 = \frac{3\cdot a}{2\cdot j} + \frac{\sqrt{a^3 + 4\cdot d\cdot j^2}}{2\cdot j\cdot\sqrt{a}}$ (6.54)

$t_5 = \frac{\sqrt{a^3 + 4\cdot d\cdot j^2}}{\sqrt{a}\cdot j}$ (6.55) $t_6 := \frac{a}{j} + \frac{\sqrt{a^3 + 4\cdot d\cdot j^2}}{\sqrt{a}\cdot j}$ (6.56)

6.3.2 Motion during time period $0 \le t \le t_1$

$J(t) = j$ (6.57) $A(t) := j\cdot t$ (6.58)

$V(t) = \frac{j\cdot t^2}{2}$ (6.59) $D(t) := \frac{j\cdot t^3}{6}$ (6.60)

6.3.3 Motion during time period $t_1 \le t \le t_2$

$J(t) = 0$ (6.61) $A(t) := a$ (6.62)

$V(t) := \frac{-a^2}{2\cdot j} + a\cdot t$ (6.63) $D(t) := \frac{a^3}{6\cdot j^2} - \frac{a^2\cdot t}{2\cdot j} + \frac{a\cdot t^2}{2}$ (6.64)

6.3.4 Motion during time period $t_2 \le t \le t_3$

$J(t) := -j$ (6.65) $A(t) := \frac{a}{2} - j\cdot t + \frac{\sqrt{a^3 + 4\cdot d\cdot j^2}}{2\cdot\sqrt{a}}$ (6.66)

$$V(t) := \frac{-3\cdot a^2}{4\cdot j} - \frac{j\cdot t^2}{2} + \frac{a\cdot t}{2} + \frac{t\cdot\sqrt{a^3+4\cdot d\cdot j^2}}{\sqrt{a}\cdot 2} + \frac{\sqrt{a^3+4\cdot d\cdot j^2}\cdot\sqrt{a}}{4\cdot j} - \frac{j\cdot d}{2\cdot a} \tag{6.67}$$

$$\begin{aligned} D(t) &= \frac{a^3}{12\cdot j^2} + \frac{a^{\frac{3}{2}}\cdot\sqrt{a^3+4\cdot d\cdot j^2}}{12\cdot j^2} \quad \frac{d}{4} - \frac{3\cdot t\cdot a^2}{4\cdot j} + \frac{t^2\cdot a}{4} + \frac{1}{4}\cdot\frac{t^2\cdot\sqrt{a^3+4\cdot d\cdot j^2}}{\sqrt{a}} \ldots \\ &+ \frac{\sqrt{a^3+4\cdot d\cdot j^2}\cdot\sqrt{a}\cdot t}{4\cdot j} - \frac{t^3\cdot j}{6} - \frac{t\cdot j\cdot d}{a\cdot 2} + \frac{d\cdot\sqrt{a^3+4\cdot d\cdot j^2}}{12\cdot a^{\left(\frac{3}{2}\right)}} \end{aligned} \tag{6.68}$$

6.3.5 Motion during time period $t_3 \le t \le t_4$

$$J(t) := -j \tag{6.69}$$

$$A(t) := \frac{1}{2}\cdot a - j\cdot t + \frac{\sqrt{a^3+4\cdot d\cdot j^2}}{2\cdot\sqrt{a}} \tag{6.70}$$

$$V(t) = \frac{3\cdot a^2}{4\cdot j} + \frac{\sqrt{a^3+4\cdot d\cdot j^2}\cdot\sqrt{a}}{4\cdot j} \quad \frac{d\cdot j}{2\cdot a} \quad \frac{j\cdot t^2}{2} + \frac{t\cdot a}{2} + \frac{\sqrt{a^3+4\cdot d\cdot j^2}\cdot t}{\sqrt{a}\cdot 2} \tag{6.71}$$

$$\begin{aligned} D(t) &= \frac{-d}{4} + \frac{a\cdot t^2}{4} - \frac{a^2\cdot 3\cdot t}{4\cdot j} + \frac{\sqrt{a^3+4\cdot d\cdot j^2}\cdot t\cdot\sqrt{a}}{4\cdot j} - \frac{j\cdot t\cdot d}{2\cdot a} + \frac{t^2\cdot\sqrt{a^3+4\cdot d\cdot j^2}}{4\cdot\sqrt{a}} - \frac{j\cdot t^3}{6} \ldots \\ &+ \frac{a^3}{j^2\cdot 12} + \frac{\sqrt{a^3+4\cdot d\cdot j^2}\cdot a^{\left(\frac{3}{2}\right)}}{j^2\cdot 12} + \frac{d\cdot\sqrt{a^3+4\cdot d\cdot j^2}}{12\cdot a^{\left(\frac{3}{2}\right)}} \end{aligned} \tag{6.72}$$

6.3.6 Motion during time period $t_4 \le t \le t_5$

$$J(t) := 0 \tag{6.73}$$

$$A(t) := -a \tag{6.74}$$

$$V(t) = \frac{a^2}{2\cdot j} + \frac{\sqrt{a^3+4\cdot d\cdot j^2}\cdot\sqrt{a}}{j} \quad t\cdot a \tag{6.75}$$

$$D(t) := -d - \frac{a\cdot t^2}{2} + \frac{\sqrt{a^3+4\cdot d\cdot j^2}\cdot t\cdot\sqrt{a}}{j} + \frac{a^2\cdot t}{2\cdot j} - \frac{a^{\frac{3}{2}}}{2}\cdot\frac{\sqrt{a^3+4\cdot d\cdot j^2}}{j^2} - \frac{2\cdot a^3}{3\cdot j^2} \tag{6.76}$$

6.3.7 Motion during time period $t_5 \le t \le t_6$

$$J(t) := j \tag{6.77}$$

$$A(t) := -a + j\cdot t - \frac{\sqrt{a^3+4\cdot d\cdot j^2}}{\sqrt{a}} \tag{6.78}$$

$$V(t) := \frac{a^2}{j} + \frac{j \cdot t^2}{2} - t \cdot a - \frac{t \cdot \sqrt{a^3 + 4 \cdot d \cdot j^2}}{\sqrt{a}} + \frac{\sqrt{a^3 + 4 \cdot d \cdot j^2} \cdot \sqrt{a}}{j} + \frac{2 \cdot d \cdot j}{a} \qquad (6.79)$$

$$D(t) - d \quad \frac{2 \cdot a^3}{3 \cdot j^2} + \frac{a^2 \cdot t}{j} \quad \frac{a \cdot t^2}{2} + \frac{j \cdot t^3}{6} + \frac{\sqrt{a^3 + 4 \cdot d \cdot j^2} \cdot \sqrt{a} \cdot t}{j} + \frac{2 \cdot d \cdot t \cdot j}{a} \ldots$$
$$+ \frac{\left(a^3 + 4 \cdot d \cdot j^2\right)^{\left(\frac{3}{2}\right)}}{j^2 \cdot \left[3 \cdot a^{\left(\frac{3}{2}\right)}\right]} - \frac{t^2 \cdot \sqrt{a^3 + 4 \cdot d \cdot j^2}}{\sqrt{a} \cdot 2} - \frac{\sqrt{a^3 + 4 \cdot d \cdot j^2} \cdot a^{\left(\frac{3}{2}\right)}}{j^2} - \frac{2 \cdot \sqrt{a^3 + 4 \cdot d \cdot j^2} \cdot d}{a^{\left(\frac{3}{2}\right)}} \qquad (6.80)$$

6.4 CONDITION C, LIFT NOT REACHING MAXIMUM ACCELERATION OR FULL SPEED

Results apply over the range $d < 2 \cdot \frac{a^3}{j^2}$ (6.81)

6.4.1 Values of t_n

$$t_1 = \left(\frac{1}{2} \cdot \frac{d}{j}\right)^{\frac{1}{3}} \qquad (6.82)$$

$$t_2 := \left(4 \cdot \frac{d}{j}\right)^{\frac{1}{3}} \qquad (6.83)$$

$$t_3 = \left(\frac{27}{2} \cdot \frac{d}{j}\right)^{\frac{1}{3}} \qquad (6.84)$$

$$t_4 := \left(32 \cdot \frac{d}{j}\right)^{\frac{1}{3}} \qquad (6.85)$$

6.4.2 Motion during time period $0 \le t \le t_1$

$$J(t) = j \qquad (6.86)$$

$$A(t) := j \cdot t \qquad (6.87)$$

$$V(t) = \frac{j \cdot t^2}{2} \qquad (6.88)$$

$$D(t) = \frac{j \cdot t^3}{6} \qquad (6.89)$$

6.4.3 Motion during time period $t_1 \le t \le t_2$

$$J(t) := -j \qquad (6.90)$$

$$A(t) := j^{\left(\frac{2}{3}\right)} \cdot 2^{\left(\frac{2}{3}\right)} \cdot d^{\left(\frac{1}{3}\right)} - j \cdot t \qquad (6.91)$$

$$V(t) := -\frac{1}{2} \cdot j^{\left(\frac{1}{3}\right)} \cdot 2^{\left(\frac{1}{3}\right)} \cdot d^{\left(\frac{2}{3}\right)} - \frac{j \cdot t^2}{2} + j^{\left(\frac{2}{3}\right)} \cdot 2^{\left(\frac{2}{3}\right)} \cdot d^{\left(\frac{1}{3}\right)} \cdot t \qquad (6.92)$$

$$D(t) := \frac{d}{6} + \frac{1}{2} \cdot j^{\left(\frac{2}{3}\right)} \cdot 2^{\left(\frac{2}{3}\right)} \cdot d^{\left(\frac{1}{3}\right)} \cdot t^2 - \frac{1}{2} \cdot j^{\left(\frac{1}{3}\right)} \cdot 2^{\left(\frac{1}{3}\right)} \cdot d^{\left(\frac{2}{3}\right)} \cdot t - \frac{j \cdot t^3}{6} \qquad (6.93)$$

6.4.4 Motion during time period $t_2 \leq t \leq t_3$

$$J(t) := -j \qquad (6.94) \qquad A(t) := -j \cdot t + 2^{\left(\frac{2}{3}\right)} \cdot d^{\left(\frac{1}{3}\right)} \cdot j^{\left(\frac{2}{3}\right)} \qquad (6.95)$$

$$V(t) = \frac{-1}{2} \cdot j^{\left(\frac{1}{3}\right)} \cdot 2^{\left(\frac{1}{3}\right)} \cdot d^{\left(\frac{2}{3}\right)} - \frac{j \cdot t^2}{2} + j^{\left(\frac{2}{3}\right)} \cdot t \cdot 2^{\left(\frac{2}{3}\right)} \cdot d^{\left(\frac{1}{3}\right)} \qquad (6.96)$$

$$D(t) := \frac{d}{6} - \frac{1}{2} \cdot j^{\left(\frac{1}{3}\right)} \cdot t \cdot 2^{\left(\frac{1}{3}\right)} \cdot d^{\left(\frac{2}{3}\right)} + \frac{t^2}{2} \cdot j^{\left(\frac{2}{3}\right)} \cdot 2^{\left(\frac{2}{3}\right)} \cdot d^{\left(\frac{1}{3}\right)} - \frac{j \cdot t^3}{6} \qquad (6.97)$$

6.4.5 Motion during time period $t_3 \leq t \leq t_4$

$$J(t) = j \qquad (6.98) \qquad A(t) := -2 \cdot 2^{\left(\frac{2}{3}\right)} \cdot d^{\left(\frac{1}{3}\right)} \cdot j^{\left(\frac{2}{3}\right)} + j \cdot t \qquad (6.99)$$

$$V(t) = 4 \cdot j^{\left(\frac{1}{3}\right)} \cdot 2^{\left(\frac{1}{3}\right)} \cdot d^{\left(\frac{2}{3}\right)} - 2 \cdot j^{\left(\frac{2}{3}\right)} \cdot t \cdot 2^{\left(\frac{2}{3}\right)} \cdot d^{\left(\frac{1}{3}\right)} + \frac{j \cdot t^2}{2} \qquad (6.100)$$

$$D(t) := \frac{-13 \cdot d}{3} - j^{\left(\frac{2}{3}\right)} \cdot t^2 \cdot 2^{\left(\frac{2}{3}\right)} \cdot d^{\left(\frac{1}{3}\right)} + 4 \cdot j^{\left(\frac{1}{3}\right)} \cdot t \cdot 2^{\left(\frac{1}{3}\right)} \cdot d^{\left(\frac{2}{3}\right)} + \frac{j \cdot t^3}{6} \qquad (6.101)$$

6.5 CONDITION TO CONFIRM MAXIMUM ACCELERATION IS REACHED BEFORE MAXIMUM SPEED

The case where the lift reaches maximum speed, but not maximum acceleration has not been considered as this would be a non-sensical design. To confirm the system does not have this anomaly, refer to Figure 6.2 (A) to write down:

$t_3 \geq 2 \cdot t_1$ which by substitution yields $a^2 \leq v \cdot j$ (6.102)

6.6 MINIMUM TRAVEL DISTANCES

During a lift journey, a new landing or car call may be introduced such that the lift needs to stop before the destination it is currently travelling to. The following results enable the lift control system to check whether the lift can stop in time for the new call. If the current D(t) is less than d_{min}, the software routines implementing the equations given in for Conditions A to C can be reset with a new value of d mid-way through a journey. The D(t), V(t), A(t) and J(t) profiles generated will remain continuous.

6.6.1 Condition A

While $0 \le t \le t_1$ refer to condition C results and set $t = t_1$

$$t := \left(\frac{d_{min}}{2\cdot j}\right)^{\frac{1}{3}} \quad \text{yields} \quad d_{min} = 2\cdot t^3\cdot j \qquad (6.103)$$

While $t_1 \le t \le t_2$ refer to condition B results setting $t = t_2$

$$t = \frac{-a}{2\cdot j} + \frac{\sqrt{a^3 + 4\cdot d_{min}\cdot j^2}}{2\cdot j\cdot\sqrt{a}} \quad \text{yields} \quad d_{min} := a\cdot t^2 + \frac{a^2\cdot t}{j} \qquad (6.104)$$

If $t_2 \le t \le t_3$ the velocity profile must continue to t_3, so

$$d_{min} - 2\cdot D(t_3) \quad \text{yields} \quad d_{min} \quad \frac{v\cdot a}{j} + \frac{v^2}{a} \qquad (6.105)$$

If $t_3 \le t \le t_4$ the lift commences decelerating at t_4, so set

$$t := \frac{d_{min}}{v} \quad \text{yields} \quad d_{min} = t\cdot v \qquad (6.106)$$

If $t_4 \le t$ the lift has already started decelerating, so $d_{min} := d$ (6.107)

6.6.2 Condition B

For $0 \le t \le t_1$ condition A result applies, so $d_{min} = 2\cdot t^3\cdot j$ (6.108)

For $t_1 \le t \le t_2$ condition A result applies, so $d_{min} = a\cdot t^2 + a^2\cdot\frac{t}{j}$ (6.109)

When $t_2 \le t$ the lift has already begun slowing down, so $d_{min} := d$ (6.110)

6.6.3 Condition C

For $0 \le t \le t_1$ condition A result applies, so $d_{min} := 2\cdot t^3\cdot j$ (6.111)

When $t_1 \le t$ the lift has already begun slowing down, so $d_{min} := d$ (6.112)

6.7 APPLICATIONS

6.7.1 Motor speed reference

Motor speed reference curves are commonly held in software look up tables. It is envisaged that a software implementation of the equations presented in this paper will provide a fast, flexible and efficient way of generating optimum reference speed profiles, on line in lift system controllers. This application is modelled in the following two chapters of this thesis where the equations are applied to generate profiles for the motor model and lift simulation.

6.7.2 Lift traffic analysis

To calculate the handling capacity and performance of a lift system it is necessary to know how long it takes a lift to travel given distances. Using the appropriate formulae taken from the previous sections, the travel time of a variable speed lift (with optimum control) can be written down as follows:

if $d \ge \frac{a^2 \cdot v + v^2 \cdot j}{j \cdot a}$ then $\text{Journey\_Time} := \frac{d}{v} + \frac{a}{j} + \frac{v}{a}$ (condition A)

if $\frac{2 \cdot a^3}{j^2} \le d < \frac{a^2 \cdot v + v^2 \cdot j}{j \cdot a}$ then $\text{Journey\_Time} := \frac{a}{j} + \frac{\sqrt{a^3 + 4 \cdot d \cdot j^2}}{\sqrt{a \cdot j}}$ (condition B)

if $d < 2 \cdot \frac{a^3}{j^2}$ then $\text{Journey\_Time} := \left(32 \cdot \frac{d}{j}\right)^{\frac{1}{3}}$ (condition C)

It is advisable to add an additional time component to allow for motor start up time and any deviations from the optimum speed profile. Depending on drive quality, Day and Barney(6.1) recommend that this component should be between 0.2 and 0.5 seconds. These equations are applied in Chapter 4 of this thesis.

6.8 DISCUSSION

Ideal lift kinematics provide the basis for optimum speed control of lifts, an essential component for fast, efficient and comfortable transportation.

Equations by Motz(6.2) give us points on these curves. The equations derived in this chapter allow continuous, optimum functions of jerk, acceleration, speed and distance travelled profiles to be plotted against time. These profiles can be generated for any journey distance given inputs for maximum jerk, acceleration, and speed.

The equations are complex, but have been implemented in software by the author. The users of this software do not need to work through the calculations taking place, but can concentrate on entering the required inputs to generate the profiles quickly and easily.

The ability to plot profiles for any inputs gives additional flexibility in the design of lift controllers. In later chapters we will explore how building this functionality into a control system can help us save energy in a green lift system.

The results also have applications in lift traffic analysis for calculating journey time, as already discussed in Chapter 4 of this thesis.

Although there is some guidance(6.1) on the choice of maximum jerk and acceleration for a lift installation, there have been no major studies on the relative levels of comfort experienced by passengers given different values of these variables. Applying the work discussed in this chapter, it would be feasible to carry out such an investigation. This would yield useful results for specification and design.

The work presented in this chapter has been widely published. A summary of the research and results was presented at the Elevator Technology Conference, ELEVCON '95(6.7). The written conference paper was re-published by the trade magazines, Elevator World in April 1996 and by Elevatori in May/June 1996. A more detailed paper, including details of the derivation was published in the International Journal of Elevator Engineers (IJEE)(6.8).

REFERENCES

6.1 (Various authors) *CIBSE Guide D, Transportation Systems in Buildings* The Chartered Institution of Building Services Engineers (1993)

6.2 Motz H D *On the kinematics of the ideal motion of lifts* Forden und haben 26 (1) (1976) (in German)

6.3 Motz H D *On the ideal kinematics of lifts* Elevatori 1/91 (1991) and Elevatori 2/92 (1991) (in English and Italian) (beware typographical errors in formulae)

6.4 Roschier N R and Kaakinen M J *New formulae for elevator round trip time calculation* Elevator World 28 (8) (August 1980 supplement)

6.5 Schroeder J *Elevator trip profiles* Elevator World 35 (10) (November 1987)

6.6 Barney G C and Loher A G *Elevator Electric Drives* Ellis Horwood, Chichester (1990)

6.7 Peters R D *Ideal Lift Kinematics: Complete Equations for Plotting Optimum Motion* Elevator Technology 6, Proceedings of ELEVCON'95 (The International Association of Elevator Engineers) (1995) (republished by Elevator World, April 1996 and by Elevatori, May/June 1996)

6.8 Peters R D *Ideal Lift Kinematics: Derivation of Formulae for the Equations of Motion of a Lift* International Journal of Elevator Engineers, Volume 1 No 1 (1996)

Chapter 7

MOTOR MODELLING

List of Symbols

$a(t)$	lift acceleration at time t (m/s^2)
d_s	motor sheave diameter (m)
g	gravitational acceleration constant (m/s^2)
g_r	gear ratio (:1)
E	electromotive force (Volts)
E_t	total energy consumption of trip (Joules)
JT	lift journey time (s)
J	total moment of inertia (kgm^2)
J_b	brake moment of inertial (kgm^2)
J_g	gear moment of inertia (kgm^2)
J_m	motor moment of inertia (kgm^2)
J_p	pulleys total moment of inertia (kgm^2)
J_s	sheave moment of inertia (kgm^2)
M_c	mass of car (kg)
M_{cw}	mass of counterweight (kg)
M_p	mass of passengers in car (kg)
M_r	mass of ropes (kg)
KI_f	motor magnetising constant (amps)
$I_a(t)$	armature current at time t (ohms)
$I_{ph}(t)$	converter phase current at time t (amps)
I_n	amplitude of nth harmonic current (amps)
$PF(t)$	power factor at time t

$P(t)$	power consumption at time t (Watts)
R_a	armature resistance (ohms)
r_r	roping ratio (:1)
T_L	load torque (Nm)
$T(t)$	required motor torque at time t (Nm)
$V_a(t)$	armature voltage at time t (Volts)
V_{line}	phase-phase line voltage (Volts r.m.s.)
$v(t)$	lift velocity at time t (m/s)
$\alpha(t)$	converter firing angle at time t (radians)
$\varepsilon(t)$	motor drive angular acceleration at time t (rad/s^2)
η	gear efficiency (0-1)
ω_s	supply angular frequency (rad/s)
$\omega(t)$	motor drive angular velocity at time t (rad/s)

7.1 INTRODUCTION

So(7.1) provides a comparison of the energy efficiency for a range of drives using motor models. The comparison is for a single lift trip with a fixed journey profile, load torque and inertia.

The purpose of this section of the research is to derive a motor model similar to that used by So, and to develop it to the point that it can be built into a lift simulation program. We can then calculate the total energy consumption of a lift system for a given passenger traffic profile and lift control system. This will allows us to investigate possible energy savings.

So considers AC 2 speed, AC variable voltage, AC variable voltage variable frequency, DC Ward Leonard and DC static converter drives. The AC variable voltage variable frequency and DC static converter drives are shown to be the most efficient. The drive modelled in this chapter has a separately excited DC motor, fed from a fully controlled 6 pulse converter. A diagrammatic representation of the drive is shown in Figure 7.1.

The following calculations have being prepared using Mathcad mathematical software. The results are calculated and plotted directly from the equations entered in standard mathematical notation. To test for consistency, input parameters have been chosen to correspond with So.

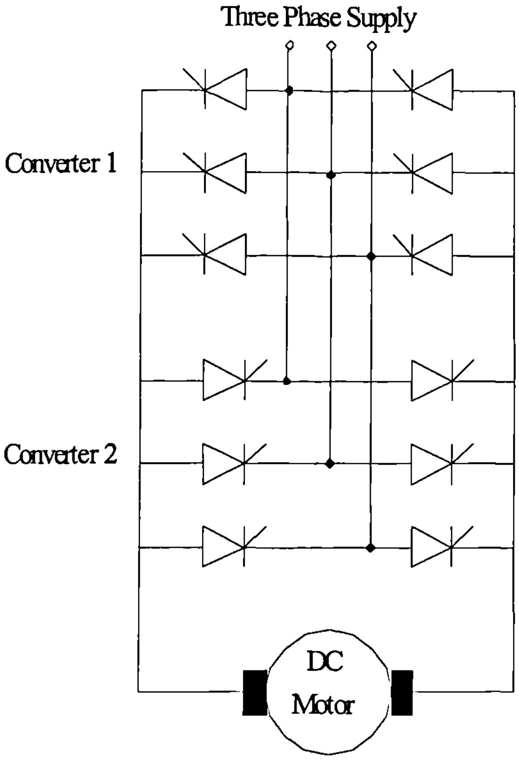


Figure 7.1 Static converter drive

7.2 LIFT MOTION

So does not consider linear motion, but takes angular velocity and acceleration as input to his model. The translation between linear and angular motion is a function of the sheave diameter, gear ratio and roping ratio, as described in equations 7.1 and 7.2.

$$\omega(t) = \frac{v(t)\cdot 2\cdot g_r\cdot r_r}{d_s} \tag{7.1}$$

$$\varepsilon(t) = \frac{a(t)\cdot 2\cdot g_r\cdot r_r}{d_s} \tag{7.2}$$

Applying the ideal lift kinematics equations derived in Chapter 6, we can generate suitable velocity and acceleration plots, as shown in Figure 7.2.

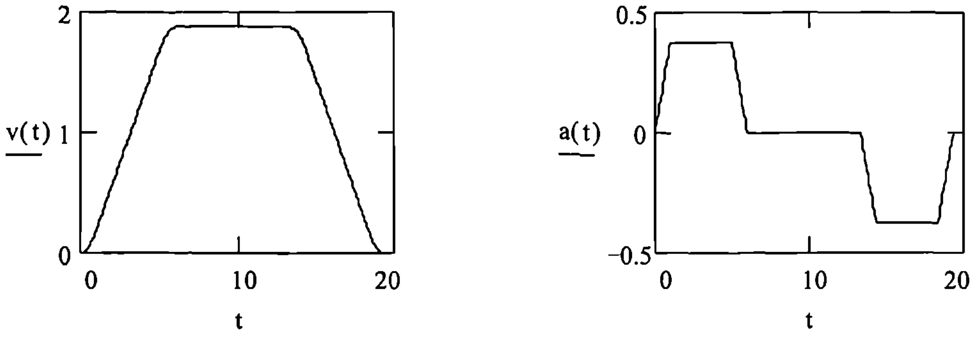


Figure 7.2 Velocity and acceleration profiles

To plot angular velocity and acceleration we apply equations 7.1 and 7.2. In this example take drive sheave diameter d_s = 0.5 , gear ratio g_r - 20 , and roping ratio r_r - 1. This gives us the profiles in Figure 7.3, which are consistent with the input to So's model.

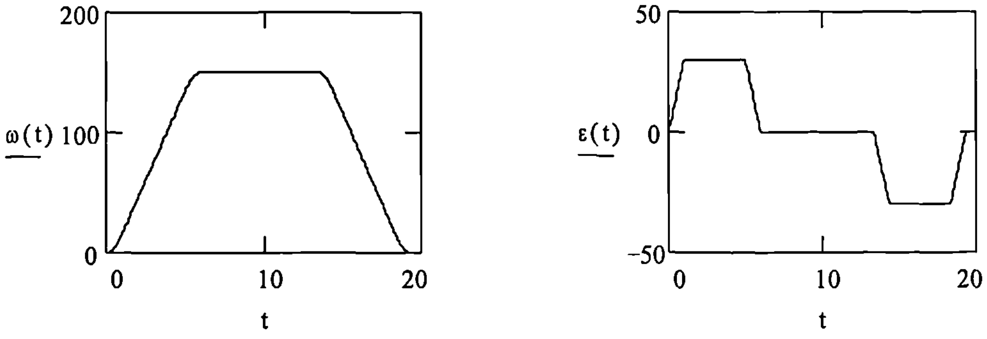


Figure 7.3 Angular velocity and acceleration profiles

7.3 LOAD TORQUE

The load torque is the result of the imbalance in static loads either side of the driving sheave as shown in Figure 7.4. Again, So does not calculate a load torque, but uses a fixed value. We need to calculate load torque if we are to apply the model in a simulation.

The torque is applied at the rim of the driving sheave, thus it is calculated as the difference in weight between the loaded car and counterweight times the radius of the driving sheave. We are interested in the load as "seen" by the motor, so must take into account the reducing effect of the roping ratio, gear ratio, and the losses caused by inefficiencies in the gear unit.

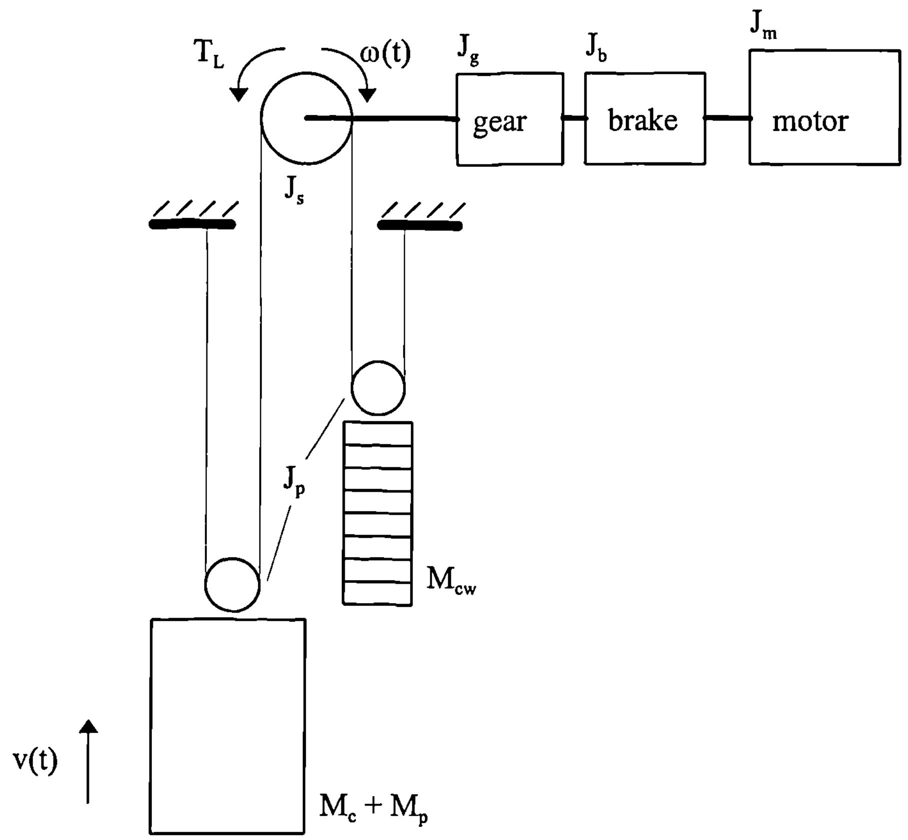


Figure 7.4 Schematic representation of traction lift
(2:1 roping ratio shown in this diagram)

Thus we can write down an expression for the load torque as follows

$$T_L = \frac{\left(M_c + M_p - M_{cw}\right)\cdot g\cdot\frac{d_s}{2}}{g_r\cdot r_r\cdot\eta} \qquad (7.3)$$

Note that difference in rope weight either side of the shaft has not been included. Where there is a significant differential in rope weight, it is normal practice to include compensation roping which resolves any imbalance.

So uses the value $T_L := 60$ in his model, which we shall use for the remainder of this calculation.

7.4 LOAD INERTIA

The moment of inertia of a lift system is made up of a number of components including contributions from: motor, brake, gear, driving sheave, pulleys, ropes, lift car, counterweight, and passengers. So takes a fixed value for load inertia, but again we need to be able to calculate a value for use in a lift simulation.

Referring to Figure 7.4, the inertia of rotating components are summed, except for those rotating at a lower speed because of the gear; these must be divided by the square of the gear ratio to determine their equivalent inertia, as seen by the motor. (Note the kinetic energy of a rotating body is ½ J ω^2, hence the introduction of squared terms when considering angular velocity reductions by gear and roping ratios.)

The inertia of the car, counterweight, and ropes are seen by the motor as point masses on the edge of the driving sheave. Hence their equivalent inertia is the sum of their masses times the square of the radius of the driving sheave, divided by the appropriate gear and roping ratios.

Thus the equivalent moment of inertia that the motor sees is:

$$J = J_m + J_b + \frac{1}{g_r^2} \cdot \left(J_g + J_s + J_p\right) + \frac{d_s^2 \cdot M_r}{4 \cdot g_r^2} + \frac{d_s^2}{4 \cdot \left(g_r \cdot r_r\right)^2} \cdot \left(M_c + M_{cw} + M_p\right) \qquad (7.4)$$

Zhou presents a similar equation in his paper on the *Analysis of Motion Equations of Elevator Drive Systems*(7.2), but does not consider a term for roping ratios. Equation 7.4 is consistent with Zhou's equations are consistent for 1:1 roping.

So uses the value J = 10 in his model which we shall use for the remainder of this calculation.

7.5 MOTOR TORQUE

The torque required from the motor is the load torque plus the torque required to accelerate or decelerate the lift. Thus,

$$T(t) := T_L + J \cdot \varepsilon(t) \qquad (7.5)$$

which is plotted in Figure 7.5.

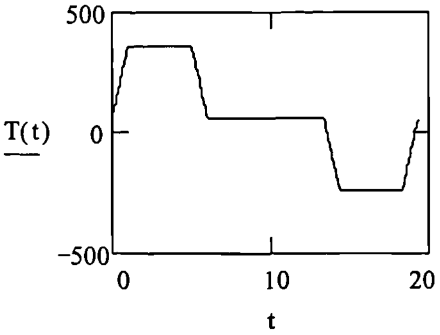


Figure 7.5 Required motor torque

7.6 MOTOR MODEL

DC Motor steady state performance equations are well known:

$$V_a \quad E + I_a \cdot R_a \qquad (7.6)$$

where

$$E := \left(KI_f\right) \cdot \omega \qquad (7.7)$$

and the torque developed is

$$T := \frac{E \cdot I_a}{\omega} \qquad (7.8)$$

By substitution, the steady state equations can be rearranged to determine the required armature voltage and resultant current for the functions of torque and angular velocity which we have already determined. This approach assumes an ideal feedback control system. Thus,

$$V_a(t)\quad \left(KI_f\right)\cdot\omega(t)+\frac{T(t)}{KI_f}\cdot R_a \qquad (7.9)$$

$$I_a(t)\quad \begin{matrix}T(t)\\ KI_f\end{matrix} \qquad (7.10)$$

For our example, let R_a 0.2 and KI_f = 1.6. The functions of armature voltage and current in Figure 7.6 can than be plotted by applying Equations 7.9 an 7.10.

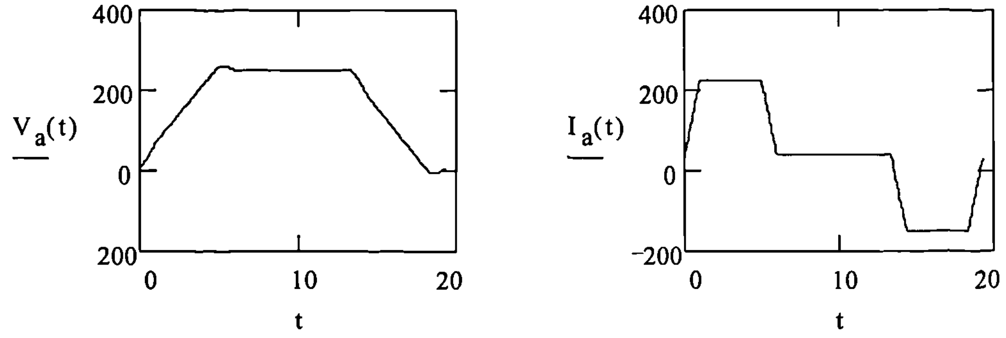


Figure 7.6 Armature voltage and current

The power consumption of the motor (ignoring field excitation) during the trip is

$$P(t) = I_a(t)\cdot V_a(t) \qquad (7.11)$$

and is plotted in Figure 7. This profile is the same as So's result.

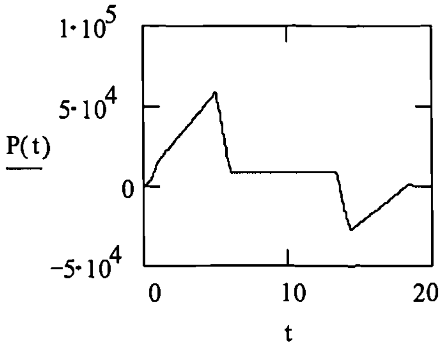


Figure 7.7 Power consumption

The total energy consumption of the DC motor during the trip is

$$E_t = \int_0^{JT} P(t)\,dt \qquad (7.12)$$

which yields $E_t = 1.911 \cdot 10^5$ Joules, which again is consistent with So's results.

7.7 CONVERTER OPERATION

The voltage applied to the DC motor is controlled by the firing angle of the converter. For a fully controlled, three phase 6 pulse converter, ignoring overlap, the firing angle for the required mean dc voltage is(7.3)

$$\alpha(t) = \operatorname{acos}\left(\frac{\pi}{3} \cdot \frac{V_a(t)}{V_{line} \cdot \sqrt{2}}\right) \qquad (7.13)$$

For a fully controlled converter, the firing angle is equal to the phase angle(7.3), so the power factor

$$PF(t) = \cos(\alpha(t)) \qquad (7.14)$$

Taking So's value of $V_{line} := 380$ and applying equations 7.13 and 7.14 we can plot the power factor profile shown in Figure 7.8. This is consistent with So's result.

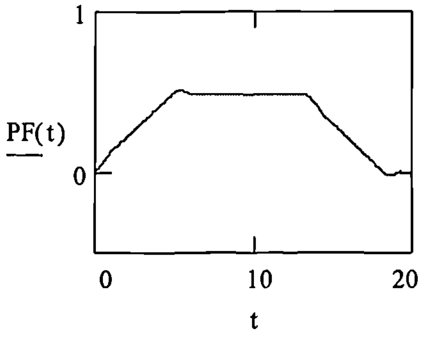


Figure 7.8 Power factor

7.8 SUPPLY SYSTEM HARMONICS

Supply system harmonics are not considered by So, but are known from the literature. By Fourier analysis, ignoring overlap, the quasi square-wave phase current of an ideal six-pulse converter can be shown to be$^{(7.4)}$

$$I_{ph}(t)=\frac{2\cdot\sqrt{3}}{\pi}\cdot I_a(t)\cdot\left[\begin{array}{l}\cos\left(\omega_s\cdot t\right)\quad\frac{1}{5}\cdot\cos\left(5\cdot\omega_s\cdot t\right)+\frac{1}{7}\cdot\cos\left(7\cdot\omega_s\cdot t\right)-\frac{1}{11}\cdot\cos\left(7\cdot\omega_s\cdot t\right)\ldots\\+\frac{1}{13}\cdot\cos\left(13\cdot\omega_s\cdot t\right)\quad\frac{1}{17}\cdot\cos\left(17\cdot\omega_s\cdot t\right)+\frac{1}{19}\cdot\cos\left(19\cdot\omega_s\cdot t\right)\end{array}\right]$$

$$-\ldots\ldots\quad+\ldots..\quad\text{etc.}\qquad(7.15)$$

Thus, the amplitudes relative to the fundamental of the 5th, 7th, 11th and 13th harmonic currents are 20%, 14.3%, 9.1% and 7.7% respectively. The total harmonic distortion of the current is defined as

$$\frac{\left(\sum_{n=2}^{\infty} I_n^{\,2}\right)^{0.5}}{I_1}\qquad(7.16)$$

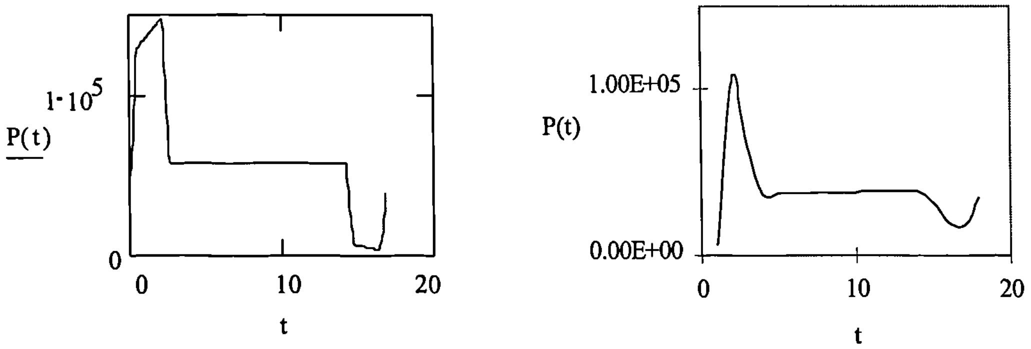
which is approximately 27% in this case.

DC system harmonics have not been considered in this research project, but are discussed and analysed by Graham A D and Schonholzer E T$^{(7.5)}$.

7.9 SITE TESTING

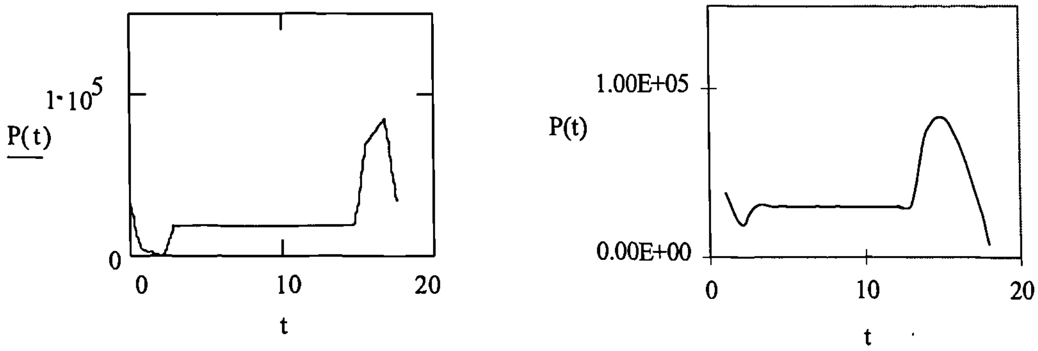
Initial site tests of the model have been undertaken on a static converter DC drive at Sheffield University Art Tower.

Restricted access to the site, and limited manufacturer's data has meant that some input variables have had to be estimated. However, the consistency between calculated and actual profiles for both up and down travel (empty car) shown in Figures 7.8 and 7.9 ascribe greater confidence to the model as a whole.



(i) (ii)

Figure 7.8 (i) Calculated and (ii) measured power consumption for up journey



(i) (ii)

Figure 7.9 (i) Calculated and (ii) measured power consumption for down journey

This drive is not regenerating. Some static converter drives do not regenerate as their braking energy is dissipated in a resistor chopper circuit rather than being returned to the mains. In this instance, there is no cut off in the profile at zero power. Thus, the absence of regeneration is believed to be due to inefficiencies in the drive, e.g. as the result of a high motor magnetising constant. The motor in question is dated (>20 years), presumably having being kept after a more recent upgrade of the drive control from motor generator set to static converter.

It should also be noted that the lift continues to take power when it is stationary (in this case approximately 5 kW). This power take will come from a combination of sources which may include brake, brake and motor fan, motor field excitation, no-load consumption of static converter.

7.10 DISCUSSION

The motor model developed by So for a DC static converter drive has been implemented and extended. The model now uses, as an input, the motion profiles generated from the kinematics research discussed in Chapter 6. Equations for load torque and load inertia have been developed as So uses fixed values.

We can now model the operation and power consumption of a lift trip for any journey, direction and loading. This motor model is included in the lift simulation program, *Liftsim*, which is discussed in Chapter 8 of this thesis. In Chapter 9 we will see how the model can be used to develop and test green lift control strategies.

Results from the model are consistent with those presented by So. Initial site tests have suggested that the model is generating consistent power consumption profiles, and can at least not be rejected. A continuous "base" load may be added to the model to account for miscellaneous small loads such as the power consumption of the brake, brake and motor fans, motor field excitation, and static converter losses. Some of these vary during the trip, but taking an average no-load value is unlikely to increase our margin of error as they are relatively insignificant during actual lift trips.

Further research into the modelling of this and other lift drives would be valuable. More comprehensive site tests would need the full co-operation of the lift manufacturer, installer and building owner. Some of the variables required are difficult to measure, and so cannot be established without full access to manufacturer's design data.

Currently designers rely on empirical methods to estimate the power consumption of a lift installation. Building motor models into simulation programs such as *Liftsim* will improve our predictions of power consumption and allow us to demonstrate the value of energy saving features.

Major elements of the research discussed in this chapter were presented at the CIBSE National Conference 1995 in the paper, *Mathematical Modelling of Lift Drive Motion and Energy Consumption.* The paper was republished by Elevator World in July 1996.

REFERENCES

7.1 So A T P *Computer simulation-based analysis of elevator drive systems* HKIE Transactions No.3 (1992)

7.2 Zhou T *Analysis of Motion Equations of Elevator Drive Systems* Elevator Technology 4, Proceedings of ELEVCON '92 (The International Association of Elevator Engineers)(1992)

7.3 O'Kelly D *Performance and Control of Electrical Machines* (Maidenhead: McGraw-Hill Book Company Ltd)(1991)

7.4 Bradley D A *Power Electronics* (Wokingham: Van Nostrand Reinhold Co. Ltd) (1987)

7.5 Graham A D and Schonholzer E T *Line Harmonics of Converters with DC-Motor Loads* IEEE Transactions on Industry Applications, Vol IA-19, No.1 (January/February 1983)

Chapter 8

LIFT SIMULATION SOFTWARE

8.1 INTRODUCTION

The lift simulation program, *Liftsim* has been written as a development platform for "green" lift control systems. It may also be applied as an advance lift traffic analysis tool.

Development of a lift simulation program is not unique. Manufacturers(8.1), researchers(8.2) and consultants(8.3) have previously used lift simulation programs ranging from the crude to the sophisticated. The features of *Liftsim* believed to be unique are:

- it applies object oriented programming technology.

- it implements the ideal lift kinematics research discussed in Chapter 6 of this thesis allowing total control over the lift speed profiles. Often lift simulation packages use a "single floor jump time"; this ignores complexities such as lifts which do not reach full speed in a single floor jump, and calculations to determine if a travelling lift can stop in time for a new call.

- it implements a motor model, calculating the energy consumption of the lift drives during the simulation; these calculations based on research discussed in Chapter 7 of this thesis.

- it implements a passenger generator based on arrival rates and destination probabilities as discussed in Chapters 3 and 5; the use of "periods" allows sets of different arrival rates and destination probabilities to be defined such that changing levels of traffic can be modelled.

The program has been written using Microsoft Visual C++ (for Windows 95 and Windows NT). C++ is a complex object oriented language, but it produces very fast programs, and easily reusable/portable code. It is the current Arup standard for new technical software development projects.

8.2 OVERVIEW OF OBJECT ORIENTED PROGRAMMING

Traditional structural programming techniques break a program into several smaller tasks by defining a set of functions. Object oriented programming (OOP) builds on this by introducing objects. In an object, both the variables and functions are grouped together. The behaviour (i.e. the variables and functions) of an object is defined by the class to which it belongs. Each object is an "instance" of a class.

Object-oriented programming uses abstraction to allow the programmer to consider the important details of the problem in hand, and to ignore unnecessary complexities. Encapsulation is applied to hide the details of a solution so that the solution is easier to understand.

For an example of how OOP is mimicking the real world, consider *Ginger* the cat in Figure 8.1.

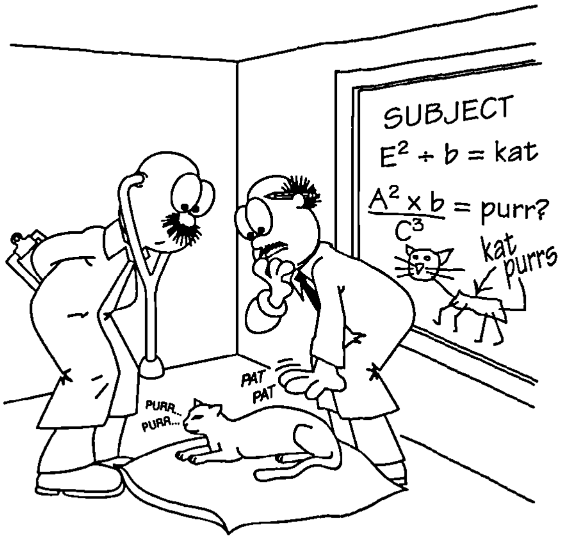


Figure 8.1 Ginger the cat graphic from (8.4)

The world has a class *cat*. Everything in the *cat* class has a set of the same variables (no of paws, age, sex, etc.) and a range of functions (if you chase it runs; if you pat it, it purrs). *Ginger* is an object, and an instance of the cat class. He has all the functions and variables of a cat. The *cat* class utilises abstraction and encapsulation: If we feed Ginger, he will eat without us having to understand the complexities of his digestive system; we can concentrate on the tasks in hand such as preparing his food and stroking him.

Returning to lifts, we can define the class *lift* with variables such as *capacity* and *speed*, and functions such as *StartJourney()*. We can create as many lift objects as we need; each lift object is independent, but may use all the variables and functions defined by the class.

OOP helps break down complex problems into manageable parts that are easy to work with as they represent familiar ideas or components.

8.3 PROGRAM CLASSES

8.3.1 General

Liftsim has seven main simulation classes which define the behaviour of the system. These are:

8.3.2 Building class

The *building* class defines the building in terms of number of stories and story heights. Its variables and functions are summarised in Table 8.1.

Class Information	Description
member variables	
int m_NoFloors;	no of floors in building
double m_FloorPositions[MAX_FLOORS];	array of floor heights
functions	
double BuildingHeight();	calculates building height

Table 8.1 Building class variables and functions

8.3.3 Motion class

The *motion* class implements the ideal lift kinematics discussed in Chapter 6 of this thesis. Programs using the class can specify the journey distance, rated velocity, etc. and output the current distance travelled, velocity, etc. at any time, t since the journey began. Its variables and functions are defined in Table 8.2.

Class Information	Description
member variables	
double m_d;	journey distance,(+ for up travel, - for down) (m)
double m_D;	absolute value of m_d (m)
double m_v;	rated speed, (always +) (m/s)
double m_a;	rated acceleration, (always +) (m/s/s)
double m_j;	rated jerk (always +) (m/s/s/s)
double m_Tstart;	motor start up delay (s)
double m_t;	time elapsed since journey commenced (s)
double m_StartTime;	time journey commenced (s past ref.)
double m_CurrentTime;	current time (s past ref.)
double m_StartPosition;	start position (m above ref. height)
functions	
double JourneyTime();	journey time for trip (s)
char Condition();	journey condition (A, B, or C)
int Slice();	calculates which time slice journey is in
double Distance();	calculates the current distance travelled (m)
double Velocity();	calculates the current velocity (m/s)
double Acceleration();	calculates the current acceleration (m/s/s)
double Jerk();	calculates the current jerk (m/s/s/s)
double Position();	calculates current position (m above ref.)
double EndTime();	time when journey will be complete (s past ref.)
double MinDistance();	calculates minimum journey distance if lift begins slowing down immediately (m)
int ConfirmDestination();	confirmation that lift can no longer change destination, that MinDistance() is same as m_D (1- confirmed, 0 - may change)
void DataChecks();	data checks called by constructor

Table 8.2 Motion class variables and functions

8.3.4 Lift class

The *lift* class defines a lift (rated speed, capacity, floors served, etc.) and its current status (position, speed, load, etc.). The *motion* class is applied to enable the lift to move according to the selected journey profile. The *lift* class includes algorithms to allow lifts to answer landing and car calls according to the principles of directional collective control. (Most lift control systems adopt a directional collective control strategy regardless of the complexities of the dispatcher algorithms.) *lift* class variables and functions are defined in Tables 8.3 and 8.4.

Class Information	Description
about the lift	
int m_Capacity;	nominal lift capacity (kg)
double m_Velocity;	rated lift velocity (m/s)
double m_VelocityMultiply;	multiplier set by green dispatcher
double m_Acceleration;	rated lift acceleration (m/s/s)
double m_AccelerationMultiply;	multiplier set by green dispatcher
double m_Jerk;	rated lift jerk (m/s/s/s)
double m_MotorStartDelay;	motor start up delay (s)
double m_DoorPreOpen;	door pre-opening (s)
double m_DoorOpen;	door open time (s)
double m_DoorClose;	door closing time (s)
double m_DoorDwell1;	door dwell time 1 (s) (time doors will wait until closing if beam not broken)
double m_DoorDwell2;	door dwell time 2 (s) (time doors will wait until closing after beams have been broken/cleared)
int m_DoorBeams;	flag for status of door beams (corresponding to passenger transfer - 1 beams broken, 0 clear)
how the lift serves the building	
int m_NoFloors;	no of floors in building
int m_Home;	home floor/default parking position
double m_FloorPositions[MAX_FLOORS];	positions of floors in building (m above ref.)
int m_FloorsServed[MAX_FLOORS];	floors served by lift (1 yes, 0 no)
about the current status of the lift	
int m_CarCall[MAX_FLOORS];	car calls registered (1 registered, 0 not)
int m_ParkCall[MAX_FLOORS];	parking calls; lift does not open doors on arrival
int m_ParkOpenCall[MAX_FLOORS];	parking calls, lift parks with doors open
int m_UpLandingCalls[MAX_FLOORS];	up landing calls allocated to lift by dispatcher
int m_DownLandingCalls[MAX_FLOORS];	down landing calls allocated to lift by dispatcher
int m_TravelStatus;	travel status, (1 travelling, 0 at floor)
int m_Direction;	direction of travel (-1 down, 0 neither, 1 up)
double m_DestinationPosition;	current destination position (m above ref.)
double m_StartPosition;	position current journey started (m above ref.)
double m_JourneyStart;	time lift journey started (s past ref.)
int m_CurrentLoad;	current car load (kg)
int m_DoorStatus;	door status (1 fully open, 2 closing, 3 fully closed, 4 opening)
double m_DoorsStart;	time doors started opening/closing (s past ref.)
double m_TimerT1;	time timer T1 began (s past ref.),
double m_TimerT2;	time timer T2 began (s past ref.),
double m_PersonStart;	time current person began loading/unloading (s past ref.)
double m_CurrentTime;	current time (s past ref.)
double m_DestinationTime;	arrival time next planned stop (s after ref.)
double m_CurrentPosition;	current position (m above ref.)
double m_CurrentDistance;	distance travelled on current trip (m)
double m_CurrentVelocity;	current velocity (m/s)
double m_CurrentAcceleration;	current acceleration (m/s/s)
double m_CurrentJerk;	current jerk (m/s/s/s)
double m_QuickestStopPosition;	next possible stop lift can make (m above ref.)
int m_DestinationFloor;	current destination floor no.

Table 8.3 Lift class variables

Class Information	Description
void Reset(building b);	sets lift to home position, cancels all calls, etc.
int StartJourney(int floor);	start journey to destination "floor"
int ChangeJourney(int floor);	change journey, new destination, "floor"
void UpdateDestination();	check for calls allocated to lift and set destination
void SetDestination();	set destination/direction travel
void Update(double CurrentTime);	update time (s); this function updates the status of the lift (position, speed, door operation, etc.)
void RemoveLandingCall(int direction, int floor);	removes landing call - called by class when lift arrives at landing.
int LowestFloorServed();	returns number of lowest floor served by lift
int HighestFloorServed();	returns number of highest floor served by lift
int FloorAt();	return floor no if not travelling
int FloorNo(double position);	returns floor no at position
double QuickestStopPosition();	next stop lift could make (m above reference)
double QuickestStopTime();	time of next stop lift could make (s after ref.)
int QuickestFloorStopFloor();	floor of next stop lift could make
double QuickestFloorStopPosition();	position of next stop lift could make
double QuickestFloorStopTime();	time of next stop lift could make (s after ref.)

Table 8.4 Lift class functions

8.3.5 Dispatcher class

The *dispatcher* class defines rules for allocating which lift serves which calls. The default dispatcher logic has been based on conventional group control with dynamic sectoring as defined by Barney and dos Santos(8.5). The class variables and functions are defined in Table 8.5.

Class Information	Description
member variables	
int m_Algorithm;	dispatcher algorithm no. selected
int m_NoFloors;	number of floors in building
int m_NoLifts;	number of lifts
double m_FloorPositions[MAX_FLOORS];	floor positions (m above reference)
int m_UpLandingCalls[MAX_FLOORS];	up landing calls registered with dispatcher
int m_DownLandingCalls[MAX_FLOORS];	down landing calls registered with dispatcher
member functions	
void CancelLandingCalls(lift l[MAX_LIFTS]);	cancel landing call when lift arrives at floor
void Reset(building b,int NoLifts,lift l[MAX_LIFTS]);	resets dispatcher, sets up member variables
int Update(double CurrentTime,lift l[MAX_LIFTS],motor m[MAX_LIFTS], double SimulationTimeStep);	update dispatcher; this function updates the status of the dispatcher, allocating calls, etc.

Table 8.5 Dispatch class functions and variables

8.3.6 Person class

The *person* defines a person, what time he/she arrives at the landing station, where he/she wants to go, their mass, etc. Once the journey is complete, the class provides details about passenger waiting and transit times. Waiting time *is calculated as the actual time a prospective passenger waits after registering a landing call (or entering the waiting queue if a call has been registered) until the responding elevator doors begin to open.* This definition has been taken from the NEI Vertical Transportation Standards(8.6). For continuity, transit time is calculated from *the time the responding elevator doors begin to open to the time the doors begin to open again at the passenger's destination.* Variables and functions of the person class are defined in Table 8.6.

Class Information	Description
member variables	
double m_TimeArrived;	time passenger arrived at landing (s past reference) (taken to be when call button pressed).
int m_ArrivalFloor;	arrival floor
int m_Destination;	destination floor
int m_Mass;	passenger mass (kg)
int m_LoadingThreshold;	threshold determining whether passenger will get into this lift or wait for the next (%) e.g. 80% means that passenger will not load lift if the lift will then be >80% full
double m_LoadingTime;	passenger loading time (s)
double m_UnloadingTime;	passenger unloading time (s)
double m_TimeBeganTransfer;	variable used to store when passenger transfer (loading and unloading) began (s past reference)
int m_CurrentStatus;	current status of passenger's journey; 1 yet to arrive, 2 waiting, 3 loading, 4 travelling, 5 unloading, 6 journey completed
int m_LiftUsed;	lift used by passenger
double m_TimeLiftArrived;	time responding lift arrived, taken from when the doors began to open (s past reference)
double m_TimeReachedDestination;	time responding lift reached destination, taken from when the doors began to open (s past reference)
member functions	
void NewLandingCalls(double CurrentTime,dispatch& d);	registers new landing calls when passenger arrives
void Update(double CurrentTime,int NoLifts,lift l[MAX_LIFTS],dispatch& d);	update status of passengers, adjust lift load, break/clear beams, etc.
int Direction();	returns direction of call (1 up, -1 down)
double WaitingTime();	passenger waiting time (s)
double TransitTime();	passenger transit time (s)

Table 8.6 Person class functions and variables

8.3.7 Traffic class

The *traffic* class converts arrival rate and destination probability data into a corresponding set of person objects.

Class Information	Description
member variables	
int m_NoTrafficPeriods;	number of traffic periods
double m_u[MAX_TRAFFIC_PERIODS] [MAX_FLOORS];	array of arrival rates (persons/s)
double m_d[MAX_TRAFFIC_PERIODS] [MAX_FLOORS][MAX_FLOORS];	array of destination probabilities (%)
double m_StartTime[MAX_TRAFFIC_PERIODS];	start times for traffic periods (s past reference)
double m_EndTime[MAX_TRAFFIC_PERIODS];	end times for traffic periods (s past reference)
int m_Mass[MAX_TRAFFIC_PERIODS];	passenger mass for each traffic period (kg)
int m_LoadingThreshold[MAX_TRAFFIC_PERIODS];	loading threshold for each traffic period (%)
double m_LoadingTime[MAX_TRAFFIC_PERIODS];	loading time for each traffic period (s)
double m_UnloadingTime[MAX_TRAFFIC_PERIODS];	unloading time for each traffic period (s)
int m_NoPassengers;	total no of passengers generated
member functions	
int MakePeople(person p[MAX_PERSONS], building b);	converts traffic flows into list of people
double AverageWaitingTime(person p[MAX_PERSONS]);	average waiting time for passengers who have completed their journey
double AverageTransitTime(person p[MAX_PERSONS]);	average journey time for passengers who have completed their journey
int AllJourniesComplete(person p[MAX_PERSONS]);	1 if all passenger journeys are complete, 0 otherwise
double CallsAnsweredInTime(double seconds, person p[MAX_PERSONS]);	Returns percentage of calls answered within specified no of seconds - use to plot waiting time
double TransitCompleteInTime(double seconds, person p[MAX_PERSONS]);	Returns percentage of transits complete within specified no of seconds - use to plot transit time
double JourneyTime(double seconds, person p[MAX_PERSONS]);	returns percentage of waiting + transit times completed with specified no of seconds - use to plot journey time distribution
double LongestWaitingTime(person p[MAX_PERSONS]);	longest passenger waiting time;
double LongestTransitTime(person p[MAX_PERSONS]);	longest passenger transit time;
double SimulationStartTime();	calculates from when first passenger could arrive

Table 8.7 Traffic class functions and variables

Different "periods" can be defined, each with separate arrival rates, designation probabilities, passenger mass, etc. The start and end time of periods may overlap if necessary. This allows the program user to generate traffic flows which vary in intensity, e.g. arrival rates at floor n starting at 5 persons per five minutes, then rising to 10 persons per five minutes, etc. And to analyse different types of loads being transported at the same time, e.g. in a hospital the traffic intensity of walking and wheelchair-bound passengers could be defined separately. Variables and functions of the traffic class are defined in Table 8.7.

8.3.8 Motor class

The *motor* class defines the characteristics of the drive. The class calculates the energy consumption and other characteristics of a DC six pulse static converter drive as discussed in Chapter 7. Motor class variables and functions are given in Table 8.8.

Class Information	Description
member variables	
double m_Acceleration;	current lift acceleration (m/s/s)
double m_ArmatureResistance;	armature resistance (ohms)
double m_GearEfficiency;	efficiency of gear (range 0 to 1)
double m_GearRatio;	gear reduction ratio (:1)
double m_Jmotor;	moment of inertia of motor (kgm^2)
double m_Jbrake;	moment of inertia of brake (kgm^2)
double m_Jgear;	moment of inertia of gear, measured from output side (kgm^2)
double m_Jpullies;	moment of inertia of diverter pulleys (kgm^2)
double m_Jsheath;	moment of inertia of drive sheath (kgm^2)
double m_LineVoltage;	phase-phase line voltage (Volts rms)
double m_MassCar;	mass of lift car including finishes (kg)
double m_MassCounterweight;	mass of counterweight (kg)
double m_MassPassengers;	mass of passengers in car (kg)
double m_MassRopes;	mass of ropes (kg)
double m_MotorMagConst;	motor magnetising constant (amps)
int m_MotorStatus;	current motor status, (1 running, 0 stopped)
double m_RealPower;	total real power consumption (kWhr)
double m_RopeRatio;	roping ratio (:1)
double m_SheathDiameter;	motor sheath diameter (m)
double m_Velocity;	current lift velocity (m/s/s)
member functions	
double AngularAcceleration();	current angular acceleration (rad/s/s)
double AngularVelocity();	current angular velocity (rad/s)
double ArmatureCurrent();	resultant armature current (amps)
double ArmatureVoltage();	armature voltage required (volts)
double FiringAngle();	firing angle of 6 pulse converter (rad)
double LoadTorque();	load torque (Nm)
double MomentInertia();	total inertia of system (kgm^2)
double MotorTorque();	required motor torque (Nm)
double Power();	current power consumption of DC motor (W)
double PowerFactor();	power factor of converter
void Reset();.	reset total power consumption, etc
void Update(lift l, double SimulationTimeStep);	updates power consumption, etc

Table 8.8 Motor class variables and functions

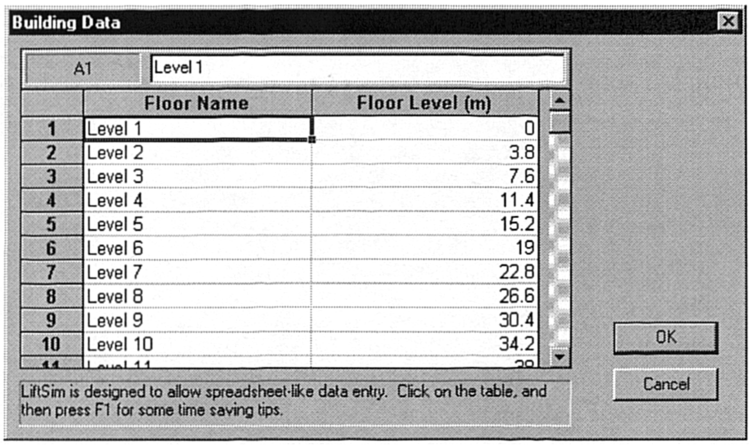
8.4 INTERFACE DESIGN

8.4.1 General

The interface is Windows based, and allows the user to edit all the system data in dialogue boxes containing standard Windows controls (radio buttons, drop downs, etc.), and a spreadsheet-like control for tabular data entry. The program uses a multi-document interface, so the user can be working on a number of different simulations at the same time.

In addition to the standard Windows features (save, print, etc.) there are five data entry dialogue boxes which can be accessed via the menus or button bar:

i. *building data* in which the user enters floor names and levels, as shown in Figure 8.2.



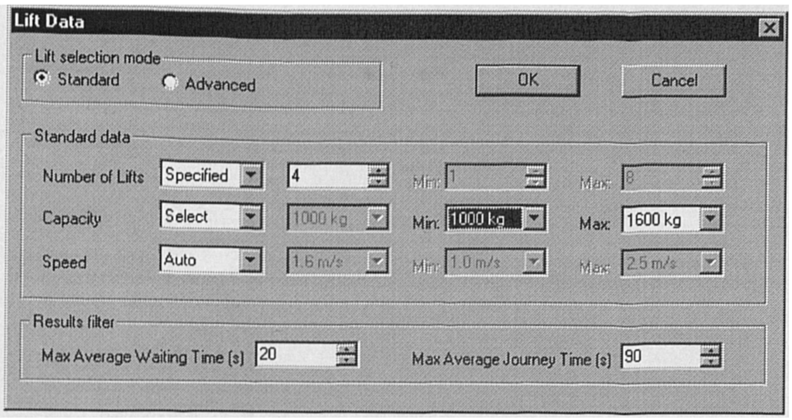
A1 Level 1

	Floor Name	Floor Level (m)
1	Level 1	0
2	Level 2	3.8
3	Level 3	7.6
4	Level 4	11.4
5	Level 5	15.2
6	Level 6	19
7	Level 7	22.8
8	Level 8	26.6
9	Level 9	30.4
10	Level 10	34.2

LiftSim is designed to allow spreadsheet-like data entry. Click on the table, and then press F1 for some time saving tips.

Figure 8.2 Building data dialogue box

ii. *lift data* in which the user enters details about the lifts; ranging from the number of lifts, the capacity, speed, etc. to the drive details and roping ratio, etc. The dialogue box has two modes, standard and advanced. In the standard mode, the program takes default values for all but the most basic inputs. The standard mode allows the user to cycle through a range of lift configurations with different numbers of lifts, capacities and speeds; this can be useful when searching for a solution to suit a particular traffic flow.



Lift selection mode: ● Standard ○ Advanced

Standard data

Number of Lifts: Specified 4 Min: 1 Max: 8

Capacity: Select 1000 kg Min: 1000 kg Max: 1600 kg

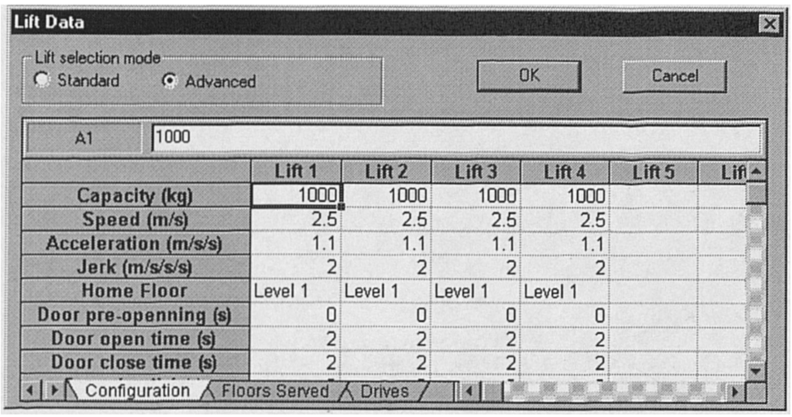
Speed: Auto 1.6 m/s Min: 1.0 m/s Max: 2.5 m/s

Results filter

Max Average Waiting Time (s): 20

Max Average Journey Time (s): 90

Figure 8.3 Lift data dialogue box, standard mode



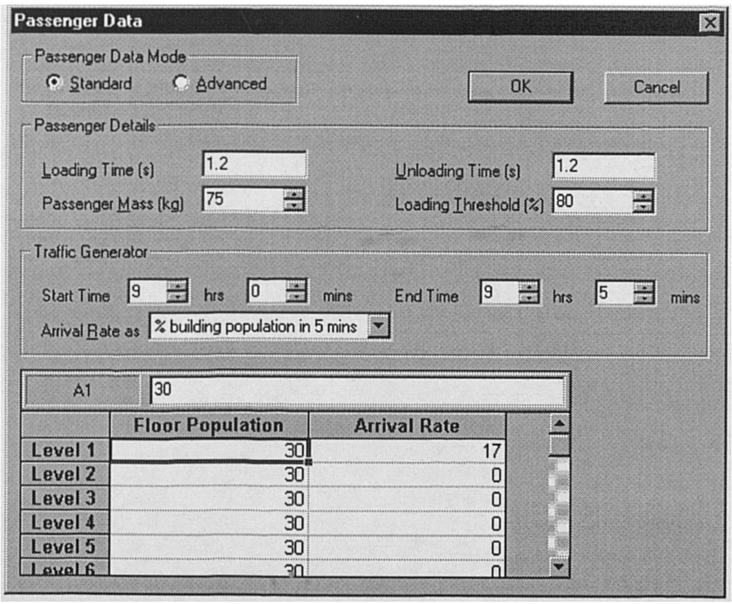
Lift selection mode: ○ Standard ● Advanced

A1: 1000

	Lift 1	Lift 2	Lift 3	Lift 4	Lift 5	Lif
Capacity (kg)	1000	1000	1000	1000		
Speed (m/s)	2.5	2.5	2.5	2.5		
Acceleration (m/s/s)	1.1	1.1	1.1	1.1		
Jerk (m/s/s/s)	2	2	2	2		
Home Floor	Level 1	Level 1	Level 1	Level 1		
Door pre-openning (s)	0	0	0	0		
Door open time (s)	2	2	2	2		
Door close time (s)	2	2	2	2		

Figure 8.4 Lifts data dialogue box, advanced mode

iii. *passenger data* in which the user enters details of the estimate traffic flow in terms of arrival rates, etc. Again, there are standard and advanced modes.



Passenger Data Mode: ● Standard ○ Advanced

Passenger Details

Loading Time (s): 1.2

Unloading Time (s): 1.2

Passenger Mass (kg): 75

Loading Threshold (%): 80

Traffic Generator

Start Time: 9 hrs 0 mins

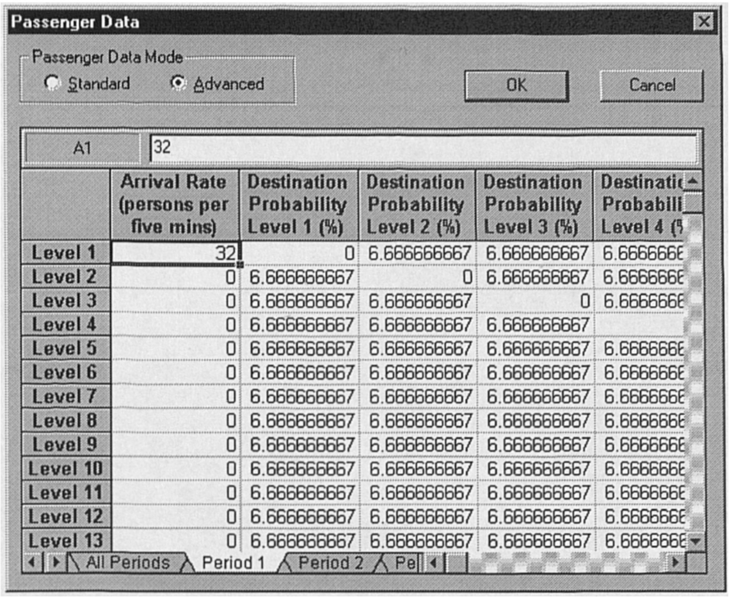
End Time: 9 hrs 5 mins

Arrival Rate as: % building population in 5 mins

A1: 30

	Floor Population	Arrival Rate
Level 1	30	17
Level 2	30	0
Level 3	30	0
Level 4	30	0
Level 5	30	0
Level 6	30	0

Figure 8.5 Passenger data dialogue box, standard mode

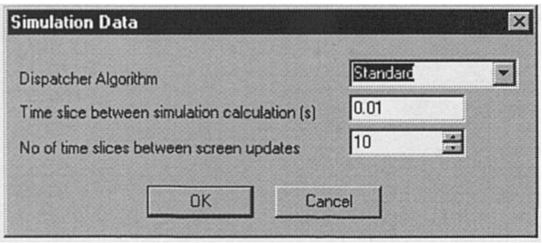


A1 32

	Arrival Rate (persons per five mins)	Destination Probability Level 1 (%)	Destination Probability Level 2 (%)	Destination Probability Level 3 (%)	Destinati Probabili Level 4 (
Level 1	32	0	6.666666667	6.666666667	6.6666666
Level 2	0	6.666666667	0	6.666666667	6.6666666
Level 3	0	6.666666667	6.666666667	0	6.6666666
Level 4	0	6.666666667	6.666666667	6.666666667	
Level 5	0	6.666666667	6.666666667	6.666666667	6.6666666
Level 6	0	6.666666667	6.666666667	6.666666667	6.6666666
Level 7	0	6.666666667	6.666666667	6.666666667	6.6666666
Level 8	0	6.666666667	6.666666667	6.666666667	6.6666666
Level 9	0	6.666666667	6.666666667	6.666666667	6.6666666
Level 10	0	6.666666667	6.666666667	6.666666667	6.6666666
Level 11	0	6.666666667	6.666666667	6.666666667	6.6666666
Level 12	0	6.666666667	6.666666667	6.666666667	6.6666666
Level 13	0	6.666666667	6.666666667	6.666666667	6.6666666

Figure 8.6 Passenger data dialogue box, advanced mode

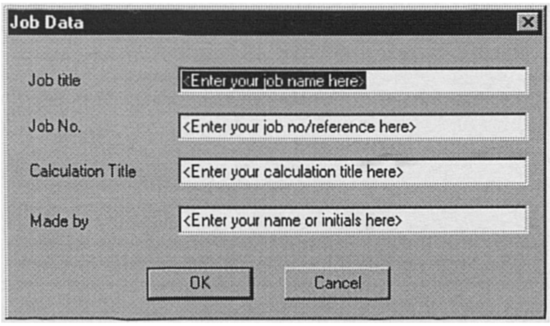
iv. *simulation data* in which the user can select the control algorithm, time slice, and frequency of the graphical display being updated.



Dispatcher Algorithm: Standard
Time slice between simulation calculation (s): 0.01
No of time slices between screen updates: 10

Figure 8.7 Simulation data dialogue box

v. *job data* in which the user can enter job titles, etc.

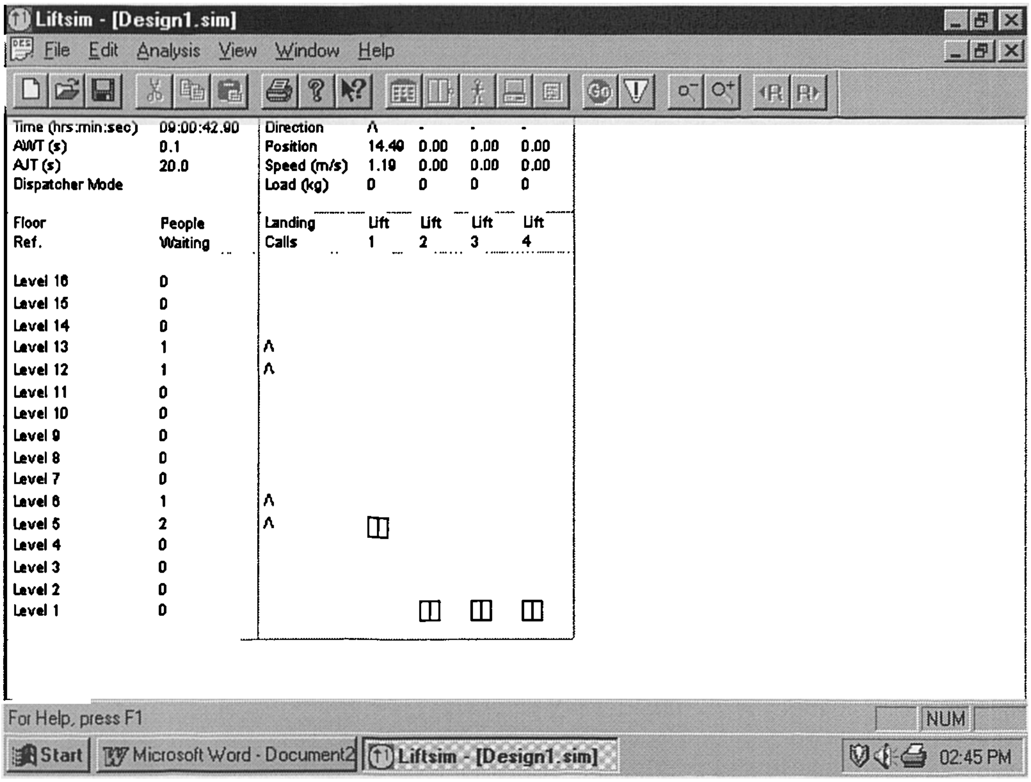


Job title: <Enter your job name here>
Job No.: <Enter your job no/reference here>
Calculation Title: <Enter your calculation title here>
Made by: <Enter your name or initials here>

Figure 8.8 Job data dialogue box

The main area of the screen is used for the simulation display (Figure 8.9), and for a print preview of the data and results once the simulation is complete. The user can zoom in/out of these displays using the zoom buttons.

Further menu items and buttons are provided for stopping and starting the simulation; and for cycling through the results of a simulation which has looked at a range of lift configurations.



```
Time (hrs:min:sec)  09:00:42.90   Direction      Λ      -      -      -
AWT (s)             0.1           Position       14.49  0.00   0.00   0.00
AJT (s)             20.0          Speed (m/s)    1.19   0.00   0.00   0.00
Dispatcher Mode                   Load (kg)      0      0      0      0

Floor               People        Landing        Lift   Lift   Lift   Lift
Ref.                Waiting       Calls          1      2      3      4

Level 16            0
Level 15            0
Level 14            0
Level 13            1             Λ
Level 12            1             Λ
Level 11            0
Level 10            0
Level 9             0
Level 8             0
Level 7             0
Level 6             1             Λ
Level 5             2             Λ              ◫
Level 4             0
Level 3             0
Level 2             0
Level 1             0                                   ◫      ◫      ◫
```

Figure 8.9 Simulation display

8.5 OPERATION OF SIMULATION

The program is a time slice simulation; it calculates the status (position, speed, etc.) of the lifts, increments the time, re-calculates status, increments time, and so on. As Windows is a multitasking operating system, the program cannot take full control of the computer's resources and run in a continuous loop. It must wait for a processing "thread" to become available, run one cycle of the simulation, then wait for the next thread to become available. Provided that there are not too many other demands on the computer's processor, the simulation will run faster than real time on a Pentium PC using a time slice of 0.01 seconds. A flow diagram of a single cycle of the simulation is given in Figure 8.10

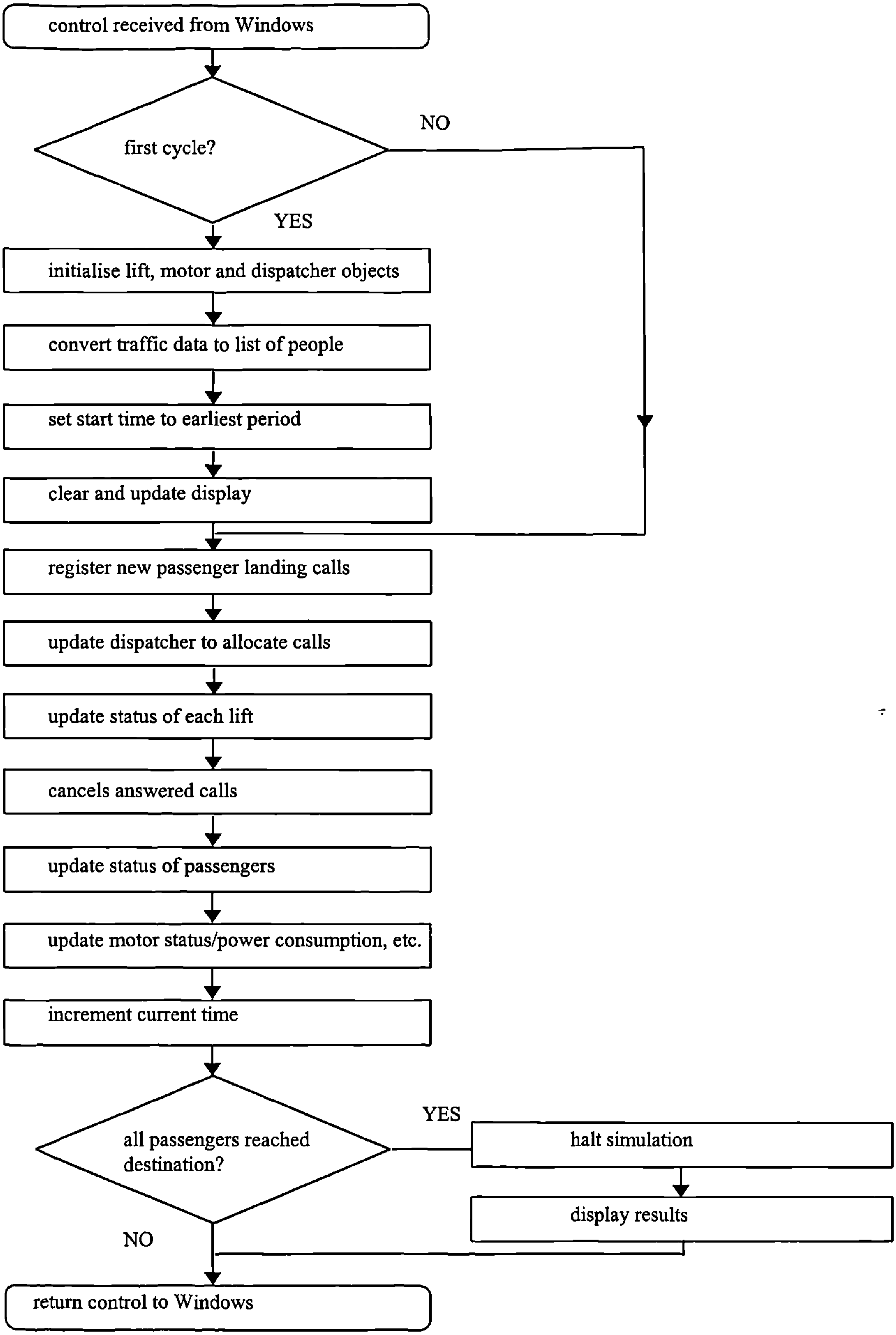


Figure 8.10 Simulation flow chart, one cycle

8.6 RESULTS

Once the simulation is complete, the results print preview includes:

- the input data
- results for average waiting time, longest waiting time, and a plot of the waiting time distribution
- results for average transit time, longest transit time, and a plot of transit time distribution
- the total power consumption for each lift, and total number of motor starts

A Comma Separated Variable (CSV) file with the input data and results is also generated. This can be imported into a spreadsheet so that the user can present the information in his/her own format. For further spreadsheet analysis, this CSV file also includes a table containing details of every passenger generated by Liftsim: what time they arrived, at which floor, what was their destination, what were their waiting and transit times, etc.

8.7 TESTING

The testing program for Liftsim has included:

- where practical, individual classes run in test programs before being added into Liftsim, e.g. a simple plotting routine was used to test the motion class.
- reviewing the graphical display of the lifts in operation; this identified most errors and omissions in the original program code.
- Mathcad was used to model individual journeys, confirming that the waiting and transit time, and energy consumption results were being calculated correctly.

A separate testing program was undertaken by others in Arup Research & Development; this confirmed Liftsim's waiting and transit time calculations for journeys for multiple passengers and trips. It also identified some minor interface bugs.

8.8 DISCUSSION

Liftsim has been written as a development platform for "green" lift control systems. The program implements the kinematics and motor model research discussed in previous chapters.

The passenger generator creates passengers in software based on arrival rate and destination probability data entered by the user. The program performs a time slice simulation, providing a graphical representation of the lifts as they serve the passengers' calls.

Liftsim is written in Microsoft Visual C++. It uses object oriented techniques, breaking down the programming tasks into classes. These classes represent objects (e.g. lift, person, building) which are straight forward to conceptualise, and therefore easier to work with. The interface is Windows based. The user enters data into dialog boxes: *building data*, *lift data*, *passenger data*, *simulation data* and *job data.*

Once the simulation is complete, *Liftsim* displays results on screen in a print preview format. These results include details of input data, waiting times, transit times, and power consumption.

The built in control system is based on conventional group control with dynamic sectoring. In Chapter 9 we discuss the application of green control strategies to this system, and make comparisons in terms of performance and energy consumption.

The program also has applications as an advanced traffic analysis tool, and is being tested on some current Arup jobs.

It is envisaged that there will be further enhancements to *Liftsim* including the development of:

- (i) a fuller range of control systems
- (ii) additional motor models
- (iii) double deck lift version

An abstract for a paper discussing *Liftsim* has been submitted to the International Elevator Technology Conference, ELEVCON '98.

REFERENCES

8.1 Schroder R *Elevator Traffic Simulation: The Perfect Analytical Tool* Elevator World (April 1991)

8.2 Hamdi M, Mulvaney D *Visual Interactive Lift Simulator* Elevator Technology 7, Proceedings of ELEVCON '96 (The International Association of Elevator Engineers)(1992)

8.3 Jenkins K *Elevator Simulation Techniques* Elevator Technology 4, Proceedings of ELEVCON '92 (The International Association of Elevator Engineers)(1992)

8.4 Perry G, Ross J *Visual C++ By Example* (Indianapolis: Que Publishing) (1994)

8.5 Barney G C, dos Santos S M *Elevator Traffic Analysis Design and Control* (London: Peter Peregrinus) 2nd edition (1985)

8.6 National Elevator Industry Inc., *7th Edition Vertical Transportation Standards,* 1994 Supplement.

Chapter 9

GREEN LIFT CONTROL STRATEGIES

9.1 INTRODUCTION

Barney and dos Santos(9.1) define a group supervisory control system as *a control mechanism to command a group of interconnected lift cars with the aim of improving lift system performance.* Conventionally this system performance has concerned maximising the handling capacity of the lift system, and minimising passenger waiting and transit times. So(9.2) provides a review of the increasing advanced control strategies applied by designers in order to realise improved performance in these terms.

It would be counterproductive to ignore conventional system performance criteria as excessive waiting for lifts is very frustrating for passengers. So let us define a green lift control system as a *group control system that considers conventional measures of system performance, as well as means to reduce energy consumption.*

In this chapter we shall consider three strategies that would be appropriate to a green lift control system. The strategies have been implemented and tested using *Liftsim.*

9.2 GREEN STRATEGY NO.1 - CONTROL OF KINEMATICS

Conventionally lifts have the same maximum velocity, acceleration and jerk (rate of change of acceleration) for every trip. If the system does allow any variation, this is generally pre-set by the lift service engineer or building owner.

The ideal lift kinematics research discussed in Chapter 6 of this thesis has allowed us to generate, quickly and easily, motion profiles for any input of journey distance, velocity, acceleration and jerk. This allows us to consider control systems that vary all these parameters on line in lift system controllers.

One reason for varying the lift kinematics could be for energy saving purposes. Indeed simulation results suggest that significant savings can be achieved without a significant overall reduction in performance from the passenger's prospective. To understand how these savings can be realised, consider:

When a lift leaves the ground floor full of passengers, it is motoring, requiring predominantly positive torque in a positive direction. As passengers are dropped off up the building, the counterweight becomes heavier than the lift, so the motor is providing predominantly negative torque in a positive direction. Similarly for a journey down the building, a negative direction, the motor can be required to deliver both positive and negative torque. Thus the lift motor is said to operate in "four quadrants", as represented graphically in Figure 9.1.

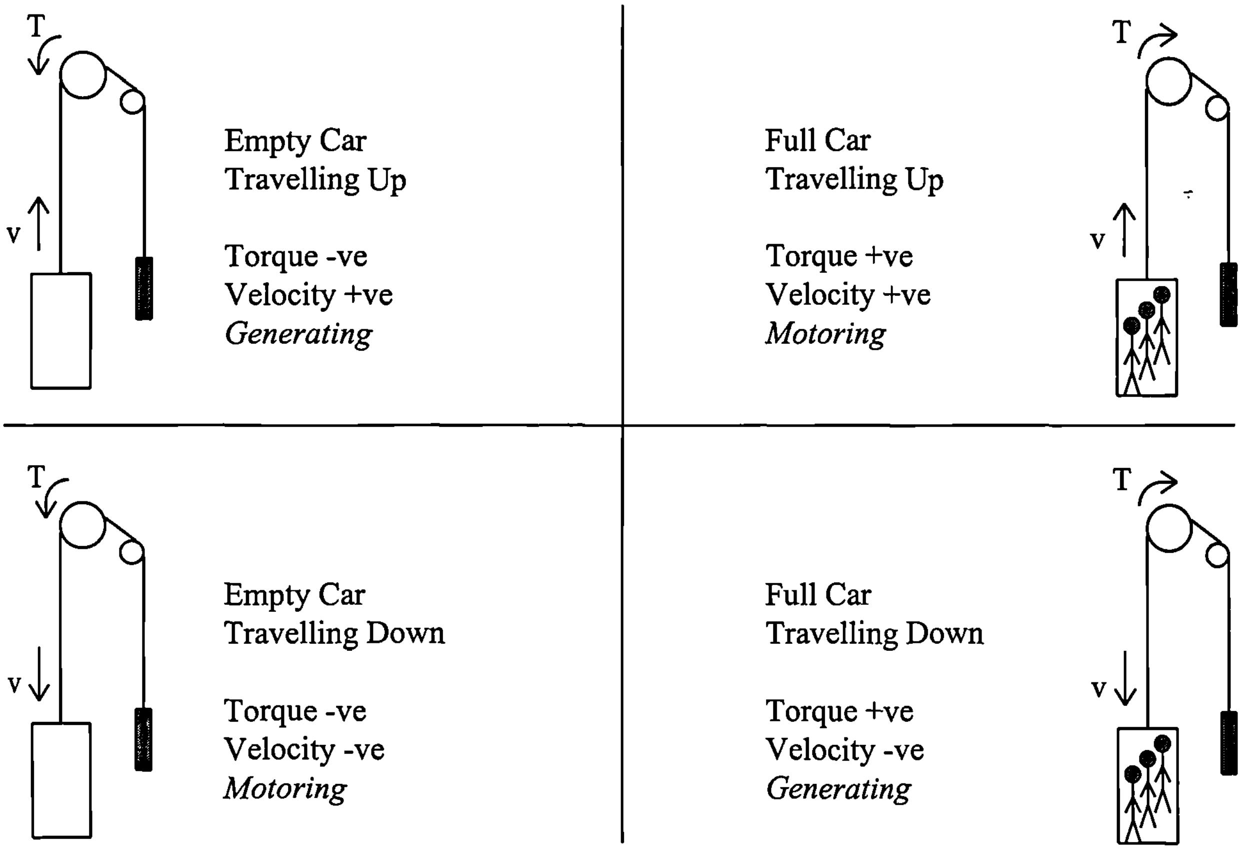


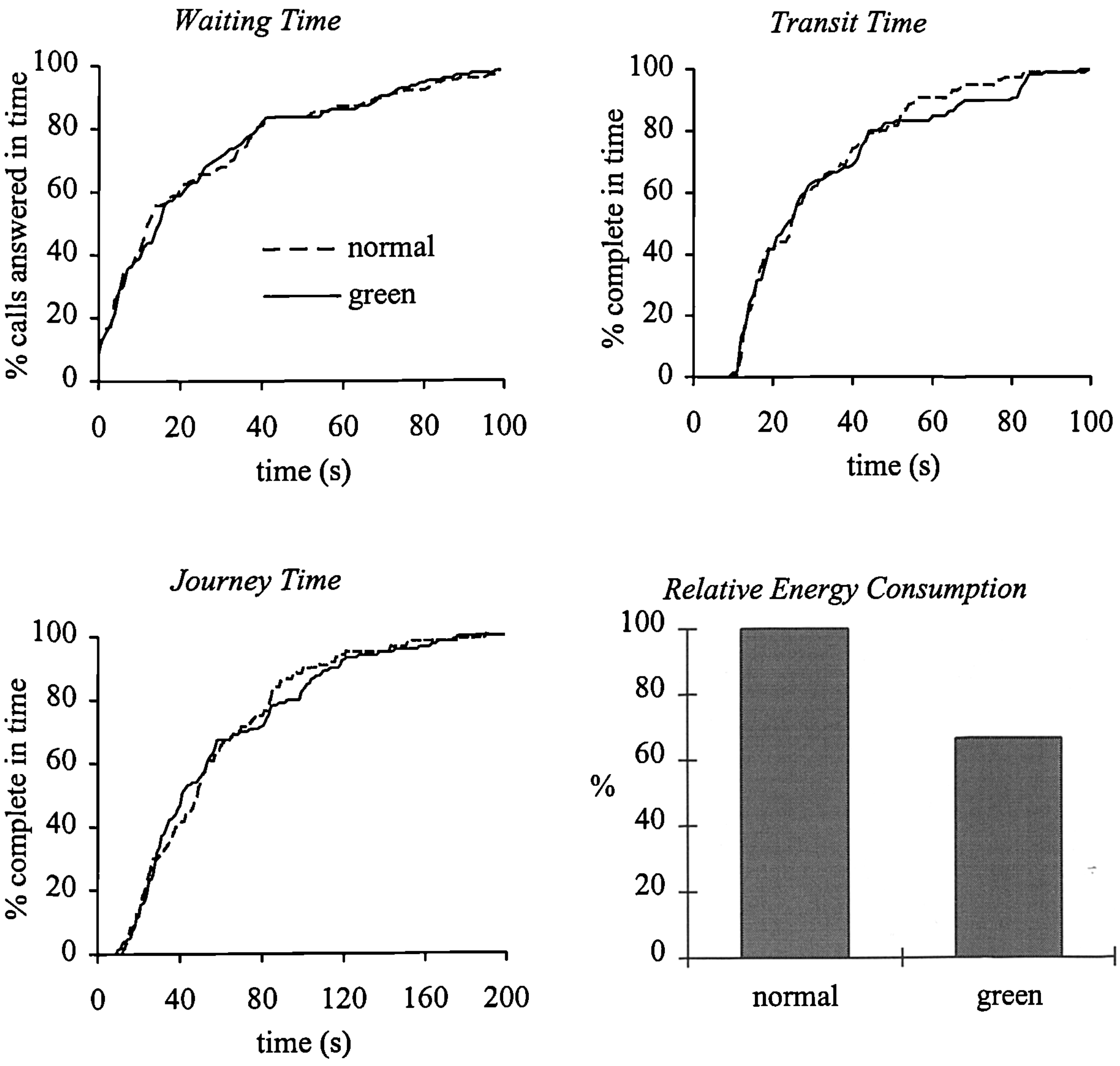
Figure 9.1 Four quadrant operation of lift drive

(This well known example of how a lift operates in four quadrants is not the whole story as the required motor torque is a function of not just the static load, but also of the angular acceleration and inertia of the system. Equations for calculating how the load torque varies over a lift trip are given in Chapter 7 of this thesis.)

In general terms, reducing the performance of the lift when it is "motoring", and increasing it when it is "generating" can provide an energy saving in both instances, without a significant overall effect on passenger waiting and transit times.

An algorithm has been developed that tests a range of velocity and acceleration options (ranging ± 20% from rated velocity and acceleration) before the start of each trip. The algorithm then chooses the most energy efficient option. Figure 9.2 summarises the results of tests for a 10 storey building with 4 lifts. An inter-floor passenger traffic profile has been used.

In this instance a 33.4% saving in energy consumption has been achieved. The average journey time has increased by just 1.3 seconds.


Waiting Time

Transit Time

Journey Time

Relative Energy Consumption

Figure 9.2 Simulation results for Green Strategy No.1 - Control of Kinematics

9.3 GREEN STRATEGY NO.2 - REDUCING THE NUMBER OF STOPS

Figure 9.3 demonstrates the energy consumed by a lift over a single trip (motoring), as presented in Chapter 7 of this thesis. The energy consumption peaks during the acceleration phase, and is relatively low once the lift reaches full speed. There is regeneration during the deceleration phase, but this is less in total than the energy expended during the acceleration phase. Thus it is reasonable to assume that there will be energy savings if we can transport the same number of passengers, with less stops, but without an increase in the overall distance travelled by the lifts.

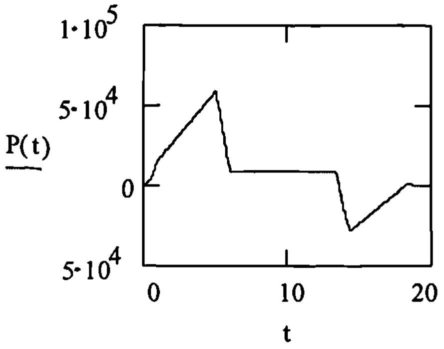


Figure 9.3 Energy consumed by a lift over a single trip (motoring)

One way to achieve this is by forcing the dispatcher to allocate a landing call to a lift when it is:

- already due to stop at that floor for a passenger's car call, and
- travelling in the right direction to serve the landing call.

This condition for a "forced" allocation may not occur for some time, e.g. it is unlikely during solely up peak traffic, or during light inter-floor traffic. But most lift systems are likely to benefit from the strategy at some time during their daily cycle.

Figure 9.4 records the results of a simulation of a 14 storey building with 6 lifts. The traffic profile is based on the beginning a the lunch period in an office building - down peak traffic to the ground floor, plus inter-floor traffic.

In this case, the "green" algorithm implementing the discussed strategy causes a 3.2% reduction in the number of motor starts, leading to a 6.2% reduction in the energy consumption. The waiting time distribution remains very similar, but there is a minor improvement in transit times. The improvement in transit time performance is explicable as the strategy will result in some passengers experiencing less intermediate stops during their journey.

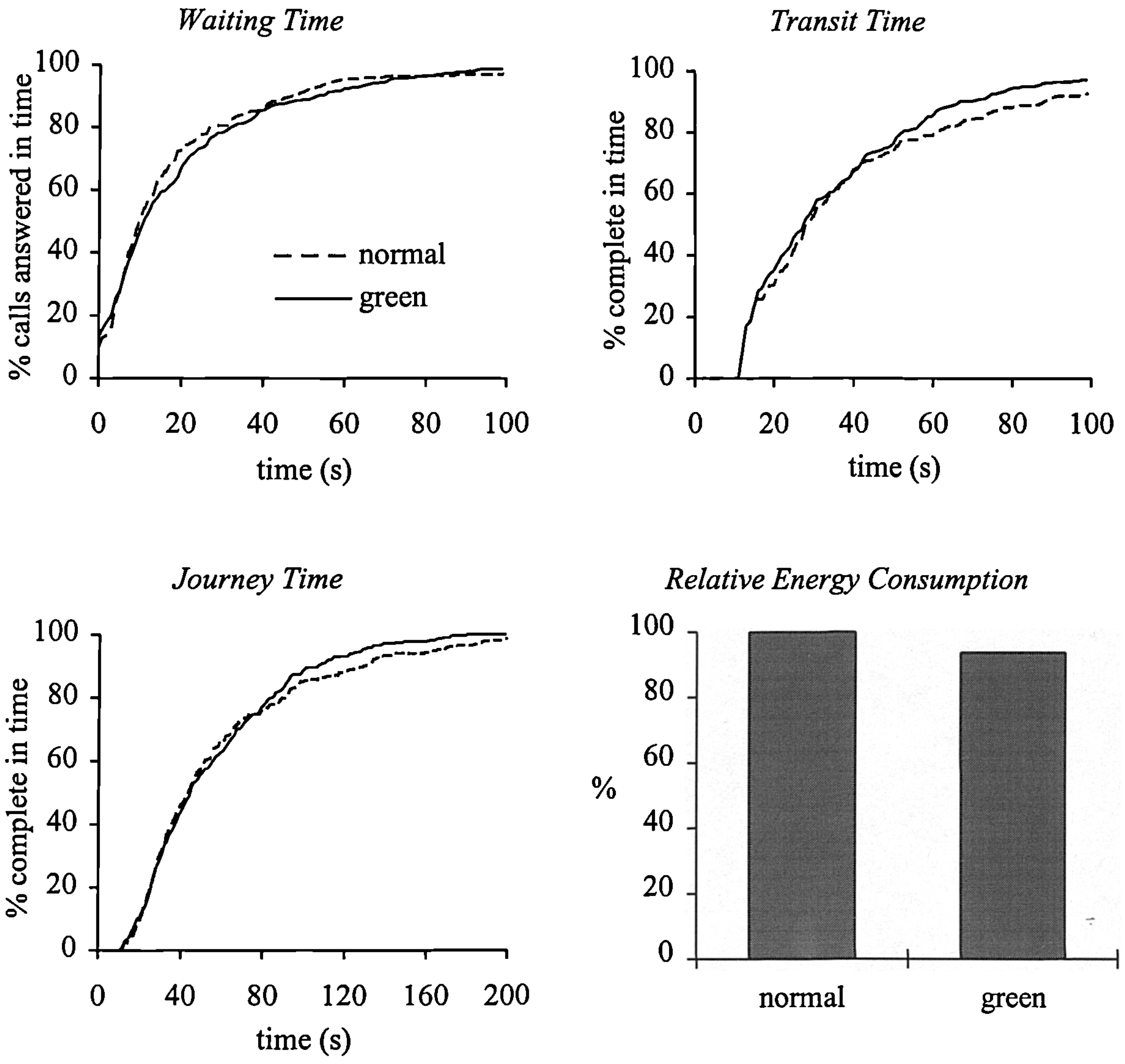


Figure 9.4 Simulation results for Green Strategy No.2 - Reducing the Number of Stops

Reducing the number of stops is not a new goal for lift control systems. This is because reducing the number of stops reduces the round trip time, increasing the passenger handling capacity of the lift system, and sometimes the lift performance. Other systems that reduce the number of stops include:

- fixed zone systems where lifts are divided into groups to serve groups of floors, e.g. 4 lifts serving ground and levels 1 to 10, 4 lifts serving ground and levels 11 to 20.

- dynamic zoning systems, where the dispatcher indicates to the waiting passengers which floors a lift will be serving every round trip, e.g. Channelling as presented by Powell(9.3).
- call allocation systems, as described by Barney and dos Santos(9.1), where passengers are required to register their destination (as opposed to direction of travel) at the landing.

While these systems do result in less stops, they do not necessarily result in an energy saving as:

- the overall distance travelled by the lifts is sometimes greater.
- the number, speed, capacity, etc. of the lifts will differ from a corresponding conventional, single zone design.

To assign credit for energy saving based on these methods, a designer would need to carry out a direct comparison of alternative schemes for the project in question.

9.4 GREEN STRATEGY NO.3 - SELECTIVE PARKING POLICIES

When a lift has answered all its calls and becomes free, it can be "parked" at the floor it last answered a call, or sent to another floor in anticipation of future calls. Barney & dos Santos(9.1) describe how re-positioning a free car to a particular floor as part of a parking strategy can improve the overall performance of a lift system.

For instance, consider the morning up peak in an office building where the main passenger traffic flow is from the ground floor to upper floors. In this scenario, the dispatcher can improve system performance by returning free cars to the ground floor, and parking them with their doors closed. When a preceding lift departs from the ground floor, and another is needed, a free lift is available immediately rather than having first to be brought to the ground floor.

Similarly during off-peak traffic, answering a series of calls may leave free lifts poorly positioned to answer future calls. Consequently, lift control systems sometimes apply parking policies to improve performance in these scenarios as well.

From the energy saving viewpoint, we should apply parking policies selectively. Figure 9.5 summarises the results of the simulation of a fifteen storey building with very light inter-floor traffic. The simulation has been run with and without a parking policy that implements a parking strategy.

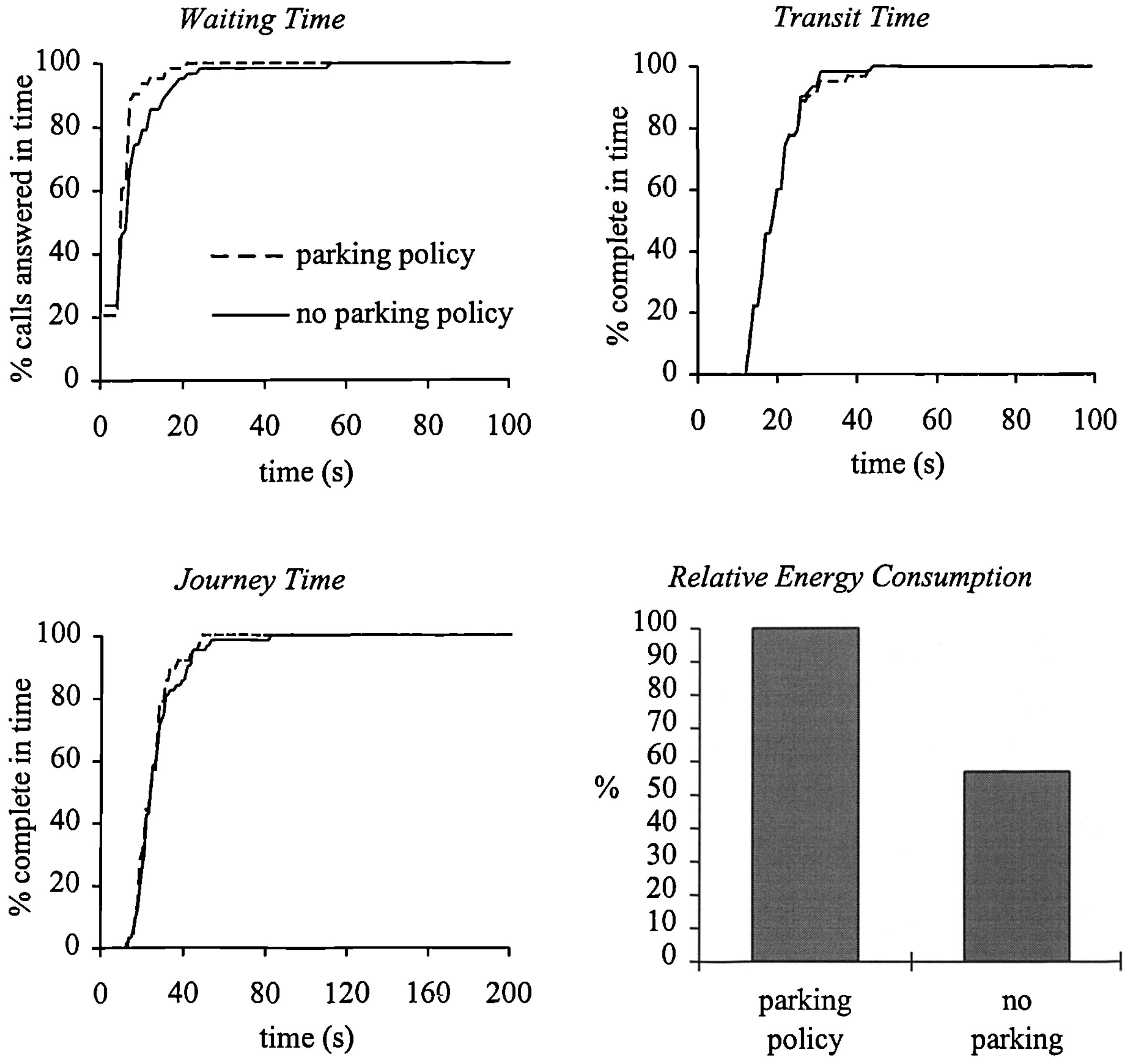


Figure 9.5 Simulation results for Green Strategy No.3 - Selective Parking Policies

The results demonstrate that the parking policy improves performance. The question is whether the improvement in performance justifies that additional energy consumed; in this instance, probably not. Other scenarios will be less clear cut.

Green control systems should place parking calls selectively. This could be achieved by the dispatcher reviewing the potential contribution to system performance of parking calls before deciding whether or not they should be made.

9.5 DISCUSSION

Applying the kinematics, motor modelling and simulation tools discussed in previous chapters, we have developed and tested three green lift control strategies:

(i) *Control of kinematics* where different values of maximum acceleration and velocity are chosen for each trip to minimise the energy consumption.

(ii) *Reducing the number of stops* where dispatcher allocations are chosen in order to reduce the total number of stops made by the lifts.

(iii) *Selective parking policies* which shows that parking policies can be applied inappropriately, yielding a marginal improvement in performance in return for a significant increase in energy consumption.

Simulation has demonstrated that each of these strategies will allow green control systems to reduce energy consumption without a significant deterioration in passenger waiting and journey times. The magnitude of energy savings is a function of the installation and traffic flow, so cannot be declared absolutely. However, simulation suggests that we can achieve an energy saving in excess of 30%.

These results are for a DC static converter drive. It is reasonable to assume that there would be similar savings in applying these strategies with other regenerative drives. The development of additional drive models, as suggested in Chapter 7, would enable us to confirm this assumption.

There is considerable scope for further development and testing of green lift control strategies using *Liftsim*. The performance of existing strategies needs to be tested across a wider range of installations and traffic flows. Other strategies are likely to arise as the simulation is applied and experimented with. It is envisaged that the research will ultimately lead to green lift control systems being implemented by control systems manufacturers.

A paper discussing this research in green lift control strategies has been accepted for publication by the International Journal of Elevator Engineers.

REFERENCES

9.1 Barney G C, Dos Santos S M *Elevator Traffic Analysis Design and Control* (London: Peter Peregrinus) 2nd edition (1985)

9.2 So A T P, Liu S K *An Overall Review of Advances Elevator Technologies* Elevator World (June 1996)

9.3 Powell B A *Important Issues in Up Peak Traffic Handling* Elevator Technology 4, Proceedings of ELEVCON'92 (The International Association of Elevator Engineers)(1992)

Chapter 10

CONCLUSIONS AND FURTHER WORK

10.1 GREEN LIFTS

This project aims to contribute to a reduction in the environmental burdens of vertical transportation systems.

The most widely used vertical transportation system is the lift or elevator, which has been the focus of most of the research. A "green lift" can be defined as *a lift system that delivers good passenger service at an acceptable cost while incurring minimum environmental impact.*

To determine the environmental impact of a lift system, Life Cycle Analysis has been applied. This shows that energy consumption is by far the most important factor. Thus this project has focused on ways of reducing the energy consumption of lift systems. Further environmental analysis would be of academic interest only. We should apply sensible practices in the choice of lift materials, transportation, etc., but these are secondary issues, and should be regarded as such. Further work in this area should be focused on communicating these findings.

The lift system will not normally be the largest energy user in a building. Other systems have higher loads and can offer greater energy savings. Nevertheless, there is correspondingly more research in environmental friendly HVAC, lighting, etc. systems. Energy saving lifts should not be disregarded as the potential savings are still worthwhile.

A number of basic principles for green lifts have been identified. The choice of drive, position of stairs, etc. all have a major effect on the energy consumption of the vertical transportation system. As a starting point, these choices should be made with energy saving in mind. We can then go on to consider more advanced strategies.

10.2 PLANNING ISSUES

10.2.1 The need for good planning

Lift designers need to have a good understanding of passenger traffic demand, and analysis techniques to assess the performance of possible lift configurations. If both of these are not in place, then there is a high probability that installed systems will be either inadequate or over-designed. The first alternative is unacceptable to passengers. The second is unnecessarily expensive, and will consume more energy.

10.2.2 Assessing traffic demand

Designers normally assume that the up-peak is the busiest period in commercial buildings. Calculations used to select the number, size, speed, etc. of lifts required are based on this assumption.

Surveys undertaken for this research project suggest that this assumption is outdated, and need to be revised. The up-peak seen in commercial buildings is less marked than when current design criteria were formulated. The lunch time peak is now the busiest period.

Further surveys need to be carried out to confirm these results. However, they are consistent across the office buildings surveyed by the author, and with anecdotal evidence from designers to whom this work has been presented.

In carrying out further surveys, researchers should use automated people counting techniques as it is very time consuming to collect large amounts of data manually. A range of surveying techniques has been reviewed. Currently the author favours an infra-red beam system as the best available technology, although further research in passenger counting techniques would be beneficial. The author continues to collect data, and has been encouraging others to publish their results so that improved design criteria can be established.

10.2.3 Traffic calculations

Traffic analysis techniques based on Round Trip Time calculations have been developed and extended. Round Trip Time calculations are good planning tools as they give consistent results, and are not dependant on any one control system. They are likely to be our primarily design tools for some years to come.

The author of this research project has made two contributions to the up-peak analysis calculation. Firstly, to derive formulae to determine flight time for any travel distance and lift dynamics. This extends the standard method, which uses tabulated results.

Secondly, the author has implemented in formulae, "corrections" that were recommended for lifts not reaching full speed in a single floor jump, and for non-equal inter-floor heights. A sensitivity analysis on these corrections has demonstrated that the variations between original and corrected results are relatively small (less than 2%). It can be argued that this variation is too small to warrant changes to the standard up peak calculation procedure. In itself, this is an interesting and useful result.

The up-peak calculation has been implemented in a computer program which, it is intended, will be issued with the revised version of CIBSE Guide D, *Transportation systems in buildings*.

As we believe the lunch period is the most onerous time for the lifts, it is important to be able to assess this period with traffic calculations. We can do this using the General Analysis calculation technique, which the author derived prior to joining the EngD programme. The General Analysis assesses a lift system's performance given any peak passenger demand.

This General Analysis is a relatively complex technique to implement and to apply. Therefore further research to determine the equivalent lunch time handling capacity relative to a given up-peak handling capacity would be beneficial. This would allow designers to assess lunch time performance while retaining well known and understood up-peak analysis techniques.

10.2.4 Environmental benefits

The results of traffic surveys have been tested on Arup designs. Analysing the up-peak and lunch peak, it is apparent that revising our design criteria is unlikely to result in fewer lifts, but would reduce car sizes, say from 1250 kg to 1000 kg. And therefore lead to energy savings.

10.3 TRAFFIC ANALYSIS FOR DOUBLE DECK LIFTS

Double deck lifts provide greater handling capacity per shaft than conventional lifts. This is particularly attractive for high rise buildings, where the core space taken by the lifts is a high percentage of the total floor area.

Formulae have been derived and implemented that allow analysis of any peak traffic flow for any practical configuration of double deck lifts. Previously only up-peak formulae had been known. The approach taken for double deck lifts could be extended to cover triple and quadruple deck lifts if required.

This section of research has arisen primarily from commercial pressures to analyse the performance of lift systems in high rise buildings. A study of the relative energy consumption of double versus single deck lifts for a range of lift installations would be useful further work.

10.4 MATHEMATICAL MODELS OF LIFT MOTION AND DRIVES

10.4.1 The need for mathematical models

In order to develop strategies for energy saving, we need models to experiment and test our ideas. Mathematical models allow us to test a wider range of systems than it would be practical or affordable to build in real life. The motion and drive models developed for this project were implemented in the simulation program, *Liftsim*. This was used to develop energy saving control strategies.

10.4.2 Ideal lift kinematics

The equations derived allow continuous, optimum functions of jerk, acceleration, speed and distance travelled profiles to be plotted against time. These profiles can be generated for any journey distance given inputs for maximum jerk, acceleration, and speed. Previously the shapes of these curves where known, but only certain points could be plotted.

The ability to plot profiles for any inputs gives additional flexibility in the design of lift controllers. This functionality has been applied in the design of green control strategies.

The equations are complex, but have been implemented in software by the author. The users of this software do not need to work through the calculations taking place, but can concentrate on entering the required inputs to generate the profiles quickly and easily.

The flight time formulae discussed with reference to traffic calculations are a result from this section of the research.

Although there is some guidance on the choice of maximum jerk and acceleration for a lift installation, there have been no major studies on the relative levels of comfort experienced by passengers given different values of these variables. Applying the research lift kinematics, it would be feasible to carry out such an investigation. This would yield useful results for specification and design.

10.4.3 Motor model

A motor model developed by So for a DC static converter drive has been implemented and extended. The model now uses, as an input, the motion profiles generated from the kinematics research. Equations for load torque and load inertia have been developed as So uses fixed values.

We can now model the operation and power consumption of a lift trip for any journey, direction and loading. This motor model is included in the lift simulation program, *Liftsim*, which was used to develop and test green lift control strategies.

Results from the model are consistent with those presented by So. Initial site tests have suggested that the model is generating consistent power consumption profiles, and can at least not be rejected.

Further research into the modelling of this and other lift drives would be valuable. More comprehensive site tests would need the full co-operation of the lift manufacturer, installer and building owner. Some of the variables required are difficult to measure, and so cannot be established without full access to manufacturer's design data.

Currently designers rely on empirical methods to estimate the power consumption of a lift installation. Building motor models into simulation programs such as *Liftsim* will improve our predictions of power consumption and allow us to demonstrate the value of energy saving features.

10.4.4 Environmental benefits

The motion and motor models developed allow us to test the energy consumption of individual lift trips. We have full control over the inputs to the system, so can consider any lift speed, size, loading, etc. This provides us with the basis for testing energy saving ideas.

10.5 LIFTSIM AND GREEN CONTROL STRATEGIES

10.5.1 Reasons for development

The lift simulation program, *Liftsim* has been written. The program implements the kinematics and motor model research, providing a development platform for "green" lift control systems.

10.5.2 Overview of program

Liftsim is written in Microsoft Visual C++. It uses object oriented techniques, breaking down the programming tasks into classes. These classes represent objects (e.g. lift, person, building) which are straight forward to conceptualise, and therefore easier to work with. The interface is Windows based. The user enters data into dialog boxes: *building data*, *lift data*, *passenger data*, *simulation data* and *job data.*

Liftsim's passenger generator creates passengers in software based on arrival rate and destination probability data entered by the user. The program performs a time slice simulation, providing a graphical representation of the lifts as they serve the passengers' calls.

The built in control system is based on conventional group control with dynamic sectoring. Additional control systems could be added, which would be worthwhile further work.

Once the simulation is complete, *Liftsim* displays results on screen in a print preview format. These results include details of input data, waiting times, transit times, and power consumption.

Three green lift control strategies have been developed and applied to the dynamic sectoring control algorithm:

(i) *Control of kinematics* where different values of maximum acceleration and velocity are chosen for each trip to minimise the energy consumption.

(ii) *Reducing the number of stops* where dispatcher allocations are chosen in order to reduce the total number of stops made by the lifts.

(iii) *Selective parking policies* which shows that parking policies can be applied inappropriately, yielding a marginal improvement in performance in return for a significant increase in energy consumption.

Simulation has demonstrated that each of these strategies will allow green control systems to reduce energy consumption without a significant deterioration in passenger waiting and journey times. The magnitude of energy savings is a function of the installation and traffic flow, so cannot be declared absolutely. However, simulation suggests that we can achieve an energy saving in excess of 30%.

These results are for a DC static converter drive. It is reasonable to assume that there would be similar savings in applying these strategies with other regenerative drives. The development of additional drive models would enable us to confirm this assumption.

There is considerable scope for further development and testing of green lift control strategies using *Liftsim*. The performance of existing strategies needs to be tested across a wider range of installations and traffic flows. Other strategies are likely to arise as the simulation is applied and experimented with. It is envisaged that the research will ultimately lead to green lift control systems being implemented by control systems manufacturers.

The program also has applications as an advanced traffic analysis tool, and is being tested on some current Arup jobs.

10.5.3 Environmental benefits

Liftsim is a power lift simulation program. It brings together the project research in traffic modelling, kinematics, and motor modelling. The program has been applied in the development of energy saving control strategies.

It has been shown that, by the application of green control strategies, we could achieve energy savings in excess of 30%.

10.6 CONTRIBUTION TO KNOWLEDGE

The project has yielded a “contribution to knowledge” through:

- environmental assessment of vertical transportation system
- improvements in lift system models
- development of green control strategies

The research has been widely published at conferences, in journal papers, and through the national and international vertical transportation trade press. A full list of publications is included in Appendix A of this thesis.

Appendix A

LIST OF PUBLICATIONS

A1 JOURNAL PAPERS

Peters R D, Mehta P, Haddon J *Lift Traffic Analysis: General formulae for double decker lifts* Building Services Engineering Research and Technology, Volume 17 No 4 (1996)

Peters R D *Ideal Lift Kinematics: Derivation of Formulae for the Equations of Motion of a Lift* International Journal of Elevator Engineers, Volume 1 No 1 (1996)

Peters R D *Lift Traffic Analysis: Formulae for the general case* Building Services Engineering Research and Technology, Volume 11 No 2 (1990) (republished by Elevator World, December 1990) *(published before joining EngD programme)*

A2 CONFERENCE PAPERS

Peters R D *Risk and the Vertical Transportation Industry* Elevator Technology 7, Proceedings of ELEVCON'96 (The International Association of Elevator Engineers) (1996)

Peters R D, Mehta P, Haddon J *Lift Passenger Traffic Patterns: Applications, Current Knowledge, and Measurement* Elevator Technology 7, Proceedings of ELEVCON'96 (The International Association of Elevator Engineers) (1996) (also presented at IAEE London Lift Seminar May 1997)

Peters R D *Mathematical Modelling of Lift Drive Motion and Energy Consumption* Proceedings of CIBSE National Conference 1995 (The Chartered Institution of Building Services Engineers) (1995) (republished by Elevator World, July 1996)

Peters R D *Ideal Lift Kinematics: Complete Equations for Plotting Optimum Motion* Elevator Technology 6, Proceedings of ELEVCON'95 (The International Association of Elevator Engineers) (1995) (republished by Elevator World, April 1996 and by Elevatori, May/June 1996)

Peters R D *General Analysis Double Decker Lift Calculations* Elevator Technology 6, Proceedings of ELEVCON'95 (The International Association of Elevator Engineers) (1995) (republished by Elevator World, December 1996 and by Elevatori, May/June 1997)

Peters R D *Green Lifts?* Proceedings of CIBSE National Conference 1994 (The Chartered Institution of Building Services Engineers) (1994) (republished by Elevator World, June 1995 and by Elevation, Autumn 1995)

Peters R D *The Theory and Practice of General Analysis Lift Calculations* Elevator Technology 4, Proceedings of ELEVCON'92 (The International Association of Elevator Engineers) (1992) *(published before joining EngD programme)*

Appendix B

PROGRESS REPORTS

Progress reports written during of the course of the project are included in this Appendix. The reports are unedited, except for re-numbering and minor language corrections. The original report appendices are omitted for brevity.

B1 PROGRESS REPORT MAY 1994

B1.1 Introduction

This report summarises the project work I have carried out over the first six months of the Engineering Doctorate programme. The project progress was discussed with my Academic and Industrial Supervisors, Dr Pratap Mehta and John Haddon at a meeting on the 11th March 1994. A copy of the documents issued at the meeting are included in Appendix B of this report and are referred to in this text.

B1.2 Project objectives

The following project objectives were given in the original project proposal and are included for context:

Preamble

Buildings account for about a third of all the energy we consume. Lifts make up a significant proportion (5 to 10%) of the electrical load in large developments and there are potential energy savings and cost savings to be made by good planning design, control strategies and the use of high efficiency motors.

The research outlined below will provide the basis for design and specification of vertical transportation systems which are both energy efficient and provide passengers with a good service by defined standards.

Project recommendations are expected to influence lift design and specification on a national and international basis through the work of the Ove Arup Partnership, and through publications in technical journals and design guides.

Objectives

i. Measure vertical passenger traffic and lift/escalator energy consumption so as to build up pedestrian circulation and corresponding energy models for offices, residential buildings, airports, leisure complexes, etc.

ii. Compare use and performance of lifts/escalators/stairs to existing lift traffic analysis models and assumptions. Compare performance of driving motors to electrical models.

iii. Develop computer programs implementing verified analysis/simulation traffic analysis models and corresponding energy models.

iv. Use verified models to calculate: the benefits of developing and implementing energy efficient lift control algorithms, the savings achievable through the use of high efficiency motors, and the benefits of energy conscious planning strategies.

v. Establish guidelines for predicting traffic in new and refurbished buildings. Make planning and specification recommendations that reflect the need to design energy efficient buildings.

B1.3 Breakdown of time spent

In a typical week I spend two days in Arup offices, two days at Brunel University and a day working at home or on site. I log the use of my time, which has, in summary been divided as follows:

32% Pure research - literature search, background reading, developing theories, writing computer programs and drafting papers specifically for the research project

21% Arup job related - Working on Arup projects related to the research

16% EngD course work - time spend attending courses and completing course work

14% LIFT program - implementing new theories and ongoing development of Arup

LIFT program which is used on Arup lift projects

10% Electrical Computing - as Chairman of the Arup Electrical Computing Working party I spend part of my time monitoring and managing Electrical Computing Development in Arup.

8% Holiday/illness

B1.4 Project research topics

Ideal lift kinematics

To model a lift system accurately, we need to consider its equations of motion or "kinematics". Some published material on this subject is given in references (1)(2) - Professor Motz is credited as having formulated equations which allow us to plot points on the corresponding time versus distance, speed, acceleration and jerk curves. I have furthered this work by deriving a set of equation that allow the equations of motion of a lift to be plotted as continuous functions for any inputs.

There appear to be errors in the original work by Motz which I have identified in reference (3). This, together with my ideal kinematics paper (4) is currently being reviewed by Dr Pratap Mehta prior to being submitted for publication in the CIBSE technical journal, Building Services Research and Technology.

The next stage in this work is to implement algorithms calculating the energy consumption associated with the various types of variable speed lift motor drives when input with the ideal journey profiles. Once tested and verified against real systems, this will provide the basis for modelling the energy consumption associated with the operation of a variable speed lift system.

Double decker lifts

Lifts are particularly critical in tall buildings where few people can be expected to walk to their destination. In tall buildings with large floor plans, double decker lifts may be used to reduce the number of lifts and core space. Double decker lift traffic analysis techniques published to date have only considered the morning up peak traffic scenario. I have derived and implemented general analysis formulae which allow any peak lift traffic to be analysed.

A draft paper summarising this technique is given in reference (5).

Oasys LIFT 6.0 Enhancements

I am the principle author of Oasys LIFT which is used internationally on Arup projects to select lift configurations for major developments. The major development for LIFT in the past six months has been the inclusion of my double decker lift traffic analysis technique. A number of minor enhancements have also been made to the user interface.

CIBSE National Conference paper

The main theme for this years Chartered Institute of Building Services Engineers National Conference in Brighton, October 1994 is environmental engineering and communications. I submitted a synopsis, reference (6), for a paper with the title "Green Lifts?" which was accepted in January. I submitted a draft of the final paper in April.

Traffic data collection

Initial site surveys collaborate the view that our standard office lift traffic design criteria are outdated due to changes in working practices and tend to result in the installation of excess lift handling capacity. Moving large, heavy lifts up and down a building when they a virtually empty at peak time is not energy efficient.

Current industry standard design criteria have been in use for many years. In order to justify proposals to change British Standard and CIBSE recommendations I will need to provide a comprehensive set of survey results.

My initial surveys have been manual counts using a notebook computer to time stamp events. This is time consuming, tedious and only provides data for one floor at any one time. I am investigating two other approaches:

- Computer video counts - using video cameras, frame grabbers and computer based (often neural network) algorithms to determine the number of people using lifts. This technology is relatively new and very expensive if purchased as a package. Colleagues at Brunel are writing a lift control algorithm which uses people counting, and the associated video based people counting methods may yield an affordable solution to my traffic data collection problem.

- Traffic analysers - some lift engineers use the data available from lift control systems (lift button presses, etc.) as a measure of lift traffic and lift system performance. But no information is known about the number of people waiting or being transported. I am currently developing a theory which applies a mathematical model to traffic analyser data in order to estimate the actual passenger traffic flow in persons per five minutes. The preliminary simplified algorithm is promising. If further testing and development is successful, this approach would allow me to collect an enormous amount of traffic data relatively simply at minimal expense.

Arup projects

I have been advising on a range of lift projects in Arup - from a single lift in a 3/4 storey building to a 50 storey building (for which a typical scheme has 36 lifts in various zoned/express lift combinations).

I have also acted as an expert witness in a Rent Review arbitration case. Included in my proof of evidence were references (7) and (8) which are a traffic survey of the building in question and an explanation of Oasys LIFT calculations.

B1.5 Comments on progress and next stage of project

I am satisfied with the progress of the first six month of my project and confident that the work carried out is in line with objectives originally agreed for the project. I am conscious of the diverse range of research topics I am investigating, but believe that the various strands should come together when I start modelling the complete lift system by simulation during the next six months. The intention is to write a lift simulation program which will:

i. use traffic data collected for the project as input
ii. implement the ideal kinematics formulae for modelling lift movement
iii. output energy consumption associated with each lift trip
iv. provide a platform for testing lift control strategies that use energy efficiency as criteria

A project programme for the second six months of the project and an overview plan for years 2 to 4 are given in Appendix A

B1.6 List of Contents for Appendices of Progress Report B1

Appendix A

Project Programme

Appendix B

i. Extract from CIBSE Guide on Ideal Lift Kinematics
ii. On the ideal kinematics of lifts by Prof Molz
iii. Commentary: On the ideal kinematics of lifts by Prof Molz
iv. Ideal lift kinematics: Formulae for the equations of motion of a lift
v. Lift traffic analysis: general formulae for double decker lifts (draft)
vi. CIBSE National Conference, "Green Lifts?" synopsis
vii. Report of Traffic Survey at 33 Wigmore Street, London on Friday 18th February 1994 (please treat as confidential)

viii. Basis of the Oasys LIFT 5.0 program implementation of general formulae for lift traffic analysis (please treat as confidential)

B2 PROGRESS REPORT MAY 1995

B2.1 Introduction

This report summarises the work I have carried out over the first 18 months of the Engineering Doctorate programme, outlines my "contribution to knowledge" in the form of published papers, and discusses future work.

B2.2 Green Lifts?

Key paper

The Environmental Technology basis for my research was demonstrated in the *Green Lifts?* paper presented at the EngD end of Year I conference. In this paper I applied Life Cycle Analysis to show that the dominant source of environmental burdens for lift systems are the non-renewable resources depleted, the waste created and the emissions generated through the production of electricity for the operation of lifts while in use.

I highlighted three areas I am working to realise a reduction in energy consumption. These are:

Modelling of lift movement and corresponding energy consumption. This provides the tools to investigate possible savings associated with varying performance, selecting different drive types, alternative lift configurations and, through the use of light modern materials.

Reviewing current traffic design criteria. I am questioning current lift design criteria which, in my opinion, are outdated due to changes in working practices and tend to result in the installation of excessive handling capacity. The goal here is to avoid excessive over sizing of lift cars. Moving large, heavy lift cars up and down buildings when they are virtually empty at peak times is not energy efficient.

Green Lift Control Algorithms. Lift control algorithms generally give consideration to optimisation of traffic flow, and minimisation of waiting and journey times. In due course I will be writing lift control algorithms that also consider energy consumption in their allocation of lifts to calls.

Paper readership/audience

The *Green Lifts?* paper was originally prepared for the Charted Institution of Building Services Engineers National Conference, for which it was refereed by two independent experts. I presented the paper at the CIBSE Conference in October 1994 to an audience of practising building services engineers.

I also presented the paper to the EngD 1994 Conference, a Brunel Research Seminar, various Arup audiences (Arup Environmental, Arup Electrical Engineers, Arup Hong Kong office), and to Hong Kong Polytechnic University Building Services students.

The paper has also been circulated to major lift manufacturers for comment (Kone, Express, Otis and Schindler).

I understand that the paper will be reported in the next edition of the CIBSE Lift Newsletter, and may be re-published in the international elevator magazine, Elevator World.

The response to the paper has been positive, affirming that the direction of the work is valid. There has been minimal previous research in this area, although it has been generally acknowledged that vertical transportation is a major building electrical load, after electric heating/air conditioning (where applicable) and lighting.

Putting the project in perspective

I am sometimes asked to discuss the significance of my research into the environmental impact of vertical transportation systems. In summary:

Buildings account for about a third of the energy we consume. The most important greenhouse gas is carbon dioxide, which is steadily increasing due to the burning of fossil fuels for energy generation and vehicles.

Where they are installed, lifts and escalators are a significant proportion of the building load - a draft CIBSE Energy Efficiency Guide suggests 4 to 7%, Kone documentation suggests 5 to 10%.

The importance of energy efficient HVAC and lighting systems is generally accepted - the wealth of related research and development in both these fields reflects this. Energy efficient vertical transportation systems are among the next in line for "greening".

I am in a excellent position to be able to encourage and guide the vertical transportation industry along the Environmental Technology route - Arup is probably one of the largest specifiers of vertical transportation systems in the world, I have supplementary sponsorship from the Chartered Institution of Building Services Engineers who publish various related journals and guides, and I am already known to the lift industry for my research publications.

B2.3 Elevcon '95

Conference visit

Elevcon is an international conference arranged by the International Association of Elevator Engineers. Elevcon '95 in Hong Kong had 145 participants from 18 countries. There were representatives from manufacturers, consultants, academics, and governmental institutions.

I presented two papers at the conference, one on ideal lift kinematics, the other on double decker lifts. The papers have been published in *Elevator Technology 6*. I also chaired a session on *Neural Network Based Traffic Control* and sat on a *Panel of*

Experts answering general questions on vertical transportation.

Copies of my two papers are attached to this report in Appendix A. A brief summary of the work follows:

Ideal Lift Kinematics

Ideal lift kinematics are one element of my *Green Lifts?* research into *Modelling of lift movement and corresponding energy consumption.* They describe the optimum motion that a lift can achieve given restraints imposed by human comfort criteria. I have derived equations which enable ideal lift kinematics to be plotted as continuous functions for any values of journey distance, velocity, acceleration and jerk (rate of change of acceleration).

Ideal lift kinematics are, in themselves, an important area of lift design. For the conference I presented a paper on my work in this field. I discussed previous research, the significance of my own contribution, the mathematical derivation of ideal kinematics equations, and applications for the work.

Double Decker Lifts

Prior to joining the EngD course I derived the General Analysis technique. This allows us to analyse the performance of a lift system for a given peak passenger traffic flow. I implemented the technique in the Oasys LIFT Program, which has been used throughout the international Arup Partnerships for analysis/selection of lift systems since 1989.

More recently, I have extended the technique so that it can be used to analyse double decker lifts. Double decker lifts have two separate cabs built into a single unit so that upper and lower cabs serve adjacent floors simultaneously. They provide greater handling capacity per shaft than conventional lifts, making them particularly attractive for high rise buildings.

In my Elevcon paper I discussed the Double Decker General Analysis technique, its derivation and implementation. I gave an example comparing the results with a more simple analysis technique, before looking at a scenario that only the General Analysis technique can consider.

Double decker lifts are reported to be more energy efficient than single decker lifts - as they serve two floors simultaneously, they have less starts and stops per round trip. This is easy to see for peak traffic. But what is the position for non-peak traffic, when the (large and heavy) double decker lifts are only transporting a few people at a time? I shall be investigating this in more detail when I commence simulation modelling.

Other activities

I took the opportunity while in Hong Kong to visit Arup's offices where I gave an extended lunchtime presentation of my work. I was also invited to, and gave a two hour lecture to Hong Kong Polytechnic University students.

B2.4 Traffic Surveys

I have now carried out four major traffic surveys:

Offices at 33 Wigmore Street
The Ritz Hotel
Arup head office in Fitzroy Street
British Standards Institution head office, Chiswick

Analysis of results from traffic surveys is ongoing, and will form the basis for recommendations for revised traffic design criteria towards the end of my project.

Surveys to date have been carried out by manual count. I had hoped to test the automatic people counting theory I am developing at the BSI office, but the controller manufacturer was unable to down load the data I required from the lift system. I am exploring other contacts to find a site where I can test this work.

B2.5 Motor Modelling

My Academic Supervisor, Dr Pratap Mehta has an undergraduate student working on an actual scale model of a lift. It is intended that this will give me a lab based testing facility for mathematical motor models. I have been developing a DC drive motor model to tie up with the installed system.

B2.6 Lift Simulation

I have started learning C++ which I will use to program the proposed lift simulation program. The lift simulation program will be used to bring together my work on ideal lift kinematics, motor modelling and lift traffic surveys. With these implemented, I can then design and test my "green lift control algorithms".

B2.7 Arup Projects

I continue to give general advise on vertical transportation issues from my base in Arup Research & Development. This involves me, to various degrees, in several different projects most weeks.

In my role as Chairman of the Electrical Computing Working Party, I have co-ordinated Arup Electrical Computing Development Fund Applications for the year April 1995/96, and been involved in discussions concerning the strategy of Arup program development.

B2.8 Programme

A copy of my current programme is enclosed in Appendix B. There has been some slippage, particularly in the Poisson people counting algorithms, and motor modelling. This is mainly due to EngD course work taking longer than planned for.

B2.9 List of Contents for Appendices of Progress Report B1

Appendix A

i. Peters R D *Ideal Lift Kinematics: Complete Equations for Plotting Optimum Motion* Elevator Technology 6, Proceedings of ELEVCON'95 (The International Association of Elevator Engineers) (1995)

ii. Peters R D *General Analysis Double Decker Lift Calculations* Elevator Technology 6, Proceedings of ELEVCON'95 (The International Association of Elevator Engineers) (1995)

Appendix B

Project Programme

B3 END OF YEAR II DISSERTATION OCTOBER 1995

B3.1 Summary

This dissertation summarises project progress over the first two years. The environmental basis of the research has been defined in the paper "Green Lifts?". Life Cycle analysis demonstrates that the dominant source of environmental burdens for lift systems are the non-renewable resources depleted, the waste created and the emissions generated through the production of electricity for the operation of lifts while in use. Several areas of research are being considered in order to realise a reduction in energy consumption; progress in each of these areas is reviewed. A summary of Arup project work, and development to the Oasys LIFT program is presented. Masters level modules completed as required by the EngD programme, are listed. An outline programme for the remaining two years of the project is given.

B3.2 Introduction

This project is based at Brunel University and sponsored by Ove Arup and Partners. Supplementary sponsorship is received from the Chartered Institution of Building Services Engineers. Richard joined Arup as a graduate electrical engineer in 1987. His special interest in vertical transportation led to the publication of a number of research papers, prior to joining the EngD programme in 1993.

In this dissertation we will review the project objectives, the environmental basis of the research, and the work carried out in each of the areas defined. Associated work, the EngD taught modules and Arup project work will also be discussed. A plan for the next two years work is proposed.

Some of the contents of the EngD Portfolio and previous progress reports are repeated to allow a complete overview of the work to date in a single document.

B3.3 Project Objectives

The original project objectives were set out in the project proposal 6 June 1993. These were:

i. Measure vertical passenger traffic and lift/escalator energy consumption so as to build up pedestrian circulation and corresponding energy models for offices, residential buildings, airports, leisure complexes, etc.

ii. Compare use and performance of lifts/escalators/stairs to existing lift traffic analysis models and assumptions. Compare performance of driving motors to electrical models.

iii. Develop computer programs implementing verified analysis/simulation traffic analysis models and corresponding energy models.

iv. Use verified models to calculate: the benefits of developing and implementing energy efficient lift control algorithms, the savings achievable through the use of high efficiency motors, and the benefits of energy conscious planning strategies.

v. Establish guidelines for predicting traffic in new and refurbished buildings. Make planning and specification recommendations that reflect the need to design energy efficient buildings.

These objectives remain an integral part of the research. However, the environmental basis and focus of the project has become more clearly defined, as discussed in the following section.

B3.4 Establishing the Environmental Basis of the Project

The environmental basis for the project was set out in the paper "Green Lifts?", which was presented at the EngD Conference (September 1994) and the Chartered Institution of Building Services Engineers (CIBSE) National Conference (October 1994). Most recently, this paper was reproduced in the international trade magazine, Elevator World; a copy is included in Appendix A. By applying Life Cycle Analysis, it has been demonstrated that the dominant source of environmental burdens for lift systems are the non-renewable resources depleted, the waste created and the emissions generated through the production of electricity for the operation of lifts while in use.

Putting this finding into prospective, it is worth considering that buildings account for about a third of the energy we consume. The most important greenhouse gas is carbon dioxide, which is steadily increasing due to the burning of fossil fuels for energy generation and vehicles. Where they are installed, lifts and escalators are a significant proportion of the building load - a draft Chartered Institution of Building Services Engineers (CIBSE) Energy Efficiency Guide suggests 4 to 7%. Kone Lifts Ltd documentation suggests 5 to 10%.

The importance of energy efficient HVAC and lighting systems is generally accepted - the wealth of related research and development in both these fields reflects this. Vertical transportation systems are among the next in line for "greening".

Three areas of research are being considered in order to realise a reduction in energy consumption. These are:

i. *Modelling of lift movement and corresponding energy consumption* Providing the tools to investigate possible savings associated with varying performance, selecting different drive types, alternative lift configurations and, through the use of light modern materials.

ii. *Reviewing current traffic design criteria* Questioning current lift design criteria which, we believe, are outdated due to changes in working practices and tend to result in the installation of excessive handling capacity. The goal here is to avoid excessive over sizing of lift cars. Moving large, heavy lift cars up and down buildings when they are virtually empty at peak times is not energy efficient.

iii. *Green Lift Control Algorithms* Lift control algorithms generally give consideration to optimisation of traffic flow, and to the minimisation of waiting and journey times. Lift control algorithms that also consider energy consumption in their allocation of lifts to calls are being considered.

B3.5 Modelling of Lift Movement and Corresponding Energy Consumption

Ideal Lift Kinematics

Ideal lift kinematics describe the optimum motion that a lift can achieve given restraints imposed by human comfort criteria. Previous research by others gave us points on time versus distance, velocity, acceleration and jerk (rate of change of acceleration) curves. The author derived equations allowing ideal lift kinematics to be plotted as continuous functions for any value of journey distance, speed, acceleration and jerk.

Ideal lift kinematics are, in themselves an important area of lift design. A paper on this element of the work was presented at the Elevcon conference in March 1995, which is discussed in a following section. A copy of the paper is included in Appendix B.

This research in ideal lift kinematics provides us with the full control over the reference speed, acceleration, etc. input to lift drives so that we can investigate energy savings associated with varying the lift performance.

Motor Modelling

Electric lift drives, and their relative energy consumption are discussed in the paper prepared for the EngD Conference September 1995. A copy of this paper is included in Appendix C. The paper was subsequently presented at the CIBSE National Conference (October 1995). A mathematical model of a separately excited DC motor, fed from a fully controlled 6 pulse convertor is presented. Kinematics are input into this model to plot the required torque, armature voltage/current, and power factor. The total energy consumption over the whole trip is determined, and an assessment of the supply system harmonics is given.

This model is used to demonstrate that, by reducing the maximum accelerating by 50%, an energy saving of 16% is achieved. The increased journey time of 23%, would not be prohibitive if introduced during periods of light traffic.

This, and other motor models will be implemented in a lift system simulation to aid development and testing of "green" control strategies.

B3.6 Reviewing Current Traffic Design Criteria

General

The need for reviewing current lift traffic design criteria was discussed in section 3.

Traffic surveys can be carried out in a number of ways. Manual surveys are time consuming and tedious to carry out, so the main focus has been on developing automatic counting techniques. If successful, this will allow large amounts of, and therefore more representative, traffic data to be obtained for a wide range of building types.

Manual counts

Manual lift traffic surveys have been carried out at:

i. Offices at 33 Wigmore Street
ii. The Ritz Hotel
iii. British Standards Institution head office, Chiswick
iv. Arup head offices in Fitzroy Street

Surveys (i) to (iii) are documented in reports prepared for Arup clients. Survey (iv) is currently being documented. A summary report of the manual surveys will be prepared.

Poisson Counting

In the "Green Lifts?" paper the author discussed applying a mathematical model to traffic analyser (or lift control system) data in order to estimate actual passenger traffic flow in persons per five minutes.

To date, the main difficulty has been collecting the data required for analysis (time of lift button presses, etc.). This data is sometimes collected by traffic analysers which you hard wire into the lift system. The proprietary traffic analysers reviewed process and analyse the data themselves before giving the user an analysis. The "raw" data we require is not available.

Now that lift manufactures use microprocessors in their lift controllers, it should be possible to interface and download the data we require directly. Through the CIBSE Lift Committee the author has approached the major lift manufacturers (Otis, etc.) to establish if their microprocessor based lift controllers can download the appropriate data. To date, the answer has been no, although Thyssen are currently investigating adding a serial port to one of their lift controllers. However, many manufacturers can remotely monitor their sites and current lift operation, so are effectively broadcasting the data required for the analysis.

One such manufacturer, The Thames Valley Lift Company, has provided a copy of their software which allows us to monitor their sites remotely by modem. As they are unwilling to provide the program source code so that modifications can be made to log the incoming data to disk, we need to use a second program to monitor and time stamp data for analysis. Because communications software uses "handshaking" there are difficulties in two programs monitoring the data simultaneously. We hope to overcome this difficulty shortly.

Video Counting

Three of the four manual surveys carried out have used video cameras to record passenger movements. This allows us the possibility of using computer programs to count the traffic. These programs are a relatively new development. A Brunel people counting program is currently being tested on the Arup head office traffic survey videos.

B3.7 Lift Simulation Program

The purpose of the lift simulation program is to:

- implement the research in ideal lift kinematics, motor modelling for power consumption and traffic survey data.
- Provide a test tool for lift control algorithms
- provide and advanced traffic/lift performance analysis tool

A draft outline specification for the development is included in Appendix D.

We are currently negotiating with a lift Thames Valley on possible co-operation, in particular including their lift control algorithm in the simulation. The benefits of this co-operation would be:

- we would have a benchmark “modern” lift control system against which to test development control algorithms
- development algorithms would be developed in a similar format, making them more straight forward to implement on real systems

B3.8 Oasys LIFT Program

Prior to joining the EngD, the author derived the General Analysis technique. This allows us to analyse the performance of a lift system for any given peak passenger traffic flow. The technique is implemented in the Oasys Lift Program and has been used throughout the international Arup Partnerships for analysis/selection of lift systems since 1989.

The technique has now been extended so that it can be used to analyse double decker lifts. Double decker lifts have two separate cabs built into a single unit so that upper and lower cabs serve adjacent floors simultaneously. They provide greater handling capacity per shaft than conventional lifts, making them particularly attractive for high rise buildings.

A paper discussing the Double Decker General Analysis technique, its derivation and implementation was presented at Elevcon '95, and is included in Appendix E.

Double decker lifts are reported to be more energy efficient than single decker lifts - as they serve two floors simultaneously, they have less starts and stops per round trip. This is easy to see for peak traffic. But what is the position for non-peak traffic, when the (large and heavy) double decker lifts are only transporting a few people at a time? This will be investigate in more detail using the simulation model.

B3.9 EngD Modules and Electives

As part of the EngD programme, Research Engineers are required to complete a number of Masters modules (or equivalent). To date the following core modules have been completed:

- Leadership and LCA 1
- LCA 2 and Research Training Programme
- Global Monitoring
- Risk Perception 1
- Introduction to Sociology
- Hands on Audit and Introduction to Legislation
- Environmental Measurement
- Risk Communication and Project Management
- Environmental Law
- Sociology of the Environment

- Advanced Leadership

And the following elective modules:

- Neural Networks
- Project Management of EngD Conference 1995

Copies of module assignments are kept in the EngD Portfolio.

B3.10 Arup Project and Related Work

General

As an engineer in Arup Research and Development, I am regularly called upon to advise line group engineers on all aspects of vertical transportation engineering. Queries range from the simple, "what size lift shaft do I require?" to the more interesting "can we have a 13 person lift which travels on a curved incline to follow the building structure?".

I also advise on some of the more complex traffic analysis problems. These range from high rise buildings with express lifts and sky lobbies, to unusual traffic flow scenarios such as back stage in a theatre.

I acted as an expert witness for a rent review arbitration case concerning the office building, 33 Wigmore Street in London. The quality of lift service was in question, and I presented, and was cross examined on evidence relating to the lift traffic analysis and the performance of the lift installation in question.

Electrical Computing Working Party

As chairman of the Arup Electrical Computing Working Party, I oversee the development and application of computer programs for Electrical Engineering in

Arup. Arup have historically developed most of their own programs, many of which remain technically superior to other, commercially available programs. The building services software market is now developing fast, and we are having to review the strategy of developing our own programs. We are currently reviewing "cable" distribution software to determine whether the building services software companies can provide us with a program of high enough quality, and at a cost that makes it no longer worthwhile for us to continue to develop our own program.

CIBSE Guide

Prior to joining the EngD programme, I contributed to the computer programs section of CIBSE Guide D, *Transportation systems in buildings*. This guide has been a success, and a second, revised edition is being planned. I have been asked to look at three sections in particular relating to planning of installations, lift monitoring, and computer programs. This is an excellent opportunity to establish elements of "green" research into common design practice.

B3.11 Elevcon '95 Conference Report

Elevcon '95 was the 6th international conference on Elevator Technology, held on 13-16 March 1995 at the Riverside Regal Hotel in Sha-Tin, Hong Kong. The conference had 145 participants from 18 countries. There were representatives from manufacturers, consultants, academics, and governmental institutions. Subjects discussed included components, traffic, control, monitoring, education and training, escalators and drive systems.

Elevcon is the only international conference in this field, and a valuable opportu for lift engineers and researchers to learn about and to discuss new technologies. Some particularly interesting papers were:

- *Elevator Group Control System with Fuzzy Neural Network Model* - just one of several papers describing how the latest in artificial intelligence thinking can be applied to lift control systems.

- *Active Noise Control of Elevator Noise From Ventilator* - describing how noise can be reduced by emitting sounds that are anti-phase to noise sources.

- *Marketing Strategy of Lifts and Escalators in the Far East* - an outline of the development and analysis of market demand in Far East Asia, reporting on economic growth and identifying opportunities for foreign investment.

- *A Super High-Rise Escalator with a Horizontal Mid-Section* - describing an escalator with a horizontal mid section in the middle of its 42 m rise.

- *The User's Ideal Lift* - an interesting survey of Italian lift users, and a reminder that the user's main concern is safety.

- *The Latest Drive Technology for Elevators* - discussing inverter control of electric and hydraulic lifts.

The author presented two papers at the conference, *Ideal Lift Kinematics*, and *General Analysis Double Decker Lift Calculations*. The author also chaired the session on *Neural Network Based Traffic Control* and sat on a *Panel of Experts*. The panel answered general questions on vertical transportation issues ranging from the ownership of data collected by remote monitoring (does it belong to the client or lift supplier?) through to a questioning of our current reliance on mechanical (as opposed to electronic) safety devices.

All the papers have been published *Elevator Technology 6*.

Besides the main sessions, there were workshops, tutorials and seminars. The author participated in two seminars, one on remote monitoring and data logging, another on lift traffic design and control.

B3.12 Future Programme

An outline programme for the remaining two years of the project is included in Appendix F. The main work will be development of the simulation program, which is in the early stages of coding. As discussed in previous sections, the simulation program brings together the main elements of the research - kinematics, motor modelling, traffic data, and green lift control algorithms. A period has been set aside for testing the simulation models against real systems, and making modifications as necessary.

B3.13 Conclusions

The environmental basis of the work has been established and widely reviewed within the building and vertical transportation industry through the paper "Green Lifts?". Several key areas of work have been defined, and significant progress has been made in developing these areas.

The doctorate requirements of "contribution to knowledge" have been demonstrated through the publication of refereed conference papers.

The remaining project programme outlines plans for the next two years. The remaining work is primarily focused on the development of a lift simulation program, various "green" control algorithms, and the testing of these models against real systems.

B3.14 Acknowledgements

The author would like to thank his supervisors, lecturers and colleagues at Brunel University, Ove Arup & Partners and the CIBSE Lift Group for sharing their knowledge and experience which are providing an excellent basis for his research. The author acknowledges, with gratitude, financial support from the Engineering and Physical Sciences Research Council, The Ove Arup Partnership, and the Chartered Institution of Building Services Engineers.

B3.15 List of Contents for Appendices of Progress Report B3

Appendix A

Peters R D *Green Lifts?* Proceedings of CIBSE National Conference 1994 (The Chartered Institution of Building Services Engineers) (1994)

Appendix B

Peters R D *Ideal Lift Kinematics: Complete Equations for Plotting Optimum Motion* Elevator Technology 6, Proceedings of ELEVCON'95 (The International Association of Elevator Engineers) (1995)

Appendix C

Peters R D *Mathematical Modelling of Lift Drive Motion and Energy Consumption* Proceedings of CIBSE National Conference 1995 (The Chartered Institution of Building Services Engineers) (1995)

Appendix D

Outline Specification for Lift Simulation Program

Appendix E

Peters R D *General Analysis Double Decker Lift Calculations* Elevator Technology 6, Proceedings of ELEVCON'95 (The International Association of Elevator Engineers) (1995)

Appendix F

Project Programme

B4 PROGRESS REPORT APRIL 1996

B4.1 Introduction

This project is addressing the finding that the dominant source of environmental burdens for lift systems are the non-renewable resources depleted, the waste created and the emissions generated through the production of electricity for the operation of lifts while in use.

A comprehensive background to the project, and progress in the two years to October 1995 is given in the end of Year II dissertation, a copy of which is kept in the project portfolio. This report assumes the reader has reviewed this dissertation.

B4.2 Simulation Development

The main focus of the work is now the development of a simulation program which brings together the main elements of research carried out to date. This includes the work on ideal lift kinematics, motor modelling and traffic survey data.

The simulation will enable development of green lift control algorithms. And enable users to test the performance of lift systems, both in terms of energy consumption and passenger service. A specification for the program was included in the appendices of the End of Year II Dissertation.

I have previous programming experience in Fortran, Basic and Pascal. But C++ has been chosen as the language for this program due to its speed, portability, functionality, code re-usability, and industrial acceptance as *the* professional programming language. Arup Computing have also moved to C++ in recent years, so support and development of the program after the end of the project will be viable.

C++ is a complex language, and getting to a stage where useful code can be written has taken considerable effort. But having got to this stage, its advantages are proving very valuable. Key concepts such as "object-orientation" and "encapsulation" play a major part in breaking down and simplifying programming.

At this stage I have developed two major C++ "classes", a motion class and a lift class. The motion class implements all the work on ideal lift kinematics for use in the simulation. The lift class represents a lift - each instance of the class (i.e. an "object") represents a lift in the simulation - it has a nominal capacity, speed, door times, etc. And functions that allow you to move it up and down, make it answer calls, etc. The most recent header files for these classes are included in Appendix A. Header files are the programmer's interface to the coding of a class, showing its functionality and how to access it without needing to see its implementation (i.e. the detailed C++ coding). The variables and functions are commented in detail, and most should be self-explanatory to readers with an elementary knowledge of computer programming.

Next stages in developing the simulation include writing classes to represent the motor power consumption, people, and "green" dispatcher control algorithms. Time has been put aside towards the end of the project for testing and verification of the simulation model against real systems.

B4.3 EngD Course Work Activities

An optional elective module on Clean Technology was attended the week commencing 30 October 1995. This proved to be very thought provoking; we were challenged to consider our own environmental "paradigm shift".

An EngD core module on Risk Assessment took place on the week commencing 8 January 1996.

A Life Cycle Analysis Workshop was held 8 February 1996 at Surrey University, attended by EngD RE's together with staff and students of Surrey's Universities' Centre for Environmental Strategy. This was a good opportunity to present the Life Cycle (inventory) Analysis prepared for the *Green Lifts?* paper. A useful discussion reached a consensus view that the basis of my claims were well founded i.e. that the dominant source of environmental burdens for lift systems are the non-renewable resources depleted, the waste created and the emissions generated through the production of electricity for the operation of lifts while in use. A more detailed Life Cycle Analysis of lift systems could be carried out; in fact it could be a four year project in itself. But for the purposes of demonstrating that energy consumption was the key issue for vertical transportation, the assessment is quite adequate.

B4.4 Papers, Seminars and Publications

Elevcon '95 papers on ideal lift kinematics and double decker lifts have been developed further, and offered for publication in professional journals. The paper, *Ideal Lift Kinematics: Derivation of Formulae for the Equations of Motion of a Lift* has been accepted for publication in the International Journal of Elevator Engineers. This includes new results which allow calculation of minimum stopping distances once a lift journey has commenced (found to be useful in the lift simulation when new calls are registered after a trip has commenced). A copy of the final submission incorporating referees comments is included in Appendix B. The paper, *Lift Traffic Analysis: General formulae for double decker lifts* has been submitted, and is currently being reviewed by the CIBSE Journal, Building Services Engineering Research and Technology (BSERT).

A seminar titled, *Lift Controls for the Future* was given for a CIBSE Regional meeting at Reading University on 7 November 1995. And repeated as a Brunel Research Seminar 15 November 1995. Some of the ideas discussed in this seminar are being developed by a group of Arup colleagues to contribute towards an article for the CIBSE Building Services Journal (a trade magazine).

Abstracts for two papers have been accepted for Elevcon '96 in Barcelona, October 1996. The first, *Lift Passenger Traffic Patters: applications, current knowledge and measurement* is intended to bring together my research in this area. The second, *Risk and the Vertical Transportation Industry* is intended to bring together, and apply to the lift industry, the lessons learnt from the three EngD risk modules. (This paper is being accepted by our tutor as an alternative to the module assignment.) Abstracts for both these papers are included in Appendix C.

I have been using the Internet occasionally for work purposes, and in my own time to develop a home page for the IEE South Bucks Younger Member Section (of which I am a committee member). I wrote an article about my experiences for feedback to Arup, which is at the early stages of exploring this medium. The article was published in our in-house *Computer News*, and is included in Appendix D.

B4.5 Arup Project and Related Work

The Oasys LIFT program has been extended to allow imperial calculations, as requested by the Arup USA office.

As chair of the Electrical Computing Working Party, I have overseen the preparation of computer development fund applications for the year 1996/97, totalling approximately 31 man weeks work. These include applications relating to lift, lighting, cable sizing, power systems analysis and CAD software.

I continue to advise line group engineers on vertical transportation issues. Recent projects of interest include a prospective high rise complex in USA (example design options given in Appendix E). And a survey of Charring Cross Hospital, which has a severely overloaded passenger lift systems; we have proposed a major modernisation of the systems (including specification of energy efficient drives), and a re-think of transportation strategy. Estimates for the proposed work suggest a budget of £3.2 million.

B4.6 CIBSE Lift Group

I am pursuing a more active involvement in the CIBSE Lift Group, and attend meetings as a member of the group. We are currently awaiting formal approval of outline proposals to revise CIBSE Guide D *Transportation Systems in Buildings*, for which I am nominated as a principle author for three sections. As discussed in the End of Year II dissertation, this will provide an excellent opportunity to establish elements of "green" design into common practice.

I am currently investigating setting up a CIBSE Open Forum on Remote Monitoring of Lifts. As noted in Guide D, and experienced in my own research, it is very difficult to obtain lift controller data. We are hoping this open forum will be one step forward to achieving (more) open systems - which would allow building owners to monitor lifts from different manufactures using the same software (possibly integrated into BMS software). And allow lift researchers/consultants to download and analyse data without being restricted by the limitations of any one manufacture's monitoring package.

The CIBSE Lift Group would like to set up Lift Training courses - from general short courses to post graduate degrees. I have initiated a training questionnaire to establish demand for various types of courses; this is being circulated by CIBSE and by the vertical transportation industry press.

B4.7 Project Programme

An updated project programme is included in Appendix F.

B4.8 Conclusions

The environmental basis of the research has been demonstrated, and doctoral requirements of "contribution to knowledge" continue to be added to through conference and journal paper publications. The main elements of the research are now coming together in the lift simulation program, the development, testing and verification (against real systems) of which is the main focus for the remainder of the project.

B4.9 List of Contents for Appendices of Progress Report B4

Appendix A

Header Files for motion and lift Classes

Appendix B

Peters R D *Ideal Lift Kinematics: Derivation of Formulae for the Equations of Motion of a Lift* International Journal of Elevator Engineers, Volume 1 No 1 (1996)

Appendix C

Abstracts for Elevcon '96:

i. “Lift Passenger Traffic Patterns: Applications, Current Knowledge, And Measurement”

ii. “Risk And The Vertical Transportation Industry”

Appendix D

Arup Computer News Article: “Surfing on the Crest of an Internet Wave”

Appendix E

High Rise Design options for prospective Arup project in USA

Appendix F

Project Programme

B5 PROGRESS REPORT OCTOBER 1996

B5.1 Introduction

The main focus of this project is energy efficient lifts. This progress report covers the period April to September 1996 (second half of Year 3). Background to the project, and progress in the preceding two and a half years can be found in:

- End of Year II Dissertation
- Progress Report April 1996

Copies of these reports are kept in the project portfolio. This report assumes that the reader has reviewed these documents.

B5.2 Simulation Development

The simulation program brings together the main elements of research carried out for the project, including ideal lift kinematics, motor modelling and traffic survey data.

The program was outlined in the 1996 EngD Conference Paper, *Green Lift Control Strategies* (a copy of this paper is held in the portfolio).

In summary, this object oriented program has six main classes:

> *building* - defines the building in terms of number of stories and story heights.
>
> *motion* - implements research in ideal lift kinematics.
>
> *lift* - defines a lift (rated speed, capacity, floors served, etc.) and its current status (position, speed, load, etc.). The motion class is applied to enable the lift to move according to the selected journey profile.
>
> *dispatcher* - defines rules for allocating which lift serves which calls. For fair

comparison of the green control strategies, the default dispatcher logic has been based on conventional group control with dynamic sectoring.

person - defines a person, what time they arrive at the landing station, where they want to go, their mass, etc. Once the journey is complete, the class provides details about passenger waiting and journey times.

motor - defines the characteristics of the drive. Calculates the energy consumption and other characteristics as per research in motor modelling.

Within the limitations of computer memory, the program will allow any number of lifts, floors, and persons. Lifts are individually defined, so if necessary can serve different floors, be different sizes, speeds, etc.

As discussed in *Green Lift Control Strategies,* the program is being used to develop "green" dispatcher control algorithms. Initial simulation results suggest that installations with regenerative drives could achieve additional savings in excess of 30% without reduction in the overall system performance. Further savings could be achieved with marginal reductions in system performance.

The next development stages for the lift simulation are:

- test the simulation against real systems
- write a user interface
- enhance, de-bug as necessary

It is envisaged that the final program will be used in Arup for lift system selection/analysis.

B5.3 EngD Course Work Activities

I presented *Green Lift Control Strategies* as a five minute talk, and as a poster-board at the EngD Conference 10-11 September 1996. The written paper was included in the conference proceedings.

I have completed the EngD distance learning Finance and Marketing module and am currently finalising the assignment.

In June 1996 I attended a four day *C Programming for Interfacing and Signal Processing* course run by the Brunel M&ES department. Parts of this work are being applied to interface with people counting devices (for lift and escalator traffic surveys).

B5.4 Publications

The paper, *Lift Traffic Analysis: General formulae for double decker lifts,* has been accepted for publication by the CIBSE Journal, *Building Services Engineering Research and Technology* (BSERT). This paper provides a more detailed review of the double decker lift research presented in a previous conference paper. A copy of the journal paper is in Appendix A of this report.

The following two papers have been accepted for the International Elevator Technology Conference, ELEVCON '96 in Barcelona, 23-25 October 1996.

- Peters R D Risk and the Vertical Transportation Industry. This paper applies EngD course material on Risk to my industry sector.
- Peters R D, Mehta P, Haddon J Lift Passenger Traffic Patterns: Applications, Current Knowledge, and Measurement. This paper summarises the lift traffic research that has been carried out for the project to date.

Copies of these papers are in Appendix B of this report.

Further past conference papers have been republished by trade magazines:

- Mathematical Modelling of Lift Drive Motion and Energy Consumption was republished by Elevator World in July 1996

- Ideal Lift Kinematics: Complete Equations for Plotting Optimum Motion was republished by Elevator World in April 1996 and by Elevatori in May/June 1996

A full list of publications is given in Appendix C of this report.

B5.5 Arup Project and Related Work

I have been appointed Convenor of a new Arup Research & Development *Look Forward Group (7-10 years)*, reviewing medium to long term business development opportunities for our department. This group will meet about three/four times a year - we had our first meeting in July 1996, which was used mainly to brainstorm possible ideas/issues for the group to address.

I have been designing lifts for an increasing number of high rise and high volume projects, the largest of which is Togok, which has six interconnecting towers, two of which are inclined. This Korean development, currently at pre-feasibility stage, will have in the region of 27,000 occupants. An extract from the design report concerning the "occupant transport systems" (which I wrote) is included in Appendix D. This project is currently confidential.

In September 1996 my colleague, Roger Howkins and I presented a day course on Vertical Transportation to Arup graduates. I covered Lift Basics, Calculating Quantity and Quality, Lift Operation, Lift Layouts, and Escalator Basics. Roger covered Specification, Codes and Standards, Commissioning, Modernisation, Building Interface, and Maintenance.

B5.6 IEE, IAEE and CIBSE

I applied for transfer to Institution of Electrical Engineers Membership in April this year and, following an interview, was accepted in September 1996 as a Corporate Member of the Institution, and as a Chartered Electrical Engineer.

The International Association of Elevator Engineers is setting up a distance learning college offering modules in Elevator Engineering. The IAEE will award postgraduate Certificates/Diplomas to successful students. And work with collaborating universities to complete associated project work/additional modules leading to a MSc. I have been invited to serve on the "academic board" of the college. The time commitment is minimal at this stage (i.e. few hours reviewing course material, opinions on students, etc.), but could develop if appropriate to my position/other commitments in future years. On this basis, I have accepted the position.

As discussed in previous reports, it has proved difficult to obtain lift controller data for my research. I agreed with CIBSE that it would be worthwhile arranging an Open Forum on the *Remote Monitoring of Lifts*, to attempt to address and progress the status of lift communications. I organised this as a joint event with the IAEE, co-ordinating arrangements with the IAEE Chairman, Dr George Barney. The event took place at CIBSE in Balham on the 13th May 1996. It was well attended and received, though the goal of "open systems" still seems a long way off. Promotional material and press cuttings are included in Appendix E. The Elevator World re-prints include the written version of my talk in their *Consultant's Forum* column.

The CIBSE Lift Group has now received formal approval to commence revising CIBSE Guide D *Transportation Systems in Buildings*. I am one of the principle authors for the new version, and will be contributing to various sections. I have also been investigating lift training on behalf of the CIBSE Lift Group. As a consequence of my findings, the Group has decided to concentrate on CPD (Continuing Professional Development) courses, and to seek to use its influence (via CIBSE course accreditation) to encourage Building Services undergraduate courses to cover vertical transportation in more depth.

B5.7 Project Programme

An updated project programme is included in Appendix F.

B5.8 Conclusions

The main elements of the research have been brought together in the lift simulation program, which is being applied as a basis for designing "green" lift systems. Further development, testing, and verification against real systems are planned. To date the project has yielded two journal papers and six conference papers, demonstrating the doctoral requirements of "contribution to knowledge". Several of these papers have been republished in lift industry trade journals, reaching a large and influential audience. I continue to broaden my experience with new roles in Arup, contributions to major construction projects, and associations with IEE, IAEE and CIBSE.

B5.9 List of Contents for Appendices of Progress Report B5

Appendix A

Peters R D, Mehta P, Haddon J *Lift Traffic Analysis: General formulae for double decker lifts* Building Services Engineering Research and Technology, Volume 17 No 4 (1996)

Appendix B

ELEVCON'96 Papers:

i. Peters R D *Risk and the Vertical Transportation Industry* Elevator Technology 7, Proceedings of ELEVCON'96 (The International Association of Elevator Engineers) (1996)
ii. Peters R D, Mehta P, Haddon J *Lift Passenger Traffic Patterns: Applications, Current Knowledge, and Measurement* Elevator Technology 7, Proceedings of ELEVCON'96 (The International Association of Elevator Engineers) (1996)

Appendix C

List of Journal and Conference Publications

Appendix D

Extract from Togok Pre-Feasibility Study

Appendix E

Remote Monitoring of Lifts Open Forum

Appendix F

Project Programme

B6 PROGRESS REPORT APRIL 1997

B6.1 Introduction

The main focus of this project is energy efficient lifts. This progress report covers the period October 1996 to March 1997 (first half of Year 4). Background to the project, and progress in the preceding three years can be found in:

- End of Year II Dissertation
- Progress Report April 1996
- Progress Report October 1996

Copies of these reports are kept in the project portfolio. This report assumes that the reader has reviewed these documents.

B6.2 Simulation Development

A lift simulation program is the main deliverable of the project. The program, Liftsim, brings together and implements the main elements of research carried out; this includes work in ideal lift kinematics, motor modelling, green control algorithms and results from traffic survey data.

Liftsim has been written using Microsoft Visual C++ and runs under 32 bit Windows (95 and NT).

My experience with Arup software has taught me that however clever a program's algorithms, it will be unpopular with users if it has a poor user-interface. Thus, in the last six months, considerable effort has been put into writing a Windows interface that is friendly and easy to use. In addition to the standard Microsoft data entry controls, I have purchased and implemented the "Formula One" software component that allows spreadsheet-like entry of data tables.

In *Passenger Data* and *Lift Data* I have allowed the user to select between *Standard* and *Advanced* modes. Again this feature is something that has arisen from my experience in software development and support. Some users want a quick analysis and expect a program to automatically (but intelligently) select inputs to all but the key variables. Programs insisting on a complete data set are deemed too complex for the task. Other users need and want full control over all analysis variables, and are prepared to put in the time and effort required to compile and enter the full data set.

In most instances designers are looking for the minimum installation specification (number of lifts, speed, capacity) that meets their design criteria. Liftsim allows a range of configurations to be analysed with a single run of the simulation, which speeds up the design process.

The program is now ready for Alpha testing, which is due to commence in April 1997. Testing will be carried out under my direction by graduates seconded to ARD as part of their training. Liftsim will be put on general release to Arup before the conclusion of my EngD.

Liftsim is likely to become the primary Arup lift design tool for the foreseeable future, with developments continuing beyond the conclusion of my EngD project. Budgets for maintenance and support of the program have been included in the Arup 1997/98 Electrical Computing Development Fund Applications (for my time post 1st October 1997).

Screen shots of the program, and example output are given in Appendix A of this report.

The remaining tasks for the lift simulation are:

- de-bugging and testing, including against real systems
- manual/on line help authoring
- further enhancements as time allows

B6.3 EngD Course Work Activities

I have completed and submitted the *Finance and Marketing* assignment.

I attended the *Talking to the Media* module and contributed to the group assignment which was to produce a 5-10 minute promotional video about the EngD program aimed at prospective sponsors.

B6.4 BSc Project Supervision

I have taken the lead role in supervising a final year engineering BSc project student, Shirley Yeung. The project is to implement and to apply my single deck *general* lift traffic analysis technique. The engineering and computing concepts are complex, but Shirley has worked hard to understand the mathematics, and to expand her BASIC computing knowledge to write C++ code.

B6.5 Arup Project and Related Work

As discussed in my last progress report, I have been appointed Convenor of a new ARD *Look Forward Group (7-10 years)*. This group meets to discuss prospective business opportunities for ARD. As an indication of our discussions, minutes of our second meeting 10 January 1997 are included in Appendix B of this report. Further to this meeting I gave a progress report to the ARD management meeting (EXCO).

Vertical Transportation (elevators and escalators) design is a successful and profitable part of ARD, and it is envisaged that our activities will be broadened and expanded into "Arup Lift". In the past few months we have had a number of discussions about developing new business areas, parts of which arise from expertise developed through the EngD programme. In particular the simulation program, Liftsim, is likely to be an important design and sales tool.

In Arup we bid annually for computing development fund resources. As Chairman of the Electrical Computing Working Party, I co-ordinate the electrical engineering applications. This involves taking submissions from various electrical working groups, chairing discussions about the proposals, and obtaining backing for the work from the Arup Electrical Co-ordination Committee. A summary of the 1997/98 applications that we have submitted is included in Appendix C of this report.

I continue to give general advice on Vertical Transportation for various projects in Arup. I was pleased to be given a copy of a client's letter which showed that I had made a positive impression (see Appendix D). I was the Electrical and Vertical Transportation Project Engineer for this 1,000,000 ft^2 commercial and residential development in Egypt in 1992/93. I continue to be consulted, particularly on vertical transportation issues.

B6.6 Elevcon '96

I attended the IAEE International Elevator Technology Conference, ELEVCON '96 in Barcelona, 23-25 October 1996, presenting papers on *Risk and the Vertical Transportation Industry,* and *Lift Passenger Traffic Patterns: Applications, Current Knowledge, and Measurement.* Copies of the written papers were included in my October 1996 progress report.

I also presented the paper, *Time, Distance, Speed, Acceleration and Jerk in Elevator Starting and Stopping* by Dr. Kepa Zubia. Dr Zubia was expected to present his own paper, but was delayed on his way to the conference. As the subject was within my area of expertise, I was asked to present the work instead. Presenting someone else's conference paper at an hour's notice, with just the conference proceedings and hastily prepared acetates was a challenging, but valuable experience.

A number of papers at Elevcon '96 were directly related to my research, and I was able to discuss this work directly with the authors, both during and following the conference.

The Elevcon conferences are the only truly international forum at which to present vertical transportation research. I have been very fortunate in being able to participate in two of these conference during my EngD.

B6.7 Institutional Activities

In November 1996 I was elected as Secretary of the CIBSE Lifts Group. As an indication of the Group's activities, I have included in Appendix E a copy of the 1996 progress report, prepared for *Building Services, The CIBSE Journal* by Dr G Barney.

The revision of CIBSE Guide D, *Transportation Systems in Buildings* is progressing. At the last Guide D meeting my proposed synopses for *Planning and selection of equipment and performance of transportation systems,* and *Remote monitoring and interfacing with BEMS* were accepted. I will be writing the first drafts of these sections (with input from other contributors) in the next six months. Copies of the my synopses are included in Appendix F of this report.

As discussed in my last progress report, I have accepted an invitation to serve on the academic board of the International Association of Elevator Engineers distance learning college. I attended the first meeting at Elevcon '96.

B6.8 Publications

The paper, *Lift Traffic Analysis: General formulae for double decker lifts,* was published in the CIBSE Journal, *Building Services Engineering Research and Technology* (BSERT), Volume 17 No 4 1996. A copy of final submission of this paper was included in my October 1996 progress report.

Ideal Lift Kinematics: Derivations of Formulae for the Equations of Motion of a Lift, was published in *The International Journal of Elevator Engineering*, Volume 1 1996. A copy of the final submission of this paper was included in my April 1996 progress report.

My Elevcon '95 paper, General Analysis Double Decker Lift Calculations was republished by Elevator World in December 1996.

My article, *Surfing the Internet on the Crest of an Internet Wave*, written originally for the Arup in-house *Computer News*, was adapted and published in the Autumn 1996 edition of *Elevation*. (The original version is included in my April 1996 progress report.)

Following an approach by the publishers E & FN Spoon, I am acting as a referee for the second edition of the *Elevator & Escalator Micropedia* by Dr G Barney, D Cooper and J Inglis.

An updated list of journal and conference publications is given in Appendix G of this report.

B6.9 Project Programme

An updated project programme in included in Appendix H.

B6.10 Conclusions

The main element of work in this past six months has been developing Liftsim from a research tool into a program that can be used by others to apply my work in their design of vertical transportation systems. Liftsim has been very well received in the initial demonstrations that I have carried out, and I am confident it will be applied for many years to come.

My academic and industrial experience continues to develop through various roles and responsibilities at Brunel, Arup, and in Institutional business.

I believe that I am in a good position now to finalise the research and writing up in time to submit a completed portfolio in October 1997.

B6.11 List of Contents for Appendices of Progress Report B6

Appendix A
Liftsim Screen Shots & Example Printed Output

Appendix B
Sample Minutes of "ARD Look Forward Group (7-10 years)"

Appendix C

1997/98 Electrical Computing Development Fund Applications

Appendix D

Client commendation

Appendix E

CIBSE Lifts Group Progress Report 1996

Appendix F

CIBSE Guide D Synopsis for sections

i. Planning and selection of equipment and performance of transportation systems

ii. Remote monitoring and interfacing with BEMS

Appendix G

List of Journal and Conference Publications

Appendix H

Project Programme

BOOK 2 OF 2

VERTICAL TRANSPORTATION PLANNING IN BUILDINGS

A Portfolio Thesis for the Degree of Doctor of Engineering in Environmental Technology

by

Richard David Peters

Department of Electrical Engineering and Electronics, Brunel University

February 1998

CONTENTS BOOK 2

This book contains the Engineering Doctorate assignment submissions.

1 PERSONAL COMMUNICATION AND TEAM SKILLS

Brunel/Surrey
Engineering Doctoral programme
1993-94

Assignment 1
Personal Communication and Team Skills

During the next month we would like you to reflect on a major part of the induction week and undertake a SELF-APPRAISAL:

i. as an oral communicator
ii as a team member

This appraisal should take the form of a type written essay of approximately 1,500 words in length. It should aim to information, ideally entertaining the reader and showing your enthusiasm (or otherwise) for the theory against which your discussion should be tested. The appraisal should be forward looking using the knowledge gained during the induction week, especially the practical exercises. It should indicate how you intend to reveal your potential as a communicator or team worker. The oral and written material presented to you during the induction week should provide sufficient theoretical basis for your appraisal, but you may wish to use other sources/theories as the basis for your discussion. However, it is your self appraisal capabilities and not literature searching that we wish to develop in this assignment whose aim is threefold:

i. to reinforce and further test the learning on communication and teamwork skills.

ii. to give you the opportunity to reflect on the usefulness of the theoretical part of the week and its value to your (and your sponsoring company's) research operation.

iii. to indicate your prowess in written communication skills.

In particular

Communication

Use the videoed record of your presentation, and comments from colleagues, in conjunction with the notes on effective presentation and relate to use:

i. your present strengths and weaknesses as a presenter.

ii. the value of the information presented to you in improving your skills.

iii. other skills you wish to learn more about such as "handling difficult questions", "handling the media" etc.

Team Roles

Use the theoretical and practical knowledge of your team roles during the induction week, your early involvement with the company and your life long knowledge of yourself to:

i. describe your strengths and weaknesses as a team member. Also indicate whether, and if so what, insights the Belbin analysis has given you about such a role.

ii. describe the team roles adopted by three people who will work closely with your doctoral programme. Ideally this would be three people who work closely with you at the sponsoring company; however, you could also assess your academic supervisor. This description can be from your own observation alone or, if you feel confident that using Belbin with colleagues will not be a problem, using his questionnaire. Copies of the necessary sheets accompany this paper. You can also borrow the hardware/software if you would like to have a fuller exploration in company of the Belbin ideas (See Dr Chris France). The aim here could be to get an interesting discussion going within your company about team work, perhaps led by yourself:

iii. your view of the Belbin theory and its potential value to you

Your critical appraisal will be treated in strictest confidence by us although you can clearly use it in whatever way you see fit. The self appraisal is your view and we hope you will feel able to be constructively critical if you believe the guidance theory offered is inappropriate or lacking. Your response will also give us a feel of how you valued a major part of the induction course.

Please return the type written assignment of 1,500 words with a postmark no later than 15th November 1993 to Professor James Powell, Department of Manufacturing and Engineering Systems, Brunel University, Uxbridge, Middlesex, UB8 3PH. If you have any queries or requests for information please contact Dr Chris France in the first instance (0895 274000 x2927) or Professor James Powell (0895 203300).

Good luck in your first assignment.

PROFESSOR JAMES POWELL
6 October 1993

Note: **The written material presented by different parties on Belbin has slightly different terminology. The appended sheet ties all terminology together.**

ENGD ENVIRONMENTAL TECHNOLOGY PROGRAMME

Assignment 1 - Personal Communication and Team Skills

Richard D Peters, Arup Research & Development

INTRODUCTION

It is suprisingly difficult to write an approximatley 1500 word essay in response to an approximatley 700 word brief, and be sure of answering all the question, but here goes....!

ORAL COMMUNICATION

What was learnt from the induction course

The lectures and exercises on oral communication were excellent. They reinforced good advice I have learnt at least in part from other similar courses and from experience. The practical exercises were helpful and challenging, in particular having to present a talk on my research subject at short notice. This exercise was subsequently applied in earnest when I was asked to talk for 5 minutes about my project at a Chartered Institute of Building Services Engineers seminar in October with only the time at tea break to prepare. Great!

Assessment of my performance during the induction week

I was satisfied with my performance in the presentation exercises, although there is obviously room for improvement. My main weaknesses are pausing for "umms and errs", fidgeting and being bossy with the audience (a trait from my musical director role). It was noted that I made little reference to the overheads during my talk and turned to look at them when I could have looked at the foil itself - I am more used to slides and need to adapt to the overhead projector. In a more formal presentation I would have dropped the audience participation experiment, but felt this was appropriate to the exercise and added interest and surprise at a stage of the talk where interest may have been waning. I should have made time to practice my finalised talk in front of an audience as I was expecting to have plenty of time for questions, but had none. I used my fiancee's artistic skills to help me with the first overhead, which made the rest of my overheads look bland. In future I will try to be more consistent, or perhaps end with the star graphic so that expectations are not raised early on in the presentation. ✓ ✓

My major strengths are enthusiasm, self-confidence and experience as a performer. I enjoy being in front of an audience (an exhibitionist!) when I am confident about what I am doing. I had an advantage over most of my colleagues in this exercise as I have worked in my field for six years, and spoken on my subject several times before. ✓

"Revealing my potential"

I am not a naturally spontaneous with words - my confidence and experience come from regularly singing and playing music in front of hundreds, occasionally thousands of people. Thankfully, this leaves my nerves dead, otherwise I would be a nervous wreck by now! ✓

However, I do get nervous when I am speaking, which manifests itself in the weaknesses discussed. I intend over the course of this Engineering Doctorate programme to increase my experience of speaking to an audience - I think I am familiar with the theory, but need more practice.

Good!

Watching myself on video was very helpful, and I shall make a point of practising talks in front of a video camera in future.

I disagree with the lecturer who said that some nerves are helpful. I would rather my adrenalin came from being excited about my subject and having the opportunity to share it with other people. This is how I feel when I am performing in a musical role.

Other skills

The "other skills" suggested in the brief, about handling questions and the media, would be very useful. I would be particularly interested in a lecture about writing for and presenting to non-technical audiences as this is the mass audience we as engineers tend to communicate with badly.

We will try to put this on [illegible] [illegible].

TEAM ROLES

My strengths and weaknesses

I have several years of experience of being part of working teams, and have being chairing committees for most of my working life. I found the EngD course exercises particularly fascinating as I am not used to working with such highly intelligent and motivated teams (that is a confidential sentence!). I had to adapt my team leadership and membership stye after the first session when I found the group I was in with was full of ideas, listening to each other and working together well as a matter of course.

My strengths as a team leader are that I can give a strong lead when required (which proved unnecessary and counterproductive during our team exercises). I am an enthusiast, an encourager and a lateral thinker. However, I can be bossy, prefer to follow my own ideas, and get frustrated with team members who do not pull their weight. I tend not helicopter, but will move into the action if the task is not being carried out to my satisfaction. I do not prescribe to helicoptering all the time as personally I respect a manager who will make the tea or get stuck into a CAD drawing to help meet a deadline.

Team roles adopted by people in my sponsoring company

My research is very much self-driven, and the roles adopted by people in the sponsoring company associated with my work are not those of a typical project team.

Day to day contact is with my colleague in Arup Research and Development, Roger Howkins, who has as a lifetime's experience and wealth of expertise in the Lift Industry. Roger is a very practical engineer, which contrasts well with my more theoretical bias. I believe we work well together (we have done successfully for several years) because we share a common interest from different angles, and respect each other's different, but complimentary skills.

My Industrial Supervisor, John Haddon, is the most senior Electrical Director in Arup. John was my "mentor" as a graduate engineer, and in the last few years I have watched him being promoted towards the top of the company at great speed. In my opinion, John is successful because he is a both technically excellent, and a good team leader. He has authority, but listens, encourages, and supports initiative. If you have a good idea, he is broad minded and long sited enough to support it.

The other person I have dealt with directly concerning the EngD programme (he gave the authorization for me to apply for the programme) is Turlogh O'Brien, a main board Director of the Ove Arup Partnership. Turlogh has the quiet aura of authority which reminds me of the headmaster at my Grammar School who could silence a thousand boys just be entering the main hall! I have been lucky enough to see Turlogh in action in committee, where his quiet authority enables all views to be heard without stronger members dominating the discussion. His summing up of discussion points ensures a clear course of action is understood by all. Turlogh is a busy man, but like John makes time to talk individually with the people he is responsible for, which fosters good working relationships and respect.

If the Belbin analysis was applied to Roger, Turlogh and John I would expect to see Turlogh and John classified primarily as Chairs, and Roger as a Specialist.

My view of the Belbin theory and its potential value to me

I find it very hard to enthuse about Belbin's Team Role Analysis and other people appraisal techniques to which I have been introduced previously. When I put together a project team, I ask for the best engineers and technicians I know - forget about team role analysis, I will take Einstein even if he does not have the right profile for my team!

Belbin has observed the characteristics of a successful team. Yes, a good mix of personalities is helpful, but in my opinion, of secondary importance. I believe good leadership can realise the potential of each individual and of the team as a whole. And if you put a group of people together, the natural leaders become obvious after a short time - the qualities I would look for (subconsciously) are authority, listening skills, intelligence, communication and encouragement.

I was part of the most successful team in the team exercises, which we established had a poor profile according to Belbin. While it is unfair to judge a technique on a single example, my natural scepticism for the analysis was not helped! If we are to consider Belbin further, I would be interested in assessing how people adjust their role according to the make up of a specific group, which is where the analysis could have gone wrong for out team.

I would not apply a Belbin analysis in a business environment as I am not convinced!

"Revealing my potential"

I have lead and been a part of successful teams. I intend to demonstrate further my potential as a team member by delivering and communicating valuable research.

CONCLUSIONS

I enjoyed the first week of the EngD course and value the communications and team role training given. I have covered some of the communications material before, but benefited in particular from the practical exercises. Again, I learned most from the practical team exercises which broadened my experience and prospective on the working of teams. However, I am have yet to be convinced that Belbin's analysis has real value for putting together real industrial teams.

This is a well argued case, logical and sustained. I am sorry you did not get as much out of Belbin as I have. I have found an [illegible] interdisciplinary work team balance is essential. I'm sorry not to have convinced you. That is my fault. Yours [illegible] examination

RP/ENGD/335.wp
15 November 1993

2 LIFE CYCLE ANALYSIS USING PEMS

LIFE CYCLE ASSESSMENT: COMPUTER SOFTWARE MODULES

DEMONSTRATION CASE STUDIES

The problem definition is straightforward. You are asked to compare three packaging scenarios for a liquid foodstuff (fruit juice). These are

(i) Glass bottle versus paper carton (with plastic liner)

(ii) Glass versus PET bottle

(iii) Two different metallic containers (aluminium and steel)

Attention should be given to

(a) specifying the <u>functional unit</u> of use

(b) defining the system boundaries
- from raw material extraction to final product disposal and including all intermediate transport, production, and energy consumption stages

(c) moving from <u>inventory</u> to <u>assessment</u>
- quantifying environmental burdens

(d) analysing and displaying the results of the LCA

Case study (i) should allow for direct re-use of (a portion of) the glass bottles, whilst giving the option of energy recovery from the carton via incineration

Case study (ii) should allow for direct product re-use as well as energy recovery for the polymer product

Case study (iii) should focus on the primary production of metals

ENGD ENVIRONMENTAL TECHNOLOGY PROGRAMME

Assignment 2 - Life Cycle Assessment using PEMS

Richard D Peters, Arup Research & Development

1. INTRODUCTION

Pira International describe PEMS (PIRA Environmental Management System) as a computer model which allows its users to carry out Life Cycle Assessment for products, processes and activities.

In our group (Helen Evans, Zeljko Tufekcic and myself), we used the model to carry an analysis of glass bottles, plastic (PET) bottles and plastic cartons. Computer print outs are attached to this report.

2. ANALYSIS ASSUMPTIONS

Our main assumptions were as follows:

Glass

- use of the PIRA PEMS materials database
- the functional unit was 1000 bottles (equal capacity was assumed for each of the examples in this exercise) weighing 470kg
- 80% of the bottles were re-cycled after each use and 20% went to landfill.
- the bottles were steam washed (no detergent) and the water in and out of the process balanced, so could be ignored
- transport to/from the shop had a utility of 90% because the van that delivered the bottles would also pick up the empties
- plastic caps were used (5 grams)
- bottles were packaged in corrugated cardboard cases holding 12 bottles

Plastic Bottles

- use of the PIRA PEMS materials database
- the functional unit was 1000 bottles weighing 30kg
- 80% of the bottles were re-cycled after each use and 20% were incinerated
- new and used bottles were steam washed (no detergent) and the water in and out of the process balanced, so could be ignored
- transport to/from the shop had a utility of 90% because the van that delivered the bottles would also pick up the empties
- plastic caps were used (5 grams)

- bottles were packaged in corrugated cardboard cases holding 12 bottles
- Energy generated through incineration of the bottles was credited back to the filling process

Plastic Cartons

- use of the PIRA PEMS materials database
- the functional unit was 1000 cartons weighing 25kg
- 100% of the cartons were incinerated after use
- PE laminated bleached paper was used directly to manufacture cartons
- transport to/from the shop had a 50% utility as the van returned from the shop empty
- plastic caps were used (5 grams)
- bottles were packaged in LDPE
- Energy generated through incineration of the cartons was credited back to the filling process

3. OBSERVATIONS CONCERNING VALIDITY OF ANALYSIS

In our analysis the re-cycled plastic bottle is shown to be have the least environmental load. The exercise was a desk study incorporating significant variables that could have been obtained fairly simply with input from the relevant industries. Consequently, I would not attribute any particular value to our results, although the work we did was a useful exercise to learn about the program and carrying out of LCA's.

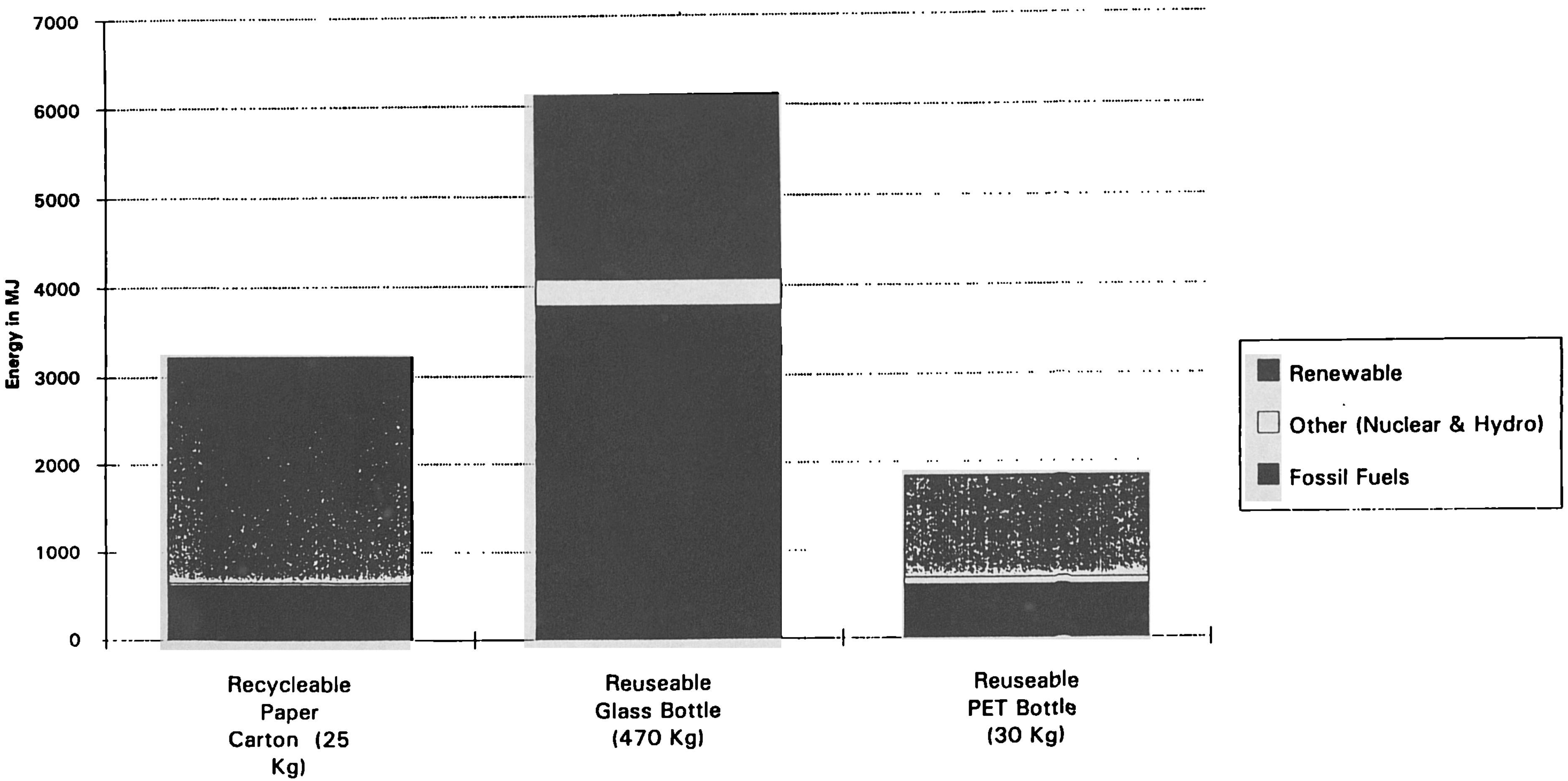
Given industry data, I would still treat results with extreme caution. From our discussions and from the material presented it is obvious that there are extreme variations in the results of LCA analysis, often influenced by the vested interests of the those carrying out the calculations and providing data. Just like political interpretation of health service statistics, comparative LCA's are so open to interpretation though changing of assumptions/system boundaries, that they are at risk of becoming equally useless!

Notwithstanding, LCA is a logical approach to assessing environmental impact, and if applied objectively through environmental as opposed to commercial motives, obviously yields valuable results. It is particularly helpful in establishing the elements of a process that are dominant from the environmental viewpoint so that we can concentrate on reducing the impact of these elements.

4. COMMENTS ON THE LIMITATIONS OF PEMS

The value of PEMS is its database. Although the data is bias for the paper and packaging industries, it is broad enough to have general applications.

Systems Energy Graph



Note - For systems including the incineration of waste with energy recovery, the Net Energy of the System will be shown.

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PEMS does have a poor user interface by today's standards. Although Windows programs, and Excel in particular are user friendly, my experience is, and this program demonstrates that it is difficult to write user friendly macro driven spreadsheet programs for all but simple applications. This manifests itself in very poor editing facilities and a program that in not intuitive to use. If the model is to be developed to further levels of sophistication, PIRA should be looking at C++, etc.

The printed output does not include or properly identify input data which is essential if an analysis is to be checked by the user and others.

The flow diagram and inventory link could be improved. It would be more intuitive to draw the flow diagram first.

The limitation of inputs to five requires additional processes to be defined unnecessarily. The model would benefit from a recycle option in addition to the option to re-use materials. For instance, it should be possible to give credit for glass bottles broken up and used for road building.

5. APPLICATIONS IN MY COMPANY AND RESEARCH PROJECT

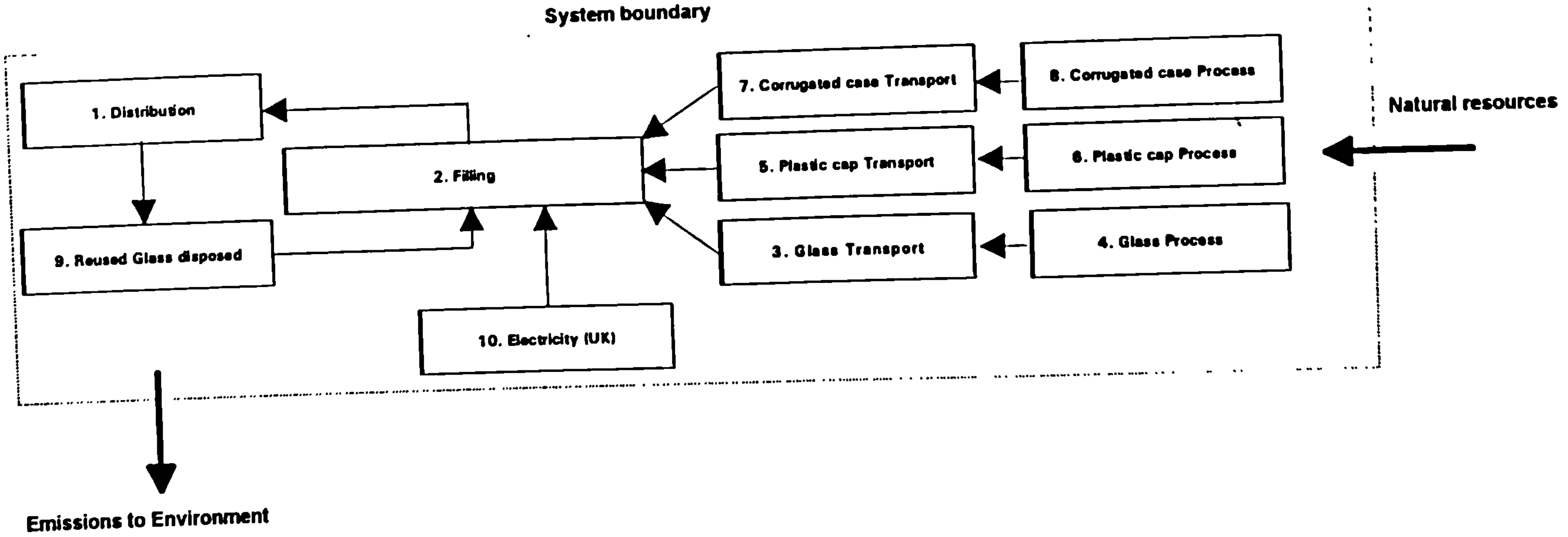
My project is on Vertical Transportation Planning in Buildings. The lift industry has only recently begun to look at green issues, but some manufacturers are already beginning to claim that their systems are "green" by comparison with those of their competitors.

I intend to use LCA, and possibly the PIRA model to identify the dominant environmental issues for the process of moving people up and down buildings. The life of a lift or escalator can be in the region of 20 years, so I expect to find that energy in use is the most dominant factor, although manufacture and transportation will also be considered.

As a consultant engineer writing specifications, I would like to be able to specify a maximum environmental burden associated with supplying and installing a lift, and a second maximum environmental burden for the lift in use measured against a specified passenger traffic profile. (This assumes we can define environmental burden in terms of a single unit, which I believe we will have to if LCA is to come into general use.) To meet this "performance specification", the lift manufacturer would have to use energy efficient motors and control algorithms as well as ensure the materials used and the their transportation are appropriate.

Secondly, environmental burden could be calculated by good planning strategies which require knowledge of actual passenger traffic profiles. This week I made some proposals for lifting a 50 storey building in Indonesia. The alternative solutions are almost endless (express/zoned lifts, shuttle lifts, etc.), but to the best of my knowledge, no one has ever calculated energy consumption, etc. associated with alternative schemes.

Flow Diagram for Re-cyclable Glass



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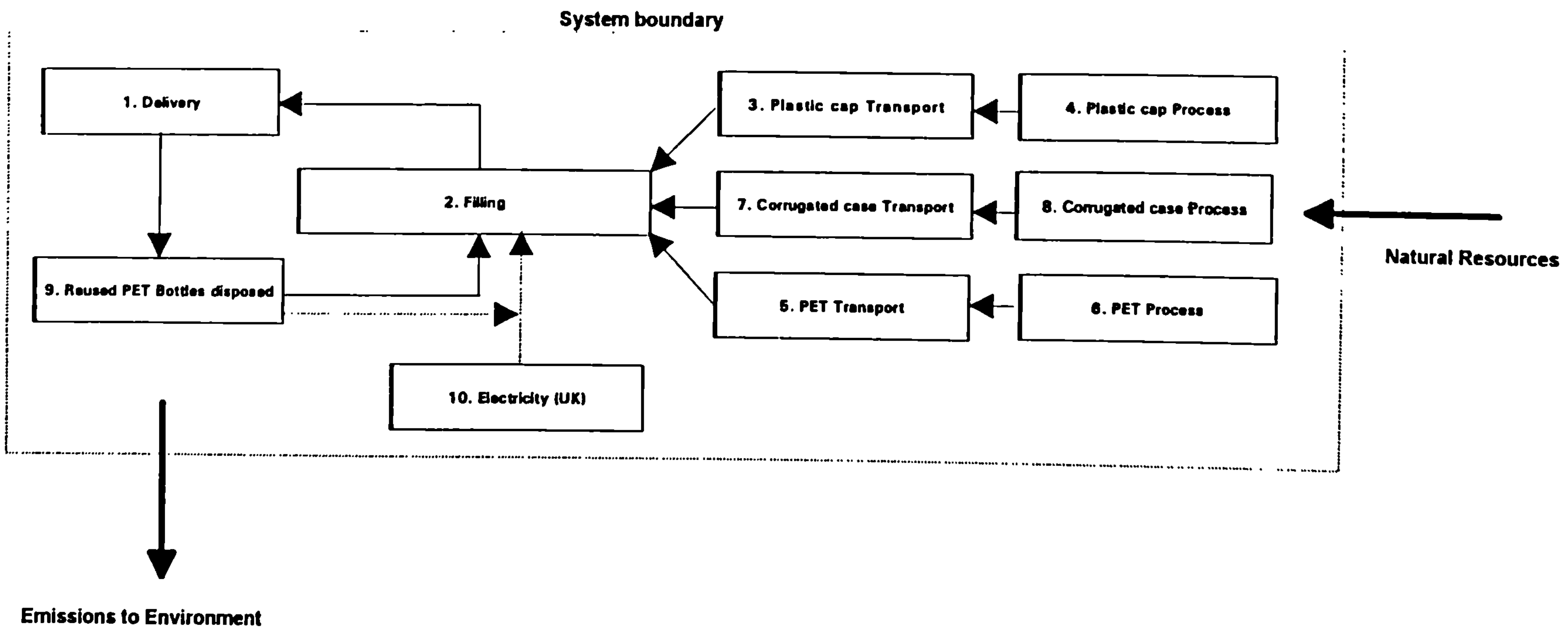
REGLASS.XLS - (11/12/93)

Reuseable Glass Bottle (470 Kg)

			1. Distribution			2. Filling			3. Glass Transport			4. Glass Process			5. Plastic cap Transport	
		TOTAL	NOTE	REF	CAL.	NOTE	REF.	CAL.	NOTE	REF	CAL	NOTE	REF.	CAL.	NOTE	REF.
	INPUTS (CLOSED LOOP)		(MJ)			Electricity (UK)	72 000	70.721								
	(MJ)															
	(Kg)		1000 Bottles *	1000.000	470 000	Glass	90 090	88 490	Glass *	1000 000	88 490				Plastic cap *	1000.000
						Plastic cap	6 005	4.916								
						Corrugated case	23 500	23 083								
						Reused Glass	360.380	353 959								
	INPUTS (STANDARD)	(Kg)														
	Nuclear Electricity (MJ)	178.155		2.317	1.089					3.222	0.285		709 895	62.818		3.222
R	Other/Hydro Electricity (MJ)	115.194		1 605	0.754					2 231	0.197		491.650	43 506		2.231
E	Coal Reserves	42.765		0.425	0.200					0 591	0.052		186.449	16 499		0.591
S	Oil Reserves	27.891		10.014	4.707					13 921	1 232		74.508	6 593		13.921
O	Gas Reserves	25.914		0 028	0.013					0.039	0 003		270.442	23.931		0.039
U	Other Non Renewables	123.214		0.000	0.000					0.000	0.000		1390.647	123.058		0.000
R	Renewable Resources	128.327		0.019	0.009					0.027	0 002		15.566	1.377		0.027
C	Ancillaries	6.558		0.006	0.003					0.009	0.001		53.573	4.741		0.009
E	Water	2871.788		91.298	42.910					126.916	11.231		10644.423	941.921		126.916
S	Air (Net)	398.012		22.178	10.424					30.966	2.740		3395.562	300.472		30.966
	Other	33 188		0.283	0.133					0 394	0 035		124.322	11.001		0.394
	OUTPUTS (CLOSED LOOP)		(MJ)													
	(MJ)															
			(Kg)													
	(Kg)															
	OUTPUTS (STANDARD)															
	Co Product															
	1000 Bottles	470.000	1000 Bottles	1000.000	470.000	1000 Bottles *	478.500	470.000	Glass	1000.000	88.490	Glass *	1000.000	88.490	Plastic cap	1000.000
	Waste water	2858.666		91.298	42.910					126.916	11.231		13219.206	1169.763		126.916
A	CO.	0.714		0.056	0.026					0.207	0.018		2.401	0.212		0.207
I	CO2 (Non Renewable)	243.870		31.496	14.803					43.776	3.874		1539.490	136.229		43.776
R	CO2 (Renewable)	48.444		0.023	0.011					0.032	0.003		18.543	1.641		0.032
B	NOx	2.641		0.553	0.260					0.828	0.073		20.128	1.781		0.828
O	SO2	1.899		0.144	0.068					0.202	0.018		8.646	0.765		0.202
R	VOC	1.715		0.111	0.052					0.105	0.009		15.401	1.363		0.105
N	Dust	1.216		0.035	0.017					0.050	0.004		11.469	1.015		0.050
E	Halides	0.018		0.000	0.000					0.000	0.000		0.167	0.015		0.000
	Other Air	4.430		0.043	0.020					0.059	0.005		19.299	1.708		0.059
O	Oils & greases	0.008		0.002	0.001					0.002	0.000		0.043	0.004		0.002
T	Heavy Metals	0.064		0.000	0.000					0.000	0.000		0.716	0.063		0.000
H	Landfill weight	158.056		0.353	0.166					0.491	0.043		169.550	15.003		0.491
E	Open Loop Outputs	92.642		0.007	0.003	Broken Bottles + Waste Caps	0.455	0.447		0.009	0.001		113.127	10.011		0.009
R	Other Solid	41.493		0.000	0.000					0.000	0.000		1.918	0.170		0.000
W	Other water	1.039		0.001	0.000					0.001	0.000		11.329	1.002		0.001
A	TDS	1.009		0.132	0.062					0.183	0.016		3.941	0.349		0.183
T	TSS	0.136		0.000	0.000					0.000	0.000		0.124	0.011		0.000
E	COD	0.024														
R	BOD	0.004														
	Landfill Volume (dm3)	143 077		0 441	0.207					0.614	0 054		204.780	18.121		0.814
	MASS BALANCE						0 000	0 000					-0 005			

	Reuseable Glass Bottle (470 Kg)		6. Plastic cap Process			7. Corrugated case Transport			8. Corrugated case Process			9. Reused Glass disposed		100 00%	10 Electricity (UK)		
		CAL	NOTE	REF.	CAL.	NOTE	REF	CAL.	NOTE	REF.	CAL	NOTE	REF	CAL	NOTE	REF.	CAL.
	INPUTS (CLOSED LOOP)																
	(MJ)													116.041			
	(Kg)	4.916				Corrugated case	1000.000	23 083					1000 000	470 000			
	INPUTS (STANDARD)																
	Nuclear Electricity (MJ)	0.016		992.405	4.879		3.222	0 074		4062.097	93.764		6.736	0.782		204.305	14.449
R	Other/Hydro Electricity (MJ)	0 011		687.307	3.379		2.231	0 051		2813 276	64.938		4 665	0.541		25.674	1.816
E	Coal Reserves	0 003		184.537	0.907		0 591	0 014		745.726	17 213		1 244	0.144		109.336	7.732
S	Oil Reserves	0.068		1494.489	7.347		13.921	0 321		287.131	6 628		3 662	0 425		8.063	0.570
O	Gas Reserves	0 000		156.637	0.770		0.039	0.001		50.470	1.165		0.087	0.010		0.275	0.019
U	Other Non Renewables	0 000		0.922	0 005		0.000	0.000		6.584	0.152		0.000	0.000		0.000	0.000
R	Renewable Resources	0.000		8 832	0 043		0.027	0.001		5496.974	126.884		0.057	0.007		0.046	0.003
C	Ancillaries	0 000		16.183	0.080		0.009	0 000		75.076	1.733		0.002	0.000		0.005	0.000
E	Water	0.624		104343.286	512.961		126.916	2.930		48984.288	1130.682		36 042	4.182		344.267	24.347
S	Air (Net)	0.152		1829.162	8 992		30.966	0.715		2713 634	62.638		9 493	1.102		152.394	10.777
	Other	0 002		123 052	0 605		0.394	0.009		699.697	16.151		0 828	0.096		72.907	5.156
	OUTPUTS (CLOSED LOOP)															1000.000	70.721
	(MJ)																
	(Kg)																
	OUTPUTS (STANDARD)											Reused Glass		353.959			
	Co Product																
	1000 Bottles	4.916	Plastic cap *	1000.000	4.916	Corrugated case	1000.000	23.083	Corrugated case	1000.000	23.083						
	Waste water	0.624		104360.942	513.048		126.916	2.930		47206.068	1089.636		36.042	4.182		344.202	24.342
A	CO.	0.001		2.482	0.012		0.207	0.005		18.586	0.429		0.059	0.007		0.048	0.003
I	CO2 (Non Renewable)	0.215		2404.639	11.821		43.776	1.010		2465.329	56.906		13.840	1.806		243.281	17.205
R	CO2 (Renewable)	0.000		10.521	0.052		0.032	0.001		2024.254	46.725		0.067	0.008		0.055	0.004
B	NOx	0.004		15.945	0.078		0.828	0.019		15.092	0.348		0.214	0.025		0.726	0.051
O	SO2	0.001		12.187	0.060		0.202	0.005		25.059	0.578		0.083	0.010		2.750	0.195
R	VOC	0.001		12.044	0.059		0.105	0.002		7.641	0.176		0.039	0.004		0.671	0.047
N	Dust	0.000		0.193	0.001		0.050	0.001		7.554	0.174		0.013	0.001		0.027	0.002
E	Halides	0.000		0.049	0.000		0.000	0.000		0.085	0.002		0.000	0.000		0.012	0.001
	Other Air	0.000		18.541	0.091		0.059	0.001		79.441	1.834		0.016	0.002		10.663	0.768
O	Oils & greases	0.000		0.293	0.001		0.002	0.000		0.052	0.001		0.001	0.000		0.001	0.000
T	Heavy Metals	0.000		0.056	0.000		0.000	0.000		0.015	0.000		0.000	0.000		0.002	0.000
H	Landfill weight	0.002		143.819	0.707		0.491	0.011		873.253	20.157		1000.241	116.069		83.368	5.896
E	Open Loop Outputs	0.000		154.773	0.761		0.009	0.000		3527.170	81.416		0.020	0.002		0.016	0.001
R	Other Solid	0.000		0.148	0.001		0.000	0.000		1786.542	41.238		0.722	0.084		0.005	0.000
W	Other water	0.000		0.254	0.001		0.001	0.000		1.027	0.024		0.002	0.000		0.150	0.011
A	TDS	0.001		20.040	0.099		0.183	0.004		17.256	0.398		0.057	0.007		1.040	0.074
T	TSS	0.000		0.126	0.001		0.000	0.000		5.160	0.119		0.001	0.000		0.075	0.005
E	COD			0.599	0.003					0.898	0.021						
R	BOD			0.196	0.001					0.126	0 003						
	Landfill Volume (dm3)	0 003		179 773	0.884		0 614	0.014		1139 254	26.297		776.677	90.127		104.210	7.370
	MASS BALANCE			0 048	0 000					-0 004							

Flow Diagram for Re-cyclable PET Bottles



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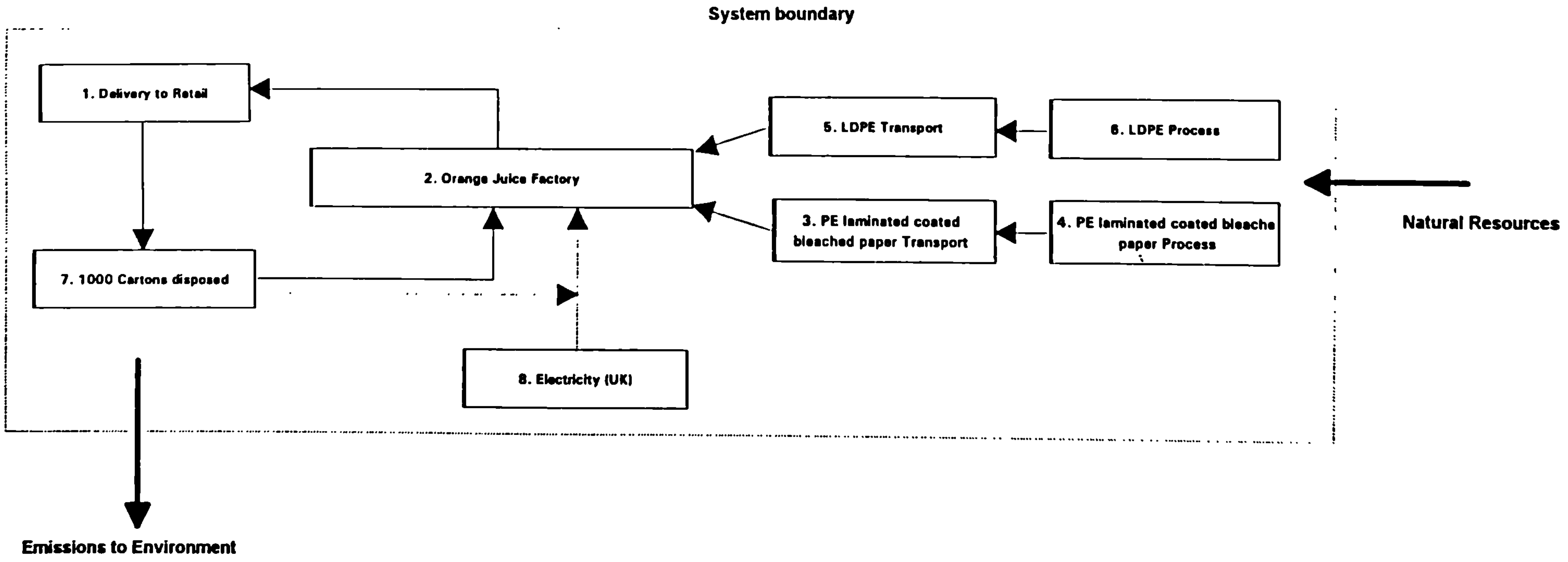
Reuseable PET Bottle (30 Kg)

			1. Delivery			2. Filling			3. Plastic cap Transport			4. Plastic cap Process			5. PET Transport	
		TOTAL	NOTE	REF.	CAL.	NOTE	REF.	CAL.	NOTE	REF.	CAL.	NOTE	REF.	CAL.	NOTE	REF.
	INPUTS (CLOSED LOOP)		(MJ)			Electricity (UK)	72.000	40.374								
	(MJ)															
	(Kg)		1000 Bottles *	1000.000	30.000	Plastic cap	5 005	2 807	Plastic cap *	1000.000	2.807				PET *	1000.000
						PET	5.005	2 807								
						Reused PET Bottles	20 020	11.226								
						Corrugated case	23.500	13.178								
	INPUTS (STANDARD)	(Kg)														
	Nuclear Electricity (MJ)	39.530		5.369	0.161					5.091	0.014		992.405	2.785		3.222
R	Other/Hydro Electricity (MJ)	39.770		3.719	0.112					3 526	0.010		687.307	1.929		2.231
E	Coal Reserves	0.148		0.985	0.030					0.934	0 003		184 537	0.518		0.591
S	Oil Reserves	11.680		23.201	0.696					22.001	0 062		1494.489	4.194		13.921
O	Gas Reserves	1.955		0.066	0.002					0.062	0 000		156.637	0.440		0.039
U	Other Non Renewables	0.091		0.000	0.000					0.000	0.000		0.922	0 003		0.000
R	Renewable Resources	72.634		0.045	0.001					0 042	0.000		8.832	0.025		0.027
C	Ancillaries	1.548		0.015	0.000					0.014	0.000		18 183	0.045		0.009
E	Water	1534.612		211.527	6.346					200.580	0.583		104343.286	292.844		126.916
S	Air (Net)	59.824		51.609	1.548					45.943	0.129		1829.162	5.134		30.966
	Other	2.766		0 657	0.020					0.623	0.002		123.052	0.345		0.394
	OUTPUTS (CLOSED LOOP)		(MJ)													
	(MJ)															
			(Kg)													
	(Kg)															
	OUTPUTS (STANDARD)															
	Co Product															
	1000 Bottles	30.000	1000 Bottles	1000.000	30.000	1000 Bottles *	53.500	30.000	Plastic cap	1000.000	2.807	Plastic cap *	1000.000	2.807	PET	1000.000
	Waste water	1612.047		211.527	6.346					200.580	0.563		104360.942	292.893		126.916
A	CO.	0.326		0.345	0.010					6.295	0.018		2.482	0.007		0.207
I	CO2 (Non Renewable)	69.632		72.961	2.189					60.426	0.170		2404.639	6.749		43.776
R	CO2 (Renewable)	28.910		0.053	0.002					0.050	0.000		10.521	0.030		0.032
B	NOx	0.390		1.379	0.041					0.825	0.002		15.945	0.045		0.828
O	SO2	0.153		0.337	0.010					0.122	0.000		12.187	0.034		0.202
R	VOC	0.123		0.175	0.005					0.721	0.002		12.044	0.034		0.106
N	Dust	0.105		0.084	0.003					0.000	0.000		0.193	0.001		0.060
E	Halides	0.001		0.000	0.000					0.000	0.000		0.049	0.000		0.000
	Other Air	0.326		0.099	0.003					0.094	0.000		18.541	0.052		0.069
O	Oils & greases	0.002		0.004	0.000					0.004	0.000		0.293	0.001		0.002
T	Heavy Metals	0.000		0.000	0.000					0.000	0.000		0.056	0.000		0.000
H	Landfill weight	4.153		0.618	0.025					0.776	0.002		143.819	0.404		0.491
E	Open Loop Outputs	47.015		0.016	0.000	Waste Caps + Waste Bottles	0.030	0.017		0.016	0.000		154.773	0.434		0.009
R	Other Solid	23.547		0.001	0.000					0.001	0.000		0.148	0.000		0.000
W	Other water	0.126		0.001	0.000					0.001	0.000		0.254	0.001		0.001
A	TDS	0.242		0.305	0.009					0.289	0.001		20.040	0.056		0.183
T	TSS	0.062		0.001	0.000					0.001	0.000		0.126	0.000		0.000
E	COD	0.022											0.599	0.002		
R	BOD	0.004											0.196	0.001		
	Landfill Volume (dm3)	5.820		1.023	0.031					0.970	0.003		179.773	0.505		0.614
	MASS BALANCE	0.000			0.000					0.000	0.000		0.048	0.000		

	Reuseable PET Bottle (30 Kg)		6. PET Process			7. Corrugated case Transport			8. Corrugated case Process			9. Reused PET Bottles disposed		100.00%	10. Electricity (UK)		
		CAL.	NOTE	REF.	CAL.	NOTE	REF	CAL.	NOTE	REF.	CAL.	NOTE	REF.	CAL.	NOTE	REF.	CAL.
	INPUTS (CLOSED LOOP)												Surplus energy produced in the waste management				
	(MJ)													18.774			
	(Kg)	2.807				Corrugated case	1000 000	13.178					1000 000	30.000			
	INPUTS (STANDARD)																
	Nuclear Electricity (MJ)	0.009		1722.599	4.635		3 222	0.042		4062.097	53.629		0.810	0.015		204.305	-21.881
R	Other/Hydro Electricity (MJ)	0.006		1193.016	3.348		2.231	0.029		2813 276	37.072		0.561	0 011		25.674	-2.747
E	Coal Reserves	0 002		519.414	1.458		0.591	0 008		745.726	9.827		0.149	0 003		109.336	-11.699
S	Oil Reserves	0 039		1218.240	3.419		13.921	0 183		287.131	3.784		3.500	0 066		8.063	-0.883
O	Gas Reserves	0 000		312.412	0.877		0.039	0.001		50.470	0.665		0 010	0.000		0.275	-0.029
U	Other Non Renewables	0.000		0.758	0.002		0.000	0.000		6.684	0.087		0.000	0 000		0.000	
R	Renewable Resources	0.000		62.475	0.175		0.027	0 000		5496.974	72.437		0.007	0.000		0.046	-0.005
C	Ancillaries	0.000		182.686	0.613		0 009	0.000		75.076	0.989		0.002	0.000		0.005	-0.001
E	Water	0.356		222186.011	623.674		126.916	1.672		48984.288	645.494		31.911	0.599		344.287	-38.837
S	Air (Net)	0.087		3042.132	8.638		30.966	0.408		2713.634	35.759		1306.449	24.627		152.394	-16.306
	Other	0.001		345,336	0.972		0.394	0 005		699.897	9.220		0.099	0 002		72.907	-7.801
	OUTPUTS (CLOSED LOOP)												31400.000	589.498		1000.000	-107.001
	(MJ)																
	(Kg)																
	OUTPUTS (STANDARD)											Reused PET Bott		11.226			
	Co Product																
	1000 Bottles	2.807	PET *	1000.000	2.807	Corrugated case	1000.000	13.178	Corrugated case	1000.000	13.178						
	Waste water	0.356		222475.235	624.386		126.916	1.672		47206.068	622.061		31.911	0.599		344.202	-38.830
A	CO.	0.001		8.157	0.023		0.207	0.003		18.586	0.245		1.308	0.025		0.048	-0.005
I	CO2 (Non Renewable)	0.123		3610.634	10.133		43.776	0.577		2466.329	32.487		2303.007	43.236		243.281	-26.031
R	CO2 (Renewable)	0.000		74.422	0.209		0.032	0.000		2024.254	26.675		0.008	0.000		0.055	-0.006
B	NOx	0.002		24.651	0.069		0.828	0.011		15.092	0.199		5.202	0.098		0.728	-0.078
O	SO2	0.001		21.767	0.061		0.202	0.003		25.059	0.330		0.411	0.008		2.750	-0.294
R	VOC	0.000		17.967	0.050		0.105	0.001		7.641	0.101		0.030	0.001		0.671	-0.072
N	Dust	0.000		1.018	0.003		0.050	0.001		7.554	0.100		0.063	0.001		0.027	-0.003
E	Halides	0.000		0.288	0.001		0.000	0.000		0.085	0.001		0.000	0.000		0.012	-0.001
	Other Air	0.000		137.214	0.385		0.059	0.001		79.441	1.047		0.015	0.000		10.863	-1.162
O	Oils & greases	0.000		0.268	0.001		0.002	0.000		0.052	0.001		0.001	0.000		0.001	
T	Heavy Metals	0.000		0.124	0.000		0.000	0.000		0.015	0.000		0.000	0.000		0.002	
H	Landfill weight	0.001		401.088	1.126		0.491	0.006		873.253	11.507		0.123	0.002		83.368	-8.920
E	Open Loop Outputs	0.000		30.266	0.085		0.009	0.000		3527.170	46.480		0.002	0.000		0.015	-0.002
R	Other Solid	0 000		1.629	0.005		0.000	0.000		1786.542	23.542		0.000	0.000		0.005	-0.001
W	Other water	0.000		45.488	0.128		0.001	0.000		1.027	0.014		0.000	0.000		0.150	-0.016
A	TDS	0.001		19.890	0.056		0.163	0.002		17.256	0.227		0.046	0.001		1.040	-0.111
T	TSS	0.000		0.454	0.001		0.000	0.000		5.160	0.068		0.000	0.000		0.075	-0.008
E	COD			2.914	0.008					0.898	0.012						
R	BOD			0.470	0.001					0.126	0.002						
	Landfill Volume (dm3)	0 002		501.359	1.407		0.614	0.008		1139.254	15.013		0.154	0.003		104.210	-11.161
	MASS BALANCE			0 002	0.000			0.000		-0.004				0.000			

Flow Diagram for Paper Carton



Helen Evans
Zeljko Tufekcic
Richard Peters

PAPCART XLS - (11/12/[illegible])

Recyclable Paper Carton (25 Kg)

			1 Delivery to Retail			2 Orange Juice Factory			3 PE laminated coated bleached paper Transport			4. PE laminated coated bleached paper Process	
		TOTAL	NOTE	REF.	CAL	NOTE	REF	CAL	NOTE	REF	CAL	NOTE	REF.
	INPUTS (CLOSED LOOP)		(MJ)			Electricity (UK)	100 000	92 593					
	(MJ)												
	(Kg)		1000 Cartons	1000 000	25 000	PE laminated coated bleached paper	25 250	23 380	PE laminated c	1000 000	23 380		
						LDPE	2 000	1 852					
	INPUTS (STANDARD)	(Kg)											
	Nuclear Electricity (MJ)	11.639		9.665	0 242					3 222	0 075		956.508
R	Other/Hydro Electricity (MJ)	15.694		6.693	0 167					2 231	0 052		662.447
E	Coal Reserves	-2.380		1.773	0.044					0 591	0 014		183.621
S	Oil Reserves	14.701		41.762	1 044					13 921	0 325		468.813
O	Gas Reserves	1.124		0.118	0 003					0 039	0 001		35.444
U	Other Non Renewables	1.636		0.000	0 000					0 000	0 000		69.903
R	Renewable Resources	160.759		0.080	0 002					0.027	0.001		6874.891
C	Ancillaries	2.978		0.027	0 001					0 009	0 000		127.030
E	Water	2547.218		380.748	9.519					126.916	2 967		97369.657
S	Air (Net)	87.279		92.897	2.322					30 966	0.724		2852.037
	Other	-1.557		1 182	0 030					0 394	0 009		123 725
	OUTPUTS (CLOSED LOOP)		(MJ)										
	(MJ)												
			(Kg)										
	(Kg)												
	OUTPUTS (STANDARD)												
	Co Product												
	1000 Cartons	25.000	1000 Cartons	1000.000	25.000	1000 Cartons *	27.000	25.000	PE laminated c	1000.000	23.380	PE laminated co	1000.000
	Waste water	2587.870		380.748	9.519					126.916	2.967		99106.851
A	CO.	0.718		0.621	0.016					0.207	0.005		28.541
I	CO2 (Non Renewable)	47.719		131.329	3.283					43.776	1.023		1481.946
R	CO2 (Renewable)	103.569		0.096	0.002					0.032	0.001		3239.184
B	NOx	0.439		2.483	0.062					0.828	0.019		13.132
O	SO2	0.112		0.606	0.015					0.202	0.005		10.201
R	VOC	0.118		0.315	0.008					0.105	0.002		5.595
N	Dust	0.283		0.150	0.004					0 050	0 001		11.921
E	Halides	0.007		0.000	0.000					0 000	0.000		0 234
	Other Air	0.023		0.178	0.004					0 059	0 001		29.325
O	Oils & greases	0.003		0.007	0.000					0.002	0.000		0.086
T	Heavy Metals	0.000		0.000	0.000					0.000	0.000		0.013
H	Landfill weight	11.901		1.473	0.037					0.491	0 011		666.333
E	Open Loop Outputs	1.946		0.028	0.001	Waste Cartons	0.250	0.231		0 009	0 000		70.739
R	Other Solid	56.209		0.001	0.000					0.000	0 000		2404.132
W	Other water	-0.003		0.002	0.000					0.001	0.000		0.247
A	TDS	0 675		0 549	0 014					0.183	0 004		29.324
T	TSS	0.165		0.001	0.000					0 000	0 000		7.273
E	COD	0.003											0.080
R	BOD	0 001											0 026
	Landfill Volume (dm3)	14 873		1 841	0 046					0 614	0 014	PAPCART.XLS ·	832.789
	MASS BALANCE	0 001									0 000		0 043

	Recyclable Paper Carton (25 Kg)		5 LDPE Transport			6 LDPE Process			7. 1000 Cartons disposed		100.00%	8 Electricity (UK)		
		CAL	NOTE	REF	CAL	NOTE	REF	CAL	NOTE	REF.	CAL	NOTE	REF	CAL.
	INPUTS (CLOSED LOOP)									Surplus energy produced in the waste managemen				
	(MJ)													
											25 000			
	(Kg)		LDPE *	1000.000	1 852				1000 Cartons	1000 000	25 000			
	INPUTS (STANDARD)													
	Nuclear Electricity (MJ)	22.363		5 091	0.009		1288.737	2.387		1 142	0 029		204 305	-13.465
R	Other/Hydro Electricity (MJ)	15 488		3 526	0 007		892 537	1 653		0 791	0 020		25.674	-1.692
E	Coal Reserves	4 293		0 934	0 002		252 528	0 468		0 210	0 005		109 336	-7.206
S	Oil Reserves	10 961		22.001	0 041		1497 665	2 773		3.509	0 088		8 063	-0.531
O	Gas Reserves	0 829		0 062	0 000		167.135	0 310		0 014	0 000		0 275	-0.018
U	Other Non Renewables	1 634		0 000	0 000		0 932	0 002		0 000	0 000		0 000	
R	Renewable Resources	160.732		0.042	0.000		14 521	0 027		0 010	0 000		0.046	-0.003
C	Ancillaries	2 970		0.014	0.000		3 907	0 007		0 002	0 000		0.005	
E	Water	2276.467		200.580	0 371		151081.136	279 780		32 142	0.804		344.267	-22.690
S	Air (Net)	66.680		45.943	0 085		1821.703	3.374		965 527	24.138		152.394	-10.044
	Other	2 893		0 623	0 001		168 388	0 312		0 140	0 003		72 907	-4.805
	OUTPUTS (CLOSED LOOP)													
	(MJ)									25360.000	634.000		1000.000	-65.907
	(Kg)													
	OUTPUTS (STANDARD)													
	Co Product													
	1000 Cartons	23.380	LDPE	1000.000	1.852	LDPE *	1000.000	1.852						
	Waste water	2317.081		200.580	0.371		151099.234	279.813		32.142	0.804		344.202	-22.685
A	CO.	0.667		6.295	0.012		2.493	0.005		0.683	0.017		0.048	-0.003
I	CO2 (Non Renewable)	34.647		60.425	0.112		2572.859	4.765		796.918	19.923		243.281	-16.034
R	CO2 (Renewable)	75.731		0.050	0.000		17.298	0.032		1112.261	27.807		0.065	-0.004
B	NOx	0.307		0.825	0.002		16.098	0.030		2.703	0.068		0.728	-0.048
O	SO2	0.238		0.122	0.000		13.975	0.026		0.368	0.009		2.750	-0.181
R	VOC	0.131		0.721	0.001		10.514	0.019		0.030	0 001		0.671	-0.044
N	Dust	0.279		0.000	0.000		0.178	0.000		0.040	0.001		0.027	-0.002
E	Halides	0.005		0.000	0.000		0.070	0.000		0.075	0.002		0.012	-0.001
	Other Air	0.686		0.094	0.000		25.456	0.047		0.015	0.000		10.863	-0.716
O	Oils & greases	0.002		0.004	0.000		0.294	0.001		0.001	0.000		0.001	
T	Heavy Metals	0.000		0.000	0.000		0.058	0.000		0.000	0.000		0.002	
H	Landfill weight	15.579		0.776	0.001		195.065	0.361		56.229	1.406		83.368	-5.495
E	Open Loop Outputs	1.654		0.015	0.000		32.880	0.061		0.003	0.000		0.015	-0.001
R	Other Solid	56.208		0.001	0.000		0.258	0.000		0.041	0 001		0 005	
W	Other water	0.006		0.001	0.000		0.338	0.001		0.000	0.000			
A	TDS	0 686		0.289	0.001		20.674	0.038		0.000	0.000		0.150	-0.010
T	TSS	0.170		0.001	0.000		0.173	0.000		0 047	0.001		1.040	-0.069
E	COD	0.002					0.601	0.001		0.000	0.000		0.075	-0.005
R	BOD	0 001					0.196	0.000						
	Landfill Volume (dm3)	19 470		0.970	0 002		243 830	0.452		70.286	1.757		104 210	-6.868
	MASS BALANCE	0 001		0 000			0 002	0 000		0 000				

3 GLOBAL MONITORING STUDY

14 Case Study

Water Supply Situation
in
Province of Mbindi, Zarunda

14.1 Introduction

In the following you will find background information about health and water supply situation in the province of Mbindi, Zarunda. The participants are requested to simulate being consultants for the government for a short period of time. The terms of reference for the groups are to work out an appropriate drinking water quality surveillance scheme for the given province.

A) Define and list the responsibilities of your advisory team.

B) Define the budget of the surveillance work, covering staff salaries, operation and maintenance of the inspection, remedial activities and monitoring work.

C) Define the criteria which you will adopt for selecting villages in the pilot project area. How will you increase surveillance ?

✗ D) Design appropriate water quality standards for use in the area.

E) Design appropriate inspection forms for the local survey teams.

F) *Define the organizational structure and composition of the survey teams.*

G) Take into consideration the location of water sources and the distribution of the population in your design of the sampling and inspection programme.

H) Consider introducing remedial action plan including operation and maintenance of private water facilities.

I) Define a training programme for the local surveillance staff.

J) Discuss and indicate the help and collaboration you expect from international and bilateral agencies.

The groups are expected to submit report on their advisory work and to present the report for discussion in a accordance with the course programme.

14.2 The Republic of Zarunda

14.2.1 History and Geography

The Democratic People's Republic of Zarunda has a population of 6.5 millions. The country has been an independent state since 1945 and following a popular military coup against a corrupt regime in 1979 civilian rule was established in 1982. Since 1982, the country has made a good progress in economic development and the Government now places a very high priority on health and education.

14.2.2 Economy

The Gross National Product of Zarunda, which was 280 US$ pr. person in 1983, has been increasing by 1.2 % pr. year. The country economy is based on production of coffee, cotton, sisal, tobacco, cashew nut and different fruits and spices. More than 80 % of all export income derives from these cash crop export. Copper mining play a secondary role. Manufacturing output remains low. Foreign debt has decreased since 1979 from 30.5 % of GNP to 22.6 % in 1985.

14.2.3 Socioculture

The official language of Zarunda is Kiswahili, however, some Arabic and much tribal Bantu languages are spoken. English is spoken particularly in the capital city of Zarunda. Despite rapid increases in literacy in the capital, adult literacy in the country is only 42 %.

The annual growth rate of the entire population is 1.9 % (1980 - 1985), but that of Ndarashu is higher at 3.2 %. Due to the war in the neighboring country of Kenigeni, some 55,000 refuges have entered the central and northern provinces of Zarunda since 1981. Many of these refugees have semi-permanent status in camps supervised by international relief organizations.

42 % of the economically active labor force is involved in agriculture. There has been no acute food shortage since 1974 and calories available per head of population are approximately 2 % greater than estimated requirements. There are only 26 trained engineers and scientists for every 100,000 population (compare with the US which has more than 200).

Life expectancy in Zarunda is 51 for men and 54 for women (compare with Denmark with 74 for men and 77 for women). Infant mortality reduced by 35 % between 1979 and 1985 and is presently less than 80 per 1000 live births. The improvements are thought to be mostly due to increases in health care provision in Richardville and the success of ORT schemes in the southern and western provinces.

14.3 The Province of Mbindi

Mbindi is the least developed and poorest of the 7 regions of Zarunda. There are 550 villages in Mbindi spread over an area of 21,000 km^2. Mbindi has a population of 340,000 of whom 19,000 are refugees living in camps around the northern border. The population of the provincial capital Ndarashu is 90,000, but during the dry season this may increase to more than 120,000. 70 % of the villages in Mbindi have a population of less than 500 people and 20 % have a population in a range 500-1000 persons.

The provence is tropical. There is desert to the west and in the south-east of the Province are the mountains of Sulu. Mbindi relies heavily on substance agriculture. There is no access to ocean ports and there is no railway (although there is a plan to extend the railway from the western province of Nhugo to Ndarashu). Road transport to the capital takes 36-48 hours and is largely on unmade roads. The State airline Zarundaair flies to Ndarashu two times per week, and intends to increase this frequency to four times per week in 1988.

All transport is unreliable during the wet season, especially air travel. Rainfall is restricted to the months of March - June, and unlike many countries of the region, it has not failed in recent times.

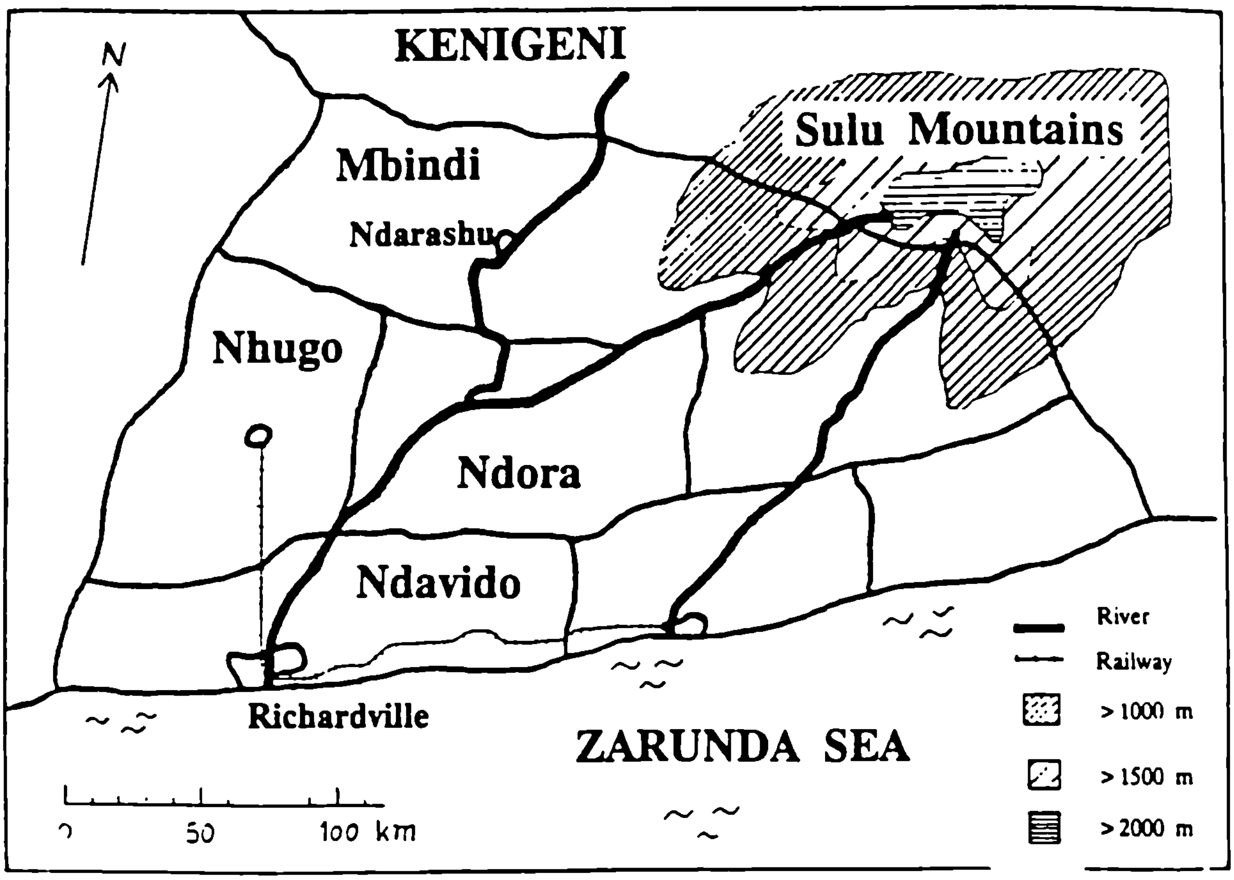


FIG. 14 1 Map of the Democratic People's Republic of Zarunda

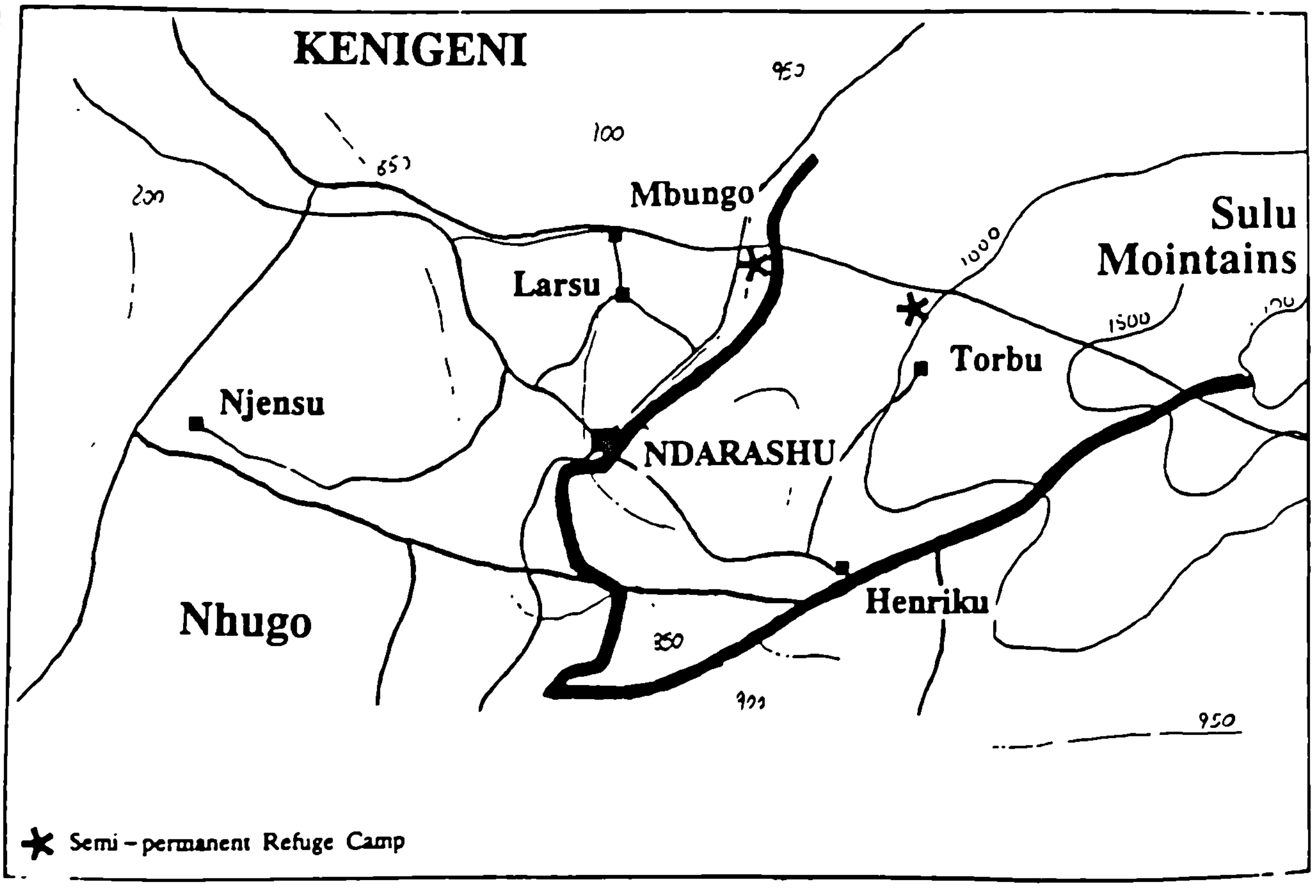


FIG. 14 2 Map of the province of Mbindi in Zarunda.

14.4 Health in Mbindi

In Zarunda as a whole, 25,000 deaths are directly attributable to diarrhoeal disease every year. An estimated 70% of infant mortality (0 - 5 year age group) is associated with diarrhoeal disease. Although there are no reliable statistics for Mbindi, there is no reason to suspect that the problem of high infant mortality due to diarrhoea is any less in the Province.

Indeed, many consultants and development agencies believe that the health status of the people of Mbindi is actually much worse than the rest of the country. In particular, several reports have suggested that a high proportion of diarrhoeal disease in Mbindi is water related. This includes endemic giardiasis in many areas, and there have been outbreaks of acute gastro-enteritis and typhoid in Kenigeni refugee camps.

A recent survey of nutritional status in Ndarashu found some evidence that cases of malnutrition were mostly clinical (caused by recurrent diarrhoeal disease) rather than due to dietary deficiency. Special blame was placed on the town's water supply which is generally believed to be a disaster; the treatment works break down frequently, supplying untreated surface water to the population. It has been estimated that approximately 60% of all patients admitted to Ndarashu hospital suffer from diseases associated with poor water supply and sanitation. Of the 980 children admitted to the paediatric ward in 1985/86. 491 were cases of acute gastro-enteritis. There are no equivalent data for the rural areas.

Due to certain political difficulties during the last 10 years, the ministry of Health has not functioned well in Mbindi. They have insufficient resources and major problems of transportation in the rural areas. A system of Primary Health Care (PHC) is being developed slowly. A network of rural health centres has been established, but to date these have been principally concerned with the provision of basic drugs and oral rehydration salt sachets (Oralyte). The health centres have not been directly involved in public health initiatives concerned with water or sanitation

The Ministry of Health in Richardville is trying to promote programmes of Control of Diarrhoeal Disease (CCD) and Extended Programme of Immunization (EPI) for the whole country, but a large amount of training and major expansion of the Regional Ministry of Health is required in order to establish the basis for PHC in Mbindi.

14.5 Water Resources

Typical rural water supplies are based on dams and dug wells in the rural Mbindi. It has been estimated that only 2 % of surface water in Mbindi is used for water resources (usually by damming of rivers during the wet season or diversion of rivers into reservoirs). The remainder of surface water is lost through drainage to the River Mbindi seepage and evaporation.

The aquifers of the region are productive and accessible (usually 10 - 30 metres below surface). They are relatively unexploited at present, but there are no plans to install handpumps in 300 more rural villages by 1995.

The responsibility for management of water resources in Mbindi resides with the Mbindi Regional Water Authority (BRWA). It is directly responsible to the Regional Government; but also forms a constituent part of the national Department of Water Supply and Sanitation (part of the Ministry of Public Works and Development).

14.6 Water Demand

The resources described in table 1 only provide 38 % of existing water demand. They do not include water abstracted from simple dug wells, brick wells or private supplies. However, the scarcity of water resources is responsible for lower consumption rates than normally considered essential. In a survey of 125 rural villages, the average per capita consumption of water was observed to be only 15 litres per day.

Population projections imply that water demand for human consumption will rise to 19.5 million m^3 per annum by the year 2000. Meanwhile, animal consumption of water is expected to rise from 23.4 million m^3 (in 1987) to 28.1 million m^3 in the year 2000. These figures are based on per capita consumption of 70 litres per person per day in the urban sector, 40 lpppd in the peri-urban sector and 25 lpppd in the rural sector. In the analysis, animals are allowed the following volumes of water per day: cattle - 35 litres, camels - 60 litres, sheep and goats - 15 litres per day.

Existing resources which are the responsibility of the Regional Water Authority are illustrated in Table 14.1

TAB. 14.1 Existing water resources in the Province of Mbindi (Data from the Mbindi Regional Water Authority - excludes wells etc).

	Rural Area	Urban Area	Total
Mountain Stream/Spring	5	0	5
Surface reservoirs			
Water Yards	133	0	133
Lakes & Dams	21	2	23
Rivers	2	2	4
Dug Wells	Many	Many	Many
Boreholes			
Shallow Aquifer	170	10	180
Deep Aquifer			

TAB. 14.2 Water quality data from the Ndarashu urban water supply and from household containers in five rural villages of Mbindi.

	Ndarashu Town	Njeasu Village	Henriku Village	Torbu Village	Larsu Village	Mbungo Village
Population	90,000	580	1500	400	270	750
Water sources Coverage (%)						
Dams	60	-	60	10	10	20
Dug Wells	10	90	20	90	60	80
Deep Boreholes	30	-	-	0	30	0
Water Quality of Main Sources:						
FC (n)[a]	0-450(41)	0-1(13)	250-1720(7)	12-2000(5)	50-420(3)	71-981(5)
Free Cl (n)	0-0.3(120)	0*	0*	0*	0*	0*
Turbidity[b] (n)	<5-350(35)	<5(13)	25-700(7)	<5-400(5)	50-350(0)	90-500(5)
Alkalinity[c] mg/l	120-200	205-340	50-150	200-500	340-420	240-390
Chloride mg/l	100-200	110-120	140-205	300-350	250-300	120-250
1.5 Fluoride	0.1-2	0.5-1.5	4-17	6-12	0.7-2.2	0.8-1.8
50 Nitrate mgN/l	0.5-2	5-15	2-8	1-7	5-10	4-6
3 Nitrite	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ammonia	n.d.	0-3	n.d.	0.5-0.8	2-5	0.5-0.7
Hydrogen Sulfide	n.d.	n.d.	2-2.5	n.d.	1-6	-
Sulphate	33-46	20-50	25-60	19-30	30-65	25-70
Calcium	20-30	40-80	50-90	50-60	80-90	60-80
Magnesium	5-15	10-20	20-25	15-22	10-18	8-16
Iron	n.d.	0.1-0.2	n.d.	n.d.	4-6	3-8
0.5 Manganese	n.d.	n.d.	n.d.	n.d.	0.2-0 4	0.9-1

[a] n gives the number of samples taken during last year. [b] as NTU. [c] as calcium carbonate.

14.7 Water Quality

Surveys on existing hand-dug wells in rural Mbindi showed that most wells are microbial contaminated. From 120 dug wells tested, 90 % of the wells had more than 100 faecal coliforms per 100 ml of sample, see also table 14.2.

Table 14.2 describes typical water quality data from the Ndarashu water supply and five *selected rural villages in the Province.*

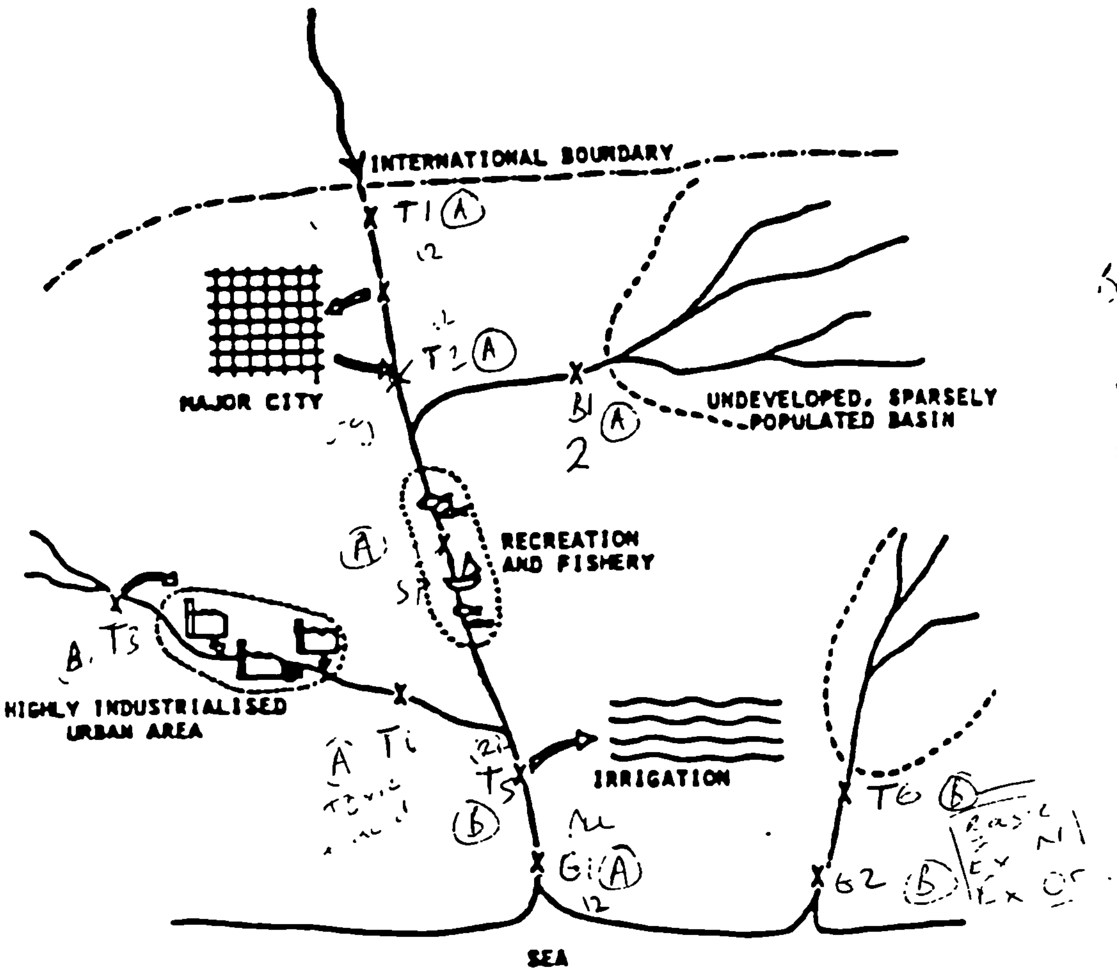
In summary, there is an urgent need to address the problems of the Ndarashu water treatment and supply system. There is also a pressing need for the hand pump installation programme for improving the quality and quantity of water resources available to the rural villages of Mbindi.

14.8 References

Wheeler, D. (1987). Case Study on Water Quality Surveillance Linked to Improveed Water Supply Province of Bazza, Vulcan. WHO Course; Sudan.

GEMS/WATER

[DRAFT ANSWER – ORIGINAL
UNOBTAINABLE FROM TEAM
MEMBER WHO LEFT COURSE]



Basic – 4

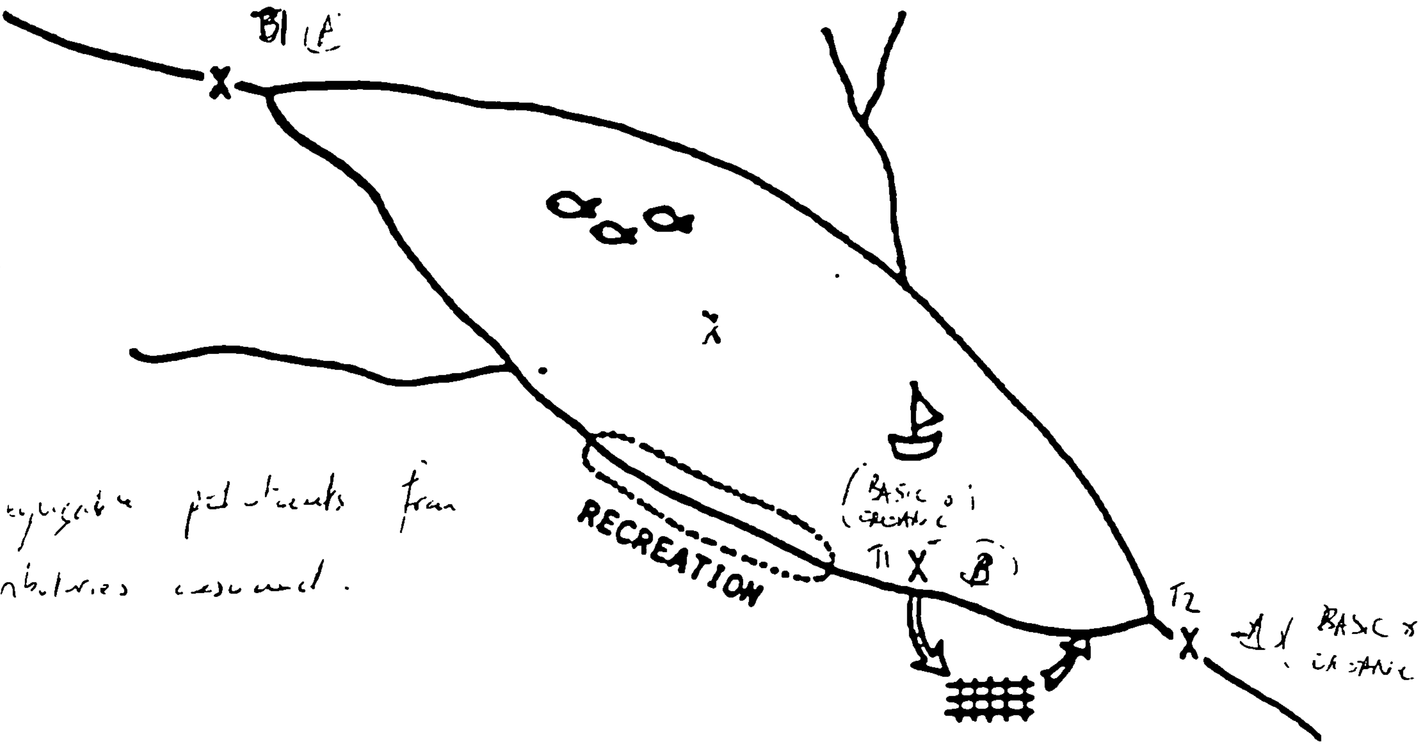
A – 22

B – 12

Station	Criteria
(A)	Group are priority stations.
B1	Baseline station to establish area natural quality conditions
T1	Trend station to establish border water quality
T2	Trend station to measure city pollutants
T4	Trend station to measure industrial pollutants assume T3 is natural water resource at similar quality to B1.
G1	Global flux station to determine flow of pollutants to sea
S?	Survey point to measure effects of pollution on fish and humans
(B)	Group are low priority, subject to funding
T3 & T6	Trend stations to establish water conditions in comparison to B1
T5	Trend station to determine water condition before agricultural effe
	to determine flow of pollutants to sea due to agricult

GEMS/WATER

[illegible]



Negligible pollutants from tributaries assumed.

Station **Criteria**

A Group one priority stations

B1 Baseline station to establish area natural quality conditions and to provide basis for comparison. (Negligible upstream pollutants assumed).

Trend station to establish pollutants from recreation and city.

Group one low priority subject to funding

T Trend station to establish ~~quality of~~ effect of recreation and general lake activity on water quality entering city.

4 RISK PERCEPTION

/engd/463
6 May 1994

ENGD ENVIRONMENTAL TECHNOLOGY PROGRAMME

Essay assignment: Discuss the reasons why the researchers of technical hazards are not collaborating with people doing research in natural hazards - use an example from your work or from a newspaper

Richard D Peters, Arup Research and Development

SUMMARY

Natural hazards can be defined as those elements in the physical environment, harmful to man and caused by forces extraneous to him eg. floods, droughts, diseases, etc. Technical hazards can be defined as those elements in the physical environment, harmful to and caused by man. eg. nuclear accidents, industrial pollution of water supplies, etc. The risks associated with some technical hazards are compounded by natural hazards and vice-versa.

A hazard which I have been associated with at work is the earthquake protection of a high rise building in Egypt. In this case there was collaboration between experts in technical and natural hazards. The basis of the essay title, that there is non-collaboration between technical and natural hazard researchers, is questioned, but accepted for the purposes of the following sections of the essay.

Reasons for possible non-collaboration between natural and technical hazard researchers are suggested. These relate to the different language (jargon), prediction methods, vested interests and levels of funding general associated with the two types of hazard. Solutions proposed are though better communications between the two research fields, quoting an accuracy band, and independent assessment of risks. Poor funding of third world hazard protection is not solely a political problem.

Natural and technical hazards are so closely related that non-collaboration and working in isolation is short sighted.

1. INTRODUCTION

I am an Electrical Engineer by training and have been working in the Construction Industry for about six years. For myself, risk assessment is naturally associated with issues such as the possibility of injury or death due to lighting hitting a building or a fault occurring on an electrical circuit. The former example is the subject of a British Standard defined analysis to calculate the probability of a building being struck and the consequential casualties. This result is then used as a basis for deciding whether or not the building in question requires a lighting protection installation and the extent of the installation required.

My knowledge of hazards such as floods or diseases is that of a layman.

This essay is the assignment to be carried out following a week's course on Risk Perception at Surrey University and the reading of reference material handed out at the course. Unfortunately I was unable to attend the final day of the week's course due to work commitments.

In this essay I shall explore the meaning of natural and technical hazards and discuss an example within my own experience. The question in the essay title will be discussed and possible reasons and solutions to the problem of non-collaboration will be proposed.

2. WHAT DO WE MEAN BY NATURAL AND TECHNICAL HAZARDS?

In order to answer the essay question, it is necessary to understand what is meant natural and technical hazards. In "The Perception of Natural Hazards in Resource Management", Ian Burton and Robert Kates propose the following definition of a natural hazard:

"Natural hazards are those elements in the physical environment, harmful to man and caused by forces extraneous to him."

Natural hazards can be divided broadly into two categories, geophysical eg. floods, droughts, earthquakes, and biological eg. diseases, infestations.

No specific definition is given in the reference material for technical hazards. For consistency with the natural hazard definition, I shall define technical hazards as follows:

"Technical hazards are those elements in the physical environment, harmful to and caused by man."

Technical hazards could be nuclear accidents, industrial pollution of water supplies, unsafe buildings, etc.

The risks associated with some technical hazards are compounded by natural hazards. For example, the technical hazard due to airplane travel is compounded if the plain flies though a natural hazard such as a hurricane.

Conversely, there is increasing evidence that the consequences of technical hazards are compounding natural hazards eg. climatic change due to carbon dioxide emissions.

3. MY EXPERIENCE OF NATURAL AND TECHNICAL HAZARDS

In a recent construction project I was designing the electrical services for a high rise building in Cairo, Egypt. During the design period, there was an earthquake in Cairo, which prompted a review of the proposed building safety in case of recurrence. The conclusion of this study was that the original design criteria (which took into account the risk of an earthquake) were satisfactory. If built to the original specification, the development would have withstood the earthquake without structural damage.

After a protracted discussion between our structural engineers, experts in earthquake prediction and the Project Managers, the Client required an upgrading of the building's earthquake classification. This resulted in changes to the structure and enhanced fixings and control measures for the electrical services installation and lifts. These were, in our professional technical opinion, unnecessary.

As far as I am aware, the Client was satisfied with our technical analysis of the earthquake risk and projected damage. This building would be much safer than many low rise buildings in Cairo. But the public perception is that even modern and well designed high rise buildings are likely to fall during an earthquake.

The Client had to be sure that people would be confident enough to let the building. Even if this meant an over-design was required.

In this case there was satisfactory collaboration between the researchers of natural hazards (earthquakes), and ourselves who were researching the technical hazards of a building structure in the event of an earthquake. The problem was communication of the safety of the design to the public.

4. COMMENTARY ON QUESTION

The essay title presumes that there is non-collaboration between the researches of natural and technical hazards. My experience, at industry level, is to the contrary. For the construction project I have discussed there was no alternative but for us to look at the natural hazard of the earthquake and technical hazard of a high rise building together as a unified design team.

In recent EngD lectures we have investigated water quality, which again requires a unified natural and technical hazard approach which does not appear to be a problem.

Perhaps in an academic environment the two fields are more clearly split than they are in industry. I shall assume that non-collaboration is a problem for the purposes of the remainder of this essay.

5. POSSIBLE REASONS FOR NON-COLLABORATION

I suggest there may be a number of possible reasons for non-collaboration:

i. Researchers of natural and technical hazards talk a different language (jargon). As an engineer I can associate with the concepts and risks associated with technical hazards. From the papers we were required to read, my (admittedly cynical) view of researchers of natural hazards is that they write long incomprehensible essays! If I were to research technical hazards in depth, I would natural tend towards a probability and statistical approach which I know would be unhelpful for many people.

ii. Natural hazards have been recorded over the years such that fairly good predictions can be made as to the risks of a disaster occurring. Technical innovations bring new technical hazards which must be calculated using fault trees and "expert" judgement in lieu of measurement. This may be considered unreliable by natural hazard researchers who, for instance, may know as little as the layman about the risks associated with nuclear power.

iii. The people who calculate technical hazards generally have a vested interest in the process, so may tend to underestimate the risk which they have or are proposing to incur. For instance, the designer of a nuclear power plant is likely to underestimate the risks associated with its operation. The opposite applies to researches of natural hazards who, if anything, benefit due to the publicity and research funding that often arises as a consequence of a potential disaster eg. earthquakes, depletion of ozone layer.

iv. Industry is primarily concerned with the technical hazards for which it is responsible. Major funding is available in order to reduce the risk of a nuclear power plant, where as the aid available to a Third World countries during a drought is often inadequate.

6. POSSIBLE SOLUTIONS FOR NON-COLLABORATION

Here are some possible solutions corresponding to the problems i. to iv. as set out in the previous section:

i. Communications - researchers of natural and technical hazards need to find a common language. Practically this means writing clear, concise and jargon-free reports and papers.

ii. Hazard prediction may benefit from being quoted with an accuracy band corresponding to the confidence in the basis of prediction (whether it is risk measured over a long period or a calculated risk dependant on an expert's opinion). eg. *The risk of this power plant causing a major accident incurring over 100 deaths is 1 in 1,000,000. The risk analysis is based on fault analysis and believed to be accurate to ± 20%.*

iii. Independent and unbiased assessment of technical and natural hazards is essential. For that, I would look to the experience of the Insurance Industry. Even if they will not insure against all possible disasters, they are experts in objective assessment of risks and could be commissioned to certify a calculated risk before it is published.

iv. The risks we consider unacceptable in developed countries are minimal in comparison with the risks and subsequent disasters we allow to occur in poorer countries. No one could argue that this is fair. A view given in lectures and papers for this course suggests that Capitalism is the cause of this injustice and that Marxism is a solution. I do not believe the solution to injustice can be found solely in political or economic policies as mankind is inherently sinful. This is consistently reflected in all human societies. I am satisfied with the compromise of Capitalism in a democratic society. But as a Christian, I believe we should encourage countries to adopt policies that reflect the selflessness and compassion demonstrated by Jesus, recorded in the Gospels.

8. CONCLUSIONS

Natural and technical hazards are so closely related that non-collaboration and working in isolation is short sighted.

I have suggested some possible reasons for non-collaboration and possible solutions. Research in both fields should feel obliged to cooperate where appropriate.

R.Peters: Reading your paper I got the feeling that you did not enjoy doing this assignment. Your writing seemed "angry". In any case you did cover the basics, but you could have done more- and where is your bibliography?....... C

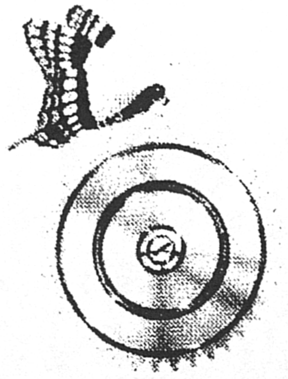
5 ENVIRONMENTAL REVIEW OF BIOCOMPATIBLES LTD.

Environmental Review of Biocompatibles Ltd.

Brunel University Science Park
Kingston Lane
Uxbridge, Middx. UB8 3PH

by

Environmental Technology EngD Group



Brunel University
27. May 1994

Acknowledgment

Special thanks to Prof. John Donaldson and Dr. Sue Grimes (Brunel University) for their encouragement and wise counsel throughout this review, to Peter Russel for the information he provided and to Mike Driver and other employees of Biocompatibles Ltd. for their cooperation, patience and support for this project.

Layout and printing by CyberArt, Tel: (0895) 238664

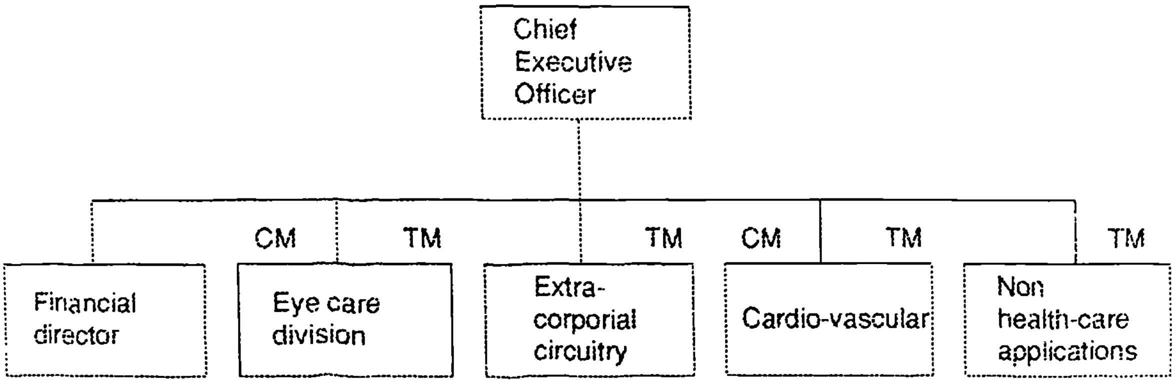
Contents

1. Introduction

1.1 Company Information

"Biocompatibles Ltd." is a small venture capital funded company established seven years ago, and has been located on the Brunel University Science Park, Uxbridge, for the last five years. The company has rapidly expanded over the past few years, now totalling some 40 employees. Their research is largely concerned with coatings and materials for the medical device industry; specifically, haemocompatible surfaces, surfaces that don't adhere bacterial organisms, and new improved contact lens materials.

The following company organogram illustrates the company management and research divisions.



CM = Commercial Manager. TM = Technical Manager

1.2 Purpose

This review has two main aims:

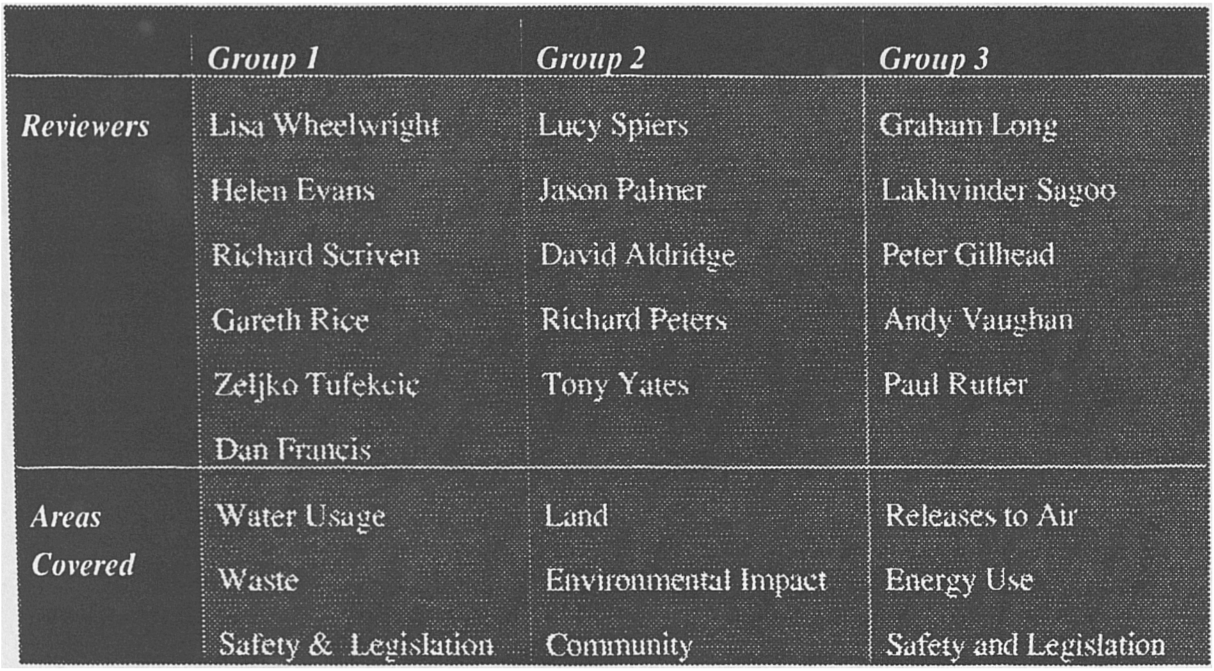
1. To familiarise the EngD research engineers with the principles, methdology and pitfalls of an environmental review by means of a hands on survey.
2. To provide "Biocompatibles Ltd." with a preliminary environmental review, and to make recommendations relating to more environmentally sound technical, safety and energy related operations.

1.3 Scope

The initial interview with the company representative Mike Driver was conducted on Tuesday, 24. May 1994. The following day, this was augmented by a 2 hour site survey and a tour of the laboratories. Interviews with representatives of company staff were also carried out. The lab tours were brief by necessity, and this review, therefore, is only representative of the information that could be gathered in this short period.

1.4 Approach

The research engineers were divided into 3 groups, each covering the areas described below. Some of the individual areas were investigated by more than one group, so as to minimise the amount of information that would be overlooked.



	Group 1	*Group 2*	*Group 3*
Reviewers	Lisa Wheelwright	Lucy Spiers	Graham Long
	Helen Evans	Jason Palmer	Lakhvinder Sagoo
	Richard Scriven	David Aldridge	Peter Gilhead
	Gareth Rice	Richard Peters	Andy Vaughan
	Zeljko Tufekcic	Tony Yates	Paul Rutter
	Dan Francis		
Areas Covered	Water Usage	Land	Releases to Air
	Waste	Environmental Impact	Energy Use
	Safety & Legislation	Community	Safety and Legislation

The information was collected during the lab tours using a pre-prepared protocol and by engaging in informal discussion with staff present. Photographs of specific and general scenes were taken with permission and presented in Appendix 1.

2. Legislation and Safety

2.1 Overview

Biocompatibles Ltd are potentially subject to emission control through the media of air, land and water. Discharges from fume cupboards are unlikely to be a problem, though strictly it is a decision of the local authority. Releases to land are covered by contract to a licensed waste disposal contractor, though as producers of solid waste they retain a legal duty of care. Responsibilities relating to aqueous waste are discussed.

The importance of effective safety and laboratory procedures, and their inherent integration with sound environmental practices is recognised with the implementation of an efficient and accessible COSHH system.

It should be noted that Biocompatibles Ltd. have a legal contract with the University concerning discharge and therefore come under the direct control of the university.

2.2 Sewerage Services

The Science Park foul drainage system is connected to the University drainage system. This comes under the responsibility of Thames Water Plc. at the Mogden treatment works in Twickenham. A consent discharge, issued by Thames Water Plc. in 1978 is still in force. Generally, contamination levels can be predicted and Biocompatibles Ltd. are under obligation to inform Thames Water of any major spills.

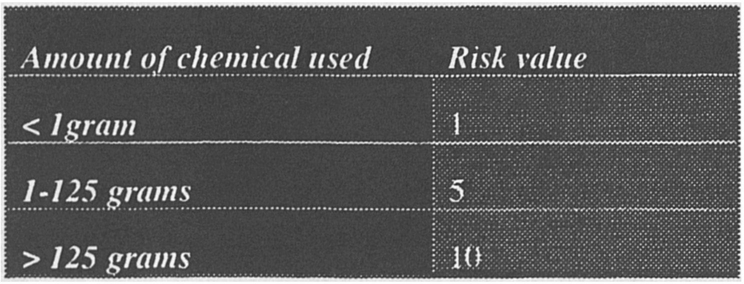
Dipping tests are occasionally carried out at a bore hole which collects water from the University and the Science Park. The tests measure mainly the concentrations of organics and metals.

NSCA refer to the The Water Industry Act 1991 in stating that [NSCA94]:

"Occupiers of trade premises may not discharge any trade effluents into a public sewer unless authorised by the sewerage undertaker. An application to discharge should contain details of the effluent, quantity to be discharged in any one day, and the highest rate at which it is proposed to discharge. In granting an application, the sewerage undertaker may impose conditions covering the rate, quantity and composition of effluent and the sewer into which it may be discharged, and the time or times of day. Conditions may also relate to provision and maintenance of inspection chambers and meters and of other apparatus for testing the effluent, record keeping and payments to the sewerage undertaker."

2.3 COSHH

Biocompatibles Ltd interpret the COSHH regulations in an efficient and comprehensive way. Staff have an effective working knowledge of the system, and relevant documentation is readily retrieved and consulted. For all chemicals used in experiments, hazard data and quantitative risk assessment values are documented. The actual value depends on the quantity and toxicity of chemical used. An example of this would be:



Amount of chemical used	*Risk value*
< 1gram	1
1-125 grams	5
> 125 grams	10

If a risk value for a chemical used is high, a more detailed risk assessment for that experiment is performed (for example, what to do in case of spillage). This procedure is individually completed for all experiments. Before being performed, experiments are written up in a lab book, detailing reaction mechanisms, side reactions, procedure, risk assessment, etc., checked by the laboratory manager and safety procedures discussed.

Material Safety and Data reports are obtained and risk assessments compiled for all new chemicals before placing an order.

COSHH spillage procedures require action to prevent hazardous chemical discharge to the sewerage system. These procedures are clearly illustrated in wall charts in a number of laboratories. The line of authority in the event of major spillage in the absence of both safety officers was unclear. The company does not consider their activities to pose a significant risk to the River Pinn.

3. Environmental Impact Assessment

3.1 Overview

Impact on the local environment attributable to Biocompatibles Ltd is minimal. There is, however, some scope for improvement.

3.2 Introduction

The object of an environmental impact assessment is normally to assess the likely effects of a proposed new development. Here, however, we propose to compare the site as it stands today with what preceded the development, i.e. green space.

The site is located on University-owned land. It is approximately 50 metres from a block of university accommodation housing some 100 students. A market garden centre is within 100 metres from the site. The River Pinn runs 200 metres down-hill from the site. The river supports some wildlife (small fish, ducks). The main road, University sports facilities and privately-owned housing are also close-by.

3.3 Salient Points

3.3.1 Physical Land Take

This is defined as the land occupied by buildings, car-parking facilities, access roads, "decorative spaces". Specific measurements are not available.

3.3.2 Estimated Emissions & Residues

There are inevitable gaseous emissions from the fume extraction points (refer Appendix 1). These will be predominantly organic solvents. The quantity of emissions will be relatively small, they are likely to disperse quickly in the atmosphere and do not represent a hazard to local residents. There could, however be a nuisance problem to local residents and other companies at the Science Park if unpleasant odours are extracted from the laboratories unchecked.

Neutralised acids and other unidentified aqueous chemicals are released into the drainage system. Little information is available with regards to specific quantities. Again, it is likely that quantities are small and contaminants will have minimal environmental impact.

There is evidence of oil and petrol spillage in the car-parking area. This has minimal local impact but contributes to the generalised problem of oil in waste water.

Solid waste is generally well managed and it is improbable that it could ever cause problems.

3.3.3 Effects on Flora and Fauna

The grounds around the site are well maintained. Foliage is plentiful, trees have been planted and the site looks pleasant. Grass alone has been replaced by many different types of flora. Birds and insects were in evidence during the review.

In the event of a major spill, contaminants could run into the River Pinn. This could have an effect on the local ecosystem.

3.3.4 Landscape

The landscape of the site has neither improved nor deteriorated as a result of the development. The site's low-rise buildings are not unattractive. Strategically planted trees block the site's visibility from many local vantage points. The site serves as an effective shield from the University campus' outline when viewing from the road.

3.4 Community

3.4.1 Overview

The environmental effects on the local community in this instance are minimal.

3.4.2 Complaints

Complaints have been received from neighbouring student residence, other Science Park companies and employees of Biocompatibles Ltd. This has been with regards to an unpleasant-smelling compound - trimethylamine - that has been emitted in small quantities.

3.4.3 Traffic

There has been a small increase in traffic on the roads in the area; not only from employees, but also from deliveries and waste collection. However, given the large volume of traffic on roads in the vicinity, the additional load from Biocompatibles Ltd. is small.

3.4.4 Communication

Bio-compatibles communicate with the University via the Science Park Manager, Peter Russel. There is no direct communication with the local community.

.4.5 Miscellaneous Odours

While it is true that small quantities of an unpleasant-smelling compound are released, this must be put into perspective with reference to background smells in the area. During our visit the gases emanating from a pile of steaming dung/silage mixture outside the garden centre provoked a greater reaction from team members than the output of ventilation shafts.

3.4.6 Noise

There is some noise at the neighbouring University residences. This is caused by the extractor fans on the site, but is a minimal nuisance.

3.5 Land

3.5.1 Solid Waste to Landfill

A quantity of general office waste is sent to landfill as ordinary refuse (this includes the Winchester bottles). Containers for chemicals are also sent to landfill through the intermediary of the waste contractor. Some solid waste will also be sent to landfill - as ash - after hazardous waste has been incinerated.

3.5.2 Incineration

Hazardous wastes (medical and chemicals) are removed by contractors for incineration. Assuming that the contractors act responsibly, incinertion should result in environmentally benign disposal of the waste. However, incineration will inevitably result in some deposits on the land.

3.5.3 Local Contamination

Although spills around the site are likely to be small, incremental increases in contamination could result from repeated small spills. Over a number of years, this may result in contamination of land around the site. Deposits from gaseous emissions through stacks, especially during periods of wet weather, will add to this build-up of contaminants.

4. Air

4.1 Overview

The majority of air released from the building is extracted by seven fume cupboards, leading to central ducts, and discharging through five stacks served by externally mounted fans. The main air contaminants are common laboratory solvents such as acetone and methanol.

4.2 Solvent Mass Balance

Records are kept of solvents incoming from suppliers and outgoing to waste contractors. The information exists, therefore, for a solvent mass balance, preferably over a period of months or even years. Unfortunately, we were unable to immediately access this information in a readily digestible form.

Solvent recovery on such a small scale is considered to be uneconomical.

4.3 Fume Cupboard Extraction

Each fume cupboard is serviced every six months by a licensed contractor. The face velocity is clearly marked, facilitating the estimation of air extraction rates. This was performed for the downstairs laboratory, revealing an air extraction rate of approximately 8000 m^3/hr, equating to 16 room changes per hour. Of the seven fume cupboards, only one contained a filter (of activated carbon). There is some confusion as to whether the fume cupboards are left on overnight or not.

In the event of a ventilation system failure, an alarm sounds and the laboratory evacuated.

4.4 Heating System

One boiler covers the whole building (which houses several companies). Consideration of the emissions arising from the heating system are therefore beyond the scope of this study.

4.5 Stacks

We were unable to gain access to the roof to inspect the state of the stacks. Stack height and exit velocity are key variables in determining the dispersion of contaminants from the building. The laboratories and extraction system were not specified for Biocompatible's specific use and may therefore not necessarily be suitable.

4.6 Summary

Small amounts of common laboratory solvents are routinely released via the laboratory fume cupboards and building extraction system. No attempt to quantify these releases have been made either by the company or the review team. The company are unaware of relevant legislation relating to the release of substances to air, and are not directly regulated by the local authority. However, the nature and scale of the system is unlikely to be of concern.

5. Water

.1 Overview

Biocompatibles Ltd consume a small quantity of water in laboratory processes. In addition to distilling water for internal use, tap water is employed in vapour condensing and domestic cleaning operations.

5.2 Quantity

There is no formal record of water consumption, as the company simply pay a specified proportion of the total Brunel University water charge. Approximately eighty litres of water are distilled and consumed per week. This, in addition to condensation and vacuum demands, is likely to constitute less water than required for domestic purposes.

5.3 Drainage

Where necessary, waste water is neutralised and discharged otherwise untreated to the municipal sewerage system. Solvents are stored prior to collection by licensed waste disposal contractors. External drains may be contaminated by car park run-off.

5.4 Spillage and Emergency Procedures

These procedures are covered by COSHH, as discussed in the "Legislation and Safety" section.

6. Waste

6.1 Overview

The waste expelled from Biocompatibles Ltd can be broadly classed into chemical, biological and general waste. The chemical waste is disposed of via licensed contractors. The biological waste items are despatched to Hillingdon Hospital for incineration. General waste is disposed of via council services, the main constituents being identified as packaging and glass . Follow up as to how these licensed services actually dispose of these various wastes (as stipulated by the Duty of Care) is **not** conducted.

6.2 Chemical Waste

Chemical waste is routinely stored prior to disposal in containers for chlorinated, non-chlorinated, benzene and polymer wastes. The quantities of organic solvent wastes are documented before being transferred to the main outside storage area. This allows exact quantities and contents of outside storage drums to be determined at any time. Quantities of chemical waste disposed are estimated at 250-350 litres four times a year (25-50 litres of solvent per week).

Other wastes include chromatography mobile phases, general analytical waste, drying agents (sodium sulphate and calcium chloride) and silica solid waste. The chemical waste is disposed of through Cleanaway, GKN Cambridge but the Duty of Care stipulation to check on disposal procedures is not conducted.

Gaseous chemical emissions via seven fume cupboards are minimal, but small volumes of hydrogen chloride gas are treated by reaction with base.

Aqueous wastes are disposed of via a policy of dilution and neutralisation, each individual being responsible for his/her own waste. No standards are known with respect to discharge consent levels.

6.3 Biological Wastes

Biological waste consist predominantly of disposables (plastics, gloves, packaging, tissues) and experimental waste (blood, plasma) with an estimated 10-12 [dustbin] bags of waste contracted to Hillingdon Hospital for incineration twice weekly. A degree of uncertainty as to quantities and types of biological waste produced from processes was detected. The Duty of Care regulation to ensure that the waste is disposed of in the appropriate manner is not carried out.

6.4 *Waste Labelling and Documentation*

Hazard labelling was in evidence on all stored waste chemicals although some labels had faded. Biohazard labelling was also apparent.

Records of waste generated by each laboratory are maintained to ensure accurate documentation on outside storage. Documentation to this effect was viewed.

6.5 *Waste Spillages*

No spillages of wastes have occurred but the company policy is to document incidents and to take future evasive action should an incident occur. COSHH policy is adhered to.

The underlying geology of the site is the London clay beds, having overlying layers of sandy clay and gravel to a depth of approximately 6.5 metres. The surface layer is a sandy clay loam of approx. 1 metre. The water table occurs at approx. 5.5 metres, within the sandy clay gravel. Therefore, any major spillage will follow normal groundwater flow to the river Pinn.

7. Energy Review

7.1 Introduction

The main aim of this section is to investigate the possible development and refinement of an environmental energy policy for the client.

7.2 Energy Policy

The objective of the energy policy is to minimise the demand for non-renewable energy sources, which principally involves electricity drawn from the national grid. Efficient use of available energy has a part to play in meeting this objective.

7.3 Review

In order to assess the client's energy use and development of an energy policy, the following areas have been considered:

- building site and external conditions
- building fabric, windows construction and use
- artificial heating and air-conditioning
- artificial lighting and use of daylight
- existing energy policy, if any
- fuel costs monitoring and management

7.4 Site Description

The building is of fairly recent design and appears to have good quality double glazing with sufficient draught-proofing. The building fabric is assumed to be reasonably well insulated in line with building regulations at the time of construction.

The window orientation is principally east/west, so summer overheating may occur on the east side in the mornings, but receives less direct sunlight during the afternoons. The majority of windows are fitted with shutters, which, at the time of review, were predominantly down with the shutters pen.

The office areas were noted to be generally warm and well heated, but the laboratories were considerably cooler due to a high ventilation rate caused by fume extraction and by the air conditioning. The air-conditioning and heating were stated as having individual thermostat controls for different areas, but there is minimal local lighting control.

Some specific equipment is in use which may result in a significant total energy demand. These devices include a Nuclear Magnetic Resonance machine, vacuum oven, fume cupboards, extraction fans, and a number of fridges and fridge-freezers. It was not clear in most cases how much of the time these devices are used for.

7.5 Findings

An existing basic energy policy was described, namely that of turning off lights and equipment when not in use. However, there is no policy identifying management of heating, air conditioning, or identifying other primary sources of energy consumption.

A policy of recording fuel bills would be beneficial in monitoring energy use, and in providing feedback on the effect of energy saving measures. This is not anticipated to require much effort to implement. However, it was suggested that the whole building is charged for energy, and that the client only pays a fixed proportion of this, so a direct measurement of energy consumption may not be possible.

Laboratory ventilation was noticeably high and caused lower working temperatures in these areas. A significant saving may result from ensuring that the ventilation rate is not higher than necessary, allowing for the regulation minimum air-flow rate at the fume points, and that only the extraction fans specifically required to be on for long periods are used as such. The power rating of these devices may contribute to a significant energy demand when used for long periods.

A policy of identifying devices with a large power rating (e.g. above 1kW) and ensuring that their use is in line with manufacturers recommendations to maintain optimum use.

Standard office equipment such as PCs, fax-machines, and photocopiers are assumed to be fairly efficient, and in constant use during the day, so these probably do not warrant a specific policy, other than turning them off overnight.

The window shutters are mainly useful for solar shading, but in a general sense they restrict daylighting, even with the shutters open, thus increasing the energy demand of artificial lighting. A policy of raising the shutters completely and only using them when necessary would help to utilise daylight and reduce the need for artificial lighting. It was suggested that the shutters also have a security function by reducing visibility from outside into areas which may contain sensitive material, but this seems unlikely to be effective unless the shutters are completely closed.

7.6 Legislation and Compliance

There are no specific regulations regarding energy consumption.

1.7 Conclusion

There are a number of factors mentioned that could be incorporated into a specific energy policy, contribute to a lower energy demand, and yield financial benefit. Of the areas mentioned, the most significant appear to be the ventilation rate in the labs, and the use of certain equipment which have higher power ratings (e.g. NMR machine, vacuum oven, extraction fans).

8. Management Systems

8.1 Introduction

An assessment of the current management systems was carried out to see if an environmental management system could be applied and identify areas within the organisation that would clearly benefit.

8.2 Overview

The management systems at present are organised and structured. Environmental management could be integrated into the quality management system that is presently being phased in throughout the organisation.

8.3 Site Management Procedures

The present management structure divides the company up into four main divisions. These were:

1. Eye care
2. ECC
3. Cardio-vascular
4. Non-health care

In addition to this, there is a financial wing which does not conduct research. Each division has a technical manager who assumes responsibility for the project research and other management related subjects including COSHH. Beneath the technical manager there is a deputy technical manager.

Managers attend a number of structured meetings each year. These involve them in the commercial aspects of their products and research. They also have responsibility for ensuring that records are maintained and that staff are appropriately trained in all aspects of their work.

The management executive meets on a structured timetable and thorough minutes are taken. In addition to this they follow through a predetermined agenda.

Communication appeared to be good and well maintained. This is in line with their present objective of being certified for a quality management system such as the BS5750 or the ISO-9000 series. At present they are still implementing the quality management system procedures, and it is envisaged they will get certification by the end of the year. There have been no significant problems with the implementation of the management system.

8.4 *Findings*

The present introduction of the quality management system means that it would be quite possible in the future to introduce an environmental management system. At present the management appears well organised and has addressed the environmental issues that are of importance to the organisation through legislative demands, i.e., waste management. Management procedures for health and safety and hazardous waste management are well maintained and full records are kept. In this respect, some issues relating to environmental management have already been addressed and to further extend them would not be difficult given the nature of the present management procedures in place within the quality management system.

At present there are no specific statements relating to environmental matters in any of the mission statements or policies. The development of an environmental policy could help steer any initiatives or activities that may be undertaken. In addition to this, there is a potential marketing edge in terms of competitiveness with a publicly available environmental policy and management system which considers environmental factors that are related to organisational activities.

8.5 *Legislative Compliance*

Although there are no legislative demands for environmental management systems at present, there are areas where legislation requires management to ensure that certain procedures are followed. These include hazardous waste management and health and safety issues. In relation to these, the management system was well adapted to ensuring that there was legislative compliance. All procedures initiated through management appeared to be adhered to and consistently maintained.

8.6 *Conclusions*

The present management system is working well and does not appear to have any obvious weak areas. Present progress towards a quality management system is proceeding well and all areas where management is required in relation to factors which are environmental were covered (see Legislation). Because of the present organisation within the management structure it is noted that minor adaptation of the quality management system could allow it to include environmental issues.

9. Conclusions

An environmental review of Biocompatibles Ltd. has been carried out. In terms of general environmental policy, a variety of areas have been identified, with recommendations for improvements.

It is felt that the review process was successful; enhanced environmental performance of the company may be achieved as a result.

10. Recommendations

10.1 Legislation

- Investigate the benefits of contacting Thames Water regarding consent levels

10.2 Environmental Impact Assessment

- Some thought has obviously been given to emergency contingency plans. It would be productive to formalise and document all emergency procedures: both interior and exterior spills.
- Given the potential risk for spillage, responsibility for decanting Winchester vessels into the 25 litre drums is assigned to the Waste Manager, as would be recommended. However, an individual should be chosen to take on this responsibility in his absence.
- The possibility of using documentation on waste quantities and purchasing information to compile approximate mass balances should be investigated.
- Increased communication with local interest groups in the vicinity, including others in the science park, would help avoid unnecessary conflict in the event of both major and minor incidents.

10.3 Air

- Investigate the feasibility of using fume cupboards to achieve the required laboratory extraction rates, where applicable.
- Fume cupboards should be switched off at night.
- The ventilation system should be regularly serviced.

10.4 Water

- Mass balance for water entering and leaving building.
- Company water consumption should be monitored.
- Identification and adoption of discharge consent levels from NRA/Thames Water

- Protection of water environment from spillage risk by containment system on outside waste storage area (e.g., sump or bunding) and containment of run off from chemical and biological substance delivery points.

10.5 *Waste*

- Follow up Duty of Care - check if GKN and Hillingdon Hospital actually dispose of the waste as they are supposed to.
- Training on handling of chemical wastes.
- Install bottle bank in car park for recycling rinsed glass items.
- EPIC - enrol with Environmental Product Information Centre for free service - supplies information on recycled paper products, including details of suppliers

10.6 *Energy*

The key areas which could constitute an energy policy are as follows:

- Fuel bill record to be maintained.
- Reduction in mechanical lab ventilation.
- Minimal usage of high power equipment.
- Use of blinds and daylighting to reduce electric light usage.
- Evaluate light controls.

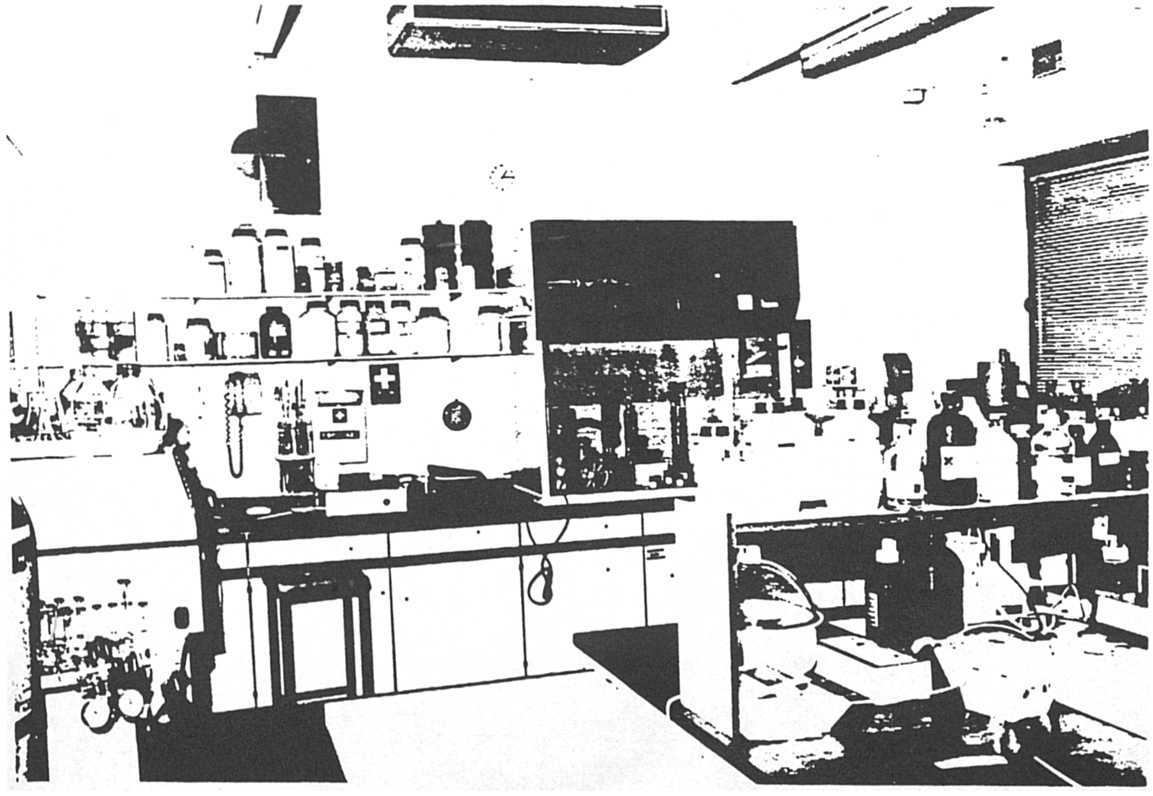
10.7 *Management Systems*

- Develop and install an environmental policy.
- Make a minor inclusion in the quality management in order to review and address environmental issues at regular intervals.
- Define target areas where improvement can be made.
- Implement the above with a view to improving competitive position through steady environmental improvement.
- Ensure that company employees are educated about environmental issues which are relevant to their work.

Appendix 1 - Site Photographs

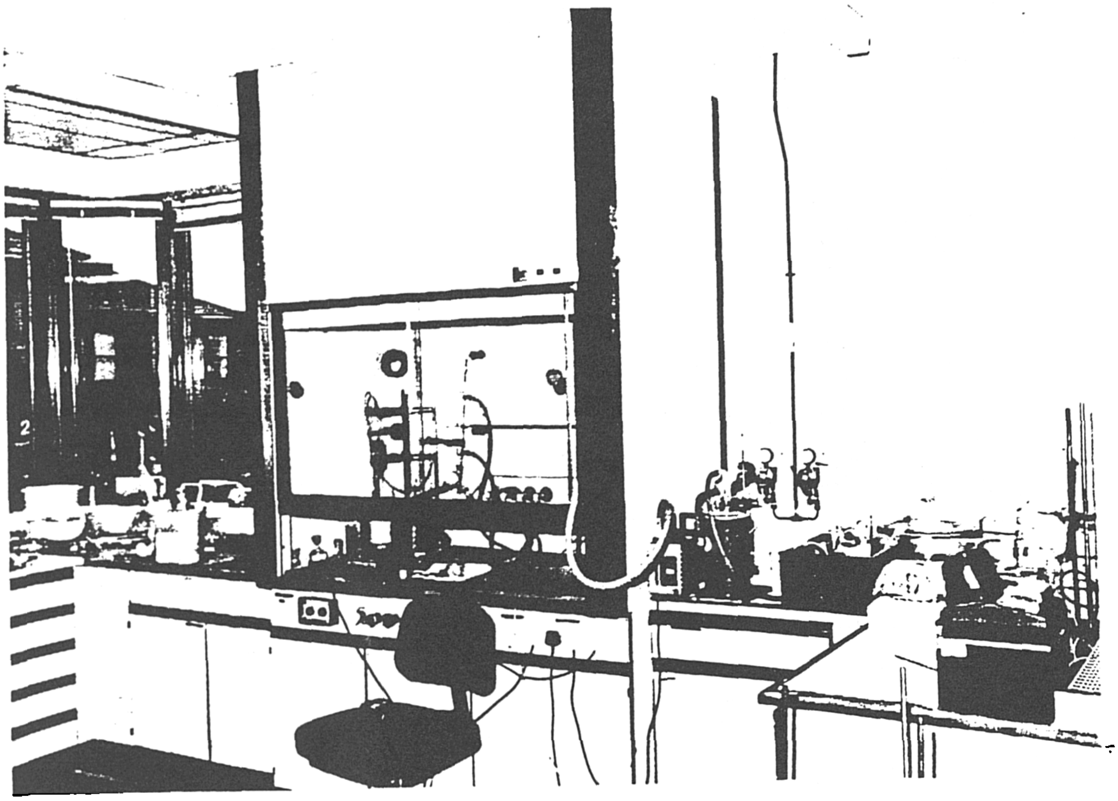
Upper photograph: The site of Biocompatibles Ltd., including the building, car park and outside waste storage area .

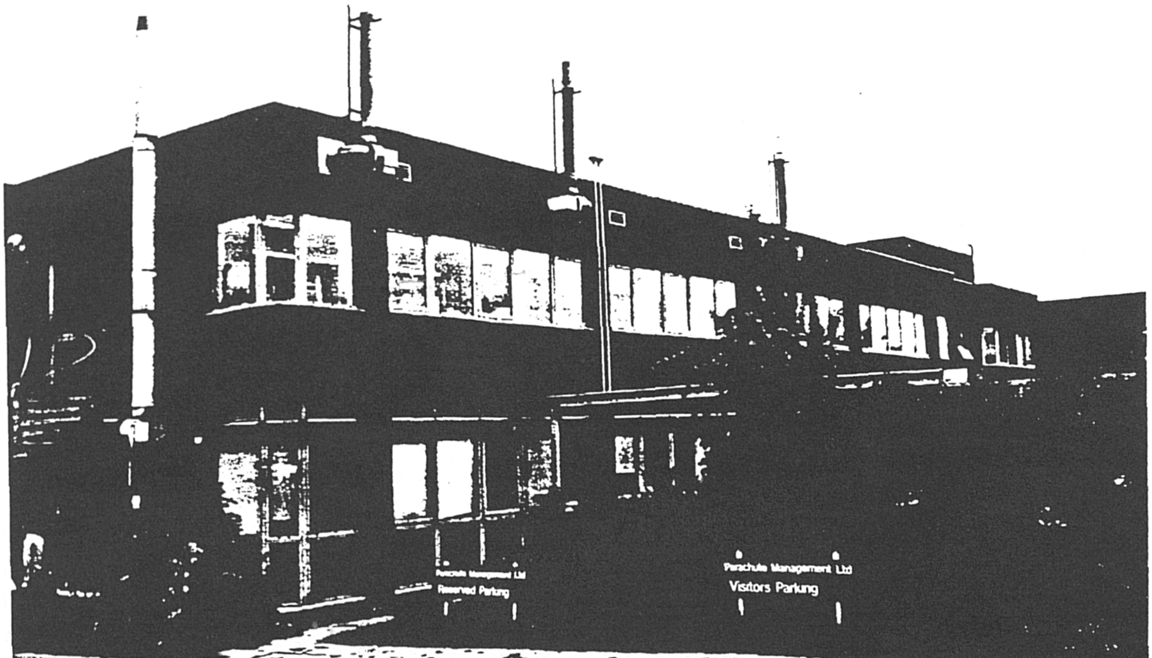
Lower photograph: Typical lab area within the company. COSHH labelling in evidence.



Upper photograph: Detail of fume cupboard incorporating solvent-safe cupboards below.

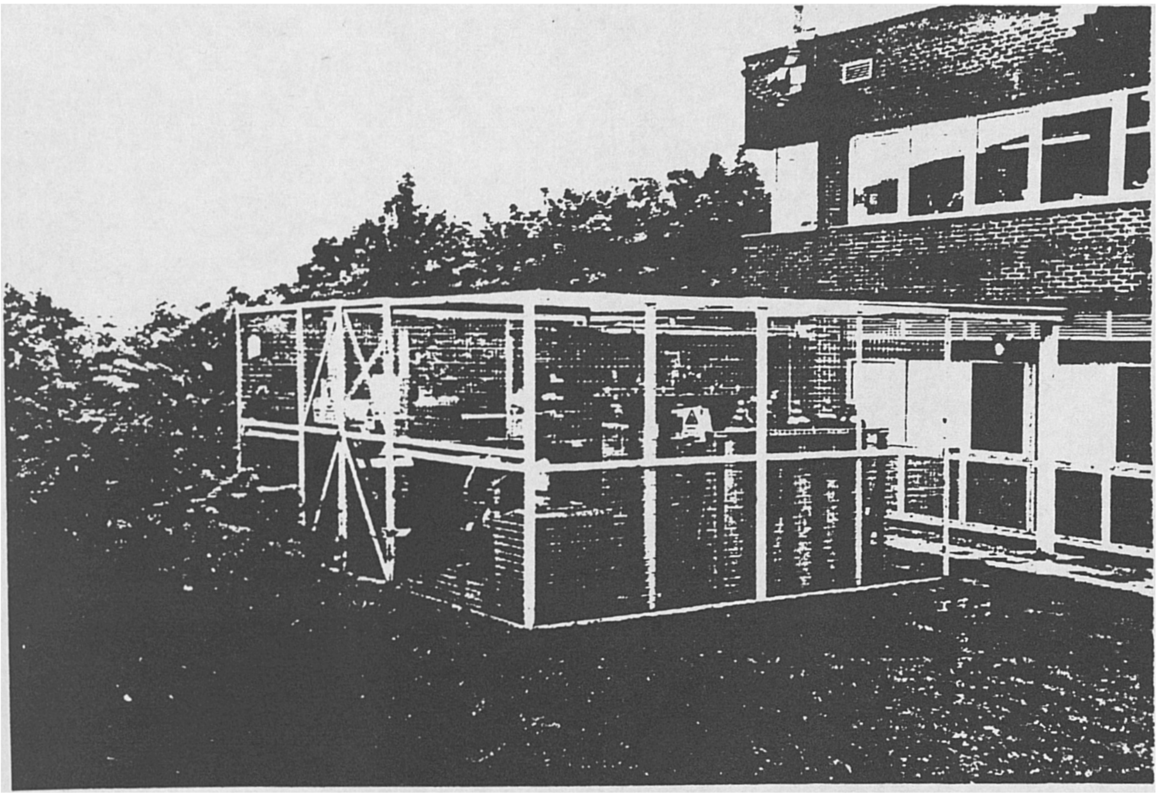
Lower photograph: Exterior of Biocompatibles Ltd., illustrationg fume cupboard extraction stacks.

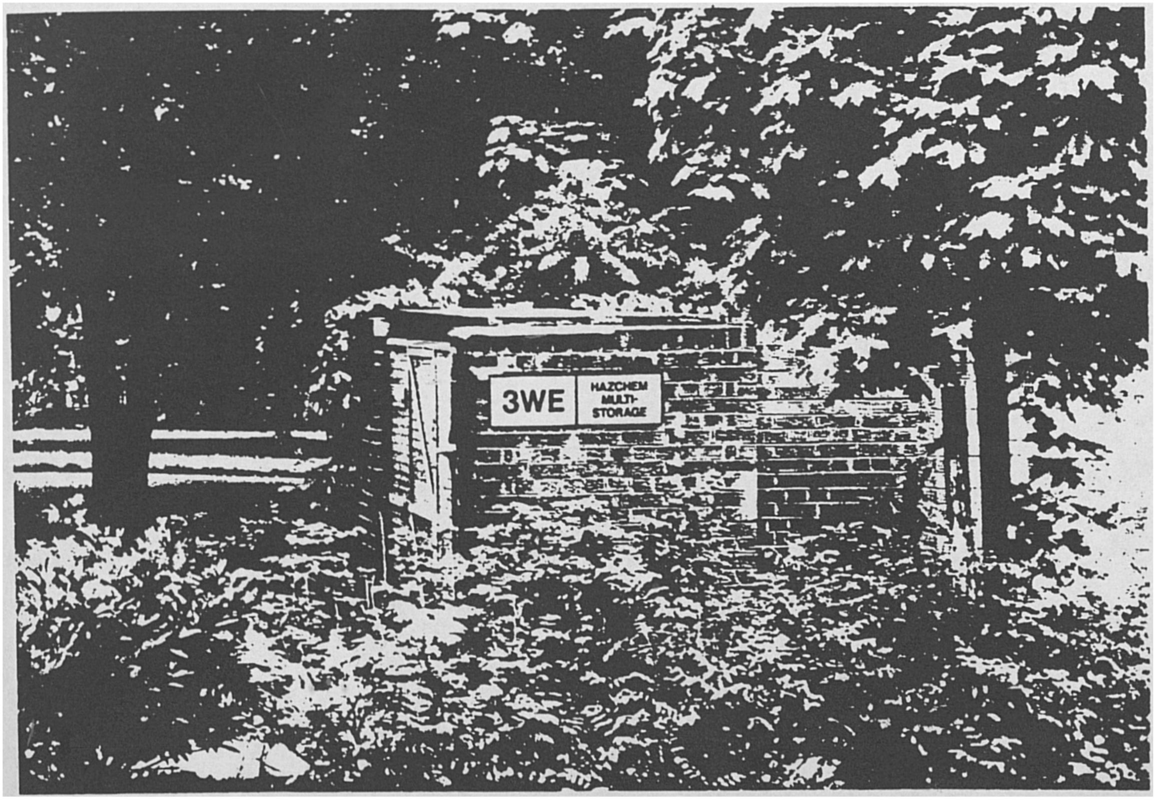




Upper photograph: Detail of external gas cylinder storage area; locked with hazard labelling.

Lower photograph: Detail of liquid storage area and general waste site.

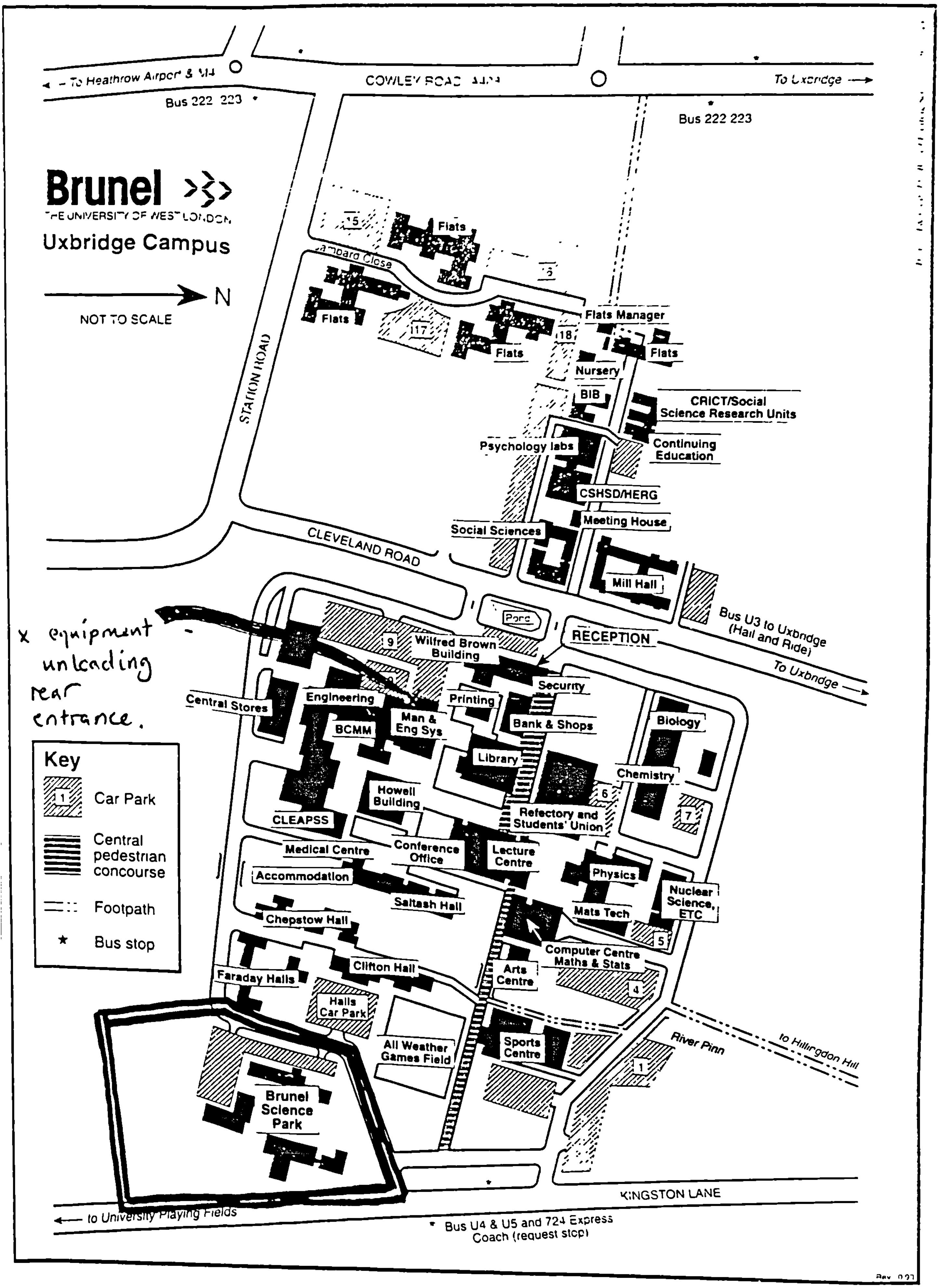




Appendix 2 - Site Plans

The following plans are enclosed:

1. General Brunel University Uxbridge Campus map, pinpointing the Science Park.
2. First Floor Plan of Biocompatibles Ltd. premises.
3. Second Floor Plan of Biocompatibles Ltd. premises.
4. Science Park site drainage plans prior to construction of buildings.

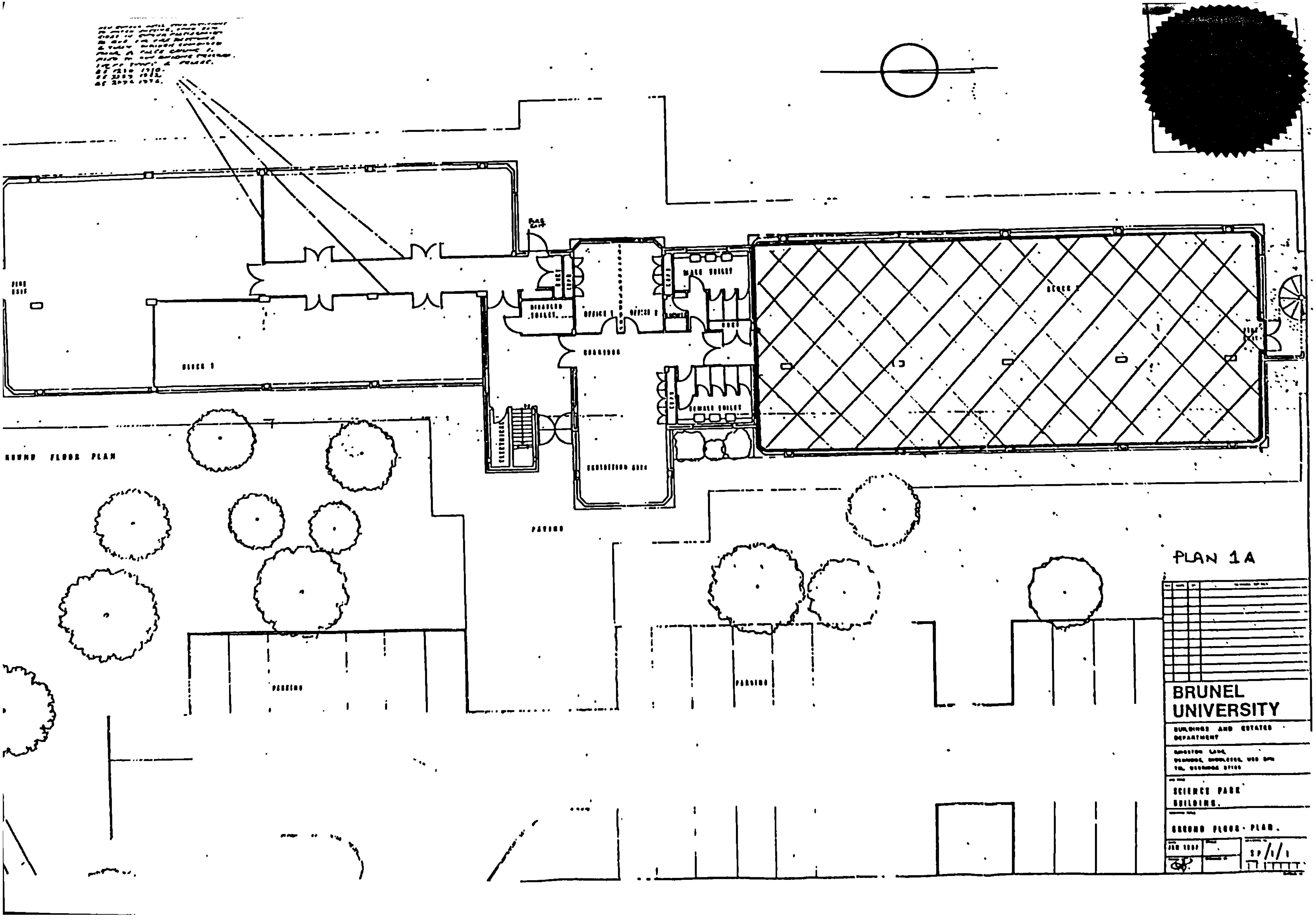


x equipment unloading rear entrance.

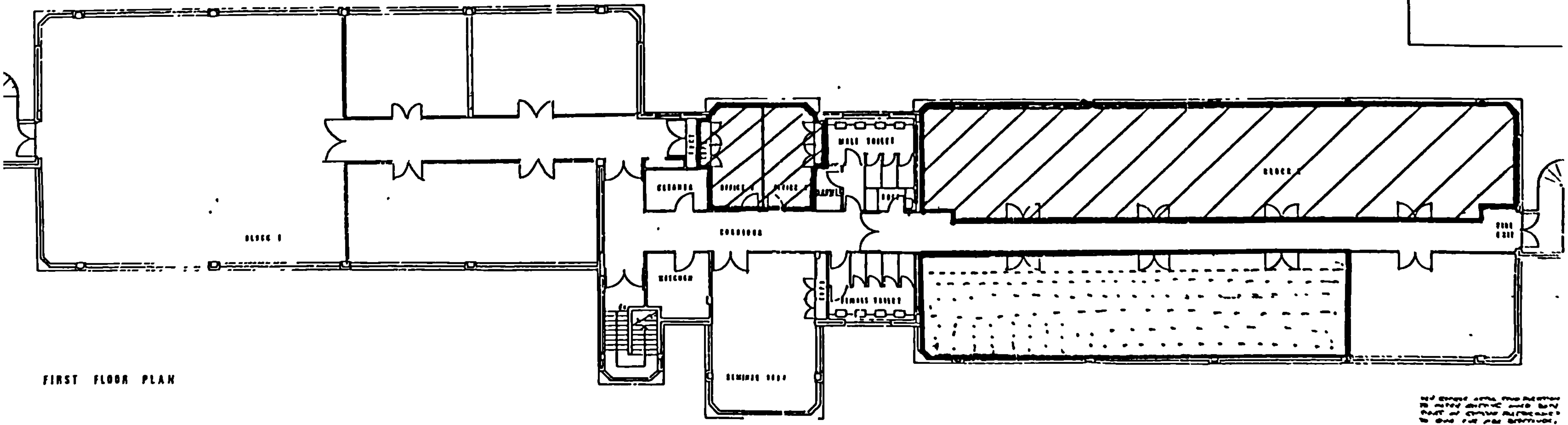
Buses

From Heathrow Central: 223 (stopping)
724 – Express Coach, (by request)
From West Drayton Station: 222, 223
From Uxbridge Station: U3, U4, U5

Alight at:
U3 – main entrance, Cleveland Road
U4 & U5 – Kingston Lane entrance
207 – Hillingdon Hill: use river path adjacent to Sports/Arts Centres
222, 223 – Cowley Road: use path via flats and Social Science buildings


PLAN 1A
BRUNEL UNIVERSITY
BUILDINGS AND ESTATES DEPARTMENT
SCIENCE PARK BUILDING.
GROUND FLOOR · PLAN.
SP/1/1
GROUND FLOOR PLAN
DISABLED TOILET
OFFICE 1
OFFICE 2
CORRIDOR
MALE TOILET
FEMALE TOILET
ELECTRICAL
EXHIBITION AREA
DUCT
PARKING
PARKING
PATIO

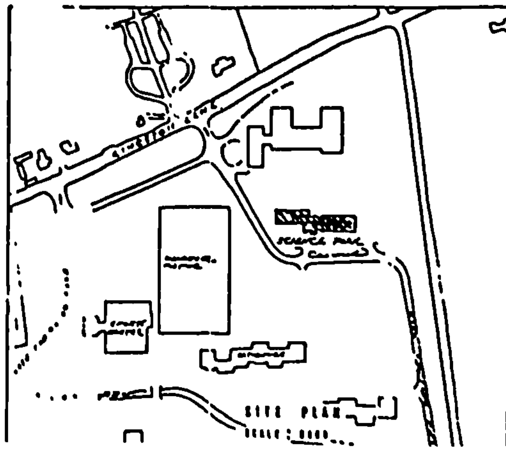
FIRST FLOOR PLAN



FIRST FLOOR PLAN

[illegible]

PLAN 1



BRUNEL UNIVERSITY

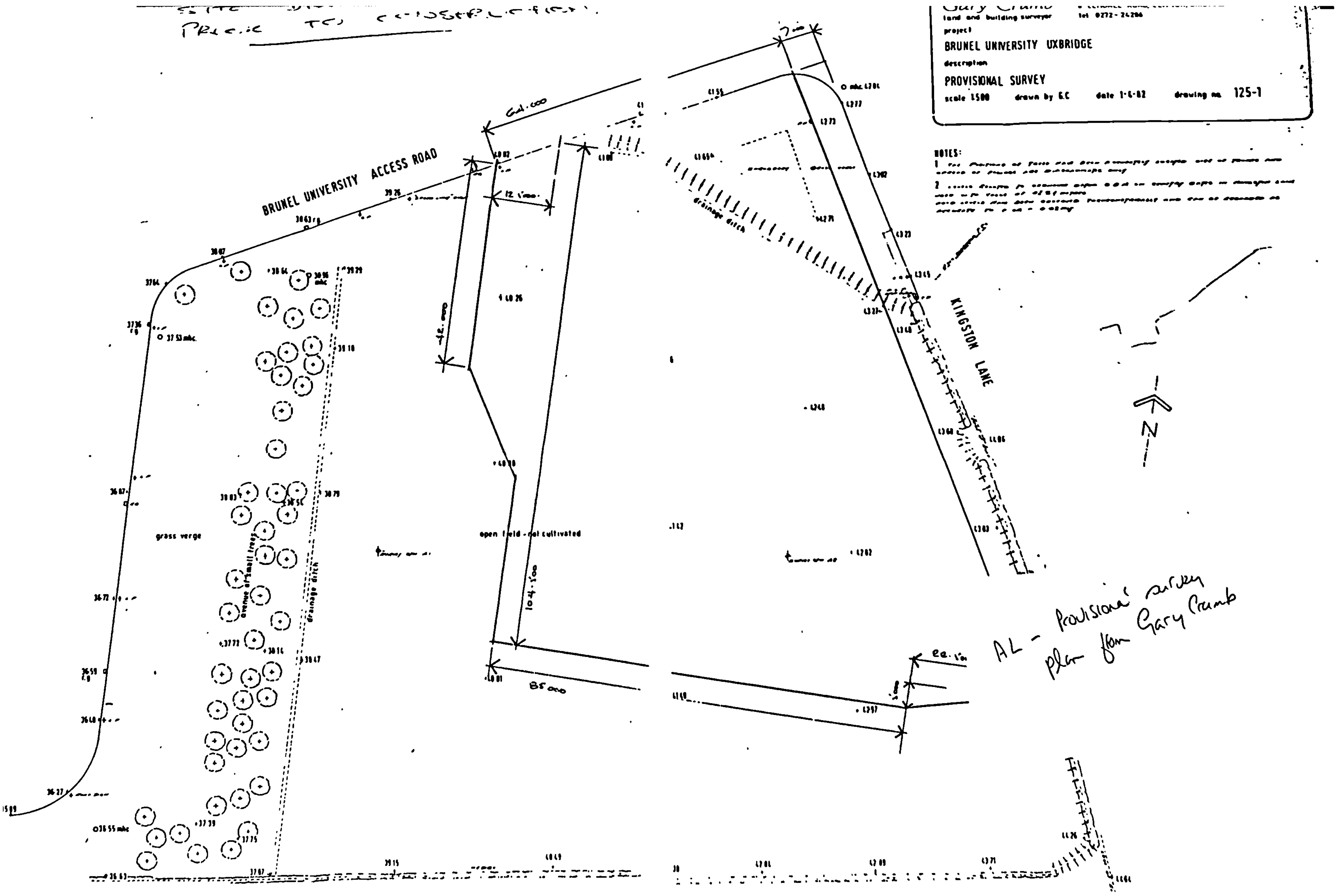
BUILDINGS AND ESTATES DEPARTMENT

KINGSTON LANE,
UXBRIDGE, MIDDLESEX, [illegible]
TEL. UXBRIDGE [illegible]

SCIENCE PARK
BUILDING

FIRST FLOOR PLAN

SITE [illegible]
PRIOR TO CONSTRUCTION.



Gary Crump
land and building surveyor tel 0272-24206
project
BRUNEL UNIVERSITY UXBRIDGE
description
PROVISIONAL SURVEY
scale 1:500 drawn by G.C date 1-6-82 drawing no. 125-1

NOTES:
1 [illegible]
2 [illegible]

AL - Provisional survey
plan from Gary Crump

Appendix 3 - Biocompatibles Ltd. Lease Extracts

The document excerpt on the next three pages is taken from the Lease Agreement for Biocompatibles Ltd. In particular, it includes clauses dealing with noise pollution, public nuisance and discharge of effluent into the sewerage system and the surrounding premises.

(12) <u>Use</u>

(A) At all times during the Term to use and occupy the Demised Premises for the following purposes:-

(i) scientific research development and education associated with or ancillary to or calculated to promote encourage or facilitate industrial production or manufacture

(ii) light industrial production and manufacture where such production or manufacture is ancillary to and forms a necessary part of the scientific research development or education permitted under sub-clause (i) hereof

(iii) office and other administrative purposes ancillary or incidental to the uses hereinbefore permitted (including the provision of library and conference facilities)

and without prejudice to the generality of the foregoing not to use or permit or suffer to be used the Demised Premises otherwise than for the purposes specified in Paragraph 9 of Schedule 1 or subject to the prior written consent of the Landlord such consent not to be unreasonably withheld for any other purpose PROVIDED that the Landlord may at any time refuse to consent to a use which is inconsistent with the use as a science park operating in conjunction with a university

(B) Not to use the Demised Premises or any part thereof nor permit or suffer the same to be used

(i) for residential purposes or as sleeping accommodation

(ii) for any public exhibition or entertainment or the conduct of any sale by auction

(iii) for any noisy noisome offensive or dangerous trade art manufacture business or occupation

(iv) for any illegal or immoral purpose

(v) in any way or for any purpose which may tend to become an annoyance nuisance damage disturbance or inconvenience to the Landlord or the owner or occupier of any adjoining or neighbouring premises or the neighbourhood

(C) Not to trade or display goods or cause any obstruction outside the Demised Premises or the front windows thereof or upon any private forecourt comprised therein nor to hang or permit to be hung anything from the windows of the Demised Premises

(D) Not to allow to pass into the Conduits serving the Demised Premises or any adjoining or neighbouring premises any noxious or deleterious effluent or other substance whatsoever which may cause an obstruction in or injure the Conduits and in the event of any such obstruction or injury forthwith to make good all such damage and any damage caused to the Demised Premises to the satisfaction of the Landlord's Surveyor

(E) Not to load or unload or park motor vehicles on any part of the Common Parts other than on the areas designated by the Landlord for the use of the Tenant and not to obstruct or suffer to be obstructed the Common Parts

(F) Not to store rubbish or refuse within the Demised Premises and to ensure that the same is cleared from the Demised Premises each day and deposited within the receptacles provided within the central refuse storage area

(13) Advertisements and signs

Not to affix or exhibit or permit to be affixed or exhibited to or on any part of the interior so as to be seen from the exterior any advertisement sign signboard fascia notice blind or flag other than such as shall have been previously approved in writing by the Landlord nor hang place deposit or expose outside any part of the buildings comprised in the Demised Premises any goods articles or things for sale and not to install or permit to be installed any flag pole outside aerial or window box on the Demised Premises PROVIDED THAT the Tenant shall be permitted to place a sign showing its name the nature of its business and its logo on the exterior doors of the Demised Premises with the previous approval of the Landlord (such consent not to be unreasonably withheld or delayed) as to the size design and exact location of such signs

(14) Nuisance

Not to do or permit or suffer to be done upon or in connection with the Demised Premises anything which shall be or tend to be a nuisance (whether indictable or not) annoyance or cause of damage to the Landlord or to any adjoining or neighbouring property or the owner or occupier thereof

(15) Overloading

Not to do or permit or suffer or bring in or upon the Demised Premises anything which may impose on the Science Park or any adjoining or neighbouring premises any load weight or strain in excess of that which any of such premises are designed or constructed to bear with due margin for safety and in particular not to overload the floors or the electrical installation or the other services of in or to the Demised Premises nor suspend any excessive weight from the ceilings or walls stanchions or the structure thereof

(16) Alienation and registration

(A) Subject to the following provisions not to assign mortgage charge underlet or otherwise part with or share possession or occupation of any part of the Demised Premises otherwise than

Appendix 4 - NRA Data

Thames National Rivers Authority (Amersham) was contacted to see if any water quality readings are taken for River Pinn. Several data sheets were provided by the NRA and are presented here. One covers the River Pinn water quality readings (shown on the next page), and two outline the water quality standards for fresh water as defined by the governing bodies (the other two pages of this Appendix), so comparisons with the River Pinn readings can be made.

U/S BRUNEL

```
[illegible]
                                            S.Solids  BOD(ATU)  DO %Sat       Amm.N.      Un-A
                                            ------------------------------------------------------
2?/01/91 1?0? --PR 0?1 UC???                           1.700    87.000        0.130        0.0
11/02/91 1025   PR 012 GC057                           3.100    73.000        0.310        0.0
08/03/91 1124 --PR 011 RU052                           3.000   103.000        0.210        0.0
05/06/91 1200   PR 001 IS201                           2.900   115.000  (     0.050  (     0.0
24/06/91 1115 --PR 001 IS247                           2.700    88.000  (     0.050  (     0.0
03/07/91 1525 --PR 001 BC349                 (         2.000   155.000  (     0.050  (     0.0
12/08/91 1215 --PR 001 RU307                 (         2.000    92.000  (     0.050  (     0.0
10/09/91 1530 --PR 000 GC462                 (         2.000   108.000  (     0.050
18/10/91 1520 --PR 001 IS488                 (         2.000    93.500  (     0.050  (     0.0
04/11/91 1230 --PR 001 SS020                           2.400    97.000  (     0.050  (     0.0
02/12/91 1355 --PR 000 SS155                           3.000   100.000
30/01/92 1305 --PR 001 IS023                 (         2.000   112.000  (     0.050  (     0.0
15/04/92 1145 --PR 002 SS609                           3.200    71.000        0.090  (     0.0
```

```
                                            S.Solids  BOD(ATU)  DO %Sat       Amm.N.      Un-A
                                            ------------------------------------------------------

MAXIMUM                                                3.200   155.000        0.310        0.0

MINIMUM                                                1.700    71.000        0.050        0.0

MEAN                                                   2.454   101.331        0.095        0.0

NUMBER OF DETERMINATIONS                                13        13           12           11
****
```

D/S BRUNEL

```
RNR.0075  RINN ABOVE TRAYS
                                            S.Solids  BOD(ATU)  DO %Sat       Amm.N.      Un-A
                                            ------------------------------------------------------
21/01/91 1015 R--R 011 GC017                           1.200    85.000        0.070        0.0
04/02/91 1035 R  R 011 GC046                           1.400   105.000  (     0.050  (     0.0
08/03/91 1152 R--R 011 RU095                           2.300   103.000        0.190  (     0.0
26/04/91 0935 R--R 001 GC190                           2.500    93.000  (     0.050  (     0.0
17/06/91 1735 R--R 000 IS223                                   118.000  (     0.050  (     0.0
24/06/91 1155 R--R 001 IS249                 (         2.000    88.000  (     0.050  (     0.0
10/07/91 1010 R--R 002 GC357                           5.200    98.000  (     0.050  (     0.0
12/08/91 1240 R--R 001 RU309                 (         2.000   114.000  (     0.050  (     0.0
15/10/91 1510 R--R 002 IS496                                    53.000        0.240        0.0
04/11/91 1315 R--R 001 SS022                 (         2.000    97.700  (     0.050  (     0.0
02/12/91 1330 R--R 000 SS157                 (         2.000    93.400
30/01/92 1140 R--R 001 IS024                           2.300   110.000        0.130        0.0
10/03/92 1300 R-PR 001 RU041                 (         2.000   130.000  (     0.050  (     0.0
15/04/92 1215 R-PR 002 SS511                           3.100    72.000        0.050  (     0.0
```

```
                                            S.Solids  BOD(ATU)  DO %Sat       Amm.N.      Un-A
                                            ------------------------------------------------------

MAXIMUM                                                5.200   130.000        0.240        0.0

MINIMUM                                                1.200    53.000        0.050        0.0

MEAN                                                   2.333    98.079        0.085        0.0

NUMBER OF DETERMINATIONS                                12        14           13           13
****
```

NATIONAL RIVERS AUTHORITY - RIVER QUALITY STANDARDS (FRESH WATER)

DETERMINAND	UNITS	MEAN	50%ile	95%ile	MAX		
		CLASS 1A					
Dissolved oxygen (min)	%sat.			80			
Dissolved oxygen (min)	mg/l		9				
BOD (ATU) 5 day	mg/l	(1.5)		3			
Ammonia as NH4	mg/l			0.4			
Ammonia, non-ionized as NH3	mg/l			0.025			
Suspended solids (105 deg C)	mg/l		(25)				
pH				6-9			
Nitrite as NO2	mg/l			(0.2)			
Cadmium	ug/l	5					LIST 1 substances
Mercury	ug/l	1					
Hexachlorocyclohexane	ug/l	0.1					
Carbon tetrachloride	ug/l	12					
Para-para DDT	ng/l	10					
DDT	ng/l	25					
Pentachlorophenol	ug/l	2					
Hexachlorobenzene	ug/l	0.03				from 01/1990	
Hexachlorobutadiene	ug/l	0.1				from 01/1990	
Chloroform	ug/l	12				from 01/1990	
Aldrin	ng/l	10				from 01/1994	) 1/1989 total 'dri
Dieldrin	ng/l	10				from 01/1994	) <- 30ng/l
Endrin	ng/l	5				from 01/1994	) & endrin
Isodrin	ng/l	5				from 01/1994	) <- 5 ng/l
Arsenic	ug/l	50					LIST 2 substances
Chromium hardness 0-50	ug/l	5					
50-100	ug/l	10					
100-200	ug/l	20					
>200	ug/l	50					
Copper hardness 0	ug/l	1					
10	ug/l	*2		(5)			
50	ug/l	6		(22)			
100	ug/l	10		(40)			
200	ug/l	10		*(76)			
250	ug/l	28		*(94)			
>300	ug/l	28		(112)			
Lead hardness 0-50	ug/l	4					
50-150	ug/l	10					
>150	ug/l	20					
Nickel hardness 0-50	ug/l	50					
50-100	ug/l	100					
100-200	ug/l	150					
>200	ug/l	200					
Zinc hardness 0	ug/l	8					
10	ug/l	*16		30			
50	ug/l	50		200			
100	ug/l	75		300			
200	ug/l	75		*350			
250	ug/l	125		*375			
>500	ug/l	125		500			

TIONAL RIVERS AUTHORITY - RIVER QUALITY STANDARDS (FRESH WATER)

			CLASS 1B				
DETERMINAND		UNITS	MEAN	50%ile	95%ile	MAX	
Dissolved oxygen (min)		%sat.			60		
Dissolved oxygen (min)		mg/l		9			
BOD (ATU) 5 day		mg/l	(2)		5		
mmonia as NH4		mg/l	(0.5)		0.9		
mmonia, non-ionized as NH3		mg/l			0.025		
uspended solids (105 deg C)		mg/l		(25)			
pH					6-9		
Nitrite as NO2		mg/l			(0.2)		
Cadmium		ug/l	5				LIST 1
Mercury		ug/l	1				substances
Hexachlorocyclohexane		ug/l	0.1				
Carbon tetrachloride		ug/l	12				
Para-para DDT		ng/l	10				
DDT		ng/l	25				
Pentachlorophenol		ug/l	2				
Hexachlorobenzene		ug/l	0.03	from 01/1990			
Hexachlorobutadiene		ug/l	0.1	from 01/1990			
Chloroform		ug/l	12	from 01/1990			
Aldrin		ng/l	10	from 01/1994		) 1/1989 total 'drin	
Dieldrin		ng/l	10	from 01/1994		) <- 30ng/l	
ndrin		ng/l	5	from 01/1994		) & endrin	
sodrin		ng/l	5	from 01/1994		) <- 5 ng/l	
Arsenic		ug/l	50				LIST 2
							substances
Chromium	hardness 0-50	ug/l	5				
	50-100	ug/l	10				
	100-200	ug/l	20				
	>200	ug/l	50				
Copper	hardness 0	ug/l	1				
	10	ug/l	*2		(5)		
	50	ug/l	6		(22)		
	100	ug/l	10		(40)		
	200	ug/l	10		*(76)		
	250	ug/l	28		*(94)		
	>300	ug/l	28		(112)		
Lead	hardness 0-50	ug/l	4				
	50-150	ug/l	10				
	>150	ug/l	20				
Nickel	hardness 0-50	ug/l	50				
	50-100	ug/l	100				
	100-200	ug/l	150				
	>200	ug/l	200				
Zinc	hardness 0	ug/l	8				
	10	ug/l	*16		30		
	50	ug/l	50		200		
	100	ug/l	75		300		
	200	ug/l	75		*350		
	250	ug/l	125		*375		
	>500	ug/l	125		500		

References

NSCA94 National Society for Clean Air and Environmental Protection *1994 Pollution Handbook*, ISBN 0 903474 36 0

6 PROJECT PLAN

Module 1a: Project Management

EngD - Year 2

Coursework Assignment

Produce a Project Plan for your Research Project to cover the four years of the period of research.

Your plan should include:

1. A preamble outlining the background to the project.
2. The aims of your research project and how you plan to fulfil these.
3. How the project will impinge on the working of your sponsoring company/organisation in the short-term and in the long-term.
4. The contribution that your project will make to the environment.
5. A family tree which shows where you (and your project supervisor) fit into the organisation of your sponsor; include any other members of the organisation who may be involved in your work.
6. A Gantt chart detailing the main activities and planned milestones.
7. A project calendar detailing your course module dates (where known) company project meetings, report deadlines, coursework deadlines, holidays etc. (it would be helpful to maintain this as a live document).
8. Provide a summary of the progress on your project, to date.

Submission Deadline

Your Project Plan is to be submitted to Alex Roberts by first mail on Friday 16 December.

1st week Jan OK.

Engineering Doctorate Project Plan

Richard D Peters
Brunel University, Uxbridge, Middlesex UB8 3PH and
Arup Research & Development, 13 Fitzroy Street, London W1P 6BQ

9 January 1995
Document ref: \engd\598.wpd

1. Preamble

My EngD sponsor, the Ove Arup Partnership, is an international firm of consulting engineers. A major part of their work is the design and specification of buildings. Arup sponsored my undergraduate degree at Southampton University and employed me as an Electrical Engineer when I graduated in 1987.

Buildings account for about a third of all the energy we consume. Lifts, my main area of expertise, make up a significant proportion (5 to 10%) of the electrical load in large developments. My project aims and objectives are based on the belief that there are significant energy savings to be made in the area of Vertical Transportation by good planning design, considered control strategies and the use of high efficiency motors.

The title of my Environmental Technology Engineering Doctorate project is *Vertical Transportation Planning in Buildings*.

2. Aim of Research Project

The aim of my research is to provide a basis for the design and specification of vertical transportation systems which are both energy efficient, and provide passengers with a good service by defined standards. I am proposing to fulfill these aims by:

i. Measuring vertical passenger traffic and lift/escalator energy consumption so as to build up pedestrian circulation and corresponding energy models for offices, residential buildings, airports, leisure complexes, etc.

ii. Comparing the use and performance of lifts/escalators/stairs to existing lift traffic analysis models and assumptions. Comparing the performance of driving motors to electrical models.

iii. Developing computer programs implementing verified analytical/simulation traffic analysis models and corresponding energy models.

iv. Using verified models to calculate: the benefits of developing and implementing energy efficient lift control algorithms, the savings achievable though use of high efficiency motors, and the benefits of energy conscious planning strategies.

v. Establishing guidelines for predicting traffic in new and refurbished buildings. Making planning and specification recommendations that reflect the need to design energy efficient buildings.

3. Implications on Sponsoring Company

In the short term, my project is raising awareness of environmental issues. I have given a talk to electrical design team leaders about *Environmental Technology and Building Services*. The purpose of this was to make them aware of environmental legislation and to introduce life cycle analysis.

In the long term I expect my project recommendations to have a strong influence on the design and specification of vertical transportation systems in Arup.

Practically, my project will provide tools to enable Arup to analyse the efficiency of alternative designs (single/double decker lifts, escalators, numbers, sizes, speeds, etc.). And the theoretical basis for writing specifications for energy efficient control systems.

The training I am gaining in environmental issues adds skills to the firm which it is envisaged will be applied over a broad range of construction projects and subject fields.

4. Contribution project will make to the environment

Electricity generation causes non-renewable resources to be depleted, waste and emissions to be generated. In my end of Year 1 EngD paper, I demonstrated that a typical lift system is the cause of over 2000 tonnes of CO_2 emissions over its lifetime.

My project's contribution to the environment will be to provide information and tools that enable us to minimise the environmental impact of vertical transportation systems, primarily through reduced energy consumption.

As one of the words largest specifiers of vertical transportation systems, Arup is very influential in the lift industry. My second sponsor, the Charted Institution of Building Services Engineer, has similar, if not greater influence. It is therefore reasonable to assume that, if my project is successful in putting forward practical, and cost effective energy saving measures, they will be implemented on a significant scale.

5. Family Tree

A simplified Arup company structure is shown in Figure 1. My industrial supervisor is John Haddon.

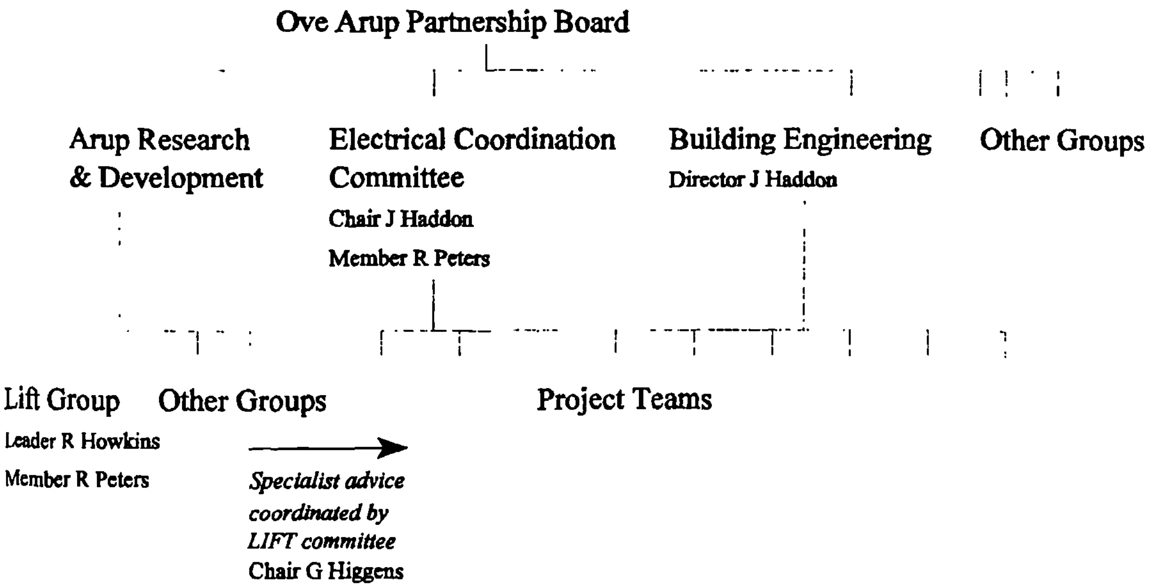


Figure 1 Simplified Arup Company Structure

6. Gantt Charts

I prepare Gantt charts for my industrial and academic supervisors every six months. Updated charts for years 1 and 2 are included in appendix A. I have not prepared charts for years 2 and 3 at this stage as the activities will depend heavily on the results of my current research (a lesson I learnt having prepared a four year chart at the beginning of the programme).

7. Project Calender

A project calender is included in appendix B.

8. Summary of Progress

In summary, I have made the following progress with my project to date:

i. Carried out a life cycle analysis on a typical lift system to confirm that energy in use in the cause of dominant environmental burden.

ii. Made progress modelling lift motion and energy consumption, providing the basis for tools to test my energy saving ideas. Related to this work, I am presenting a paper on lift kinematics at the international lift conference, Elevcon '95 in March. I am helping to supervise an undergraduate student who is building a lift model - this should provide data to test my mathematical models.

iii. Presented a paper "Green Lifts?" at the CIBSE National Conference, following this up with a direct enquiry to the major lift manufacturers to solicit their comments.

iv. Carried out initial site surveys which suggest that current design criteria tend to result in excessive lift handling capacity. One survey provided evidence for a rent review arbitration case for which I was an expert witness - the tenant claimed (incorrectly) that there was insufficient handling capacity. Establishing lower handling capacity design criteria will reduce the capacity of new lifts, therefore saving energy.

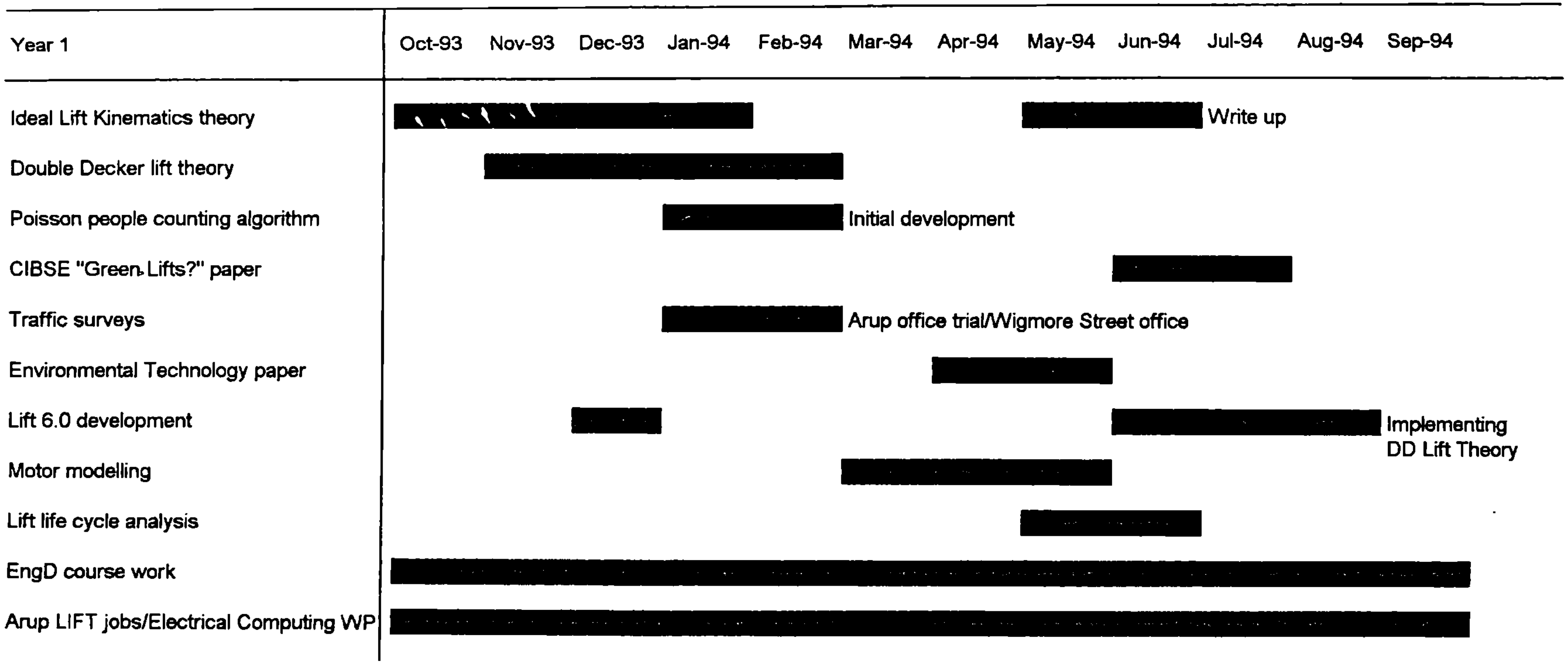
v. Carried out background research, and development of automatic traffic counting techniques to aid traffic surveys.

vi. Considered approaches to developing "green" lift control algorithms.

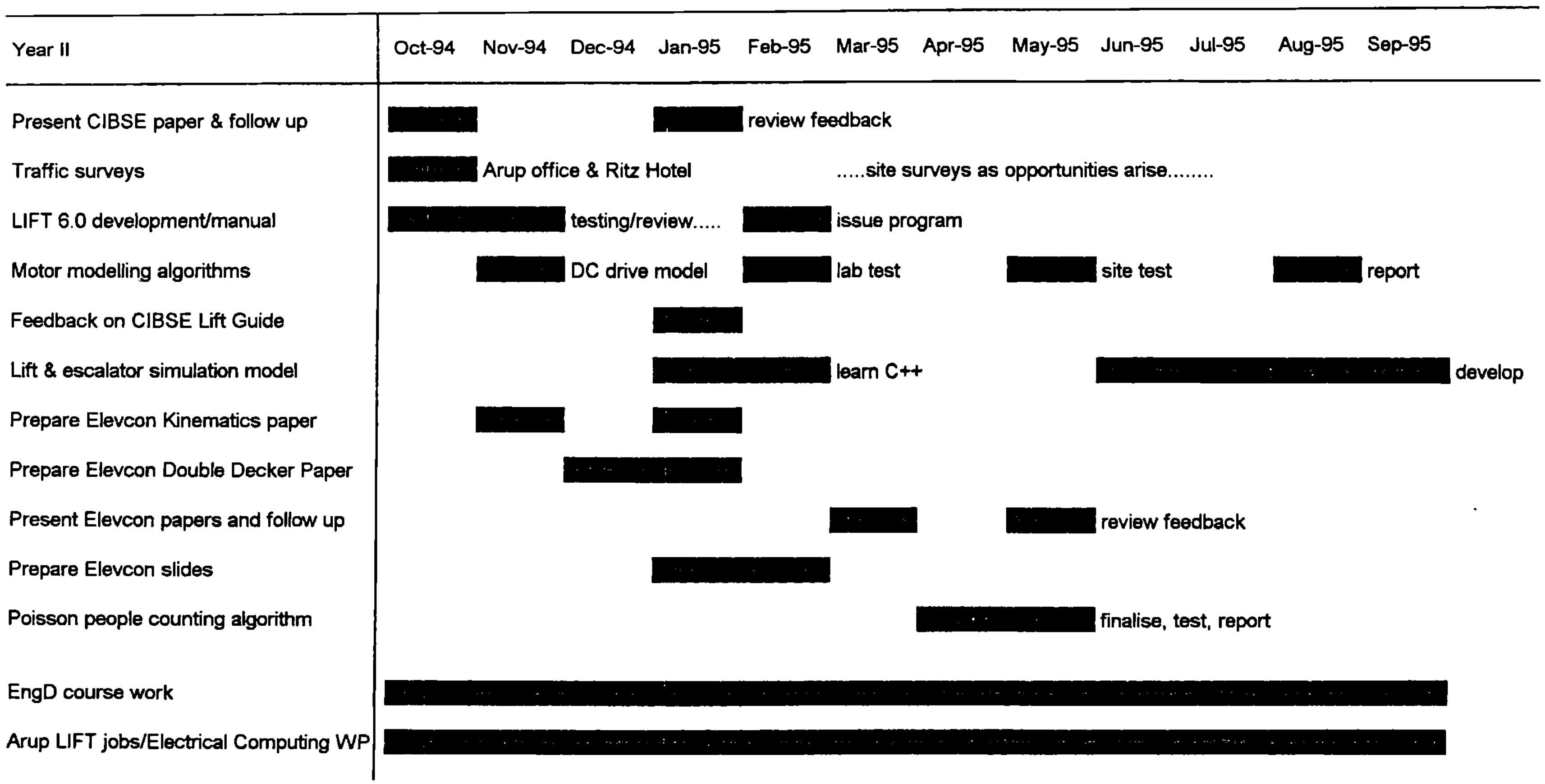
vii. Developed a traffic analysis/planning technique for double decker lifts - double decker lifts are claimed to be more energy efficient for transporting large numbers of people in high rise buildings. I am also presenting a paper on Double Decker lift traffic analysis at Elevcon '95.

viii. Input advice/analysis for a number of Arup Vertical Transportation designs.

Appendix A Project Programme



Appendix A Project Programme



Appendix B Project Calendar

October 1993	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
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Arup LIFT Committee												■																			
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Course Modules								■	■	■	■	■	LCA2/Research Training Programme/Project Management																	
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Arup LIFT Committee																														
Joint supervisor meetings																														
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December 1993	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F
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Arup LIFT Committee																															
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Arup LIFT Committee																												
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March 1994	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T
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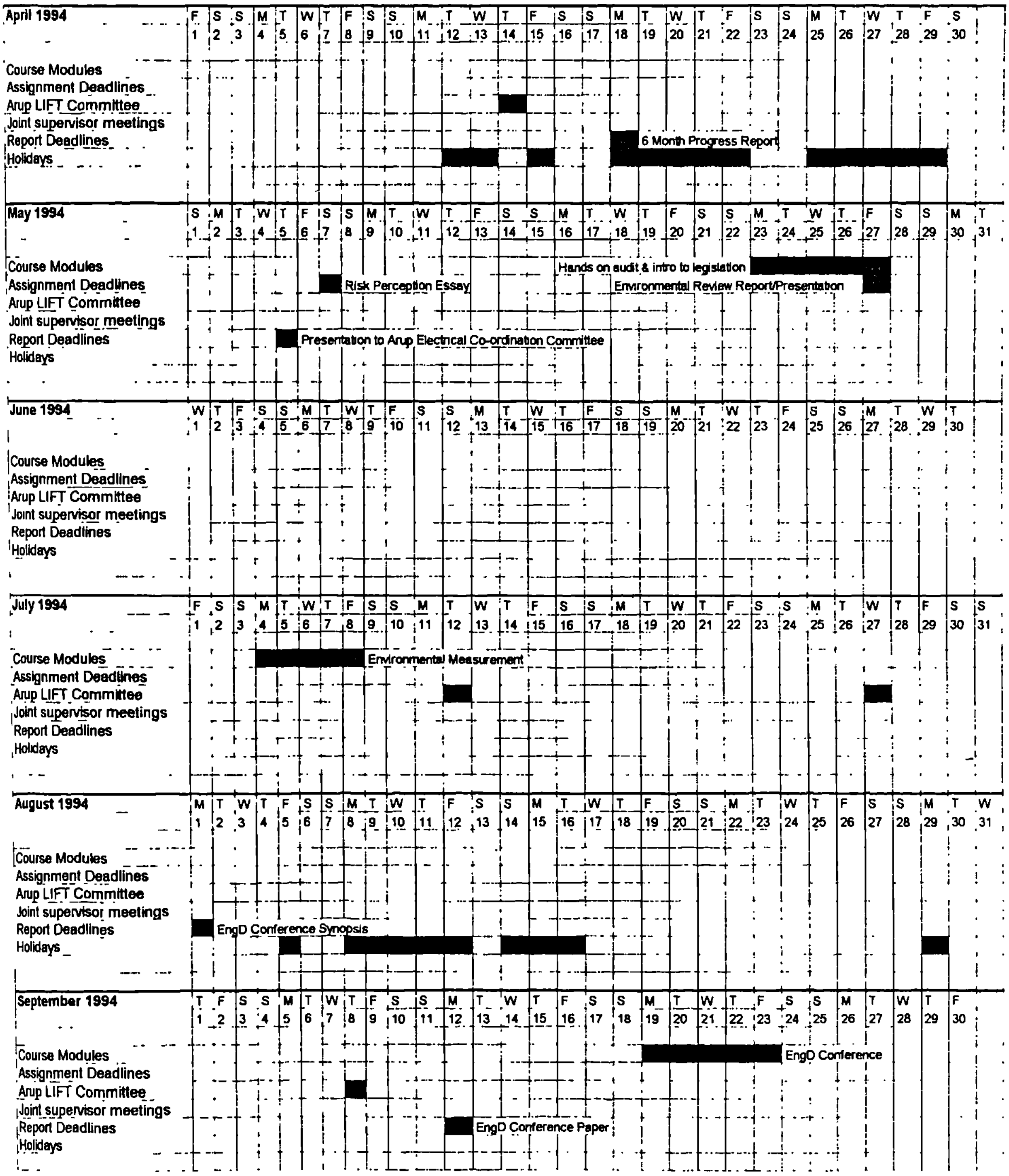
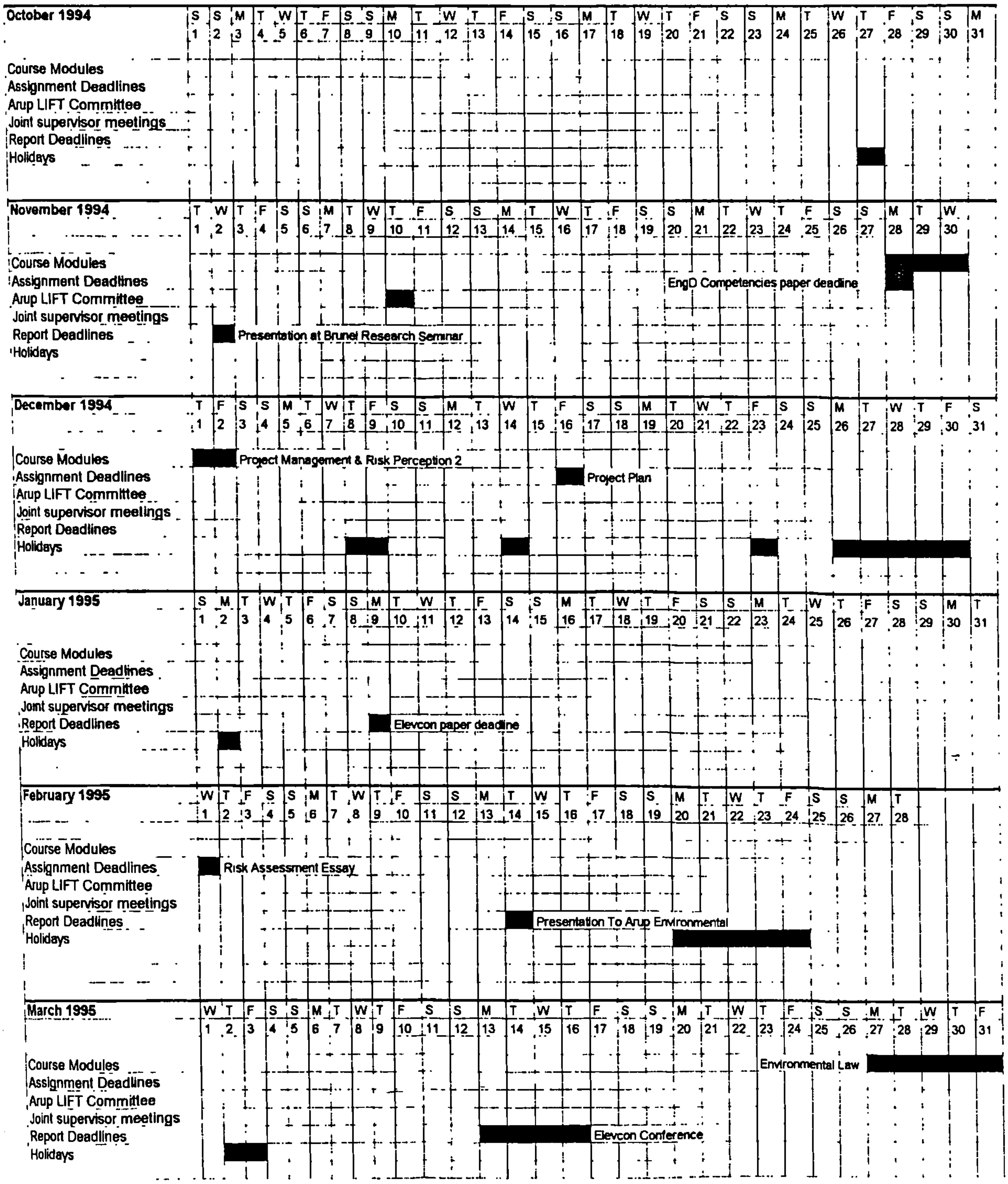
Appendix B Project Calendar



Appendix B Project Calendar



Appendix B Project Calendar

April 1995	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
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June 1995	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F
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Arup LIFT Committee																														
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Holidays																														

Richard Peters

23 March 1995

Richard

A good project plan and concise. Your style is easy to read (and digest). I was interested in your comment about not preparing Gantt charges for years 2 and 3 as you think they will change. It is still better (in my opinion) to plan even if there are changes. Your project calendar contains all the right information, but again I would prefer to see a longer look forward.

Alex Roberts

Your later submission has reduced your mark from B+ to **B-**

7 RISK COMMUNICATION

Risk Communication - Is it at a theoretical dead end?

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23 January 1995
Document ref: engd\609.wpd

1. Introduction

The term *risk communication* implies the discussion of danger. It is possibly one of the original purposes of language. Yet the study of risk communication is a relatively new research field, having evolved out of a need for risk managers to gain public acceptance for policies grounded in risk assessment methodologies.

In this essay we shall look at risk communication in the context of the environmental and health hazards caused by industrial developments. As an example we shall review the discussion that took place between industrialists, planners, pressure groups, media and the public when Elm Energy proposed to build a tyre burning plant in Slyfield Industrial Estate, Guildford.

Principles for good risk communication suggested by researchers will be presented and discussed.

The hypothesis implied by the essay title is that the research field of risk communication is at a theoretical dead end. This hypothesis will be refuted. Consolidation of existing findings will be proposed, together with proposals for possible new areas of research.

2. Case study

The need for risk communication has been introduced, but is demonstrated more clearly by an example:

In November 1994 Research Engineers from Brunel and Surrey Universities undertook a case study. The task set was to undertake a media analysis and survey of public opinion concerning a proposed tyre burning plant in Guildford.

Background

Elm Energy & Recycling would like to build an incinerator on the Slyfield Industrial Estate in Guildford. The proposed incinerator would burn 20,000 tonnes of tyres per year, generating about 5 megawatts of electricity. The proposed plant size in 60m by 40m with a 35m stack.

Media coverage

Media coverage was provided predominantly by the local paper, the Surrey Advertiser, with occasional news bulletins broadcast by local radio. The issue was introduced in the Surrey Advertiser in September 1994.

The initial media coverage outlined Elm Energy's proposals. In following weeks this initial reporting generated negative responses ranging from fears of carcinogenic emissions to dramatic and emotive statements eg. "this could be another Chernobyl". The environmental group, Friends of the Earth joined in the condemnation.

Subsequent coverage attempted to give a more balanced, informed basis for discussion. Elm Energy were reported as having received positive coverage from the BBC's Tomorrow's World programme on their incineration process. The company issued an open invitation to councillors and the public to visit their Wolverhampton plant. Elm Energy believe this plant is an asset to the community.

The introduction of the Wolverhampton plant backfired on Elm Energy as the media reported on Wolverhampton's objections to the plant. They conceded they would be making major changes to the plant design for Guildford. "Experts" from Friends of the Earth and academia disagreed on the hazards introduced by the plant process. Meanwhile, the AA awarded Elm Energy a national award for achievements in environmental concerns.

Reports of the public meeting demonstrated a defensive stance by Elm Energy and the need for more information on the actual risks of the plant. In December, a county councillor wrote to inform the paper that he and three other councillors would vote against the plans.

Public perceptions

The public survey confirmed the local paper to be the main source of information about the tyre burning plant. Other sources of information were flyers, friends and family.

The majority of people had heard about the incinerator, but felt ill-informed about the proposals. Older people and residents near the site tended to know more detail.

Drawbacks (traffic, pollution, etc) and advantages (employment, waste disposal, etc.) were recognised by some interviewees. Nevertheless, almost everyone was against the siting of the plant in Guildford. People local to Slyfield were particularly anti.

A local committee had been formed near the proposed site. They had circulated flyers, newsletters and arranges meetings. This committee was valued by residents as a trustworthy source of information. Newspapers and "experts" were considered unreliable.

Case study conclusions

The case study concluded that Elm Energy's risk communication had been unsuccessful. Elm's approach to the problem had been reactive rather than proactive. Indeed its position had been communicated better by the council and other independents. The media reporting had sensationalised the issue. And the public found itself with contradicting "expert" opinions from environmental groups, Elm Energy and academics.

A highly acclaimed method of dealing with waste tyres had effectively been vetoed by the public. The issue of alternative ways of dealing with the tyres was hardly touched upon.

3. Public and industry approaches to risk

Elm Energy misunderstood the need to communicate the risks of the tyre plant - in their "expert" opinion, the risks were minimal. Why did the public not agree?

Research by Lichtenstein et al (1978) considered individuals' assessments of causes of death ranging from heart disease to floods and botulism. The researchers observed that individuals overestimated the risk of low-probability events (such as tornadoes), and underestimated the risk of high probability events (such as diabetes). A hypotheses suggested is that people start by assessing risks of all kinds as being identical. As they acquire information about each type of risk, they revise their assessment. In this case fears perceived as misplaced by exerts do not reflect irrational behaviour, but the degree of knowledge acquired about each risk.

In industry, assessment of risk is generally based on experts' calculations and past performance - a mathematical, probabilistic approach. In new industries, risk assessments can be very approximate. Indeed, there is a natural tendency for those responsible for introducing risk, to underestimate it.

The public and industry understand and approach risk differently. It is therefore unsurprising that communicating risk is fraught with difficulties. Plough and Krimsky deduce "A partial answer to the question of why risk communication has emerged as a framing issue for environmental issues can be found in the differences between professional risk analysts and popular culture".

4. Communicating risk

Considerable research has already been undertaken to determine how best to communicate risk to the public. The main principles of risk communication determined by researchers are summarised below:

1. *Top down* or *source to target* risk communication, the "I know everything, you know nothing" approach is generally unsuccessful. It is highly dependant on the credibility of those explaining the risk.

2. For good risk communication, genuine public consultation must begin early and be ongoing. Options and alternatives are preferable to "draft" proposals. People are far more likely to accept undesirable circumstances if they have participated in the decision making process, and the issues they have raised have been acted upon. Other considerations may be necessary. For instance, introducing the possibility of a new power station shortly after an accident at an another power station is unwise!

3. Failure in risk communication can often be attributed to the lack of trust. Trust is fragile, being difficult to create and easy to destroy. Once trust is undermined, new evidence of trustworthiness has little influence.

4. It is helpful to avoid the technical language associated with quantitative risk analysis - this tends to reduce the possibility of dialogue between the public and the élites.

5. Voluntary risks are more acceptable than involuntary ones - if the public has and knows it has real power to stop a risk being introduced, it is more likely to accept that risk.

6. Detectable risks are more acceptable than non-detectable risks - independent monitoring to detect malfunctions can reduce the level of fear, especially if the community have power to shut down the malfunctioning plant.

7. Familiar risks are more acceptable than unfamiliar risks - knowledge about the source of waste and products of the treatment process will put risks in context, especially if paralleled to known industries.

8. The public is bemused by growing list of environmental and lifestyle hazards. People are less concerned about natural risks than they are about equitable risks caused by man.

9. Risks perceived as "fair" are more acceptable than "unfair" risks - making each community responsible for its own waste may be less efficient overall, but is less likely to meet public opposition.

10. The public are sceptical of media sensationalism and industry, etc. who may profit from under-estimating, or exaggerating a specific risk. Uncertainty is loathed, especially when experts disagree.

11. The introduction of a health or environmental risk may only be part of the public agenda. Others issues, sometimes not acknowledged, may be fear of reduced house prices and the fear of opening the door to other less desirable developments. The real agenda is more likely to come out in negotiation, rather than in confrontation.

12. Compensation for health risks are likely to be seen as bribes. A trust fund to protect water quality or pay out in the event of health damage is more acceptable.

5. Where do we go from here?

As has been discussed in this essay, there is already research on which to base risk communication recommendations. However examples of successful risk communication projects based on these recommendations are less evident.

If risk communication researchers are to demonstrate they are not at a dead end, they will first need to consolidate their progress by recording projects where their recommendations have been implemented, and where risk communication has been successful.

A possible subject for this consolidation from an industry field related to my work could be health risks associated with the electromagnetic fields generated by electricity distribution cables. An exercise in risk communication could be carried out at national level, and may well be sponsored by the television companies (providing material for a documentary) and the electricity distribution companies.

6. New research fields

If existing risk communication theory can be consolidated, suggested topics for research could be:

1. The relative effectiveness of risk communication techniques in the context of cultural differences. Most research to date has been USA based. Plough and Krimsky quote M Douglas who says "The question of acceptable standards of risk is part of the question of acceptable standards of morality and decency, and there is no way of talking seriously about the first while evading the task of analysing the cultural system in which the second take their form".

2. Most risk communication research is reviewed from the standpoint of transfer of information from the expert to the lay person. But communication is a two-way dialogue, and there is less research evident from those observing how the lay-person will communicate (reciprocal risk communication). Looking at the problem from a lay persons perspective may give us new insights. How should we, the public react when presented with new risks?

3. P Sandman touches on the complex debate of media handling of toxic waste issues. Review of the influence of media articles have been undertaken (Golding D, Krimsky S, Plough A and EngD case study). But how effective are other forms of media risk communication? Television news and documentaries are a major form of risk communication which remain unstudied.

4. The EngD study revealed that residents most trusted a committee made up of local people. Cooperating with a committee which has the trust of the community is obviously worthwhile. But how far can a developer go in helping, even sponsoring such a committee before community trust declines?

5. The need for risk communication has come about because of the differences in perception of risk. It is possible to communicate the order of magnitude of risks by using comparison with familiar risks (road accidents, etc.). Implementing this and other approaches to better communicate the degrees of risk may "rationalise" for analysts the public's perception of calculated risk.

7. Conclusions

In this essay we have reviewed the need for risk communication, discussed an example of poor risk communication, and considered researches' recommendations. In the writers opinion, researches now need to demonstrate that these principles of good risk communication work - by implementing them and through reporting specific projects where they have been successful. With this evidence to support the research field, it is relatively simple to identify new areas of research. Five possible topics have been suggested.

Bibliography

Various *Surrey Advertiser* 16 September 1994 to 18 November 1994

Viscusi W Kip, Magat W A *Learning about Risk* 1987 Harvard University Press

Lichtenstein, S, P Slovic, B Fischhoff, M Laymanm, B Combs *Judged frequency of lethal events* Journal of Experimental Psychology: Human Learning and Memory 4 1978

Plough A, Krimsky *The Emergence of Risk Communication Studies: Social and Political Context* (source unknown)

Löfstedt R E *Risk communication in the Swedish energy sector* Energy Policy July 1993

Slovic P *Perceived Risk, Trust and Democracy* Risk Analysis Vol 13 No 6 1993

Golding D, Krimsky S, Plough A *Evaluating Risk Communication: Narrative vs. Technical Presentation of Information about Radon* Risk Analysis Vol 12 No 1 1992

Sandman P *Getting to Maybe: Some communications aspects of siting hazardous waste facilities* Senton Hall Legislative Journal Vol 9 1985

Douglas M *Risk Acceptability According to the Social Sciences* New York: Russell Sage, 1985

[illegible]. You have a good overview of the literature and [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]. However [illegible] [illegible] [illegible] "[illegible]" into the paper [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] and the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]. (+)

R.Peters: You gave a good overview of the literature and based on your discussion it is clear that you understand the theoretical concepts of RC. It would have been better, however, if you could have put more "meat" into the paper by probing deeper into the tyre incinerator debate. There were many key issues within the EngD RC project that you and the rest of the EngD students uncovered that could have been discussed. C+

8 ENVIRONMENTAL LAW

ENVIRONMENTAL LAW

ASSIGNMENT

The United Kingdom has been divided into regional governments. You have been appointed the Minister for the Environment for the south east region which includes Greater London. The first meeting of the cabinet has decided that the system of environmental protection should be reviewed. You are requested, therefore, to produce a briefing for the next meeting which will consider proposals for a new mechanism for the enforcement of environmental laws. You should present proposals for the reorganisation of the environmental agencies and indicate how this will achieve a better system for the protection of the environment. You may support your briefing to the cabinet with diagrams as appropriate. The Minister of Justice has also asked that you comment on the role of the civil law in your proposals.

[illegible]

Engineering Doctorate Project Plan

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Arup Research & Development, 13 Fitzroy Street, London W1P 6BQ

9 January 1995
Document ref: \engd\598.wpd

1. Preamble

My EngD sponsor, the Ove Arup Partnership, is an international firm of consulting engineers. A major part of their work is the design and specification of buildings. Arup sponsored my undergraduate degree at Southampton University and employed me as an Electrical Engineer when I graduated in 1987.

Buildings account for about a third of all the energy we consume. Lifts, my main area of expertise, make up a significant proportion (5 to 10%) of the electrical load in large developments. My project aims and objectives are based on the belief that there are significant energy savings to be made in the area of Vertical Transportation by good planning design, considered control strategies and the use of high efficiency motors.

The title of my Environmental Technology Engineering Doctorate project is *Vertical Transportation Planning in Buildings.*

2. Aim of Research Project

The aim of my research is to provide a basis for the design and specification of vertical transportation systems which are both energy efficient, and provide passengers with a good service by defined standards. I am proposing to fulfill these aims by:

i. Measuring vertical passenger traffic and lift/escalator energy consumption so as to build up pedestrian circulation and corresponding energy models for offices, residential buildings, airports, leisure complexes, etc.

ii. Comparing the use and performance of lifts/escalators/stairs to existing lift traffic analysis models and assumptions. Comparing the performance of driving motors to electrical models.

iii. Developing computer programs implementing verified analytical/simulation traffic analysis models and corresponding energy models.

iv. Using verified models to calculate: the benefits of developing and implementing energy efficient lift control algorithms, the savings achievable though use of high efficiency motors, and the benefits of energy conscious planning strategies.

v. Establishing guidelines for predicting traffic in new and refurbished buildings. Making planning and specification recommendations that reflect the need to design energy efficient buildings.

3. Implications on Sponsoring Company

In the short term, my project is raising awareness of environmental issues. I have given a talk to electrical design team leaders about *Environmental Technology and Building Services*. The purpose of this was to make them aware of environmental legislation and to introduce life cycle analysis.

Decisions These, like regulations are directly applicable in law, but can be addressed to named parties (individual, companies or member states). They tend to be administrative in nature, for instance, committing the EU to international agreements.

2.2 *UK legislation*

UK environmental statutory law provides broad provisions allowing details to be dealt with in Regulations. One of the most important British statutes is the Environmental Protection Act 1990, which addresses environmental concerns including the control of pollution of a multimedia basis, air pollution, waste management, environmental nuisances and litter. Other legislation includes the Water Resources Act 1991 (pollution of natural waters), the Water Industries Act 1991 (discharge of trade effluent into public sewers) and the Clean Air Act 1993 (controlling emissions of smoke, grit and dust).

Breaching statutory environmental regulations is a criminal offence. In addition, Environmental damage to persons or property can be the basis of a civil action. Strict liability (where negligence does not have to be proved) is increasing incorporated into environmental legislation.

3 Review of Existing Agencies

3.1 *Environmental law enforcement*

In the UK offences which cause harm to the environment or endanger public health and safety are subject to criminal enforcement proceedings by the pollution enforcement agencies. A summary of the various agencies and their remit follows.

3.2 *National Rivers Authority*

The National Rivers Authority (NRA) was set up in 1989 following the privatisation of the water industry. It has responsibility for the protection of watercourses and groundwaters, and for monitoring the quality of bathing water.

The NRA can grant licences for the extraction of water from rivers/groundwater, and for the discharge of effluent.

The NRA has the power to prosecute in the criminal courts if there is a breach of legislation.

3.3 *The Drinking Water Inspectorate*

The Drinking Water Inspectorate (DWI) is responsible for enforcing standards of drinking water, although it only has resources to oversee the privatised water companies' own monitoring procedures.

3.4 *Her Majesty's Inspectorate of Pollution*

Her Majesty's Inspectorate of Pollution (HMIP) is part of the DoE and has regional divisions. It has responsibility for enforcing legislation relating to integrated pollution control, and also legislation concerning controlled waste and radioactive substances.

3.5 *English Heritage*

English Heritage is the agency responsible for caring for historic buildings and monuments.

3.6 *Health and Safety Executive*

The Health and Safety Executive (HSE) is responsible for enforcing legislation relating to the working environment. The HSE includes the Nuclear Installations Inspectorate, responsible for safety issues relating to nuclear powered generating stations.

4 Difficulties of Existing Arrangements

There are a number of difficulties with the existing arrangements of environmental agencies that make reorganisation a priority:

- Now that the UK has been divided into regional governments, the existing agencies have the additional administrative burden of reporting, and being responsible to each of the regional governments individually.
- There are various overlaps in responsibility between the agencies, and between the agencies and local government.
- The current mechanism for enforcement of environmental law has evolved as these laws have been enacted, and as national industries, such as water supply, have been privatised. Early on no one knew how important and widespread environmental law would become, but with hindsight we can now set up a more effective and efficient method of enforcement.
- Industry, already under pressure from having to comply with new legislation, has also to deal with the various agencies and local government separately.
- The current agency system does not reflect the public's increasing interest and concern for environmental issues. There is scope for increasing the public's contribution to environmental law enforcement.

4 Proposals for Reorganisation

4.1 Previous plans for reorganisation

Before the UK was divided into regional governments there were plans to set up a new independent environmental agency, bringing together the functions of the NRA, HMIP, waste regulation from local government, and some environmental protection functions of the DoE. Little progress was made in carrying out these plans, which were opposed in some quarters. In particular, concerns were raised that the reorganisation would cause disruption, and that the agencies were still getting to grips with their relevant pieces of legislation.

Now that regional governments have been set up in the UK, even the opponents of the proposed independent environmental agency acknowledge that some form of reorganisation necessary.

4.2 A coordinated approach

To ensure a coordinated approach across the UK, and effective transfer of responsibilities, we have met with the Environmental Ministers of the other UK regional governments to formulate parallel proposals for the various UK regional governments. These specific proposals follow.

4.3 Proposals

i. The South East region will have its own independent Environmental Agency, reporting directly to the Ministry of the Environment.

ii. This South East Region Environmental Agency (SEREA) will take on all the responsibilities of the NRA, DWI, HMIP, and the Nuclear Installation Inspectorate. In addition some local authority responsibilities will be taken over as described later in this section.

iii. The remainder of the HSE will continue as a separate national body as there is a relatively clear demarkation in responsibilities between it and SEREA. It is considered undesirable to reorganise this body further into regional groups at this time while it is operating satisfactorily at a national level. Similarly, English Heritage will remain a national body at this time.

iv. SEREA will cooperate with other regional environmental agencies on all issues of common interest, e.g. drafting legislation for the implementation of EU Directives. This will avoid duplication of effort and unnecessary expenditure.

v. SEREA will have a single central office responsible for policy and central services. Local SEREA departments will be set up and run from local authority offices.

vi. Local authority environmental health departments' responsibilities for noise and air pollution will be transferred to SEREA departments which will already be concerned with these issues from their inheritance of HMIP's duties.

vii. The local authority planning departments will retain their existing duties, referring to their SEREA department for expertise and advice on environmental assessments related to planning applications.

viii. Local SEREA inspection and enforcement officers will be trained to be multidisciplinary, responsible for all areas of environmental protection of all media. While there is scope for some specialism, we need to achieve cost-effective approach to inspection where one officer can review all aspects of environmental impacts in a single visit.

ix. Local SEREA departments will have powers to prosecute in the criminal courts if there is a breach of legislation. Departments will have their own legal personnel to present SEREA's case in court. The legal personnel will advise SEREA enforcement officers on legal issues relating to the issuing abatement/prohibition notices, the collection of evidence, and the requirements to achieve a successful prosecution.

x. Local SEREA departments will also advise, and where appropriate, prepare evidence for private groups and individuals wishing to bring civil actions for environmental damage. Civil actions by third parties will particularly be encouraged where proving damage "beyond all reasonable doubt" in a criminal court would be difficult and/or expensive, and the "balance of probabilities" proof required by the civil courts is more realistic.

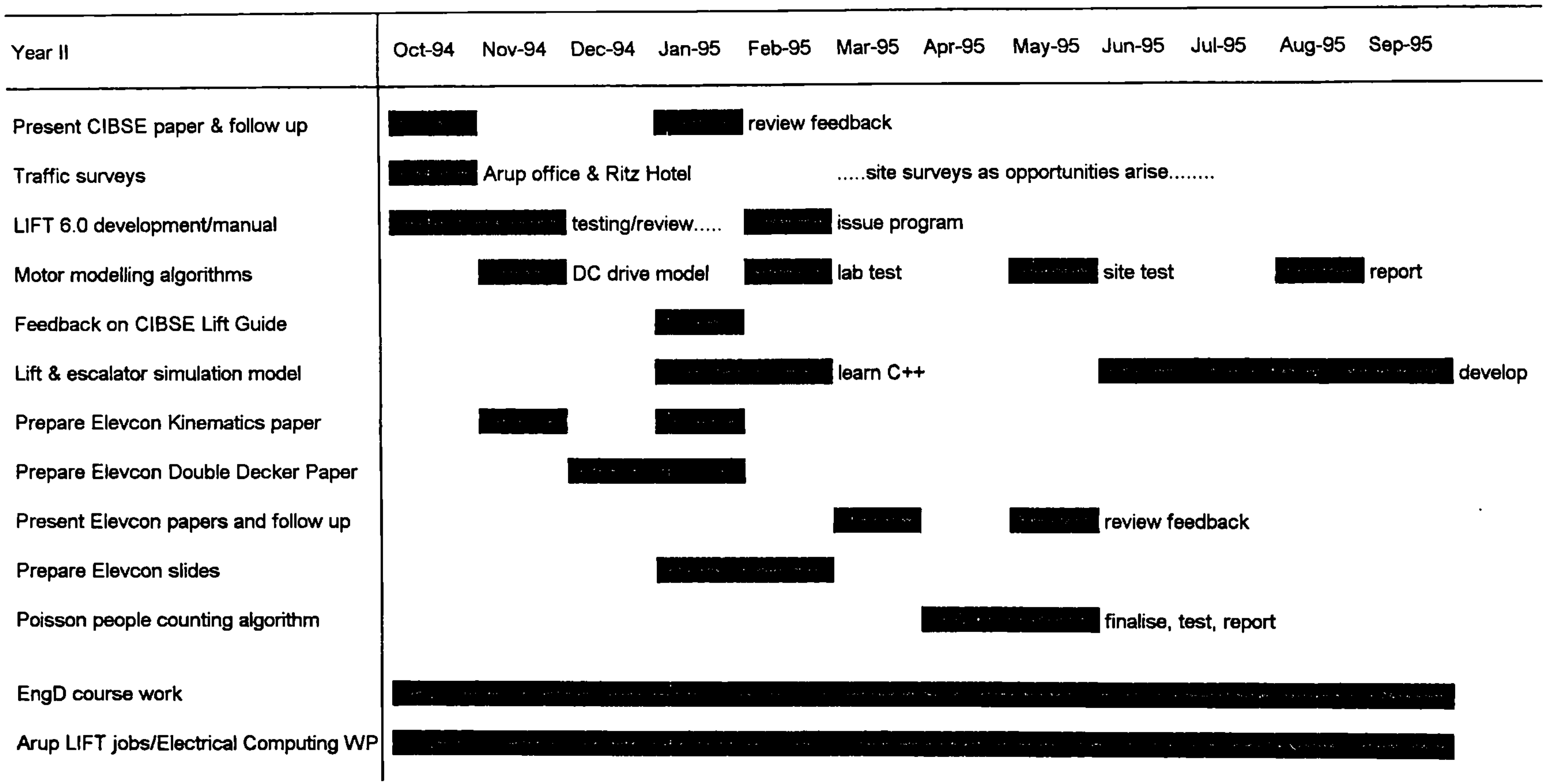
xi. Local SEREA department will call upon the public to help detect where environmental damage is occurring, so that they can investigate and prosecute where appropriate. The criminal nature of breaking environmental laws will be highlighted though using the media imaginatively, e.g. proposals for TV soap, *The Environmental Detectives* and feature on *Crime Stoppers.* Environmental help-lines will be set up for public enquiries and reports.

xii. SEREA departments will run seminars and courses for local industry on current environmental legislation, and the consequences of ignoring it - both for the environment, and for their liberty! These courses, and general advice on applications for discharge, etc. will be advertised as available, and provided "at cost" on the basis that *the polluter pays*. This *service* will be given a high priority in the department as prevention of offences is better for the environment, and more cost effective than prosecution of offenders.

xiii. SEREA central office will develop procedures for applications for discharge, etc. that are as succinct and as straightforward as possible without encouraging unnecessary, or avoidable applications. Occasional industry forums will be held to help establish industry opinions on environmental policy and procedures.

xiv. SEREA will consult with environmental groups at local and national level to address concerns, recognising their past and future role in identifying environmental issues, and their record of setting the agenda for environmental policy.

Appendix A Project Programme



A neatly organised piece of work - very clear, very logical.

A little more detail and analysis would have boosted your mark.

57%

9 SOCIOLOGY

EngD Year 2

Sociology of the Environment II

Environmentalism - What and Why?

Course Assessment

The assessment for this course is in the form of an essay of approximately 2,00-2,500 words. The essay should be based on the relevant literature, not solely on your own ideas, and references should be provided in the form outlined on the attached sheet.

1. Outline the main characteristics of New Social Movements and assess how well the description fits the Green Movement.

or

2. What distinguishes Environmentalism from Ecologism? Which do you consider offers the best strategy for moving towards sustainability?

23rd

Submission Date: Friday 2nd June 1995.

sessed work must be returned to the Sociology Office by 28 May so that it can be sent for ration. No work can be accepted after this date.

ne of Assessment
course is assessed by examinations, essays, exercises and project work and a final year .rtation. These are outlined in C.2.

ents must hand in work for assignments using the appropriate coversheet. All work must be nitted by the deadline specified, see C3.

GUIDE NOTES FOR STUDENTS IN THE PREPARATION OF ASSESSMENT ESSAYS

Preparation

Please write clearly and read through the essay when you have finished to check for missing words, spelling mistakes, grammatical errors, etc. If you have access to a typewriter, or wordprocessor and can use it, please do so. Jane Fielding can provide advice on word processing.

The finished essay should have :

(i) a title page giving essay title, your name, course and date
(ii) numbered pages
(iii) a margin for tutor's comments/corrections
(iv) a bibliography giving in full all sources consulted

(a) **References** to books and articles in your essay should give the author(s) and the year of publication in brackets, eg "as Oakley (1981) points out....". The full reference should be given in an alphabetical bibliography at the end of the essay.

(b) **Quotations.** Any material from an external source given verbatim must be placed in inverted commas, and appropriately referenced including the page number of the quotation. For example:
"Wives do not typically have equal opportunity for such participation and their class position is thus indirectly determined: that is, derived from that of the family 'head'." (Goldthorpe, 1984, p.468)
As this quotation is fairly lengthy it can be indented rather than included in the text of a paragraph.

(c) **Bibliography.** All books, journals and articles consulted when writing your essay should be presented in an alphabetically ordered bibliography. The following standard format is required:

Surname Initials (year) Book Title, Place of Publication: Publisher
Surname Initials (year) "Article Title", Journal, vol no.pp.
Surname Initials (year) "Chapter Title", Ch X in Surname Initials etc.
For example:
Goldthorpe J H, (1984), "Women and class analysis: a reply to the replies", Sociology 18, pp 491-9.
Morris L D, (1985), "Renegotiation of the domestic division of labour in the context ‹ male redundancy" in H Newby et al (eds) Restructuring Capital, Londo‹ Macmillan.
Oakley A, (1981), Subject Women, London: Martin Robertson.
Where the same authors appear on more than one occasion, present in chronologic‹ sequence.

(d) **Tables and Graphs.** Sometimes a point can be illustrated or emphasised by usin a simple graph or a short statistical table. These should be neatly and clear presented either on or facing the appropriate page of the essay itself. Tables an graphs must be labelled and the source indicated, eg:

Table 1: Trends in Migration to the UK 1966-1986
(Source: Population Trends, 49, OPCS, HMSO, Autumn 1987, Table 17).

2. Structure of the Essay

Make a rough plan of the points you want to include and the arguments for and against th evidence you want to use before you start writing the essay.

It is important that your essay specifically answers the question posed in the title, and is n‹ a random account of all you know about a specific topic. Be sure that you are aware of th distinctions between such key words as "describe", "analyse", "explain", "compare" an‹ "critically examine" which are often part of an essay title.

The finished product will usually incorporate four sections: Introductory paragraph; Main bod of the essay; Conclusion - in which all the threads of the evidence used and the argument put forward are drawn together; and alphabetically ordered Bibliography.

3. Length

There is no merit in writing more than is stipulated. It is a skill in itself to be concise and t‹ keep roughly to the number of words required. Most tutors suggest a length of 1,500-2,00‹ words for first year sociology essays. A 5,000 word essay could well be marked dow‹ because it has become repetitive, or has wandered away from the focus of the essay topic Organisation of material is very important.

4. Plagiarism

Plagiarism is defined by the University as 'academic misconduct' (Regulations for the Conduct of Examinations, para 11-16). Be careful not to plagiarise other people's work, either that of other students or presenting text from books as if it was your own work. Always indicate your sources.

Outline the main characteristics of New Social Movements and assess how well the description fits the Green Movement

Richard D Peters
Brunel University, Uxbridge, Middlesex UB8 3PH and
Arup Research & Development, 13 Fitzroy Street, London W1P 6BQ

21 June 1995
Document ref: \engd\643.wpd

Summary

In this essay we shall look at researchers' observations as to the main characteristics of the *new social movements* which emerged around the 1970's. New social movements have a number of characteristics summarised by Scott (1990): they are primarily social, located within civil society, and attempt to bring about change through changing values and developing alternative life-styles.

The Green Movement is very wide ranging. Indeed, a quarter of the public claim to be environmental activists. Three environmental groups are reviewed: anti-road protestors, Greenpeace and the Green Party. These groups show varying adherence to the new social movement model.

good use of student discussion

As a whole, the Green Movement cannot be described as a new social movement. Many individual groups do fit the model. But their own success, and the effectiveness of alternative strategies has brought pressures which have led some groups down a more institutionalised path.

1 Introduction

Daulton & Kuechler (1990) introduce new social movements as challenging democracies to change and adapt, rather than a revolutionary attack against the system. Sparked by the student movements dating back to the 1960's, new social movements have developed general public interest beyond traditional economic and class issues to new social, cultural and quality of life issues.

A new range of groups, ranging from environmental groups to more assertive women's groups and a revitalised peace movement, emerged from the 1970's. Observing these new groups, a wide range of analysts claimed that the groups themselves were qualitatively *new* (Brand et al. 1986; Meluccci, 1980; Touraine, 1983; Capra and Spetnak, 1984). These claims have been echoed by the groups themselves, particularly in Germany where movements have claimed to be unlike other interest groups or social movements.

In this essay we shall review researchers' observations as to the characteristics of new social movements, including some dissenters who claim that the *new* movements are not new at all. We will then discuss how the Green Movement fits the proposed model of a new social movement.

2 New Social Movements

2.1 Main Characteristics

Scott (1990) discusses the main characteristics of new social movements, highlighting three of their most prominent characteristics:

i. 'New movements are primarily social.' They have a focus on values and life styles, aiming to mobilise civil society rather than seize political power.

ii. 'New movements are located within civil society.' They aim to defend society against encroachment of the 'technocratic state' without challenging it directly.

iii. 'New movements attempt to bring about change through changing values and developing alternative life-styles.' They aim to achieve their goals without recourse to the political system. They have a focus on symbols and identities.

Both Scott (1990) and Daulton & Kuechler (1990) discuss more specific characteristics which are reviewed in the following sub-sections.

2.2 *Areas of interest*

New social movements are generally concerned with only limited or single issues/interests e.g. environmental, peace, women. They are not concerned with developing comprehensive political policies.

2.3 *Ideology*

It is claimed that participants in new social movements are motivated by ideological goals and by the pursuit of collective goods. They act against a feature of society which they consider unacceptable. While some participants may become active in a local issue, the 'self-interest' motivation is considered secondary to broader goals.

New social movements encourage greater involvement in decisions affecting people's lives. This may take the form of *direct democracy* or through *self-help groups*. This can result in the challenging of goals such as economic growth, which may be supported by the broader consensus. New social movements often question the pursuit of wealth and material goals, putting greater emphasis on cultural and quality of life issues.

2.4 *Membership and organisational style*

The organisational structure of new social movements is claimed to challenge the goals, structure and organisational style of Western industrial democracies.

New social movements tend to be anti-authoritarian. They have an emphasis on grass roots action/democracy and are suspicious of political parties, trade unions, etc. The grass roots approach allows them representation of those who are marginalised by the main political parties.

New social movement organisation tends to be locally based, or centred on small groups. They are organised around specific issues and characterised by a cycle of social movement activity and mobilisation. Movements may construct organisations operating with fluid structures and loose chains of command. Membership is fluid and numbers fluctuate. Their loose structure makes they 'highly adaptable and flexible in response to sudden events and new issues' (Nedlemann, 1984).

New social movements tend to display tolerance of political and class boundaries because their need for consensus is limited to limited issues.

2.5 *Politics and action*

New social movements avoid direct involvement with government because they feel they may be forced to compromise on their goals. They adopt an approach of applying political pressure and influencing public opinion. They favour unconventional political action based on direct action and place a major emphasis on the media using unconventional actions to attract interest to their cause.

2.6 *Criticism of the concept of new social movements*

Not all researchers subscribe to the view that new social movements are a new phenomena.

Eder (1993) challenges the presumption that new social movements cross class boundaries, introducing a new structural arrangements of classes of people. He claims "This innovation retrieves the concept of new social movements from the flawed assumption of the existence of structurally free-floating groups, and places new social movements within the structural configuration s of modern society". (p no.)

– what does he mean by this

A frequent criticism is that new social movements are simply a front for revolutionary and anti-system political groups. made by whom ?

3 The Green Movement

3.1 Environmental groups

Mori polls tell us that a quarter of the public claim to be environmental activists (The Independent newspaper 4.11.94). This enormous activity is spread over a wide range of groups who can fit into the category, Green Movement.
For the purposes of evaluating the new social movement model, we will review three different environmental groups which reflect, to some extent, the diversity of the Green Movement.

i. Anti-road protestors

ii. Greenpeace

iii. The UK Green Party

3.2 Anti-road protestors

Time (24.4.95) reported the storey of Emma Must, a commuter travelling though Twyford Down who was so upset by the DOT road-building programme threatening the grassland that she joined the group campaigning in an effort to halt the contractor's bulldozers. The action in Twyford Down action sparked a number of similar groups, with activists moving on when each battle was over, recruiting support from the general public irrespective of political and class backgrounds.

Road protesters justify their action as protection of the countryside under threat, challenging the "lack of transport policy" and questioning the West's dependence on the car.

Anti-road protest groups fit the new social movement model well, exhibiting most, if not all of the characteristics identified by researchers - for instance, they have challenged the road building and the car based society rather than seek election on an anti-car/road platform. Meanwhile they have focused their protests within the community where the threat exists, defending the countryside with direct action rather than through "official" channels. They have used the media to their advantage, effectively voicing their cause.

(a [illegible] – x [illegible] on alternative [illegible] based organisation

3.3 Greenpeace

Greenpeace was formed in the Seventies when a small group of pioneers caught public imagination with their direct action approach to "saving the planet". It is now a worldwide organisation with more than 1000 staff and a budget exceeding £100m. It remains involved in direct action, but now runs the risk of the courts seizing its assets. At the same time Greenpeace has become established in international lobbying, investing more effort into research, putting its arguments on sound footing and giving credence to its claims.

Greenpeace's approach is typified by its current action on the Brent Spar oil rig which Shell plan to dump in the North Sea. Greenpeace occupied the Spar, taking samples from three of its tanks which they subsequently analysed. The analysis gives rise to their claims that "the Brent Spar is carrying more than 5000 tonnes of oil and many more toxic chemicals that Shell know about". Armed with this information, they are mobilising public opinion and challenging the UK government to revoke Shell's licence to dump the Spar.

Greenpeace broadly adhere to the main characteristics of the new social movements recorded by Scott (1990) and outlined in section 2.1 of this essay. However, there are a number of inconsistencies when we look more closely:

- they are an international organisation, and would find it difficult to substantiate claims to be anti-authoritarian
- the focus, although perhaps media driven, is on Greenpeace International, as opposed to local Greenpeace groups
- they have adopted conventional lobbying of political groups as well as direct action operations.

3.4 *The UK Green Party*

The UK Green Party (previously the People, then Ecology party) was formed in 1973, but had negligible success until the 1989 European elections when it won 15% of the UK vote.

The party was set up as a vehicle for promoting green ideas and education, rather than a means to achieve political power. Success caught the party unaware as they had neither the organisation or policy in place to capitalise on their sudden new found support.

These problems, and the greening of the main political parties contributed to their down fall in membership, form 20 000 in 1889/90 to 4 571 in 1993.

The UK Green Party, and green party politics in general may have evolved from ideology formed in green, new social movements. But their approach, focused on action within the political arena, is contrary to the main characteristics cited by new social movement researchers. While they may not *aim to seize political power*, they *challenge it directly*, and have *recourse to the political system*.

4 Conclusions

Individual environmental groups, such as the anti-road protestors fit the new social movement model. But others like Greenpeace, who may have fitted the model in their early days, have now deviated from it and to some extent have adopted an institutionalised approach.

Political environmental groups, such as the UK Green Party, could never have been describes as new social movements, although they may be made up of members who once were, or still are part of new social movement environmental groups.

Offe's chapter in Daulton & Kuechler (1990) discusses the dilemma facing movements. Institutionalisation brings the danger of bureaucracy and a loss of the radical/spontaneous nature of the movement. But on the other hand, participation and representation in the political process brings benefits that cannot otherwise be achieved.

The Green Movement has no overall strategy, but has effectively evolved to champion its cause through a range of groups. As a whole, the Green Movement cannot be described as a new social movement. Many individual groups do fit the model. But their success, and the effectiveness of alternative strategies has led some groups down a more institutionalised path.

There are differences opinion on aims of N & how to organise changes. Their aims become realised i.e. Sugg that if aim is to influence politics/establishment then organisation is likely to become more institutional & bureaucratic once it begins to realise those aims i.e. Greenpeace e.g. See Scott 1992 p140

Bibliography

Brand, Karl-Werner, Detlef Busser, Dieter Rucht (1986) Aufbruch in eine neue Gesellschaft: Neue soziale Bewegungen in der Bundersrepublik Deutschland, revised end. Fankfurt/New York, Campus

Capra F and Spetnak C (1984) Green Politics, New York, Dutton

Dalton R & Kuechler M (1990) Challenging the Political Order, New Social and Political Movements in Western Democracies, Cambridge, Polity Press

Eder K (1993) The New Politics of Class, London, Sage Publications Ltd

Meluccci, A (1980) "The New Social Movements: A Theoretical Approach", Social Science Information, no.19, pp199-226

Nedelmann, B (1984) "New political movements and changes in processes of intermediation", Social Science Information, vol 23, no. 6 pp 1029-48

Scott A (1990) Ideology and the New Social Movements, London, Routledge

Touraine A (1983) Anti-Nuclear Protest, Cambridge, Cambridge University Press

Brunel / Surrey EngD in Environmental Technology

Marking form for EngD modules

Research Engineer Richard Peters

Module Title Sociology of the Environment II

Marked by Kate Burningham

Grade point awarded (please refer to scheme overleaf) B

Comments

Well organized & clearly written & exhibits sound understanding of the literature. I like the way that you looked at how well the description of NSMs fitted three different sections of the Green Movement, but would have liked to see greater detail in each case study.

Signed Kate B

Please return completed forms to Alex Roberts (Surrey) or Chris France (Brunel)

10 NEURAL NETWORKS

DEPARTMENT OF ELECTRICAL ENGINEERING AND ELECTRONICS

NEURAL NETWORKS HSM44

Objectives:

To present a comprehensive introduction to neural networks and their relationship to the symbolic paradigm in A.I. and to biological neurones. To gain a working knowledge of network architectures and learning rules for the main network types, including an ability to solve simple application problems.

Prerequisite knowledge:

Course entrance requirements

Method of teaching:

45 hours (which includes lectures, seminars, examination preparation and examination) over one semester

Method of assessment:

2 hour written examination
    5 questions. answer THREE questions

Resources statement:

Accommodation:	1 lecture theatre, 3 x 1 hour/week for 1 semester Access to Sun computer network for coursework exercises.
Student load:	1 MODULE
Staff load:	45 hours
Principal Lecturer:	Dr. K. Gurney (Department of Human Sciences)

Module approved at MSc BOS: 17/11/93
Minor revision: 4/11/94

SYLLABUS

INTRODUCTION AND BASIC IDEAS

Basic definition of a neural network.
Main features of networks.
Comparison with the symbolic and von Neumann paradigms in mainstream A.I.
Basic morphology and function of biological neurons.
Pattern space and vectors, linear separability.

SPECIFIC NETWORK TYPES

Feedforward - supervised learning

Perceptron rule.
Delta rule.
Backpropagation, theory, enhancements and some applications.
Reward-penalty.

Feedback and self-organising nets

Hopfield net: operation and dynamics; error minima; Hebb rule.
Competitive nets.
Kohonen nets.
Cube-based nets.

CLASSIFICATION OF NETWORK STRUCTURES

Need for taxonomy; tasks - associative recall classifiers, data compression. Artificial neuron types: TLU's; semilinear nodes; Cube-based nodes and RAMs. Network structures - feedforward, feedback, competitive; training algorithms - supervised versus unsupervised learning; computational resources.

OTHER ISSUES AND TOPICS (as time permits)

Historical perspective

Early years and cybernetics, work in the 60's, Minsky's rebuff of neural nets in "Perceptrons".
Resurgence in mid 80's. Current use as problem-solving tool.
Some current applications and silicon implementation.

Philosophical issues

Connectionism and A.I.
Interdisciplinary 'Neural Nets' perspectives.

Implementation

Essential Texts: -

Highly Recommended Texts:

J Dayhoff, Neural Network Architectures: an Introduction. Van Nostrand Reinhold, 1990.

Recommended Texts:

1 D E Rumelhart and J L McClelland, Parallel Distributed Processing. MIT Press, 1988.

2 I Aleksander and H Morton, An Introduction to Neural Computing. Chapman and Hall, 1990.

3 P K Simpson, Artificial Neural Systems, Foundations, Paradigms, Applications and Implementations. Pergamon, 1990.

11 CONFERENCE MANAGEMENT

EngD Conference 1995

Report on Project Management Module

Richard D Peters
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18 October 1995
Document ref: \engd\conferen\report...or..a:\report\report.wp5

Contents

1 Introduction

This report summarises the project management of Environmental Engineering Doctorate Conference 1995. The conference was held at the Brunel Runnymede Campus, 19-20 September 1995 and was attended by Year 1,2,3 Research Engineers and their supervisors. We proposed project management of the EngD conference as an elective EngD module as:

- it was a practical way for us to help with course administration and to be more involved in the running of the EngD programme

- it was an opportunity for us to apply some of the project management skills we had learnt in taught modules

- we could be called upon individually to arrange other conferences in the future, and the experience would be useful.

We prepared our own planning brief for the project, a copy of which is included in appendix A of this report. This brief was accepted by the Course Director, Chris France. Alex Roberts, Deputy Course Director and our tutor for the previous project management module, agreed to assess the project. Judith Cassingham also contributed to the project by providing administrative support (room/lunch bookings).

2 Planning

2.1 Planning meetings

Eight planning meetings were held, minutes for which can be found in appendix B. In summary the meetings operated as follows:

1. DA/RP establishing the what, how, who and when of tasks that needed to be carried out.
2. As (1), but with CF.
3. Meeting held at Runnymede with CF, AR and JC, enabling us to review the facilities and allocate related tasks.
4. Progress review meeting held with AR at Surrey during a break in another EngD module.
5. As (4).
6. Progress review meeting with CF/AR at Runnymede, with an opportunity to meet the person responsible for conference facilities.
7. Meeting with Philippa Le-Marquand to discuss publicising the conference.
8. Meeting with CF to discuss actions arising from (7).

In additional to the formal meetings, DA/RP met regularly at Brunel to progress actions together.

2.2 GANTT Chart

The project planning Gantt chart was originally sketched by hand, then input to Microsoft Project. It was updated and changed when required. A copy of the complete, updated version is included in appendix C.

2.3 Budget

A copy of the budget including the final account is included in appendix D.

3 Correspondence

3.1 EngD Database

Unfortunately electronic records of RE's and supervisor's addresses were inconsistent between Brunel and Surrey, and were not available in a suitable format for conference mail merges.

A database of names, addresses, supervisors, etc. was set up and maintained for the duration of the conference planning project. The data was based on Brunel/Surrey written records, then updated and corrected during correspondence to REs. An example database record is included in appendix E.

The database was set up in dBase format which allows it to be imported into and mail merged with any modern word processor.

At the end of the project, the dBase was handed over to JC for ongoing maintenance, together with standard forms for letters, address lists, and labels. It was suggested that the dBase file could be emailed to Surrey after each update as maintaining separate records tends to lead to inconsistencies and wastes time.

3.2 Research Engineers

Research Engineers were sent the following letters:

date	*summary of content*
24/3/95	Notification of conference date
28/4/95	Notification of requirements, deadlines for submissions, guidelines for preparing written paper
23/6/95	General information, guidelines for speakers/preparation of posterboards
23/8/95	Maps, programme and a final reminders for papers, etc.

Copies of these letters are included in appendix F.

Accommodation details were sent out by JC. There were a number of RE queries about accommodation and location of the conference, so a second set of maps and details were sent out 13/9/95.

3.3 Supervisors

Industrial and Academic Supervisors were sent the following letters:

date	*summary of content*
24/3/95	Notification of conference date
2/8/95	Formal invitation to conference, copies of abstracts/biographies, programme, registration form, map
15/8/95 & following	More detailed maps and accommodation details sent to those who requested them

Copies of these letters are included in appendix G. Details of local accommodation were sent on request.

3.4 Other Correspondence

General invites to guests as requested by CF/AR from 11/8/95. A copy of this letter is included in appendix H.

4 Publicity

The planning brief deliverable was "Publicity including press release". The main publicity areas involved were seen to be the press, both national and scientific, posters around Brunel University, Surrey University and REs companies, direct mailing to relevant individuals, and the development of a WWW page on the internet.

A uniform image on all publicity and other material was maintained using the EngD Butterfly as the focal point in everything, with the Brunel and Surrey University logos also prominent on all printed matter.

4.1 Press

Initially a meeting was arranged with Philippa Le-Marquand, the Brunel Publicity Officer. PLM suggested that a simple press release would not be worthwhile publicity, as many papers would not even run them unless they involved events of significant interest to the public. She suggested attracting a "name" to open the conference which would then attract the interest of the press to the story, and was very enthusiastic about the possibilities, including Prince Charles, David Bellamy, etc. Time was spent supplying PLM with relevant information, finding out who could sponsor sessions, where we could have a conference dinner, and so on. Unfortunately, as various obstacles arose, her enthusiasm waned and eventually was non-existent. By this time, even a simple press release was not possible, so this was not accomplished.

4.2 Posters

An A4 poster, see Appendix I, was produced and circulated to each RE to put up in their company and university department. This gave a basic outline of the conference and directed interested parties to find out more by writing, phoning, or looking at the WWW page.

4.3 Direct Mailing

A list of possibly interested individuals was generated by CF and AR, each of which was sent a personal invitation outlining the idea of the conference. This information was similar to the material sent to supervisors.

4.4 WWW page

A WWW page was created which outlined the EngD programme as a whole, and also gave details of the conference, what it was about, the programme of events, the projects covered by REs, a biography of each RE and an abstract of their paper. The address for the page, **http://http1.brunel.ac.uk:8080/~empgdca/engd/** , was included in all promotional literature and proved its use when the programme of events was changed. Two supervisors rang up shortly after the change to ask if it was correct, and were able to attend on the right day at the right time as a result.

5 Printing

The main printing needs of the conference were the conference proceedings, with further arrangements necessary for a common header for the posterboards.

5.1 Proceedings

This was a large document containing around 300 A4 sides. Competitive quotes were taken from a variety of sources, with the Brunel University Print Shop proving the cheapest. A timetable for delivering the received papers to the print shop and collecting prior to the conference was agreed, and this was held to. The original was delivered to the print shop on September 4th, and the proceedings were collected on September 18th.

The proceedings, as with all other published material, was characterised by the EngD logo as well as both Brunel and Surrey logos.

5.2 Posterboards

It was decided that, in keeping with policy for this conference, all posterboards should be headed by a title bar. This consisted of the EngD logo followed by the title of the conference and the Brunel and Surrey logos. The cost for this was estimated at £10 per board, but investigations showed the cost would in fact be double that. This price was agreed by CF after some discussion of possible alternatives.

Various quotes were sought, but few companies could print up to A0 size. The final choice was KallKwik of Richmond who were able to take the job and also gave a discount for the number of prints we required.

Having obtained A0 prints with 6 headers on each, these were guillotined into individual headers and spray mounted onto the boards. A0 boards were obtained from an art suppliers using both bulk and student discounts to obtain a good price.

6 Conference Review

6.1 General problems

We had assumed that there would be reliable electronic records of addresses, etc., and had not allowed time for setting up and maintaining the EngD database.

JC was ill immediately before the conference. As we had not prepared a contact list, we were unable to confirm bookings, etc. We had no contingency for people being ill.

The meeting with Philippa Le-Marquand gave us an insight into what could be done on the publicity front another year. However, for us it proved a time consuming side-track as the follow up work we prepared was not taken any further by Philippa despite reminder calls on several occasions.

REs more often that not failed to meet deadlines and to follow the guidelines we sent for preparation of papers, etc. Chasing RE's proved very time consuming.

We were asked to send out numerous additional invitations after the main Supervisor/General invitations were circulated at the beginning of August. Again this was time consuming. Few of those invited at the last minute accepted the invitation, although it is understood that the invitations were necessary for diplomatic and publicity reasons.

The technical content of the Year I presentations was lacking.

We were not aware of the various forms CF wanted to distribute at registration. A "conference pack" for each type of delegate (RE1, RE2, Academic Supervisor, etc.) would have simplified the registration process.

The original plan for second year RE's to present a short "advert" for their poster was scrapped, then re-introduced on the day. This could have been better thought out.

The coffee did not arrive for registration on the first morning. We believe this had been booked by JC, but that she did not have an opportunity to confirm the booking.

The toilet and washroom facilities were very poor. No-one on Runnymede staff pointed out the fact that the ground floor is actually Gents, whereas the first floor is Ladies.

The Student Union where the buffet lunch was held was not cleaned and tidied as had been promised when we had discussed arrangements with the catering manager.

On arriving at the site, the exhibition boards were not immediately available, although they had been requested by JC. After going from one individual to another all round the Runnymede site, they were eventually located. Fortunately some first year intake REs were on hand to help move these into the chapel and set them up.

6.2 Things that went particularly well

The presentation skills of Year I RE's was excellent. Timing was also excellent, and the programme ran to schedule throughout the two days. This can be attributable to good planning, appointing good chairs, and REs following the guidelines.

There was a consistent style to all published material. Specifically, WWW page, poster adverts, posterboards and proceedings all contained the EngD, Brunel, and Surrey logos in addition to any text and headings.

Sending documents to REs outlining the style expected from submissions (and providing examples of these styles) helped produce a consistent image in the proceedings.

REs were grateful for the guidelines on presenting posterboards and papers.

REs were grateful for early warnings of deadlines, and subsequent reminders. This made a big difference to getting the proceedings printed promptly with professional bindings.

6.3 Comments from other people

There were a number of general comments made by the various groups of attendees:

REs were very supportive and appreciative of the efforts made to keep them informed and up to date. Many of the '93 intake commented on the difference between communication this year and last year.

Some supervisors were impressed that REs were running the conference. Others were impressed by the general level of presentations, although there was a feeling that the academic requirements of the course were seen as being less important to some delegates.

Many delegates were grateful for the maps and accompanying literature and commented on how the instructions made attending very easy.

Other attendees were generally impressed by the professionality of the conference, perhaps having expected it to be a "student" event rather than "proper conference".

6.4 Recommendations for Future Conferences

The drawing up of an EngD contact list would have multiple uses, especially if split into various functional groupings, eg supervisors, sponsors, general interest, etc.
All groups should be invited early on to allow diary dates to be noted. None who were sent late invitations came this year.

REs seem to need very basic prompting about formatting documents and sending work. A checklist of requirements may be a useful addition to documentation in future. Another possibility would be to send each person a template for the paper on disk, with all numbering/formatting in place. This template would need to be available in all the different word processing formats.

The lunches in the SU were not up to standard. It would be useful in future to have a lunch in advance at the place selected and check facilities more thoroughly. The SU did not clean up as they promised and this caused embarrassment to the organisers.
We suggest that CF sends a letter of dissatisfaction to the SU, stating the problem and asking for some compensation.

If the chapel/Runnymede is used for further conferences, the toilet facilities must be better marked. The difference between gents/ladies on ground/first floor was not made obvious by Runnymede. Using student toilet facilities is not particularly satisfactory.

The Runnymede chapel has now reached its capacity. A new venue should be sought for next year. Alternatively, parallel sessions could be run in different rooms.

The AV was well organised. Similar arrangements to use an AV department cameraman should be made for next year.

The 1996 conference should need less organisation next year, as it will be possible to build on the work of this year and use the enclosed documents / EngD Database.

The meetings with PLM highlighted the lack of time available for publicity. An earlier start to the publicity process should be considered this year, possibly as a module for EngD REs.

JCs sickness caused problems this year. It would be useful not to be reliant on one person, perhaps by sharing documents in an EngD file area. If each person involved always used this area, kept all their contact lists etc. there, then this would help.

The general computer literacy of some EngD REs seemed to be in question. A Basic Computing (windows, word processing, spreadsheets, etc.) course may be useful as an optional module. This could also include a lecture on the use of electronic mail and other WWW basics. The sending of documents via email saves time and money, although few people know how to do it.

6.5 Top Tips for EngD Conference Project Managers

Make a project plan and only timetable useful meetings.

Decide on a suitable budget - if possible after making cost enquiries.

Keep both paper and file records of all correspondence sent and received.

Keep a list of contacts made.

Make all your documents/contact lists available to all those working on the project.

Start publicity early. Ensure anything involving other people is started early.

Make sure everyone knows what is required of them in some detail. Keep it simple, and assume that things will not be read without a reminder.

Check all practical facilities well in advance. Eat in restaurants being used well in advance of the event.

If booking facilities / services, ring and confirm them 1 week in advance, and get a contact name for the day.

7 Conclusion

The project planning module went well, demonstrated by the fact that the conference ran smoothly apart from minor glitches.

A successful project!

12 CLEAN TECHNOLOGY

CLEAN TECHNOLOGY AND SUSTAINABILITY
Written work required

1. Assessment of Module

For ***each*** of the four afternoon discussion sessions, please provide (by 10th November 1995) a critique and suggestions (not more than one side of A4 per syndicate) to cover:

1.1 Did the morning talk provide sufficient background for the discussions?
What would you like to see changed or added in the morning presentations?

1.2 What ***in your view*** were the most important points to come out in the discussions?

1.3 Do you have any suggestions for structural or detailed improvements in the module in future?

The Plenary Discussion on Friday morning was intended to bring together and apply the ideas developed in the week. On not more than one side of A4:

1.4 How valuable was this Discussion?
In what ways was it valuable?
How could it be improved?

It will also be helpful to obtain an idea of how "balanced" were the syndicate discussions and the contributions of different members. For ***each*** syndicate which you were in, please provide (by 10th November 1995) an assessment of the contribution of ***each*** member, on the form appended. The grading scale is:

5 - Important contributi[illegible] insightful; helped debate to flow and ideas to develop.
4 - Active participation [illegible] contributing ideas but occasionally getting side-tracked, "stuck" or left out.
3 - Willing participation [illegible] more to learn from than to contribute to debate.
2 - Overbearing, too pushy - held up development or inhibited progress of debate.
1 - Reluctant or ineffective participation - joined in occasionally, but didn't really contribute much.
0 - "Black hole" - might as well not have been there.

Please report ***one integer*** assessment of the contribution of each member of each syndicate in which you participated, ***including yourself***.

2. Written work

Produce a short reflective essay - not more than 8 double-spaced A4 sides - summing up your response to this week's module. Did you experience anything like a "paradigm shift"? Did it bring about any changes in the way you see your professional and personal role? If so, what are they? If not, why not? (e.g. Were you perfect already? Was the module totally pointless?) What difficulties do you see in acting in accordance with your personal and professional principles? What areas of knowledge or understanding will you pursue to continue your own intellectual,personal,and professional development?

To be submitted to Janet Martin (on one side of the paper only please)
no later than Monday 27th November

Roland Clift
October 1995

Clean Technology Module Essay Assignment

Richard D Peters
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Document ref: \engd\666.doc
23 November 1995

1 Introduction

In this essay I shall sum up my response to the EngD Clean Technology module, review my own paradigm shift, and discuss how this effects my professional and personal role.

I shall go on to discuss my understanding of Christian Green issues, which provide the basis for my motivation to be an *Environmental Engineer.*

2 The Module

Above all, the Clean Technology Module provided a challenge, and catalyst to review my reasons for being an *Environmental Engineer.*

When I applied to join the EngD programme in 1993 I stated that I valued the opportunity to influence building design in a way that encourages consideration of environmental issues. And that this was consistent with my Christian faith and values.

During the Clean Technology Module two models of the Christian approach to the environment were presented:

- a despotic, irresponsible attitude to nature derived from the biblical teaching on man having dominion, and being instructed by God to rule over the earth
- a responsible, caring attitude based on the bible's teaching that man is steward of the earth.

Obviously I place myself in the second camp. But in the discussions that took place during the module, I had to admit not to have fully researched or thought through my position, as a Christian, on environmental issues.

I did not experience a paradigm shift during the week. Just a realisation that, assuming God wants us to care for His environment, this should be the ultimate (and a very powerful) motivation for me to do so. I see my paradigm shift as having come about when I became a Christian; the implications of that event become apparent as my, very limited, understanding of God's will increases.

3 Changes in how I see my Professional and Personal Role

During the Clean Technology it very easy to criticise RTZ for their mining of titanium dioxide, and yet I buy brilliant white paint, and like my toothpaste as it is. I realise that I must take personal responsibility and blame for my actions rather than transfer my guilt to the people I buy products and services from. As an environmental engineer, pleading ignorance is a poor excuse, and I should be actively involved in educating others why we need to reduce our consumption of resources and how practically we can do this.

On a professional level, I have a responsibility to apply what I have learnt in making building design less damaging to the environment. In an industry that likes to be seen as "green", there are a lot of claims made for individual products and whole buildings which are questionable. I need to take an active role in the discussion of green construction issues to encourage good practice and to challenge questionable claims.

I am faced with a number of conflicts between my own aspirations and the need to set a positive example in both my professional and personal roles. On a personal level, I continue to struggle with the challenge to achieve the selfless lifestyle which is so much a part of my Christian faith, and essential if I am to put care of the environment before my desire for material wealth and goods. From a professional viewpoint, I believe that my EngD project will make as positive a contribution in reducing environmental burdens, and yet, I seriously doubt whether we can "engineer" our way out of the current environmental crisis. We need to move the "lifestyle" goalposts that society is aiming for (yes, a paradigm shift) to something which is sustainable - this would seem to call for me to apply myself as an evangelist rather than an engineer!

4 Self Development

As a result of the Clean Technology course, I have begun, and will continue to research my position, as a Christian, on environmental issues. This is important because:

- my motivation, ethics, thinking and actions are largely dependant on my Christian faith

- as a Christian, and as an EngD *Environmental Engineer*, it is important for me to understand, and be able to discuss my motivation for green thinking.

The remainder of this essay is a summary and discussion of this research and to date.

5 Negative Christian Attitudes to the Environment

The despotic, irresponsible Christian attitude to nature referred to in our lectures was based on a paper by Lynn White(1), *The Historical Roots of our Ecological Crisis*. In summary, Whites' arguments are:

- We live in a post Christian age, and yet our language and thinking remain based on our Judeo-Chrisitian past.

- Judeo-Christianity and its derivatives assert that God planned creation for man's rule. And that it is God's will that man exploits nature.

- Christianity replaced pagan animism that attributed a spirit to every spring, stream and hill. Christianity made it possible to "exploit nature in a mode of indifference to the feelings of natural objects".

- Scientists claimed their task and reward was to "think God's thoughts after him". If so, science is cast in the matrix of Christian Theology, shaped by the Judeo-Christian dogma of creation.

- Christianity bears a huge burden of guilt.

- St Francis proposed an alternative Christian view of nature by suggesting the equality of all creatures. The so called "doctrine of the animal soul" was quickly stamped out by orthodox Christianity.

- We shall continue to have a worsening ecological crisis until we reject the Christian axiom that nature has no reason for existence save to serve man.

Another point that White could have argued is that the Bible(2) prophesies that the world will end, therefore there is little incentive for Christians to save it:

But the day of the Lord will come like a thief. The heavens will disappear with a roar; the elements will be destroyed by fire, and the earth and everything in it will be laid bare...That day will bring about the destruction of the heavens by fire, and the elements will melt in the heat (2 Peter 3:10,12).

6 Positive Christian Attitudes to the Environment

Perhaps unsurprisingly, modern Christian literature(3)(4)(5) on Green issues takes a responsible, caring attitude based on the bibles teaching that man is steward of the earth. As I see them, the main points are as follows:

- The bible was written in a time before there was a green agenda, so it does not necessarily say anything direct about environmental issues. This does not mean there is nothings to be said on green issues, but that we need to dig a little deeper to apply the biblical message to this present day issue.
- A unifying theme running through the bible is the goodness of creation. Genesis 1 repeatedly states that creation is *good* (vv 4, 10, 12, 18, 21, 25). The Psalms record God's continued care: *You care for the land and water it; you enrich it abundantly* (Psalm 65: 9). Jesus asserts the goodness of creation by highlighting the Father's continued concern of all that he has made (particularly humans) *Look at the birds of the air; they do not sow or reap or store away in barns, and yet your heavenly Father feeds them* (Matthew 6:26).
- The "good" creation is depicted as praising God: *the meadows are covered with flocks and the valleys are mantled with corn; they shout for joy and sing.* (Psalm 65:13). During the "Triumphal Entry" to Jerusalem (Luke 19:28-44), Jesus says that if the people are silenced in their praise, the stones will cry out.
- Man's dominion over creation is meant to be a caring one: *The Lord God took the man and put him in the Garden of Eden to work it and take care of it* (Genesis 2:15). Man does not own the earth, he is only the steward: *The earth is the Lord's, and everything in it, the world and all who live in; for He founded it upon the seas and established it upon the waters* (Psalm 24:1-2).
- Many Old Testament Texts commanded the Israelites to responsible stewardship e.g. *For six years sow your fields, and for six years prune your vineyards and gather their crops. But in the seventh year the land is to have a Sabbath rest, a Sabbath to the Lord* (Leviticus 25:3-4).
- Problems of poverty and environmental degradation are inextricably linked. Israel's relationship between rich and poor was guided by the law of Jubilee (Leviticus 25:8-17) - land which had been sold was returned to the family which originally owned it every 50 years. A radical, contemporary way of applying this biblical principle would be to cancel third world debt, which is crippling nations such that environmental concerns remain unaddressed.

7 Discussion

Much of White's criticism of Christians' attitude to the environment is, in my opinion, perfectly valid. Many Christians do not see Green issues as their concern, or otherwise think of them as completely irrelevant. I believe this poor attitude is a failure of Christians as opposed to a failure of the biblical principles we aspire to follow. Where White's argument is lacking is that:

- He bases his understanding of what the Bible has to say about the environment on limited texts, concluding a Christian axiom which is inconsistent with the underlying goodness (and therefore value) of creation evident throughout the New and Old Testaments.

CLEAN TECHNOLOGY AND SUSTAINABILITY
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Roland Clift
October 1995

13 RISK

RISK AND THE VERTICAL TRANSPORTATION INDUSTRY

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ABSTRACT

Risk is a major concern for the public, scientists, engineers and policy makers alike. Yet there are major discrepancies between what the public fear and the magnitude of risks calculated by the "experts". This paper reviews current thinking on risk perception, communication, assessment and management. Examples are used to demonstrate the difficulties faced by industries who have mis-managed risk. In spite of a good passenger safety record, using lifts and escalators is frightening for some passengers, a fear sometimes amplified by media reporting. A pro-active risk management strategy for the vertical transportation industry is proposed and discussed.

1 INTRODUCTION

According to an *Equinox* documentary(1) one billion lift† journeys are made without hitch every day. An expert interviewed claimed that lifts are by far the safest means of transportation there is. In fact, "...elevators are very, very safe. When was the last time you heard of anyone getting killed on an elevator? It just doesn't happen." In the same vain, a popular British science program, *How do they do that?*(2) told its viewers that they were statistically safer taking a lift than walking up the stairs. The expert interviewed said that, to the best of his knowledge, no one had ever being killed while travelling in a lift.

The (USA) Boston Sunday Globe(3) special report headline 4 December 1994 read, *RISKY RIDE Millions of people ride the nation's 600,000 elevators and 30,000 escalators every day, assuming that they are safe. But a four month Globe investigation has found that crippling accidents - even deaths - occur with alarming frequency.* The feature goes on to record, in graphic detail, deaths and injuries sustained by lift and escalator passengers. "...horrified employees waiting for an elevator saw streams of blood flow down the closed elevator door." The article blames the incestuous nature of the industry for poor maintenance, inadequate inspections and the poor take up of new safety devices. An industry expert is quoted as saying "Our guarantee is that on a per capita basis, this is the safest form of transportation in the world." In the context of the article, his words give little reassurance.

As an industry we all know that travelling on escalators and in lifts is relatively safe. There are risks, but our experience tells us that they are minimal compared to others most of us encounter daily, such as travelling in a car. Some of us (the author is also guilty) have overstated the safety of vertical transportation systems, which undermines our credibility when articles such as the one in the Boston Globe appear. The article is sensationalist, quite possibly inaccurate and certainly presents an unbalanced view. But it is also an effective challenge to the complacent.

In this paper we shall try to understand how the public perceives risk, and discuss better ways of communicating risk to the public. The process of risk assessment and management will be

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† References to "lift" in this paper refer to English use of the word, i.e. passenger goods lifts, commonly known as elevators in American English.

outlined. Lift and Escalator ascendent statistics will be presented, together with proposals for a pro-active risk management strategy for the vertical transportation industry.

2 RISK PERCEPTION

Risk is a major concern for the public, scientists, engineers and policy makers alike. Yet there are major discrepancies between what the public fear and the magnitude of risks calculated by the experts. This discrepancy has lead to the study of risk perception which can help us to understand different attitudes to risk.

The public have to evaluate information they are supplied mainly by the media, including the opinions of scientists, engineers and policy makers. Experts often despair of the public who seem to ignore the "facts" they present showing something is safe Yet the public have the difficult job of evaluating expert views which are often contradictory or based on incomplete information from suspect sources.

2.1 Media

News media reflect a skewed representation of the risks of everyday life. For instance, an accident involving a school bus, killing say 10 children will receive more news coverage than hundreds of children killed in individual car accidents. Although sensationalism is irresponsible, it is inevitable that the media will present an unbalanced view of reality - a balanced prospective is, more often than not, boring and will not sell newspapers or attract television viewers. Media sensationalism, and the consequent disproportionate public concern and reaction, is sometimes known as the "social amplification of risk".

2.2 The Importance of Trust

Trust is key element in the perception of risk. If someone responsible for a risk is trusted, then the risk is far more acceptable than a comparable risk in the hands of someone un-trusted. Slovic(4) cites the application of chemical and radiation technologies as an example of this phenomenon - although medicines and x-rays pose significant risk, we trust the medics who manage them and, in general, consider the risks acceptable. Industry, and government officials who oversee the management of nuclear power and non-medical chemicals are not trusted; so much so that it is apparent that public perceptions and acceptance of risk is hardly influenced at all by technical risk assessments.

Trust is fragile, taking a long time to build, and an instant to destroy. Abraham Lincoln one wrote "if you once forfeit the confidence of your fellow citizens, you can never regain their respect and esteem". Slovic(4) demonstrated the fact that trust is easier to destroy than to create in a study where he asked college students to rate the impact of trust on 45 hypothetical news events relating to the management of a large nuclear power plan in their community. His results are shown graphically in Figure 1.

2.3 Issues Arising From the Importance of Trust

- People are prone to over-confidence in their own judgements. Unfortunately this applies to experts as well as to the general public. Slovic et al(5) give examples of the Reactor Safety Study and the 1976 collapse of the Teton Dam where the experts were shown to have greatly underestimated possible failures in their risk assessments. Over confident scientists, subsequently shown to be wrong, undermine the public's trust of risk assessment as a whole.

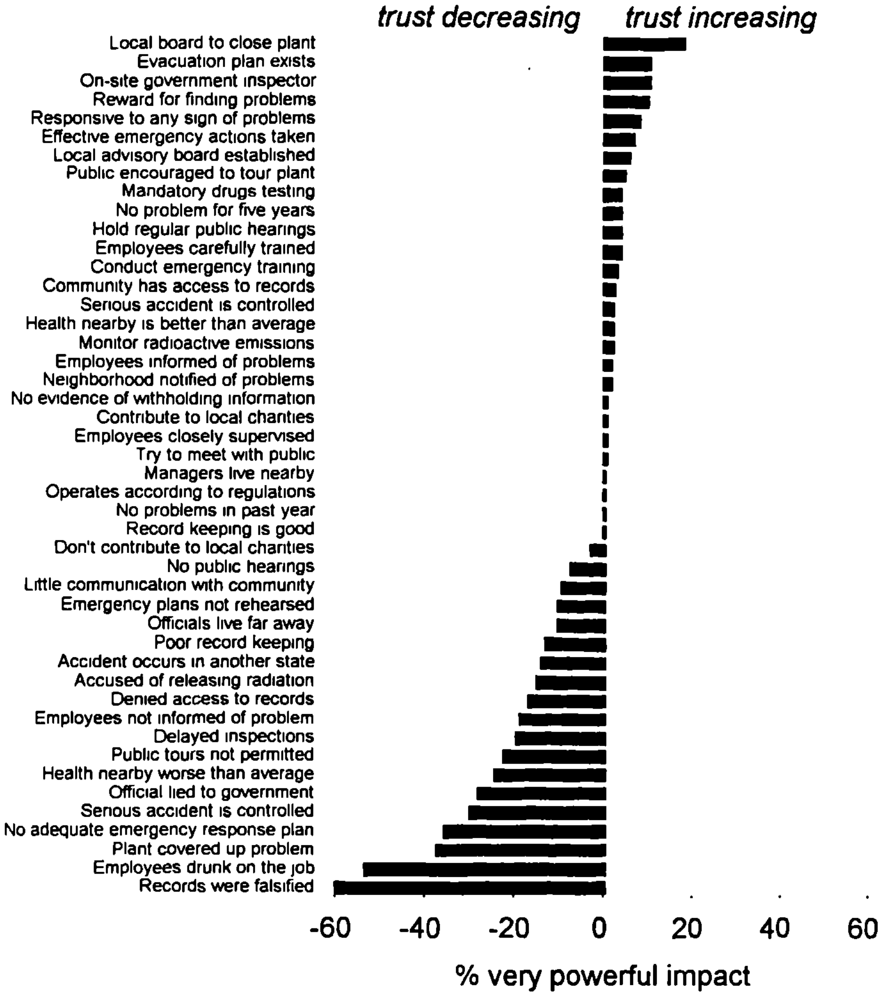


Figure 1 **Differential impact of trust-increasing and trust-decreasing events relating to the management of a Nuclear Power Plant** (Source?)

- A trait of the media is to find experts with opposing views on the same subject; it makes for lively discussions, even if one view is totally unreasonable. The disagreement of experts often undermines trust in both parties, casting doubt on both sides of the argument.

- Evidence suggests(4) that sources of bad (trust-destroying) news tend to be seen as more credible than sources of good news. For example, regulators and the public express considerable confidence in the relevance to human health of studies showing that certain substances are carcinogenic in animals. Evidence to the contrary carries little weight. This emphasis on bad, trust-destroying news is again reflected in the media.

- People with vested interests are less likely to be trusted than those with nothing to loose or gain from stating their case.

- New evidence that something is safe, presented by a person or group that is not trusted, has little impact.

2.4 Other Hypothesis on the Public Perception of Risk

- People are reluctant to let others expose them to risk; yet they freely choose to expose themselves to comparable risks. In other words, "voluntary" risks are more acceptable than "involuntary" risks. One study(6) suggests that people will accept a risk 1000 greater if it chosen than if it is imposed by others.

- People fear man-made risks (such as Chemical plants) risks more than natural risks. The US Environmental Protection Agency estimate between 5,000 and 20,000 lung cancer deaths in US homes per year are caused by radon which occurs naturally in the environment. And yet there is a predominance of public apathy about this risk(7).

- Unlikely, but potentially catastrophic disasters are feared disproportionately relative to the calculated or historic risk(5). This is considered a factor in the discrepancy between perceived risk and the frequency of death values for Nuclear power.

- Familiar risks are more acceptable than unfamiliar risks.. We are naturally afraid of the unknown.

- There is a need for certainty(8), "is it safe, yes or no?". A response to questions of risk, "the risk is minimal to the best of current knowledge", promotes fear.

3 RISK COMMUNICATION

Lofstedt(9) defines risk communication as "the process by which authorities or experts convey to the members of the public the nature and extent of risks to which they are subject". The study of risk communication has arisen out of the need to gain public acceptance for sightings of chemical plants, hazardous waste facilities, etc. Some findings are specific to this type of scenario. But others can be generalised and applied to other industries.

Approaches to risk communication can be divided broadly into two categories:

- "top down" or "source to target"
- engaging in dialogue and inviting public participation

The top down approach is based on the premiss that the expert is knowledgeable and the public needs to be educated. The dialogue approach provides information, but encourages the public to air their fears and concerns, addressing the issues raised to the extent of incorporating changes in the experts' design or viewpoint. This second approach is sometimes know as reciprocal risk communication, and is favoured by researchers.

3.1 Hypotheses and Recommendations Relating to Risk Communication

The following hypotheses and recommendations are based on generalisation of Sandman's proposals in *Getting to Maybe: Some Communications Aspects of Siting Hazardous Waste Facilities*(8):

- As trust is an important actor in public risk perception, it is also fundamental for positive risk communication.

- Greater media coverage of a safety issue tends to lead to increased public concern about a risk; media coverage should not be courted. On the other hand, setting out to conceal risk from the media and public would be short sighed as this is likely to lead to media sensationalism and to a breakdown in trust.

- Inconsistency in stance can lead to a loss of credibility and a crisis of confidence. This effect of this principle is frequently demonstrated in the political arena.

- The public can underestimate their influence. Suspecting that their fears will not be addressed, they tend to judge that they cannot afford to listen to the experts, so their only option is absolute opposition. Acknowledging the public's influence is positive step.

- Avoid suggestions that public fears are irrational or selfish. It is rational to distrust experts, who often have a stake in providing reassurance that fears are unfounded. All coherent positions require respectful response; dismissing them outright is strategically unwise.

- Establish an open information policy on safety issues. But, where possible, enable the public to rely on its own, and independent sources rather than asking for trust. This may involve contributing to the funding of the independent sources.

- Adopt a communications strategy which recognises that the public's fear of risk does not correspond to accident statistics, but is subject to issues of control, familiarity, etc. Do not try to approve or disapprove of these truths, but understand why they are true and adapt accordingly.

4 RISK ASSESSMENT AND MANAGEMENT

Risk assessment is the forming a judgement about a risk based on the information available at any one time. Risk management involves using this assessment as a means to take decisions about a risk. The decisions may balance the benefits associated with accepting the risk and issues such as the cost of reducing or removing the risk all together.

Risk assessment and management has a long history(10). There is evidence to suggest that the Aspipus people in the Tigritis-Euphraties valley were carrying out a form of risk assessment in around 3200 BC. Risk management in the construction industry had already been established in Babylonian times; the Code of Hammurabi required that if a building collapsed on completion, the architect responsible for designing it was be executed.

The assessment and management of risk has been formalised and adopted in modern law e.g. the European Community directives for safety on construction sites have been implemented in the UK through *Construction Design and Management Regulations* (CDM). Another example of the application of risk assessment and management in the UK is the *Control of Substances Hazardous to Health Regulations* (COSH).

Figure 2 identifies possible stages in risk assessment and management. Each stage is discussed below. The UK beef BSE (mad cow disease) scare is topical at the time of writing and has been used as an example.

- The description of intention is the place, product or process we are assessing e.g. the safety of eating British Beef.
- The hazard identification is the process of identifying what could reasonable be expected to cause harm e.g. BSE in cows may cause Creutzfeldt-Jakob Disease (CJD) in humans who eat infected beef products.
- The identification of consequences is the damage or injury that will be caused if the hazard is realised e.g. CJD is a fatal disease.
- The estimation of the magnitude of the consequences is an assessment of whether the damage will be negligible, minor, moderate or severe e.g. if the link between BSE and CJD turns out to be true, will CJD kill a few unlucky people, or will thousands die?
- The estimation of probability of consequences is an assessment of the likelihood of the risk occurring e.g. at the time of writing, the experts assign a high probability to their being a link between BSE in cows and CJD in humans.
- At this stage it is necessary to estimate and evaluate the risk. This can be done "scientifically" using probability event trees, quantified risk analysis, etc. But it should also take into account the lessons learnt from risk perception e.g. the "calculated" risk of humans contracting BSE is currently considered to be very small, yet there is widespread fear and confusion amongst the public. There are issues of trust (changes of stance from politicians/experts), media sensationalism, fear of the unknown, etc. all impacting on public perception of this risk.

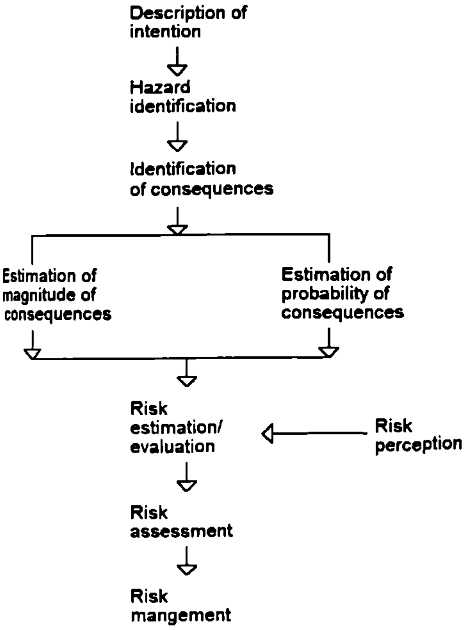


Figure 2 **Intention to risk management**

Evaluation of the risks may change as more information becomes available, so a risk assessment should generally be kept under review. In time, monitoring of the risk and its effects improve the accuracy of the risk assessment. Provided that effects of a risk are measured accurately, statistics become the most authoritative technical measure of the risk (providing the source of the risk remains unchanged). Relying on future statistics for an assessment of new risks is know as retroactive (as opposed to pro-active) risk management; this is a dangerous policy.

Those responsible for managing the risk have to take into account the risk assessment in deciding what measures, if any, are appropriate in order to reduce the risk. The cost versus benefit of each risk-reduction option must be considered. In industry impacting on the environment, this compromise is reflected in the BATNEEC (best available technology not entailing excessive cost) principle, which is widely applied.

In the British BSE scare, the evidence remains under review. Public perception of the risk makes a drastic risk management policy (mass slaughter of cows) a possible course of action, not because the experts think it necessary, but to restore public confidence.

5 LIFTS AND ESCALATORS ACCIDENT STATISTICS

5.1 United Kingdom

In the UK, lift and escalator accidents in the work-place are required to be reported either to the local authority, or to the Health and Safety Executive (HSE) according to where the accident happened. Accidents outside the work-place e.g. a domestic lift accident, are not reportable. Local Authority statistics are forwarded to the HSE for collation and publication. HSE acknowledge that, although they get to know about most work-place fatalities, only about 41% of other injuries are reported. The results are published annually, recent figures are reproduced in Table 1. The HSE database hold very general information. They will investigate more specific queries but, as only 6-8% of reported accidents are investigated, there limited scope for using there data to identify how lift and escalator safety can be improved.

Year	Group	Fatal	Major	Over 3 Day	Total
1992/93	Employees	1	3	21	25
	Members of public	-	2	-	2
1993/94	Employees	-	4	18	22
	Members of public	-	2		2

Table 1 Injuries to employees and members of the public involving lift and escalators (excluding construction hoists) reported to HSE 1992/93, 1993/94.

The Department of Trade and Industry (DTI) also maintain a database of accident statistics, extrapolated from a sample of 18 hospital accident and emergency departments throughout the UK. The database is designed to provide information for the consumer, but includes work related incidents as all major injuries are treated in hospital accident and emergency departments. The DTI database is more detailed then HSE's, and is broken down into categories of accident. A summary of their results for lift and escalator accidents is given in Table 2.

5.2 Other European Data

Lenskens presented data on lift accident for Belgium, West Germany and The Netherlands in his ELEVCON '94 paper, *Lift Safety in the Netherlands*(11) which is reproduced in Table 3. A breakdown is given of the accidents in Netherlands; around two thirds of the accidents involve users as opposed to lift company employees. Belgium's relatively poor results are ascribed to less strict regulations

	Mechanism Category						
Age group	Fall	Striking contact	Crushing /piercing	Bite /sting	acute over exertion	other/ un-specified	Row Totals
Escalator Accidents							
0-4	162	81	0	0	0	0	244
5-14	203	81	41	0	41	0	365
15-14	487	365	0	0	41	41	934
45-64	365	81	0	0	41	0	487
65-74	731	41	0	0	0	0	771
75+	1056	162	41	0	0	41	1299
Lift Accidents							
0-4	41	122	162	0	0	0	325
5-14	20	20	0	20	0	0	61
15-14	0	102	81	0	0	41	223
45-64	41	20	41	20	0	0	122
65-74	41	41	20	0	0	20	122
75+	142	102	81	0	0	20	345
unknown	0	0	20	0	0	0	20
Column Totals	3289	1218	487	41	122	162	5319

Table 2 DTI accident statistics for UK lifts and escalators based on extrapolation from the records of 18 hospital Accident and Emergency Departments

	Belgium (1975-1984)	West Germany (1981)	The Netherlands (1975-1984)
Deaths per year per 10 000 lifts	0.8 - 1	0.14	0.1 to 0 2
Serious accidents per year per 10 000 lifts	15	1.4	2

Table 3 Comparison of lift accident statistics for Belgium, West Germany and The Netherlands

5.3 Relative Safety of Lifts Compared With Other Means of Transport

Using an average of Lenskens' data, it is reasonable to estimate that there are approximately 0.27 passenger deaths per year per 10,000 lifts. According to Boston Globe's sources, 600,000 lifts correspond to 55 million lift trips per day. If you assume (this is a major generalisation) that both Lenskens and the Boston Globe's figures(3) are typical internationally, you can calculate that every time someone travels in a lift, they risk death at a probability of 8.1×10^{-10}. To put this risk in context, it has been included in Table 4, together with other transport risks taken from the paper, *Analysis of the Daily Risks of Life*(12) by R Wilson Wilson uses the measure, risks that increase the chances of death by one in a million.

Risks which increase chances of death by one in a million
Travelling 7 minutes by canoe
Travelling 10 miles by bicycle
Travelling 300 miles by car
Travelling 1000 miles by jet
Taking 1240 lift trips

Table 4 Comparable risks of death using different types of transportation

6 A STRATEGY FOR THE VERTICAL TRANSPORTATION INDUSTRY

Compared with some of the industries referred to in this paper, the vertical transportation industry is managing relatively minor risks. Yet every accident is one too many, and we (the industry) are called to account when notable incidents occur.

One major, emotive accident (say 10 children fall to their death in a lift) could initiate media focus leading to a loss of public confidence in the vertical transportation industry, and a disproportionate concern over one particular safety issue. The author suggest the vertical transportation industry should learn from the mistakes of other industries by adopting a pro-active risk strategy. Some suggestions follow:

- Understand how and why public risk perception differs from statistical evidence and adopt an appropriate risk communication strategy. Most of the findings discussed in sections 2 and 3 of this paper can be applied directly. The most important issue in dealing with public fears is to maintain trust. Every interaction, especially with the media, should be reviewed in the context of whether that interaction could undermine trust, either now or in the future.

- Press for (and if necessary subsidise) mandatory reporting of accidents to independent bodies, and for the preparation of detailed statistics. Identify common causes of accidents and address them e.g. Barney states(13) that if statistics were properly available deflector brushes would be fitted to all escalators.

  The Boston Globe(3) criticised the USA industry Safe-T Rider campaign stating "With no requirement to compile accident statistics, the industry has funded a publicity campaign that bames accidents not on unsafe equipment, but careless riders." This is an unfair criticism of a well motivated campaign. However, the best response to this type of criticism is to be in a position where its claims are insupportable. Are they?

- Avoid complacency! The lift industry knows that a partly loaded electric lift can falls up rather than down because of its counterweight. And yet lift safety gear can stop a lift falling down but not up. Modern technology can provide numerous ways of overcoming this design limitation (the much heralded rope break is only one of them). Yet most lift companies provide (and lift consultants accept) safety gear that provides no protection from a possible direction of falling which is not even protected by a buffer. This issue needs to be addressed. Are their others?

- Apply risk assessment for new technologies. Consider how public confidence may require additional safety measures to be taken above those dictated by technical risk assessment. e g. we should be able to make ropeless lifts, electronic safety gear, etc. technically safe, but will additional measures be required to ensure public confidence?

7 CONCLUSIONS

Public perception of risk is a function of many variables, or which accident statistics play only a small part. It is important that we, as an industry, maintain public confidence in vertical transportation systems. Lessons learnt from other industries' mistakes can be applied.

Maintaining the public's trust is paramount. Poor communication of risk associated with vertical transportation will undermine public confidence. Out of the public spotlight, we must strive for every better safety standards. On occasions when we are thrown to the lions in the media arena, only the Christians (i.e. the conscientious) will be saved.

ACKNOWLEDGEMENTS

The author would like to thank his supervisors, lecturers and colleagues at Brunel University, Ove Arup & Partners and the CIBSE Lift Group for sharing their knowledge and experience which are providing an excellent basis for his research. The author acknowledges, with gratitude, financial support from the Engineering and Physical Sciences Research Council, The Ove Arup Partnership, and the Chartered Institution of Building Services Engineers.

REFERENCES

1. *Equinox*, broadcast UK Channel 4 15 (October 1995)
2. *How do they do that?* broadcast UK BBC1 (1996)
3. *Risky Ride*, Boston Sunday Globe special feature (4 December 1995)
4. Slovic P *Perceived Risk, Trust, and Democracy* Risk Analysis, Vol 13, No 6 (1993)
5. Slovic P, Fischhoff B, Lichtenstein S *Rating the Risks* Environment, Vol 21, No. 3, pp14-20, 36-39 (April 1979)
6. Starr, *Social Benefit Versus Technological Risk* Science, Vol 165, pp1232-1238 (10 September 1969)
7. Golding D, Krimsky S, Plough A *Evaluating Risk Communication: Narrative vs. Technical Presentations of Information About Radon* Risk Analysis, Vol 12, No.1 (1992)
8. Sandman P, Getting to Maybe: Some Communications Aspects of Siting Hazardous Waste Facilities Seton Hall Legislative Journal, Vol 9, pp442-465 (1985)
9. Lofstedt R *Risk communication in the Swedish energy sector* Energy Policy, pp768-772, (July 1993)
10. Lofstedt R *Environmental Risk Assessment and Management* (draft/unpublished)
11. Lenskens A *Lift Safety in the Netherlands* Elevator Technology 4 Proceedings of ELEVCON '92 (The International Association of Elevator Engineers) (1992)
12. Wilson R *Analysing the Daily Risks of Life*, Technology Review, Vol.81, No.4, pp41-46 (February 1979)
13. Barney G C Editorial printed in Elevatori, issue 2/95, pp110-112 (March/April 1995)

Richard'. An imaginative paper and raises the lift industry [illegible] [illegible]. I would look at the Boston Globe article a bit more. What prompted their statements? Also there's [illegible] [illegible]. [illegible] [illegible] [illegible] in [illegible] [illegible] close to Christianity or too

Brunel/Surrey EngD in Environmental Technology

Marking form for EngD modules

Research Engineer: Richard Peters

Module Title: Risk Assessment

Marked by: Ragnar Lofstedt

Grade point awarded (please refer to scheme overleaf): **6 (B)**

Comments:

This is a good paper and should make the lift industry think a bit. I would look into the Boston Globe article some more though. What prompted the statements that they made? Also, there is the "phobia" factor. Some people are afraid of travelling in lifts due to claustrophobia and then there is the issue of lifts stopping between floors, something that the movie industry has portrayed far too many times.

Signed: ....30 April 1996

Please return completed form to Alex Roberts for Surrey-based modules and Chris France for Brunel-based modules

lxmark

14 MARKETING AND FINANCIAL MANAGEMENT

MODULE 3 - MARKETING AND FINANCIAL MANAGEMENT
ASSIGNMENT M3/1

The cut-off date for this assignment is **7 October 1996**. *You must send your completed assignment to arrive at Brunel University by the cut-off date.*

Completing your assignment

Use A4 paper for the written parts of your assignment. Assignments should be typed or produced on a word-processor; handwritten submissions will only be accepted in exceptional circumstances. Put your name, ID number and the title of the assignment at the top of each page.

Sending in your assignment

When you have completed the assignment, fill in the Assignment Submission Form and attach it to the submission. Send the assignment to the address shown in the Student Handbook. Be sure to retain a copy of the assignment for reference. For general information about the submission of assignments, you should refer to your Student Handbook.

After reading the case study on the Body Shop (enclosed) answer the following questions:

(1) *Describe the typical Body Shop consumer.* *(10)*

(2) *How important are point of sale promotions for Body Shop sales? Defend your answer.* *(20)*

(3) *Recommend suitable marketing research to ensure the packaging of Body Shop is effective in achieving its marketing objectives.* *(10)*

(4) *A grave danger with green marketing is that it relies on trust and confidence in arising from emotional appeals with the distributor or producer. What steps can the Body Shop take to control these emotions and reinforce its credibility?* *(10)*

N.B. *Please be as precise and clear as possible with your answers, in accordance with good marketing practice.*

CASE 2

The Body Shop

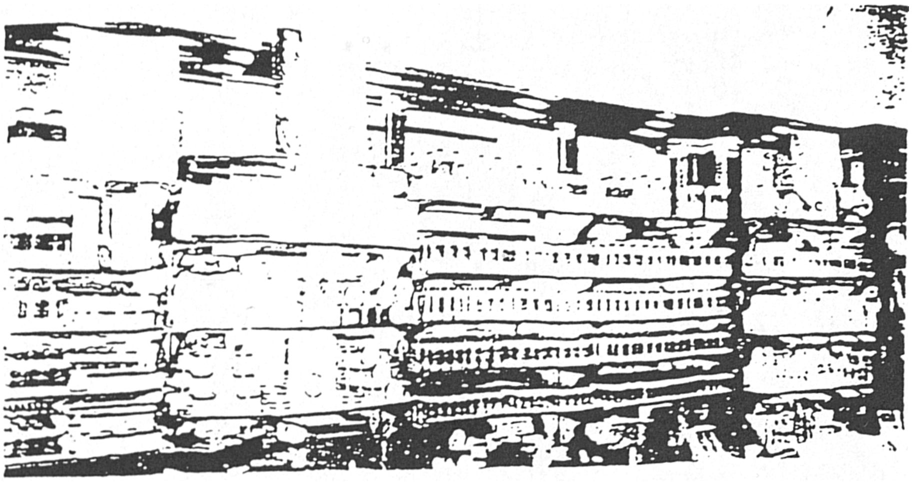
The Body Shop was founded in 1976 by Anita Roddick; its first shop was located on a side street in Brighton, England. Ms Roddick envisioned a store where customers could buy beauty items such as shampoo and skin cream in the quantities they desired, just as consumers shopped for fruits and vegetables. She had experienced some tough times of her own and could not afford to buy large quantities of shampoo and beauty care items at one time. When she opened her store she figured there were other people in the same situation and, therefore, offered five different sizes of products. These same bottle sizes are available in each store today.

The first shop sold a variety of twenty-five different natural skin and hair care products in hand labeled bottles. The labels were round and green in color only because they were inexpensive and the color was bright. People like to speculate today that the labels were green because of issues of environmental concern. Today there are over 800 Body Shops worldwide with a variety of over 350 products sold in each store. Still headquartered in West Sussex, United Kingdom, The Body Shop employs over 5,850 worldwide. The Body Shop through its concept, staff and founder, continues to have an impact on consumers, retailing, and people throughout the world.

Products

The company is committed to the research, development, manufacturing, and distribution of healthy beauty care products for men and women. Body Shop products are designed to cleanse, polish, and protect the skin and hair naturally. Consumers can buy avocado soap, apple shampoo, clay facial masks, fragrance derived from vanilla, spearmint, and cinnamon, and natural peach bath crystals. The Body Shop has also expanded into natural and non-allergenic makeup, including eye shadow, mascara, foundation, and blush. A photo of products and list of products are shown in

■ EXHIBIT 2.1 The Body Shop



■ EXHIBIT 2.2 The Body Shop Retail Environment

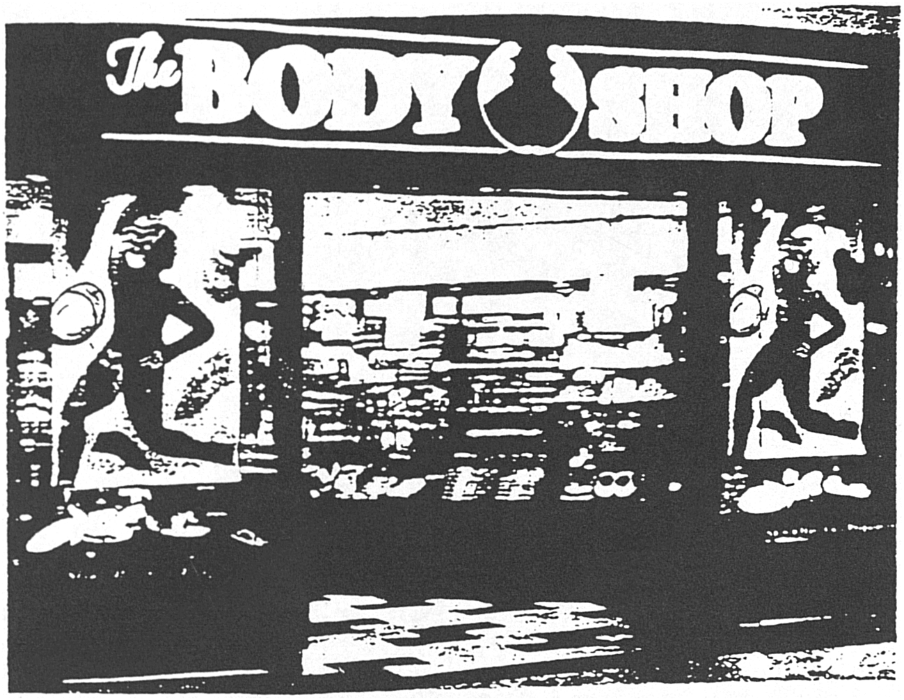
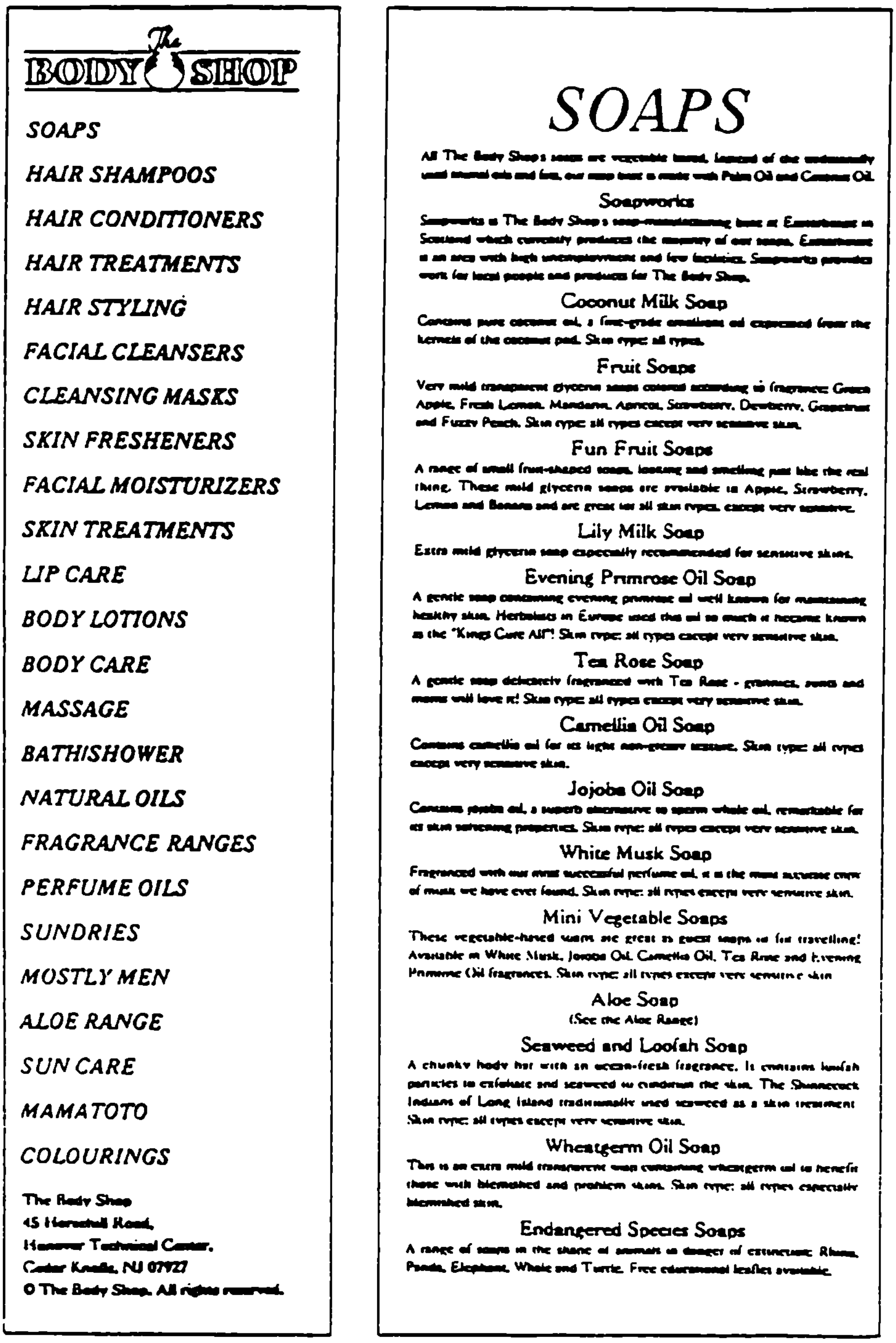


Exhibit 2 [illegible] Exhibit 2.2 shows a typical Body Shop store. Product categories are listed in Exhibit 2 [illegible] which also details the depth and variety of soaps available.

The product line at The Body Shop has evolved dramatically in the last decade. [illegible] cosmetics range [illegible] was launched in the stores in

▪ EXHIBIT 2.3 Product Categories and Soap Categories



The BODY SHOP

SOAPS
HAIR SHAMPOOS
HAIR CONDITIONERS
HAIR TREATMENTS
HAIR STYLING
FACIAL CLEANSERS
CLEANSING MASKS
SKIN FRESHENERS
FACIAL MOISTURIZERS
SKIN TREATMENTS
LIP CARE
BODY LOTIONS
BODY CARE
MASSAGE
BATH/SHOWER
NATURAL OILS
FRAGRANCE RANGES
PERFUME OILS
SUNDRIES
MOSTLY MEN
ALOE RANGE
SUN CARE
MAMATOTO
COLOURINGS

The Body Shop
45 Horsehill Road,
Hanover Technical Center,
Cedar Knolls, NJ 07927
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SOAPS

All The Body Shop's soaps are vegetable based. Instead of the traditionally used animal oils and fats, our soap base is made with Palm Oil and Coconut Oil.

Soapworks

Soapworks is The Body Shop's soap-manufacturing base at Easterhouse in Scotland which currently produces the majority of our soaps. Easterhouse is an area with high unemployment and few facilities. Soapworks provides work for local people and products for The Body Shop.

Coconut Milk Soap

Contains pure coconut oil, a fine-grade emollient oil expressed from the kernels of the coconut pod. Skin type: all types.

Fruit Soaps

Very mild transparent glycerin soaps coloured according to fragrance: Green Apple, Fresh Lemon, Mandarin, Apricot, Strawberry, Dewberry, Grapefruit and Fuzzy Peach. Skin type: all types except very sensitive skin.

Fun Fruit Soaps

A range of small fruit-shaped soaps, looking and smelling just like the real thing. These mild glycerin soaps are available in Apple, Strawberry, Lemon and Banana and are great for all skin types, except very sensitive.

Lily Milk Soap

Extra mild glycerin soap especially recommended for sensitive skins.

Evening Primrose Oil Soap

A gentle soap containing evening primrose oil well known for maintaining healthy skin. Herbalists in Europe used this oil so much it became known as the "Kings Cure All"! Skin type: all types except very sensitive skin.

Tea Rose Soap

A gentle soap delicately fragranced with Tea Rose - grannies, aunts and mums will love it! Skin type: all types except very sensitive skin.

Camellia Oil Soap

Contains camellia oil for its light non-greasy texture. Skin type: all types except very sensitive skin.

Jojoba Oil Soap

Contains jojoba oil, a superb alternative to sperm whale oil, remarkable for its skin softening properties. Skin type: all types except very sensitive skin.

White Musk Soap

Fragranced with our most successful perfume oil, it is the most accurate copy of musk we have ever found. Skin type: all types except very sensitive skin.

Mini Vegetable Soaps

These vegetable-based soaps are great as guest soaps or for travelling! Available in White Musk, Jojoba Oil, Camellia Oil, Tea Rose and Evening Primrose Oil fragrances. Skin type: all types except very sensitive skin

Aloe Soap

(See the Aloe Range)

Seaweed and Loofah Soap

A chunky body bar with an ocean-fresh fragrance. It contains loofah particles to exfoliate and seaweed to condition the skin. The Shinnecock Indians of Long Island traditionally used seaweed as a skin treatment. Skin type: all types except very sensitive skin.

Wheatgerm Oil Soap

This is an extra mild transparent soap containing wheatgerm oil to benefit those with blemished and problem skins. Skin type: all types especially blemished skin.

Endangered Species Soaps

A range of soaps in the shape of animals in danger of extinction: Rhino, Panda, Elephant, Whale and Turtle. Free educational leaflet available.

September 1986 and has been very successful. Mostly Men, a collection of skin and hair care products designed specifically, but not exclusively, for men debuted in November 1986. Mamatoto, The Body Shop's comprehensive mother-to-be and baby range, was launched in the United Kingdom in September 1990 and in the United States in September 1991. The Body Shop is looking forward to the introduction of a line of products which contain sustainable ingredients from the Rainforest in Brazil.

Unlike many major cosmetic brand name products, The Body Shop's products contain a relatively high percentage of natural base ingredients. For example, the Aloe Vera range contains as much as 98 percent pure gel from the aloe plant. Cocoa Butter Suntan Lotion is 13 percent cocoa butter.

It is not just the products that make this company unique. It is its innovative formulations, passion for the environment and social issues, and sensitivity in retailing that make The Body Shop a corporation of the future. The Body Shop cares about its consumers. Because the company has no advertising overhead and uses minimal packaging, the product cost is low compared with those products of similar quality and efficiency produced by other cosmetic companies.

The approach of The Body Shop is unique in the cosmetic industry in that it focuses on health and well-being. It is an approach that is nonexploitative. The company does not promote or sell beauty "fantasies" in its advertisements or point-of-purchase displays, as other cosmetic companies do. The Body Shop sees its consumers as beautiful in a healthy way, not from use of heavy cosmetics but because of a natural beauty enhanced by natural products. Because of this belief, there are no images of "perfect" or idealized women in its shops or in its literature.

The Body Shop has gone from serving a select niche of customers interested in natural beauty care products to serving a variety of consumers, some aware of the company's environmental ties and others who just like the products. When customers enter The Body Shop, their senses are delighted by the smells, sounds, sights, and atmosphere of the store. Retail stores have a natural and clean feel to them with the corporate commitment to the world and its inhabitants evident in the literature, brochures, and point-of-purchase information items. Shopping at The Body Shop is not a chore; it is an experience that, when coupled with quality products, keeps customers coming back.

There is an electricity that runs through the stores—from the products and their bright green labels to the friendly sales staff. Although trained to help consumers when they ask for assistance, the sales staff will not bother customers when they are shopping. The staff is trained to be sensitive to the needs of the customers and to not make them feel pressured into buying something but to help them make informed purchase decisions. Instead of pressure selling, the staff's role is to educate consumers and tell them stories about different products, their origin, and how they finally made it onto The Body Shop shelves. All of The Body Shop products are backed by information available from either brochures or the sales staff. Staff members are knowledgeable about the products as well as social/environmental issues such as animal testing.

Profitability and Philosophy

The Body Shop has learned effectively the lesson on how to grow profits. With an approximate market value of $1 billion and great stock performance, the company has earned the reputation in the City, London's equivalent of Wall Street, as the 'share that defied gravity.' Since the company went public in 1984, the share price has increased 10,944 percent. Some analysts predict that the company will grow its profits at an annual rate of 30 percent to 40 percent for the next 5 years.

While understanding the need to increase profits as it grows in sales and number of stores, The Body Shop is concerned about the using of these profits to better the world in which we live. The company believes that with profitability comes responsibility and that profits should be partnered with principles. Simply stated by Ms. Roddick, "The company operates within the world, the environment, the community. That is where our responsibilities lie—we want to give something back to society." And it does.

The Body Shop is a company that has grown quickly and successfully but has never lost sight of its corporate philosophies. Since its inception in 1976, The Body Shop's ties and commitments are to the environment and the world's inhabitants, animals, and human beings alike. One goal of the organization is for its products to reflect its philosophies. Its strong foundation and corporate philosophies can be summarized as follows:

- Use vegetable rather than animal ingredients in products whenever possible
- Prohibit testing of ingredients or final products on animals
- Respect the environment
- Use naturally based, close-to-source ingredients as often as possible
- Offer a range of sizes so that customers can buy quantity needed without buying extra

The Body Shop exemplifies its commitment to the environment by offering recycling in its stores. Consumers receive a discount on their next purchase if they participate in this program. The Body Shop feels customers should be able to buy its products without having to pay for elaborate and expensive packaging. To reduce waste and keep prices down, packaging is kept basic and to a minimum. In fact each store has a refill policy which will refill a customer's old product bottles with new products to save on packaging materials and create less waste. This policy has been in place since the store opened. At that time Roddick could only afford to buy 700 bottles in which to package her products. She asked people to bring them back to be refilled to cut costs for her and her customers. Today all Body Shop products are biodegradable, and the stores participate in recycling waste when needed. The company's commitment to recycling is further displayed in its use of recycled paper for brochures and shopping bags.

A variety of organizations involved in protecting the environment have benefited from The Body Shop's efforts. It became involved with Greenpeace in England to "Save the Whales" and with The Friends of the Earth to raise public awareness about the dangers of acid rain. In 1986 the company formed The Body Shop Environmental Projects Department to develop and coordinate environmental and community projects. While these projects might be initiated by the company or individual stores, employee participation is voluntary. The Body Shop has been involved in various projects, ranging from providing massage for the elderly and psychiatric patients to sensory therapy for the blind. By encouraging individual stores and employees to get involved, The Body Shop hopes that each store will support specific projects to help their own communities.

The organization strives to have its products reflect its philosophies. In developing "futuristic" products, The Body Shop relies on knowledge and wisdom from the past regarding natural ingredients used for remedies and preventive purposes. Traditional ingredients such as almond oil and vanilla, which are used in Body Shop products, have been used for centuries and have a history of safety and health on which The Body Shop relies in its "return to basics" approach to cosmetics. The Body Shop respects the world of nature and tries to use the ingredients in their most natural forms. Not only does the company look to nature for many ingredients, it looks to nature for inspiration.

Product formulation and business operations are also based on respect for its customers and different cultures. Roddick, still actively involved in the growth of the organization, travels the world to learn how different cultures care for their skin and hair. These beauty secrets are used in the formulation of new products for people of various cultures to enjoy. Understanding and respect for other cultures has also helped The Body Shop to be successful in a variety of markets because of the cultural empathy the company has developed. Regardless of location, The Body Shop expresses its respect for all of its customers by offering them a variety of choices of products, product sizes, and information.

Animal Testing and Cosmetics

The use of animals in the testing of cosmetics continues to be a controversial debate fought in many arenas throughout the world. Animals primarily serve two purposes in cosmetic testing: they provide raw ingredients for formulations and perfumes, and they are used in laboratory testing. The Body Shop questions the need for such practices and considers them to be cruel and unnecessary. Over 7,000 U.S. organizations with over 10 million supporters are dedicated to animal welfare and animal rights. The Body Shop, its employees, and many of its customers as well are dedicated to similar goals.

The Body Shop's position on animal testing is clear. While it understands the need to test for eye irritation, toxicity, and skin irritation to assure human safety, alternative methods should be used. This principle has been a part of The Body Shop foundation since 1976. Some of the alternative testing methods employed by the company are:

1. Use of "old and tested" ingredients. Such ingredients include beeswax and honey, which have been used by humans for hundreds of years. Even when new formulations with "old" ingredients are made, the histories of the ingredients allow the products to be tested safely on people. The Body Shop has established a panel of Animal Aid volunteers for testing conducted at The University Hospital of Wales.
2. Use of ingredients derived from plants or vegetables. These ingredients have been tested by human beings for years through food consumption. The Body Shop selects its raw ingredients and its suppliers carefully. It requires suppliers to confirm in writing that they have not used animal testing for cosmetics in a 5-year period prior to association with The Body Shop. Continual monitoring of suppliers helps ensure that this standard is always met.

New testing methods are also being developed as alternatives to animal testing. They include:

- bacterial tests
- in vitro tests: testing on cells rather than live animals
- mathematical models and imaging techniques
- computer analysis to predict how a substance will react when used on human skin

The Body Shop encourages its employees and customers to become involved in animal rights and other environmental concerns. It provides literature in its stores on such topics and invites consumers to make suggestions, ask questions, and raise issues to increase the company's level of consciousness. The Body Shop also initiates and supports letter writing campaigns for various causes. The stores become letter writing and collection stations for weeks until every customer has voiced his or her opinion on the topic at hand. Over 4 million letters were delivered by Roddick and her staff to the doors of the British government protesting animal testing. Once again, Roddick and The Body Shop made national and international headlines.

A Global Company

The Body Shop has grown into a global company with a network of retail stores spanning the continents and including such markets as Denmark, Australia, Sweden, Singapore, Hong Kong, and the United States. Although The Body Shop operates in many diverse countries, trades in seventeen languages, and employs staff members representing a variety of cultures, all retail shops look basically the same and carry the same products. The image and reputation of the company have remained strong and constant through the expansion process by staying true to corporate philosophies. Customers throughout the world respect The Body Shop's goals, philosophies, and products.

The global concern of The Body Shop extends beyond selling in foreign markets; it includes sourcing in Third World countries. By using ingredients from Third World countries, the company hopes to encourage local communities to grow specific ingredients and develop trade practices. This method of sourcing allows The Body Shop to get fresh, unique ingredients and helps Third World countries develop jobs for its people. Corporate philosophy dictates that such relationships be based on equality and respect.

When Roddick finds a group of people who have ingredients which she can use in beauty products, she shows the people, in many cases tribes in Third World countries, how they can make money with their products by adding value. For example if a South American tribe is efficient in gathering Brazil nuts, she will show them that by extracting the oil, they have something of great value for which The Body Shop will pay. Roddick is committed to fair business. If it costs The Body Shop $30.00 for a liter of extract from a wholesaler, that is the price she will pay to the South American tribe as well. She and her staff also spend time with various groups of people from whom they buy ingredients and help them establish schools and housing from the money they earn.

The Body Shop has developed a relationship with the Boys' Town Trust in Southern India, designed to provide education and training for underprivileged children who learn trades and skills such as farming, woodwork, basket making, and silk screen printing. The goal of the Trust is to help these children to become skilled and valued members of their communities. The Body Shop has also raised funds to build The Body Shop Boys' Town, a community project developed by the company to house, educate, and train underprivileged boys. The Athoor site houses eighty-five boys who work on a productive farm to support the community. Sponsorship money from The Body Shop, its employees, and customers helps sustain the boys through their schooling.

Although The Body Shop enjoyed a somewhat unique positioning for many years, recently the number of "green" cosmetic companies has grown dramatically. Some of the companies and their products that now compete with The Body Shop include the major cosmetic manufacturers as well as other specialty shops and specialty lines handled by other retailers.

Reflecting on the Future

Anita Roddick feels the thing that will keep The Body Shop growing throughout the 1990s will be its *passion*. Her definition of business is *the activity needed to keep a company alive and breathlessly excited*. She is dedicated to protect the company's employees and remain a force in society. After those goals, concerns over profits arise. Although profits are necessary to stay in business and keep growing, fun and love are what keep management on the cutting edge.

It is ironic that a company which does not have a formal marketing or advertising department is cited as a company which will sell successfully in the next decade. The Body Shop accomplishes this in many ways. First, it relies heavily on word-of-mouth advertising, but without excitement, word-of-mouth will cease. Second, the company believes in educating its consumers by giving the staff unusual product information. The staff is told anecdotes about the history and ingredients of its products and humorous stories on how some of its exotic products wound up on The Body Shop shelves. This type of information hopefully will stimulate interesting conversation between staff and customers.

Finally, it is the enthusiasm of its management which makes The Body Shop poised for growth this decade. Roddick and her team have an electricity that is contagious. It is evident in management philosophy and in the stores.

Anita Roddick has become a CEO of the future, one to be studied, admired, and understood. She has three distinct values which she carries into her business. The first one is to have fun. The second is to put love where your labor is. The third is to go in the opposite direction of everyone else.

Anita Roddick says this about running a business successfully, "I think you can trade ethically; be committed to social responsibility and global responsibility; empower your employees without being afraid of them. I think you can rewrite the book on business."

MODULE 3 - MARKETING AND FINANCIAL MANAGEMENT
ASSIGNMENTS M3/2 AND M3/3

The cut-off date for this assignment is 7 October 1996. You must send your completed assignment to arrive at Brunel University by the cut-off date.

Completing your assignment

Use A4 paper for the written parts of your assignments. Assignments should be typed or produced on a word-processor; handwritten submissions will only be accepted in exceptional circumstances. Put your name, ID number and the title of the assignment at the top of each page.

Sending in your assignment

When you have completed the assignments, fill in the Assignment Submission Form and attach it to the submission. Please note that you will have to fill in two forms, one each for M3/2 and M3/3. Send the assignments to the address shown in the Student Handbook. Be sure to retain a copy of the assignments for reference. For general information about the submission of assignments, you should refer to your Student Handbook.

Question M3/2 is designed to test your understanding of balance sheets and profit and loss accounts. It requires you to use ratio analysis and will test your understanding of ratios as a financial managerial tool. The question will also test your ability to write a concise, but clear report.

Question M3/3 is designed to test your understanding of budgets, costing methods and financial contracts.

M3/2

A friend of yours has recently been offered employment with Blundell Packaging PLC as a member of the senior management team. The company has been trading for a number of years and offers an employee share ownership scheme as part of its remuneration package. The profit and loss accounts and balance sheets for the years 1992 to 1995 inclusive attached as Appendix I have been extracted from the company's audited accounts.

Prepare a report for your friend which analyses the company's operating performance for the years 1992 to 1995 and which specifically addresses the issues which might be of concern to such a person. Marks will be allocated as follows:

i) An executive summary of your analysis amounting to no more than ONE side of A4 paper.

(10 marks)

ii) A schedule of at least ten different operating ratios for all four years. (Include all workings/calculations in an appendix to your report).

(15 marks)

iii) An analysis of the performance of the company over the period.

(50 marks)

iv) Notes outlining the limitations of the analysis you have prepared and additional information which you might suggest that your friend seeks.

(25 marks)

(100 marks in total)

M3/3

Three months later you receive a distressed phone call. As Operations Manager of the Specialist Cartons Division, your friend has been called to an urgent meeting to discuss the division's forecast results for 1996 (which is showing a loss of £100,000 compared with the profit of £80,000 shown in the budget prepared at this time last year) and to discuss the budget for 1997. There is a note of panic in your friend's voice.

> *"I'm not an accountant but I do know that our sales contracts have to be competitively priced. What I don't know is how to answer the charge that the division is making a loss, especially when sales are slightly up on budget. Half the loss seems to come from one contract with Cawley Cartons Ltd. Cawley negotiated a special price with my predecessor and is now insisting that if I want his business I have to agree to pricing it on the same basis in future, which means more losses. The Managing Director is insisting that I've got to make a profit next year and has prepared the 1997 budget on that basis. He seems to think we can just push prices up or cut materials costs. I don't see why I should have to get involved in budgeting anyway; I'm just the Operations Manager. But to cap it all, my bonus for 1997 depends on the division making the profit that the MD has forecast!"*

You arrange to meet the company's offices where you are shown the division's 1996 forecast results, some information about the basis on which they have been prepared and details of the Cawley contract. These are shown in Appendix 2.

Prepare a report covering the following aspects of the case which would help your friend and defend the division's position at the meeting which has been called:

i) *Identify the potential drawbacks of the costing method used by Blundell Packaging PLC for calculating divisional results and the flaws in the calculation of variances shown in Appendix 2. Re-draft the Specialist Carton Division's budget, forecast results and projected variance for 1996 using more appropriate techniques and explain the advantages of the alternative you have prepared.*

(35 marks)

'i) *Comment on the special contract arrangements with Cawley Cartons Ltd. Advise your friend as to flexibility there might be in pricing such a contract and the additional considerations which should be taken into account in pricing.*

(25 marks)

ii) *Outline a typical budgeting process and explain its importance in the management and control of a business. Highlight the behavioral aspects of budgeting and comment on the process which appears to be in operation at Blundell Packaging PLC. Suggest changes which might improve the management process in this regard.*

(40 marks)

(100 marks in total)

Blundell Packaging PLC

Appendix I

PROFIT & LOSS ACCOUNTS

	1995	1994	1993	1992
	£'m	£'m	£'m	£'m
urnover	1,622	1,520	1,289	1,395
ost of sales	1,185	1,122	953	1,059
ross Profit	437	398	336	336
perating Expenses	350	333	280	318
nterest Charges	7	10	11	9
rofit before tax	80	55	45	9
axation	28	21	17	14
rofit/(Loss) after tax	52	34	28	(5)
rdinary Dividend	21	17	16	16
etained Profit/(Transfer from Reserves)	31	17	12	(21)

BALANCE SHEETS

	1995	1994	1993	1992
	£'m	£'m	£'m	£'m
ixed Assets	146	144	143	141
urrent Assets				
tock	144	152	140	131
ebtors	277	234	241	247
ash	27	20	21	47
	448	406	402	425
urrent Liabilities				
rade Creditors	177	155	146	146
ax Payable	12	10	14	15
idend Payable	21	17	9	9
verdraft	19	63	69	39
	229	245	238	209
et Current Assets	219	161	164	216
OTAL NET ASSETS	365	305	307	357
APITAL & RESERVES				
rdinary Share Capital	106	106	102	102
rofit & Loss Account	144	113	96	84
	250	219	198	186
ong Term Loans	115	86	109	171
	365	305	307	357

Blundell Packaging PLC

Appendix 2

Specialist Cartons Division

Forecast profit and loss account for 1996

	Latest forecast	Original budget	Variance
	£'000	£'000	£'000
rnover	3,260	3,200	60
st of sales:			
irect materials	560	730	170
irect labour	1,200	1,000	(200)
tory overhead	400	390	(10)
tory costs of production	2,160	2,120	(40)
inistrative overheads	550	450	(100)
ling and distribution overheads	650	550	(100)
profit/(loss)	(100)	80	(180)

es:

Administrative overheads are allocated to divisions at 45% of labour costs and selling overheads at 55% of labour costs. Factory overheads are allocated on the basis of machine hours at £2 per hour.

The following breakdown of overheads is estimated:

	Factory	Administrative	Selling and Distribution
	%	%	%
Fixed	80	90	60
Variable	20	10	40
	100	100	100

Details of the contract negotiated with Cawley Cartons Ltd are as follows:

		£
Sales price		240
Materials	60	
Labour	140	
Factory overhead	30	
Administrative overheads	63	
Selling and Distribution overheads	77	370
		(50)

re-filling containers saves them money; (iv) the policy reinforces and demonstrates corporate philosophies to employees and consumers.

- Conventional *sampling* includes the use of free samples and trial-size samples. For Body Shop, the approach has been broadened to the extent that it is part of their corporate philosophy - they "offer a range of sizes so that customers can buy the quantity needed without buying extra". This policy assures customers can always try out their products in small quantities.

Non-price promotions

- The Body Shop do not offer *contests and sweepstakes* or *continuity programs.* But it encourages its customers (and employees) to become involved in its campaigns on social and environmental issues. Rather than having the possibility of winning a prize (which almost always ends in disappointment), customers are part of campaign team, with real prospects of significant influence. Ongoing interest in current and future campaigns fosters the loyalty more often promoted by credit card points/prizes schemes and store loyalty cards.

- Body Shop convey *signals of value* about their products with point-of-purchase information items. This is backed up by staff telling stories about the different products, and how they came to be Body Shop products. Thus endorsements of quality and value are inherent, though not explicitly or conventionally expressed.

These incentives to visit the store and to purchase goods may not be immediately apparent to the consumer as point of sale promotions. They fit in well with the ethos of the company, so it would be natural to assume that they are motivated by their high social and environmental principles. This may or may not be the case; but intentionally or unintentionally, the Body Shop's success appears to owe much to point of sale promotions.

3. RECOMMEND SUITABLE MARKETING RESEARCH...

Stage 1 identify objectives

Firstly we need to consider what the marketing objectives of the packaging of Body Shop are. They may include:

- conveying information about the product
- conveying value without compromising quality image
- reflect company's image and philosophies
- be easily recognisable, and distinctive from the packaging of competitors' products
- be functional, e.g. do not leak

Stage 2 identify customer issues

Ask the staff to collect customers' opinions on the packaging informally using *open ended or open response* questions. Allow the staff to ask general questions, e.g. "do you think the labelling on this shampoo is clear?", but encourage customers to lead the conversation to issues that concern them rather than suggest what is important themselves.

Stage 3 design survey

Based on results from Stages 1 and 2, design a survey to determine the relative importance of the issues raised, and how well the current packaging performs on each issue. The survey should initiate a scaled response, e.g. selecting between five cartoon faces ranging from a grimace to a smile - this can be analysed simply, and would be a reflection of the company's "fun" image. The survey should first be tested on a sample of customers, and adjustments made if necessary to enhance comprehension.

Stage 4 implement survey

Because of their history of communicating with customers on social and environmental issues, *non-response* may not be a problem for the Body Shop if the questionnaire if it is well-promoted in-store. But an incentive or "thank you" would be appropriate to the company's caring approach - offering a nominal discount on that visit's purchases if the survey was filled in there and then would help the response rate and may pay for itself through increased sales.

Stage 5 evaluation and possible re-design

Following evaluation of the surveys, packaging re-design may be appropriate. If so, new packaging alternatives should be the subject of further market research before widespread introduction; in some case changes are too severe or inappropriate in practice, and may damage the brand.

4 A GRAVE DANGER WITH GREEN MARKETING IS....

Body Shop's history as an innovator in social and green cosmetic products has made them well placed for a green marketing strategy. But when, say, Tesco introducing a look-alike range of natural, environmental friendly beauty products, Body Shop needs a sufficiently superior "green" positioning to maintain customer loyalty and to avoid switching.

Body Shop could take a range of steps to control these emotions and reinforce its credibility. These could include:

- know their customers - undertaking market research to establish the green issues that are important to them, and responding in their promotional and business activities.

- reinforce their image as innovators by researching and acting on new social and environmental issues.

- enhance Shop assistant training on environmental issues, encouraging them to discuss these issues with customers.

- train and equipping senior employees to speak on environmental issues to local groups, e.g. women's groups, churches, youth groups, etc.

- take great care to maintain integrity and trust, particularly when interacting with the media. Abraham Lincoln one wrote *"if you once forfeit the confidence of your fellow citizens, you can never regain their respect and esteem".*

- undertake an environmental audit of their operation; require/assist their suppliers to do the same. Take radical action if appropriate, e.g. strip out all store lighting and replace with more efficient sources, explaining to customers the reasons why.

- continue to use existing in-store promotions to raise social and environmental issues.

- act as recruiting bases for respected green pressure groups.

ASSIGNMENT M3/2

BLUNDELL PACKAGING PLC
Analysis of Operating Performance 1992 to 1995

1. EXECUTIVE SUMMARY

This report is an analysis of Blundell Packaging's operating performance, based on profit and loss accounts, and balance sheets for the years 1992 to 1995.

A range of Operating Ratios has been used to analyse the company's performance over the period. Key points include:

- The company performed badly in 1992, picked up in 1993, and is now maintaining steady growth.

- Profits are on the increase, but low margins mean cost control is crucial.

- The company's sales are not increasing in line with its assets. This gives some cause for concern, and will need to be addressed.

- Liquidity dipped in 1993/1994, but is now at similar levels to 1992. Liquidity is essential if a company is to be able to pay its way. However, too high liquidity can also suggest idle assets, which may be the case in this instance.

- Without details of Blundell Packaging shares, we have been limited in our calculations relating to return on equity. Based on the book value, return was very poor (negative) in 1992, but had increased significantly to a healthy 21% in 1995. Similarly, the profitability ratio demonstrates that the company has successfully turned a loss in 1992, into a yearly increasing profit.

- The levels of debt used to finance the company (as opposed to shareholder equity) decreased in 1993 and 1994, but are now rising again. Achieving a suitable level of *Gearing* is a complicated task, and this need to be monitored closely in future years.

Overall, the company's results demonstrate that it had a poor year in 1992, has recovered well in the following years, and is now operating successfully with steady growth. There are some areas of minor concern, but these are manageable.

If possible, we would like to consider further analysis. Our main concerns are performance relative to other companies in the market sector, and share performance. Accounting measures aside, it is also advisable to consider non-accounting factors such as goodwill, etc. before making a final decision about the company.

2. OPERATING RATIOS

Operating ratios provided us with a framework to assess the performance of a company. Any number of ratios can be calculated; for the purposes of this report we have concentrated on ratios relating to:

- return on assets
- profitability ratios
- liquidity ratios
- investor ratios
- gearing

The ratios in Table 1 have been calculated (using a spreadsheet model) based on the profit and loss account and balance sheets provided for the years 1992 to 1995. Details of all calculations are given in the appendix to this report.

A detailed discussion of the individual ratios, and what they tell us follows in the next section of this report.

FINANCIAL RATIO ANALYSIS	1995	1994	1993	1992
Return On Total Assets (ROTA)	23.8%	21.3%	18.2%	5.0%
Profit Margin	5.4%	4.3%	4.3%	1.3%
Sales Generation				
Sales Margin (to £1)	£4.44	£4.98	£4.20	£3.91
Fixed Asset Utilisation				
(Total) Fixed Asset Utilisation (to £1)	£11.11	£10.56	£9.01	£9.89
Current Asset Utilisation				
Stock (to £1)	£11.26	£10.00	£9.21	£10.65
Debtors (to £1)	£5.86	£6.50	£5.35	£5.65
Other Current Assets (to £1)	£60.07	£76.00	£61.38	£29.68
Liquidity Ratios				
Current Ratio (to £1)	£1.96	£1.66	£1.69	£2.03
Liquid Ratio/Acid Test Ratio (to £1)	£1.33	£1.04	£1.10	£1.41
Corporate Ratios				
Return on equity (using book value of equity)	20.8%	15.5%	14.1%	-2.7%
Profitability	14.2%	11.1%	9.1%	-1.4%
Gearing Ratios				
Gearing (Total Assets/Equity)	1.46	1.39	1.55	1.92
Debt Ratio	31.5%	28.2%	35.5%	47.9%
Gearing Ratio (Debt/Equity)	46.0%	39.3%	55.1%	91.9%

Table 1 Operating Ratios

3. ANALYSIS OF PERFORMANCE

Return on Total Assets

Return on Total Assets (ROTA) is probably the most important financial ratio, showing the relationship between operating profit and total assets. It is used to demonstrate whether a company is producing a higher/lower profit per £ of total asset relative to previous years.

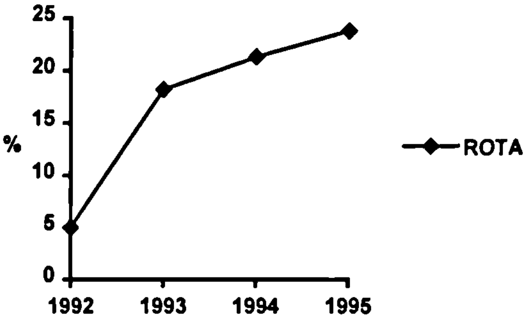

Figure 1

We have plotted the results for ROTA in Figure 1. This demonstrates a healthy growth after a poor year in 1992.

ROTA can also be a useful comparison between competitors' performance. If results for other similar companies are available, this would provide useful context for Blundell Packaging's performance in this market sector.

Profit Margin

The Profit Margin is an expansion of the key ROTA ratio, looking at relationship between operating profit and sales, i.e. profits generated for each £ of sales. Profit Margin is sometimes broken down to demonstrate the relative contributions of Material, Administrative and Employee costs, but in this instance we do not have data for this level of analysis.

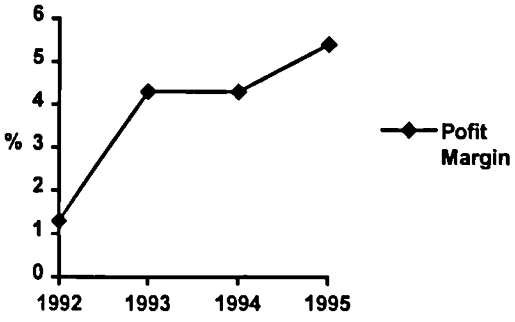

Figure 2

Figure 2 shows how Profit Margin was poor in 1992, improved dramatically in 93, stalled in 1994, but is now on the increase again. We could investigate the reasons for the stall, but this is not a priority given the subsequent upturn.

Overall the Profit Margin appears relatively low, though this is difficult to define "normal" ranges as this is heavily dependant on the market sector. (In general high volume sectors work on low margins, low volume sectors on high margins.) As with ROTA, it would be useful to establish how the company performs on the ratio in comparison with other suppliers. Given that this is a sector with low margins, cost control is likely to be critical if Blundell Packaging is to maintain profitability.

One of the problems with profit margin is that it can be too general, and hide the relative performance of individual products. Breakdown of operating profit by division or principle activity would be helpful if this is a concern.

Sales Generation

The Sales Generation ratio shows the value of sales generated for each £1 of assets.

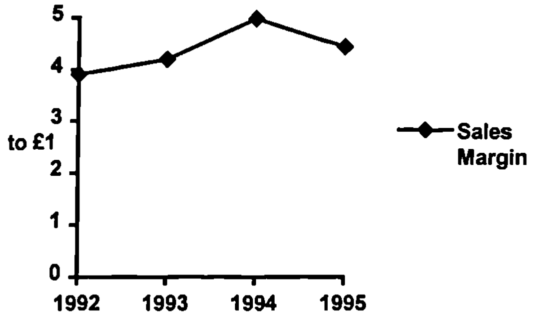

Figure 3

The Sales Generation ratio is relatively high, which is good. But again this is very industry sector dependant, and comparisons with competitors would be helpful. The current downward trend is a course for concern; the company's sales are not increasing in line with its assets. This justifies further analysis, as follows, to identify the causes:

Sales Generation is often broken down into its components. Firstly, Figure 4 shows the fixed asset utilisation, i.e. ratio of sales against fixed assets.

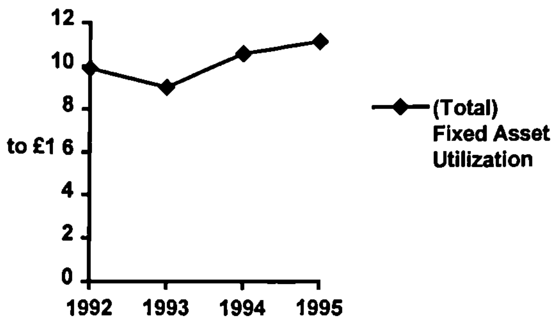

Figure 4

This is following a predominantly positive trend, which is good.

Current asset utilisation has been divided into Stock, Debtors and Others (cash) and plotted in Figures 5-7.

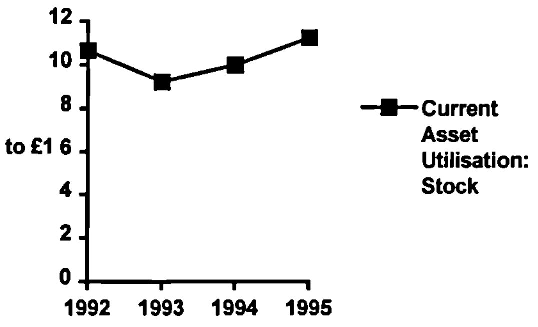

Figure 5

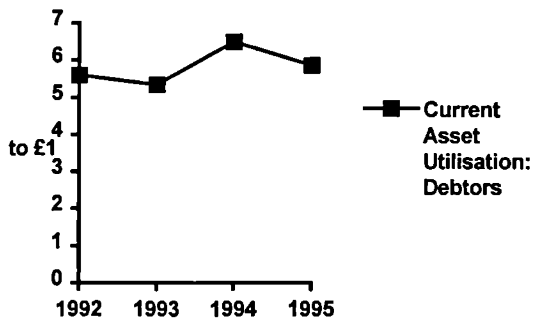

Figure 6

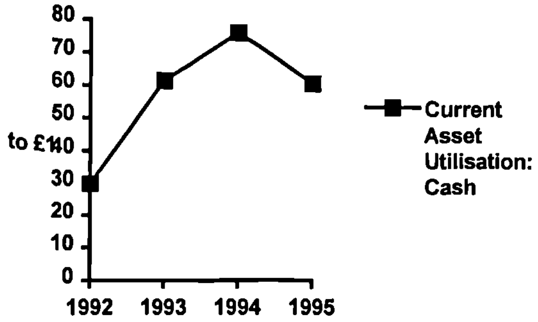

Figure 7

These graphs demonstrate that, relative to Turnover, the proportion of debtors (i.e. customers with outstanding bills), and cash held by the company, has increased in 1995. Referring to the balance sheet, the current liabilities have actually decreased, which results in further increases in net assets.

In summary, the company is not making as good use of its assets in 1995 relative to previous years, and should be looking to increase its sales and/or reduce its assets.

Liquidity Ratios

Company performance is also dependant on liquidity - a measure of a company's ability to pay its way.

The current ratio, as shown in Figure 8, is a ratio of current liabilities and current assets. This is a measure of the company's ability to meet its obligations in a one year.

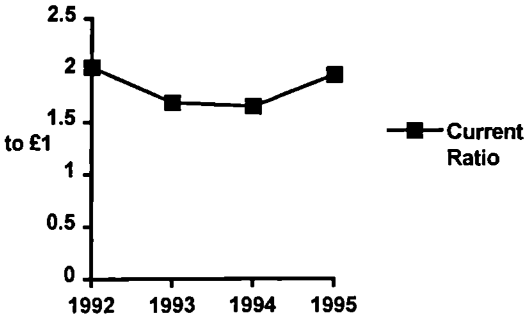

Figure 8

This current ratio, around 2, is a typical target liquidity ratio, but this is not necessarily a good thing. Unnecessarily high liquidity ratios can indicate idle facilities, stocks or debtors. This concurs with the analysis of Sales Margins that suggested that a reduction in assets may be appropriate.

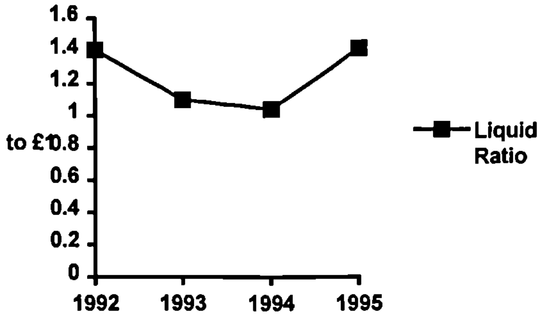

Figure 9

The Liquid (or acid test) ratio is based on current assets minus stock divided by current liabilities. It is a measure of a company's ability to pay its way in the short term without resorting to liquidating stock.

There is not a standard liquid ratio appropriate across all industries, but given that the company operated satisfactorily in 1993/94 at a level around £1 to £1, it is questionable whether the current level of £1.41 to £1 is now necessary. This, again could be an indication of idle assets.

Corporate Ratios

Corporate ratios give an indication of what the market thinks of the company, and are important to potential and actual investors. Given that a share ownership scheme is being offered, they would also provide an indication of this part of the remuneration package.

Unfortunately we do not have details of Blundell Packaging shares, so can only calculate a Return on Equity (ROE) Ratio based on the Book Value of Equity. This is plotted in Figure 10.

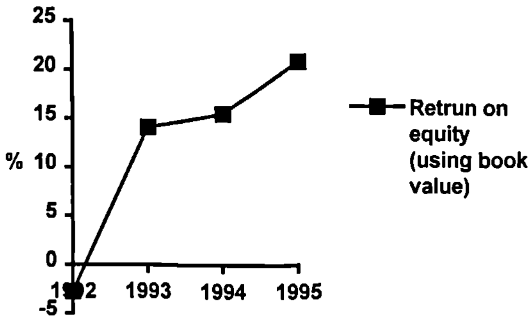

Figure 10

The ROE ratio is a measure of shareholder profitability. It is similar to ROTA, but takes into account profit deductions due to financing and taxation. ROE was negative in 1992, but rose significantly in 1993. ROE is continuing to increase, which is a good sign for the company and shareholders.

Profitability

Related to ROE, is Profitability, which is shows us the relationship between shareholders' profits, and the total assets.

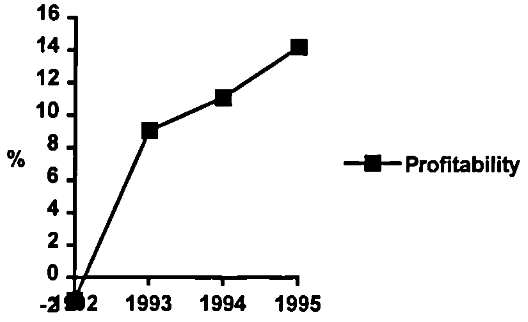

Figure 11

This is following a similar profile, with a very poor year in 1992, but on the increase ever since.

Gearing

Gearing is a measure of financial risk, and relates to the company's choice of funding between debt and equity. Loan financing is typically cheaper than equity as interest is chargeable against pre-tax profits, as opposed to dividends, which are paid from post-tax profits. However, there are increased financial risks with dept financing.

Figures 12, 13 and 14 plot Gearing (Total Assets/Equity), Debt Ratio (Debt/Total Assets as %), and Gearing (Debt/Equity as %).

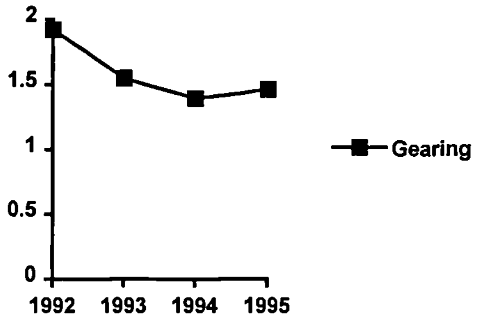

Figure 12

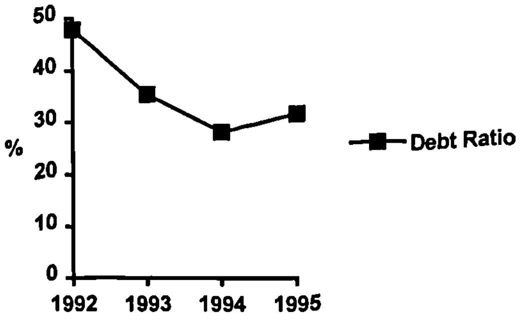

Figure 13

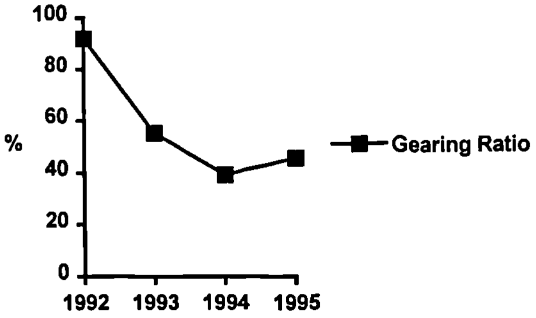

Figure 14

Having the appropriate level of gearing is important. High levels of gearing can yield greater returns on equity, but the debt has to be paid for irrespective of low profits. Indeed the relatively high levels of gearing, and subsequent interest payments were a major factor in the negative profitability in 1992.

The level of debt began rising again in 1995, and this will require close monitoring in future years to ensure appropriate levels are maintained.

4. ANALYSIS LIMITATIONS, SUGGESTED ADDITIONAL INFORMATION

We have looked at Blundell Packaging in isolation, without reference to other companies in this industry sector. This is a potential problem as the suitability of operating ratios is industry specific, (e.g. if competitors are achieving higher profit margins, they are likely to succeed in cost-cutting challenge to Blundell Packaging, dramatically reducing their market share). For this reason, we would have a better insight into future operating performance if balance sheets/profit and loss accounts could be obtained for comparable companies.

In calculating profit margin, we are limited to calculating overall performance, which could be hiding poor performance of individual products. Breakdown of operating profit by division or principle activity would be address this if figures can be made available.

Without share details, we have a very limited view of what the investors think about the company's past performance and future prospects. Obviously investor confidence, increasing share value, and return on equity is paramount to ensure continuing shareholder support. The share data required for further analysis would be Nominal Market Value, Market Value and Earnings per Share in for each of the years 1992-1995.

There are many facets of a company that are not measured or reported in accounts - goodwill (or badwill), quality of workforce, etc. These are important factors in the company's long term prospects, which should to be investigated and judged in non-accounting terms.

We do not have budgets and cash flow forecasts for review. These are important financial elements in the company's operation, and would be useful to review if they could be made available.

APPENDIX - OPERATING RATIO CALCULATIONS

	A	B	C	D	E
1	**PROFIT & LOSS ACCOUNTS**	**1995**	**1994**	**1993**	**1992**
2		**£'m**	**£'m**	**£'m**	**£'m**
3					
4	Turnover	1,622	1,520	1,289	1,395
5	Cost of sales	1,185	1,122	953	1,059
6	Gross Profit	437	398	336	336
7	Operating Expenses	350	333	280	318
8	Interest Charges	7	10	11	9
9	Profit before tax	80	55	45	9
10	Taxation	28	21	17	14
11	Profit/Loss after tax	52	34	28	- 5
12	Ordinary Dividend	21	17	16	16
13	Retained Profit/Transfer from Reserves	31	17	12	- 21
14					
15					
16	**BALANCE SHEETS**	**1995**	**1994**	**1993**	**1992**
17		**£'m**	**£'m**	**£'m**	**£'m**
18					
19	Fixed Assets	146	144	143	141
20					
21	Current Assets				
22	Stock	144	152	140	131
23	Debtors	277	234	241	247
24	Cash	27	20	21	47
25		448	406	402	425
26					
27	Current Liabilities				
28	Trade Creditors	177	155	146	146
29	Tax Payable	12	10	14	15
30	Dividend Payable	21	17	9	9
31	Overdraft	19	63	69	39
32		229	245	238	209
33					
34	Net Current Assets	219	161	164	216
35					
36	TOTAL NET ASSETS	365	305	307	357
37					
38	CAPITAL AND RESERVES				
39	Ordinary Share Capital	106	106	102	102
40	Profit & Loss Account	144	113	96	84
41		250	219	198	186
42					
43	Long Term Loans	115	86	109	171
44	TOTAL LIABILITIES	365	305	307	357

	A	B	C	D	E
51	FINANCIAL RATIO ANALYSIS	1995	1994	1993	1992
52					
53	**Return On Total Assets (ROTA)**	23.8%	21.3%	18.2%	5.0%
54					
55	**Profit Margin**	5.4%	4.3%	4.3%	1.3%
56					
57	**Profit Margin: Analysis by cost**				
58	Material Cost as a Percentage of Sales	*insufficient data*			
59	Administration Costs as Percentage of Sales	*insufficient data*			
60	Employee Costs as a Percentage of Sales	*insufficient data*			
61					
62	**Sales Generation**				
63	Sales Margin (to £1)	£4.44	£4.98	£4.20	£3.91
64		*no data for further breakdown*			
65					
66	**Fixed Asset Utilisation**				
67	(Total) Fixed Asset Utilisation (to £1)	£11.11	£10.56	£9.01	£9.89
68		*no data for further breakdown*			
69					
70	**Current Asset Utilisation**				
71	Stock (to £1)	£11.26	£10.00	£9.21	£10.65
72	Debtors (to £1)	£5.86	£6.50	£5.35	£5.65
73	Other Current Assets (to £1)	£60.07	£76.00	£61.38	£29.68
74					
75	**Liquidity Ratios**				
76	Current Ratio (to £1)	£1.96	£1.66	£1.69	£2.03
77	Liquid Ratio/Acid Test Ratio (to £1)	£1.33	£1.04	£1.10	£1.41
78					
79	**Corporate Ratios**				
80	Market to Book	*insufficient data*			
81	Market Capitalisation	*insufficient data*			
82	Return on equity (using book value of equity)	20.8%	15.5%	14.1%	-2.7%
83					
84					
85	**Profitability**	14.2%	11.1%	9.1%	-1.4%
86					
87	**Gearing Ratios**				
88	Gearing (Total Assets/Equity)	1.46	1.39	1.55	1.92
89	Debt Ratio	31.5%	28.2%	35.5%	47.9%
90	Gearing Ratio (Debt/Equity)	46.0%	39.3%	55.1%	91.9%

	A	B	C	D	E
1	PROFIT & LOSS ACCOUNTS	1995	1994	1993	1992
2		£'m	£'m	£'m	£'m
3					
4	Turnover	1622	1520	1289	1395
5	Cost of sales	1185	1122	953	1059
6	Gross Profit	=B4-B5	=C4-C5	=D4-D5	=E4-E5
7	Operating Expenses	350	333	280	318
8	Interest Charges	7	10	11	9
9	Profit before tax	=B6-B7-B8	=C6-C7-C8	=D6-D7-D8	=E6-E7-E8
10	Taxation	28	21	17	14
11	Profit/Loss after tax	=B9-B10	=C9-C10	=D9-D10	=E9-E10
12	Ordinary Dividend	21	17	16	16
13	Retained Profit/Transfer from Reserves	=B11-B12	=C11-C12	=D11-D12	=E11-E12
14					
15					
16	BALANCE SHEETS	1995	1994	1993	1992
17		£'m	£'m	£'m	£'m
18					
19	Fixed Assets	146	144	143	141
20					
21	Current Assets				
22	Stock	144	152	140	131
23	Debtors	277	234	241	247
24	Cash	27	20	21	47
25		=SUM B22 B24)	=SUM(C22 C24)	=SUM D22.D24)	=SUM E22:E24)
26					
27	Current Liabilities				
28	Trade Creditors	177	155	146	146
29	Tax Payable	12	10	14	15
30	Dividend Payable	21	17	9	9
31	Overdraft	19	63	69	39
32		=SUM B28 B31)	=SUM C28 C31)	=SUM D28 D31)	=SUM E28 E31)
33					
34	Net Current Assets	=B25-B32	=C25-C32	=D25-D32	=E25-E32
35					
36	TOTAL NET ASSETS	=B19+B34	=C19+C34	=D19+D34	=E19+E34
37					
38	CAPITAL AND RESERVES				
39	Ordinary Share Capital	106	106	102	102
40	Profit & Loss Account	=C40+B13	=D40+C13	=E40+D13	84
41		=SUM B39 B40)	=SUM C39 C40	=SUM D39 D40	=SUM E39 E40)
42					
43	Long Term Loans	115	86	109	171
44	TOTAL LIABILITIES	=B41+B43	=C41+C43	=D41+D43	=E41+E43

	A	B	C	D	E
51	FINANCIAL RATIO ANALYSIS	**1995**	**1994**	**1993**	**1992**
52					
53	**Return On Total Assets (ROTA)**	=(B9+B8)/B36	=(C9+C8)/C36	=(D9+D8)/D36	=(E9+E8)/E36
54					
55	**Profit Margin**	=(B9+B8)/B4	=(C9+C8)/C4	=(D9+D8)/D4	=(E9+E8)/E4
56					
57	**Profit Margin: Analysis by cost**				
58	Material Cost as a Percentage of Sales	*insufficient data*			
59	Administration Costs as Percentage of Sale	*insufficient data*			
60	Employee Costs as a Percentage of Sales	*insufficient data*			
61					
62	**Sales Generation**				
63	Sales Margin (to £1)	=B4/B36	=C4/C36	=D4/D36	=E4/E36
64		*no data for furthe*			
65					
66	**Fixed Asset Utilisation**				
67	(Total) Fixed Asset Utilisation (to £1)	=B4/B19	=C4/C19	=D4/D19	=E4/E19
68		*no data for furthe*			
69					
70	**Current Asset Utilisation**				
71	Stock (to £1)	=B4/B22	=C4/C22	=D4/D22	=E4/E22
72	Debtors (to £1)	=B4/B23	=C4/C23	=D4/D23	=E4/E23
73	Other Current Assets (to £1)	=B4/B24	=C4/C24	=D4/D24	=E4/E24
74					
75	**Liquidity Ratios**				
76	Current Ratio (to £1)	=B25/B32	=C25/C32	=D25/D32	=E25/E32
77	Liquid Ratio/Acid Test Ratio (to £1)	=(B25-B22)/B32	=(C25-C22)/C32	=(D25-D22)/D32	=(E25-E22)/E32
78					
79	**Corporate Ratios**				
80	Market to Book	*insufficient data*			
81	Market Capitalisation	*insufficient data*			
82	Return on equity (using book value of equit	=B11/B41	=C11/C41	=D11/D41	=E11/E41
83					
84					
85	**Profitability**	=B11/B36	=C11/C36	=D11/D36	=E11/E36
86					
87	**Gearing Ratios**				
88	Gearing (Total Assets/Equity)	=B36/B41	=C36/C41	=D36/D41	=E36/E41
89	Debt Ratio	=B43/B36	=C43/C36	=D43/D36	=E43/E36
90	Gearing Ratio (Debt/Equity)	=B43/B41	=C43/C41	=D43/D41	=E43/E41

ASSIGNMENT M3/3

BLUNDELL PACKAGING PLC
Review of Budgeting and Results for Specialist Cartons Division

1. INTRODUCTION

This report reviews the costing method applied by Blundell Packaging for calculating divisional results, suggesting corrections and improvements. Some suggestions are made about special orders, and the flexibility of accepting contract arrangements, such as exist with Cawley Cartons Ltd.

In light of the shortfalls in the current budgeting process, we have outlined better ways of budgeting, and explained the associated benefits.

2. REVIEW OF COSTING METHOD FOR DIVISIONAL RESULTS

2.1 Drawbacks of costing method for divisional results

The costing method that has been adopted appears to have a number of drawbacks:

- The budget combines variable and fixed costs. This makes it difficult to assess performance if turnover varies from budget.
- The variances are calculated relative to the original budget. A better measure of performance is to calculate variances from a "flexed" budget.
- The budget includes fixed central overheads, which the division must contribute to, but which exist whether or not the division exists. Preferred practice is not to include costs that a division/divisions manager has no or little control over. Instead, the results should record the "contribution" made by the division to profits and to central overheads.
- The allocation of overheads is inconsistent with the estimated breakdown of costs, e.g. factory overheads are allocated a £2 per machine hour, while 80% of factory costs are said to be fixed. Therefore, if production is high, allocated factory costs will exceed the actual factory costs.
- An annual budget is too long term - quarterly would be more appropriate. The budgeting process should include details of opening and closing stock levels, and refer to sales forecasts by the marketing and sales department.
- The budget should be prepared in conjunction with those responsible for the meeting the targets; they should also be achievable.

2.2 Errors in calculation of variances

The are a number of errors in the calculated variances. These have been corrected in Table 1 that follows the original budget format.

The Variance has been calculated as the *latest forecast - budget.* This demonstrates that the deficit has come about as a consequence of administrative and selling overheads, not production costs. The factory costs of production have increased proportionally in line with turnover; there has been an increase in labour costs, but this has been offset, mainly by a materials saving.

	Latest forecast £'000	Original budget £'000	Variance £'000
Turnover	3,260	3,200	60
Cost of sales			
Direct materials	560	730	(170)
Direct labour	1,200	1,000	200
Factory overhead	400	390	10
Factory costs of production	2,160	2,120	40
Administrative overheads	550	450	100
Selling and distribution overheads	650	550	100
Net profit/(loss)	(100)	80	(180)

Table 1 Original budget with corrected variances

2.3 Revised Budget

A more appropriate budget for the division is outlined in Table 2. The main advantages of this revised budget are:

- Fixed costs have been removed, and variable costs allocated in accordance with the % breakdown of costs given, e.g. factory costs 80% fixed, 20% variable, etc. This removes costs that are out of the division's control. Now the bottom line shows a contribution to the company's fixed overheads and profit. This is a better representation of the division's worth to the company, as if the division did not exist, the fixed costs would still be there.

- The budget can now be "flexed" to suit actual turnover, i.e. variable costs are adjusted to suit latest forecast turnover as opposed to budget turnover. This allows us to calculate variance from a flexed budget, which gives a better indication of how the division has performed.

	Latest forecast £'000	Original budget £'000	Variance from original budget £'000	Flexed budget £'000	Variance from flexed budget £'000
Turnover	3,260	3,200	60	3,260	
Cost of sales					
Direct materials	560	730	(170)	744	(184)
Direct labour	1,200	1,000	200	1,019	181
Other variable Costs					
Factory costs of production	80	78	2	79	1
Administrative overheads	55	45	10	46	9
Selling & distribution costs	260	220	40	224	36
Total Variable Costs	2,155	2,073	82	2,112	43
Contribution	1,105	1,127		1,148	

Table 2 Suggested alternative budget

3. SPECIAL CONTRACTS, CAWLEY CARTONS

3.1 General discussion of special orders

Having to decide whether or not to sell a product at a lower price than normal is a common dilemma. In these instances, it is important to be clear what costs are incurred in producing the product, and what costs are there irrespective of whether or not the order is accepted. The direct benefits in taking the order must exceed the costs that could be avoided by not taking the order. Given that this is the case, it is also important to consider:

- By accepting a special order, facilities may be tied up such that a more profitable order cannot be accepted in the future.
- Special orders can affect normal sales, and the future pricing structure of the product. If the availability of special orders is widely know, it will be difficult to sell the product at its normal price.
- If special orders are too widely applied, contributions to fixed overheads and profit will be inadequate.

3.2 Cawley Cartons

As presented, the contract negotiated with Cawley Cartons Ltd shows a loss. A better way to look at the contract would be to remove fixed costs that have been included. Assuming the given estimated breakdown of overheads applies, the revised figures would be as in Table 3.

		£
Sales Price		240
Materials	60	
Labour	140	
Variable factory overheads	6	
Variable administrative overheads	6	
Variable and distribution overheads	31	243
		(3)

Table 3 Contract with Cawley Cartons omitting fixed costs

This demonstrates that the contract does not even cover variable costs, and so Blundell Packaging would overall be worse off financially if they took the order. Orders at this level should not even be considered unless costs can be reduced.

3 OUTLINE OF TYPICAL BUDGET PROCESS

The purpose the budgeting process is to put a company's plans in numerical and financial terms. In these terms, targets can be set - these targets should be attainable by the managers concerned and provide an objective measure of performance.

The budgeting process can be applied to help meet defined profit and operational objectives. It is a means of planning, control, communication and motivation.

In budgeting, we need to consider:

- limiting factors, such as may be identified by an analysis of the company's Strengths and Weaknesses, Opportunities and Threats (SWOT analysis).
- is the budget achievable given the market, and the workforce/manufacturing facilities?
- does the budget yield an acceptable is the return on the investment?

A typical budgeting process could follow the following route, with annual budgets broken down into twelve, one month periods:

1. Forecast size of market and company's market share based on experience, trends and knowledge of the market.
2. Produce sales budgets by product group, division, and geographical area as appropriate.
3. Prepare budgets for selling overheads (sales force, advertising, etc.).
4. Prepare production plan to match sales budget including details of stock levels. If production plan cannot meet demand forecast in sales budget, review investment in

production facilities, or use of external contractors. If necessary, revise sales budgets down to keep within appropriate production levels.

5. Produce a production cost budget showing the material, labour and other costs relating to manufacturing the product.
6. Prepare a raw materials purchases budget to match the production budget.
7. Prepare a transport and distribution budget.
8. Prepare a budget for central services such as technical services and administration.
9. Prepare a budget for capital expenditure including items such as new equipment, expansion, etc.
10. Prepare budgets recording stock, debtor/creditors and cash levels.
11. Consolidate budgets into the master budget through the profit & loss account, balance sheet and cash flow forecast.
12. Review and revise all steps as necessary.

Budgeting can be a stressful and difficult exercise; it requires the management of each department to meet the requirements of other departments, and communicate their requirements to others. It is often an iterative process, so can be time consuming and tedious.

The results of budgeting can be motivating, or de-motivating. Targets set above budget performance, attached to bonus, can motivate. Yet inadequate, unachievable budgets pressurise staff unreasonably.

At Blundell Packaging the budgeting process appears not to be working well:

- those responsible for meeting budgets are not consulted in the budgeting process
- the targets set appear unattainable
- departments are being held responsible for costs outside their control
- targets are being set in isolation, rather than as a result of analysis of future sales
- there are errors in the accounts!

Senior management needs to overhaul the whole budgeting process, and embark on an exercise that involves all budget-holding managers.

BRUNEL UNIVERSITY & LOUGHBOROUGH UNIVERSITY

MSc in Packaging Technology

Assignment Submission Form

Name: RICHARD PETERS
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HP13 6TP

Date sent to University 15.10.96
Date received 21.10.96
Date returned
Tutor's name
Grade awarded 63%

Student ID number
Subject MARKETING & FINANCIAL MANAGEMENT
Assignment number M311

Declaration: I have read and understood the regulations for assignment submissions in the Studen Handbook, including the section on plagiarism.

Signed

Tutor's comments and advice:

Q1 Well condensed — but expansion would gain more marks. See, Stone's typology of shopping profiles.

Q2 Quite well applied. What about instances in which other forms of M/communications are more effective?

Q3. A bit lightweight. More research techniques require linkage to objectives. What about lab techniques/ secondary sources and experimentation.

Q4 Fairly creative ideas to a demanding Q! What about other reference groups/ P.R. initiatives?

63%

Date marked 12/4/97

Signed

BRUNEL UNIVERSITY & LOUGHBOROUGH UNIVERSITY

MSc in Packaging Technology

Assignment Submission Form

Name: RICHARD PETERS
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Date sent to University 18 10 96
Date received 21 10 96
Date returned
Tutor's name
Grade awarded 58/100

Student ID number
Subject MARKETING & FINANCIAL MANAGEMENT
Assignment number M3/2

Declaration: I have read and understood the regulations for assignment submissions in the Student Handbook, including the section on plagiarism.

Signed

Tutor's comments and advice:

(i) Exec Summ. Quite well focussed and succinct, but could have highlighted overall conclusion better esp. re profit. 6/10

(ii) Ratios: Rather narrow range. Make sure you understand the difference between ROTA and RONA (ROCE). Also, some of the ratios you've given are not Operating ratios, but RISK/INVESTOR ones. Ensure you understand classification. 10/15

(iii) Analysis Fine so far as it goes & attempts to link some elements of the analysis together. However lacks depth in places and fails to follow through some of the descriptive comments. 27/50

(iv) Limitations. Again fine so far as it goes, but rather brief for 25 marks. What about the inherent limitations of financial info and ratios? 15/25

58/100

Date marked 21/4/97

Signed

BRUNEL UNIVERSITY & LOUGHBOROUGH UNIVERSITY

MSc in Packaging Technology

Assignment Submission Form

RICHARD PETERS
ss: 47 THE CRESCENT
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Date sent to University 18.10.96
Date received 21.10.96
Date returned
Tutor's name
Grade awarded 77/100

t ID number
t MARKETING & FINANCIAL MANAGEMENT
ment number M3/3

ation: I have read and understood the regulations for assignment submissions in the Student ook, including the section on plagiarism.

Signed

s comments and advice:

(i) Excellent answer – but don't use "we" as it implies you had help – and this is an individual assignment!	33/35
(ii) V. Good answer	22/25
(iii) Rather brief for 40 marks Covers key procedural steps but you could have elaborated on the behavioural issues more fully.	22/40

arked 17/6/97

Signed

15 TALKING TO THE MEDIA

EngD Final Year

Talking to the Media

Group Assignment for submission by 12 noon on Monday 6 January

Produce a 5 - 10 minute promotional video about the EngD programme which is aimed at 'selling' the EngD to prospective sponsors.

Each Research Engineer in the group must make an even contribution to the completion of this assignment.

Group B
Helen Evans
Gareth Rice
Lisa Andrews
David Aldridge
Peter Gilhead
Jason Palmer
Richard Peters

The completed assignment is to reach Alex Roberts by 12 noon on Monday 6 January.

Brunel/Surrey EngD in Environmental Technology

Marking form for EngD modules

Research Engineers: David Aldridge, Lisa Andrews, Helen Evans, Peter Gilhead, Jason Palmer, Richard Peters, Gareth Rice

Module Title: Talking to the Media

Marked by: Alex Roberts

Grade point awarded (please refer to scheme overleaf): **6**

Comments:

The video uses borrowed material for its introduction. The library video material showing Brunel was not of the same high quality as the Surrey air shots. The block effect titles over some of the pictures were good.

We liked the 'Pressure' effect.

The excerpts from the interviews with CF, IC and RC were good, but the sound and picture quality of the former two were not as good as the latter. CF and IC sounded breathless.

Good message near the end about 50 companies on the scheme. However, instead of naming just a few it would have been nice to have seen all of the names in a kind of montage or in a credit scroll.

The wording of Lisa's commentary was good but her voice sounded slightly muffled.

Some good bullets at the end on the benefits: environment improvement, innovation, highly qualified research engineers, low cost (1/3 of an average graduate's salary), access to academic resources.

Signed: ....Alex Roberts...7 April 1997

tlkmedmk

16 ENVIRONMENTAL ECONOMICS

Eng D Module: Perspectives in Environmental Economics
Centre for Environmental Strategy, University of Surrey
14 - 18 April 1997

Assessment

Essay Choice

1. Assess the main environmental externalities of your sponsor organisation and/or sector and make recommendations for improvement based on economic principles.

OR

2. Evaluate your research project work (or a phase of your project work) in light of environmental economic principles and techniques and describe some aspects of your research, which in retrospect you might have approached and analysed differently.

OR

3. Choose an environmental resource problem and address how applying enviromental economic principles can improve its environmental management.

Word length - approx range. 2000 to 2500 words (excluding diagrams). Cite relevant literature and include full references.

Deadline- 30 May 1997

ASSESS THE MAIN ENVIRONMENTAL EXTERNALITIES OF YOUR SECTOR AND MAKE RECOMMENDATIONS FOR IMPROVEMENT BASED ON ECONOMIC PRINCIPLES.

Richard D Peters
Brunel University, Uxbridge, Middlesex, London UB8 3PH and
Arup Research & Development, 13 Fitzroy Street, London W1P 6BQ

4 June 1997

Document ref: \engd\856.doc

SUMMARY

The main environmental externalities of the Vertical Transportation Industry are due to the non-renewable resources depleted, the waste created and the emissions generated through the production of electricity for operation of the systems while in use. Thus in this sector our prime environmental concern is to implement energy saving systems.

Applying economic principle, a financial case for energy saving features can be made. “Green” economics strengthens these arguments by taking into account the fact that the environment has an intrinsic value not accounted for in traditional economics. It also agues against discounting which is shown to undervalue subsequent generations through making the future repair costs of environmental damage less significant.

1 INTRODUCTION

In this essay I will assess the sector in which I work, the Vertical Transportation Industry, i.e. lifts, escalators and passenger conveyors.

We will review the environmental externalities of the sector using results obtained from a life cycles assessment. And discuss engineering solutions to reducing the environmental impact.

Design decisions in the construction industry are primarily cost driven (“value engineering”) thus the economics of “green” vertical transportation is fundamental. Applying cost calculations, we will demonstrate that the application of “green” economic principles would improve the take up of environmental options.

2 ASSESSMENT OF ENVIRONMENTAL EXTERNALITIES

To assess the environmental externalities of vertical transportation systems, we first need to have some measure of environmental burdens. The science of assessing environmental impact is still in its infancy. However, increasingly companies are quoting and applying Life Cycle Analysis (or Assessment), known as LCA. LCA attempts to quantify the environmental burdens of a product or process during its entire life cycle. It considers components such as

- resource extraction of materials for manufacture
- manufacture and installation
- use of product
- re-cycling and re-use
- waste
- transportation at all stages

So, what are the environmental burdens associated with moving people up and down buildings? As part of my EngD research project I have considered a hypothetical eight floor, four lift system manufactured and installed in the United Kingdom, whose life cycle could be represented in a diagram as shown in Figure 1[1].

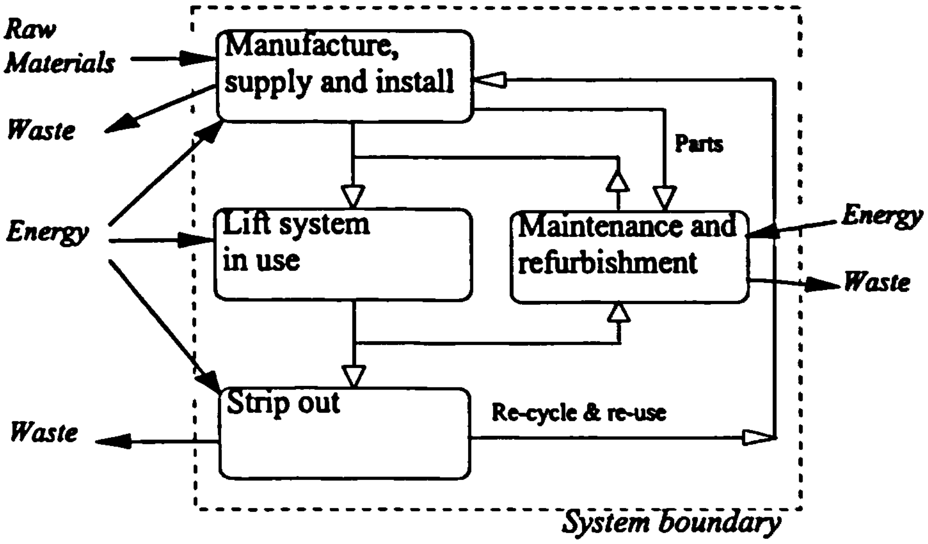

Figure 1 Hypothetical lift system Life Cycle Analysis

A computer database from the PEMS Life Cycle Analysis program has been used to analyse this lift configuration. Results are summarised graphically in Figure 2.

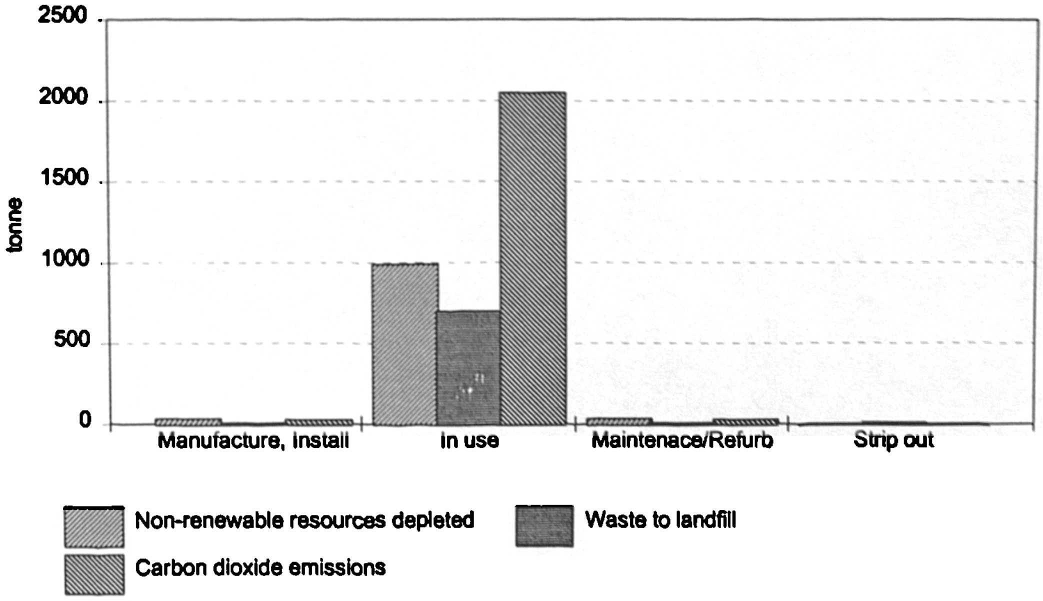

Figure 2 Lift Life Cycle Analysis results - impact over entire life cycle

The dominating environmental burdens in the life of this hypothetical lift system are the non-renewable resources depleted, the waste created and the emissions generated through the production of electricity for operation of the lifts while in use. This result is for lift systems, but the finding can be generalised to all vertical transportation systems, all of which have a high energy usage and long design life (circa 20 years).

3 REDUCING ENVIRONMENTAL IMPACT

The CIBSE Energy Efficiency Guide(2) suggests lifts and escalators account for between 4% and 7% of a building's total electricity consumption, and that energy saving measures could in some instances reduce consumption by up to 25%.

Energy saving measures that can be taken include:

- selection of appropriate energy efficient drives, e.g. AC variable frequency and DC static converter
- selection of efficient mechanical conversion systems, e.g. electric traction lifts are more efficient than hydraulic lifts
- minimisation of inertia and other resisting forces, e.g. planetary gears(3) and V-belt drives(4) have been shown to have lower inertia than the conventional worm gear.
- good planning to avoid the inefficiencies of over-design, e.g. by installing too many/large lifts or by making stairs inaccessible

4 APPLICATION OF ECONOMIC PRINCIPLES

Traditional economics concerns capital or wealth; a value is placed on goods, services, intelligence, and so on.

Arguing for the implementation of environmental options on vertical transportation systems can be challenging as the ratio of capital to operating costs does not reflect the environmental importance of the operating phase demonstrated by LCA.

For example, at a recent Lift Technology seminar, I queried an industry colleague as to the capital versus energy costs of some escalators. The escalators in question are installed in London Underground stations. They are very special because of their length and heavy use, so their capital cost is very high. The calculation presented by my colleague was as follows:

Take a typical London Underground escalator costing £1.5 million to replace.

Assume a life of 20 years, with £40,000 per annum maintenance and £6,000 per annum energy costs.

Discounted at 8%, the total life cost is

$$£1,500,000 + \sum_{t=0}^{19} \frac{£40,000 + £6,000}{(1 + 0.08)^t} = £1,987,766$$

The energy costs are

$$\sum_{t=0}^{19} \frac{£6{,}000}{(1+0.08)^t} = £63{,}622$$

Thus, the energy costs are only 3.2% of the costs of this escalator.

With energy costs only a small proportion of the total cost of the escalator, there is only a small incentive to consider energy saving measures such as energy efficient drives, or "green" control systems that would vary operating speeds according to passenger load.

Say a manufacturer was offering an energy saving feature, which reduced consumption by 10%. Excluding the manufacturer's price premium, the total life cost is now

$$£1{,}500{,}000 + \sum_{t=0}^{19} \frac{£40{,}000 + £5{,}400}{(1+0.08)^t} = £1{,}981{,}403$$

So, assuming total life costs are the purchaser's prime issue, an energy saving feature which reduced consumption by 10% could only justify a manufacturer's price premium of £6,362.

5 GREEN ECONOMICS

5.1 Valuing environmental resources

A failing of traditional economics is that it places no value on the environment. So no account is taken of use of natural resources such as air, water or coal; only the costs associated with extracting them, refining them, or obligatory reparations are considered.

In effect, the environment is a zero-priced resource. Basic economic theory demonstrates that a zero-priced resource will be overused, so inherently there is an overuse problem.

The science of environmental economics recognises that the *economy is not separate from the environment in which we live*(5). Thus a value is placed on natural resources, which although limited in availability, are provided "free" by our environment. By pricing the environment, market forces can help to regulate usage.

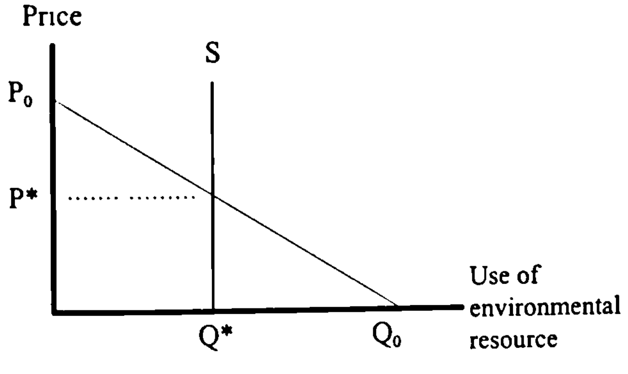

Figure 1 Economic representation of relationship between price and usage

Figure 1 provides us with an economic representation of the effects of pricing the environment. In this diagram, Q_0 represents the use of an environmental resource when there is no cost attributed. This decreases as the price of using the resource is increased, to a point P_0, when there is no use of the resource. S is the supply deemed to be an acceptable use of the environment. Thus, to achieve this level of usage, (Q*), we must price the resource at P*.

5.2 Discounting the future

Discounting is based on the assumption that "a given unit of benefit or cost matters more if it is experienced now than if it occurs in the future"(6). There are a number of criticisms that can be level at the practice of discounting costs. In this essay we are concerned primarily with the environmental implications of discounting.

Environmental economists argue that discounting contains a built in bias against future generations. Consider for example electricity generation by nuclear power, where it can be seen that we are building up stores of radioactive waste for future generation dispose of with "future" technologies.

If we budget that X pounds per tonne of waste will be spent in 20 years' time, and then discount that figure at 8%, the contribution to cost seen from today's prospective is only $£X/(1.08)^{20}$per tonne, (21% of £X). In effect, we are saying "the cost of cleaning up our environment is less important for future generations than it is for us".

6 APPLYING ECONOMIC PRINCIPLES TO SECTOR

So from the prospective of Green Economics, we could make some amendments to the energy calculation given in section 4.

Firstly let us assume that, if we are to have any hope of achieving a sustainable future, government will have to place value on the environment. Effectively this will result in their being some sort "green" tax on energy, including electricity. This is likely to be unpopular, and will probably be phased in over a number of years.

So, assume a tax on electricity is to be introduced from after year 0, progressively at a 1% increment per year for the foreseeable future. The cost of fuel, at today's prices then becomes:

$$£6{,}000 \times (1 + 0.01t)$$

Secondly, we will not apply discounting on the basis that it is unacceptable on the moral grounds in that it penalises future generations, in particular with respect to the environment.

So, our the total life cost of the escalator now becomes

$$£1{,}500{,}000 + \sum_{t=0}^{19}\left[£40{,}000 + £6000 \times (1 + 0.01t)\right] = £2{,}431{,}400$$

and the energy costs are

$$\sum_{t} £6000 \times (1 + 0.001t) = £13,400$$

which are 5.4°o of the life costs.

Now re-consider our manufacturer offering an energy saving feature, which reduced consumption by 10%. Excluding the manufacturer's price premium, the total life cost is now

$$£1,500,000 + \sum_{t\ 0}^{19} \left[£40,000 + £5,400 \times (1 + 0.01t) \right] = £2,418,260$$

So, an energy saving feature which reduced consumption by 10% could now justify a manufacturer's price premium of £13,140. This is over twice the figure in our section 4 calculation, and is therefore more likely to be adopted.

Unfortunately, a minority of clients make decisions on life costs, and more often than not a shorter pay-back period is required, e.g. 5 years. Even more difficult are the contracts where the client's first priority is capital costs, and where a tenant is responsible for all running costs. Nevertheless, energy saving features can be justified on economic grounds, and influence of "green" economics will make these features more attractive.

7 CONCLUSIONS

The deciding factor in expenditure on energy saving building services equipment such as vertical transportation systems is primarily financial, i.e. after how many years will the savings in energy costs offset the additional capital expenditure?

In this essay we have demonstrated the application of green economic principles, which make energy saving features more attractive financial.

The challenge for us, and for politicians is to see these principles implemented in practice. Firstly through legislation to implement taxes that reflect the value of the environment. And secondly in our accounting practices to ensure that we do not discount the costs that future generations will have to bear in clearing up today's environmental damage.

REFERENCES

1. Peters R D *Green Lifts?* Proceedings of CIBSE National Conference 1994 (The Chartered Institution of Building Services Engineers)(1994)
2. *CIBSE Energy Efficiency Guide*, (26 January 1994 draft), section 3.9, 1.
3. Zinke W *Planetary Gear and Frequency Inverter Set New Standards in Lift Drive Efficiency* Elevator World (January 1996)
4. Stawinoga R *New Mechanical Solutions for High Efficiency Gears* Elevator Technology 5, Proceedings of ELEVCON'93 (The International Association of Elevator Engineers)(1993)
5. Pearce D, Markandya A, Barbier E *Blueprint for a Green Economy* Earthscan Publications Ltd (1989)
6. Pearce D, Turner R, *Economics of Natural Resources and the Environment* Harvester Wheatsheaf (1990)