COST MODELLING FOR INLAND WATERWAY TRANSPORT SYSTEMS

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A thesis submitted in partial fulfilment of the
requirements of Liverpool John Moores University
for the Degree of Doctor of Philosophy

JULY 1997

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ABSTRACT

Inland waterways have proven to be a significant mode of infrastructure for the carriage of freight. Examples of this can be seen in many developed regions such as Continental Europe, the United States of America and to a lesser extent, the United Kingdom. The benefit resulting from the existence of waterways are enormous in both transportational and non-transportational benefits. Hence there are considerable benefits which will result from a sustained development of waterways.

This study identifies all relevant parameters associated with the waterways system. They include the waterway route, the barge provision to carry the cargo and terminal facilities as an interface point for cargo handling operations. Methods have been determined to enable various costs to be estimated. This estimating procedure can be very useful for a preliminary evaluation of development proposals pending a more detailed cost analysis. Estimated benefits can also be quantified at this preliminary stage.

Data has been collected from a number of reliable sources. Models have successfully been generated and each model has been validated to an acceptable level of accuracy. The analysis has been applied to a proposed development of an inland waterway transportation system in the Klang Valley region of Malaysia. The results indicate viability for the scheme and, moreover, show the degree to which designers and planners can benefit from the use of the models.

ACKNOWLEDGEMENTS

I would like to sincerely acknowledge the support of the Director of Studies, Dr Peter Smeaton, and supervisors Mr Charles Roberts and Professor Lewis Lesley of Liverpool John Moores University in ensuring the successful completion of the project. Their consistent encouragement and support have been very helpful.

I would also like to thank various organisations in the UK and Malaysia for their invaluable assistance in the data collection stages especially those who have been directly contributing the much needed information. These include the UK Inland Shipping Group, British Waterways Board, MDS-Transmodal and Manchester Ship Canal Company. In Malaysia thanks are given to Irrigation Department of Malaysia, Sarawak Rivers Board Authority, Johor Port Authority, the Ministry of Transport of Malaysia and MARA Institute of Technology.

I take this opportunity to sincerely thank my employer, Universiti Teknologi Malaysia, and the Public Service Department of Malaysia for jointly providing the sponsorship throughout the course of this study. Last but not least, I wish to thank my wife, children and my mother for their patience and support throughout the whole period of this study.

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LIST OF ABBREVIATIONS

AAPA	American Association of Port Authority
ABP	Associated British Port
ACN	Aire and Calder Navigation
ADB	Asian Development Bank
ARR	Average Rate of Return
ASCE	Association of Societies for Civil Engineering
BACAT	Barge Aboard Catamaran
B/C	Benefit over Cost ratio
BCV	Barge Carrying Vessel
BTC	British Transport Commission
BWB	British Waterways Board
CBA	Cost Benefit Analysis
CBO	Congressional Budget Office
CCI	Cost Conversion Index
CECI	Civil Engineering Cost Index
CFS	Container Freight Station
COBA	Cost Benefit Analysis manual
CPI	Consumer Price Index
CRF	Capital Recovery Factor
CUF	Crane Utilisation Factor
CVB	Committee of Waterway Administrators (in Dutch)
DCF	Discounted Cash Flow
DHA	Dock and Harbour Authority
DOT	Department of Transport
DM	Duetchmark
DWT	Deadweight Tonne
ECMT	European Council of Ministers for Transport
EEC	European Economic Community
ESCAP	Economic and Social Commission for Asia and the Pacific
EU	European Union
EUA	European Unit of Account
FEL	Front-End Loader
FIRR	Financial Internal Rate of Return
FLT	Fork Lift Truck
GBP	Great Britain Pound
GDP	Gross Domestic Product
GRT	Gross Registered Tonne
HFO	Heavy Fuel Oil
HGV	Heavy Goods Vehicle
ICHCA	International Cargo Handling Co-ordination Association
IMO	International Maritime Organisation

IPI	Industry Price Index
IRR	Internal Rate of Return
ISG	Inland Shipping Group (UK)
IWA	Inland Waterways Association (UK)
IWAAC	Inland Waterway Amenity Advisory Council
IWG	Inland Waterway Group
IWT	Inland Waterway Transport
KVWH	Klang Valley Water Highway
LASH	Lighter Aboard Ship
LO/LO	Lift on/Lift off
MDI	Marine Data International
MDO	Marine Diesel Oil
MLO	Marine Lubricating Oil
MOT	Ministry of Transport
MSC	Manchester Ship Canal
MSCC	Manchester Ship Canal Company
NCC	Nature Conservancy Council
NKVE	New Klang Valley Expressway
NPC	National Port Council
NPD	National Planning Department
NPV	Net Present Value
NRT	Net Registered Tonne
NWTA	National Waterways Transport Association
PB	Pay Back
PIANC	Permanent International Association of Navigation Congress
PSWA	Partially Smooth Water Area
RFR	Required Freight Rate
RM	Ringgit Malaysia
R&M	Repair and Maintenance
RMDN	Rhine-Main-Danube Navigation
RMG	Rail-Mounted Gantry
RO/RO	Roll on/Roll off
RPI	Retail Price Index
RTG	Rubber-Tyred Gantry
RWN	River Weaver Navigation
S&P	Store and Provision
SRB	Sarawak Rivers Board
SSYN	Sheffield and South Yorkshire Navigation
TDR	Test Discount Rate
TEU	Twenty Equivalent Unit
TRRL	Transport Road Research Laboratory
UNCTAD	United Nation Council of Trade and Development
UNDP	United Nation Development Planning
USCOE	United States Corps of Engineer
USD	United States Dollar
WAMS	Waterways Analysis and Management System
WTP	Willingness To Pay

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CHAPTER 1

Introduction

CHAPTER ONE

INTRODUCTION

1.1 General overview

The historic importance of inland waterways as centres of development of civilisation and then industry is self evident. However, since the industrial revolution in United Kingdom and elsewhere, the importance and utilisation of inland water transport have experienced fierce competition from other modes of transport. Despite their fast speed and flexibility however, these other modes have contributed significantly to both congestion and environmental damage owing to their explosive and even now, unchecked growth and hence become relatively uneconomic.

Recently however, a realisation is growing that the inland waterways, either rivers or canals, provide new opportunities for further development as a complementary or as an alternative transport to the existing road and rail networks wherever necessary. In a geographical area with difficult terrain, but with substantial river or inland waterway systems, the option provides real economic development potential where conventional transport systems are currently unavailable, or so congested that economic development is threatened [*1*]. In such situations, the development is any case concentrated.

For instance, by linking estuaries and navigable rivers or canal systems by the early nineteenth century, Britain had succeeded in creating its first truly nation-wide integrated system of communications. More recently, the legal, technical, financial, economic and operational aspects of inland waterways transportation system have been extensively discussed and published [*1*].

Since the future demand for transport, both in terms of quantity and type is difficult to predict, the major consideration for transport operators must be how to adapt rapidly and effectively to changes of technology, market and government policy. The key elements in the promotion of the inland waterway transport are therefore flexibility [2], low cost of transport, energy efficiency and low adverse environmental impact.

This study investigates and identifies the underlying requirements, infrastructure and economic aspects of extensively navigable inland waterway transport systems. Such systems can serve to enhance local economic activity, provide an efficient transport mechanism between inland and sea ports and provide a much needed alternative to existing road and rail services. As an important by-product, an efficient inland waterway transport system could also be utilised for leisure and tourism industries.

1.2 Project background

Malaysia as a maritime nation is experiencing economic prosperity. Rapid economic growth has created a demand for greater transport capacity to move commercial goods within the country. However, heavy reliance upon road and rail networks for the movement of these goods has consequently resulted in congestion and environmental problem particularly on strategic routes and in certain regions [3].

The geographical location of the country provides numerous development opportunities in the port and maritime sectors including the inland waterways. The reasons for the current restricted utilisation of inland waterways in Malaysia are in general, political rather than technical or topographical [4]. If all modes of transport to serve the industry were treated comparably, greater use of inland waterways would almost certainly result. Government and policy makers could consider to developing all modes of transport system according to their compatibility and flexibility, economically or even technically.

Due to their nature, inland waterways are most suitable to carry bulk cargoes, petroleum products and hazardous cargoes [5]. Containers too can be transported via inland waterways where economically viable. They can serve not only as an environmentally friendly mode of transport, but also provide the cheapest transport cost per tonne-kilometre of freight movement for high load factors [6]. The use of inland waterways to a far distant location in an inland area will reduce the distance travelled on road or rail, hence reducing operating cost and congestion problem. Given the opportunity and vision, Malaysia too can develop and enjoy the benefits of utilising an inland waterway transport system.

1.3 The aim of the study

The primary aim of the project is to study the development of the inland waterway transportation network system in Malaysia as a complementary transport mode in regions of road congestion and as a method of developing hitherto inaccessible regions. The study considers the role of inland waterways as an integral part of a wider multi-modal transport system in the sense of interchange platform and network synchronisation.

The study has also analysed the investment requirements for waterway channel improvements and new developments that are necessary for future projected freight capacities. In addition, the investment requirement of inland waterway carriers for freight transportation was evaluated to determine the required costs. Similarly, inland terminals serving both the carriers and freight on the inland waterways, were analysed to determine the inland terminal requirement levels and costs.

The overall objective was to model infrastructure investment requirements and investment and operational costing strategies in order to assess the development of an inland waterway network as a viable transport alternative. A financial and economic analysis was carried out to determine the viability and feasibility of the proposed development for the decision making processes.

1.4 The scopes of the study

The study starts with an identification of inland waterways' infrastructure requirements through a literature review as shown in the preceding chapters of this study. This is followed by data gathering on costs of developing, operating and maintaining the infrastructure and finally the analysis in the areas indicated in the following paragraphs to produce the generic development cost model. The model has been applied to the problems and benefits associated with inland waterway development in the Klang Valley, Malaysia.

The scopes of study were as follows:-

i. Identification of key requirements of inland waterway transport systems in terms of usage and geography. These will include the channel cross-section dimensions, vessel type and size and terminal type and facility requirements.
ii. The analysis of costs data associated with providing, developing, operating and maintaining the systems for the construction of the model.
iii. The application of a appropriate financial and economic analysis methods for evaluation of the development at present and specifically the future development.

1.5 Programme of the study

The work began with a review of a number of significant waterway systems in the UK and the Rhine and its tributaries system in Europe. UK examples included the Aire and Calder Navigation (ACN), Sheffield and South Yorkshire Navigation (SSYN) and Manchester Ship Canal (MSC). The review led to the identification of some of the major parameters relating to waterway development, hence underpinning the idea of the proposed model structure.

This preliminary work included:-

i) Studying existing systems in terms of facility requirement, operational methods and their management.
ii) Studying the network capacity in relation to the industrial environment.
iii) Studying the cost structures of the system from the initial investment, operational and maintenance requirements.
iv) Studying the financial and economic benefits in relation to the ongoing and new investment requirements.

The preliminary work and data gathering stages were accomplished by carrying out a literature review, visits to several companies and through personal communications. Data analysis was carried out to generate equations to form the required model. The model was validated through an application to a real waterway development in the past. Some corrections and adjustments were made to ensure the validity and integrity of model.

The study has extracted generic factors from the preceding preliminary studies as a template for the development of the waterway system in Klang Valley, Malaysia. The work was applied to the derived template to estimate the costs for developing, operating and maintaining the inland waterway transport system. Finally the work analysed the financial and economic viability of the proposed waterway.

1.6 Anticipated result of the study

The study was expected to provide a sound feasibility basis through analysis of the selected case studies in terms of their technical and economic aspects. The study provides a universal generic template or guidelines for the future development and/or improvement of existing inland waterway transport system using the technique or methodology derived from the study.

The principles which were established in this work is hereby, with regards to their relevance to inland waterways as integral industrial transport systems, available for adaptation to other countries and have the potential for adoption into transport syllabi. The study may subsequently evolve important material for decision makers to enable them to evaluate the potential use of inland waterway transport systems. Finally this study provides a general foundation of academic knowledge in the field of inland waterway transport.

1.7 The structure of the thesis

The work evolved in a number of stages. It began with a data collection and analysis to generate models. The models were validated to assess the accuracy through case studies. The models were applied to the Malaysian case study to identify transport requirements and costs pertaining to providing the inland waterway transport system. Later, the financial and economic analysis were carried out to determine the viability or feasibility of the proposed scheme. The thesis chapters are outlined as the following paragraphs:-

Chapter 1:

This chapter describes the research background including outlines of the primary aims of the study, the specific scope of the work and the anticipated results.

Chapter 2:

Identifies relevant parameters of the transportation system including the waterways track, inland waterway carriers and terminal requirement and facilities. It further Identifies the roles, advantages and disadvantages of inland waterway transport. It also studies the past development of commercial inland waterways in the UK and elsewhere. Finally it discusses a number of past modelling studies of transport systems relevant to this study.

Chapter 3:

This chapter identifies information and data on waterways construction requirements and costs for construction the waterway's track components. This includes channel dredging, bank and bed protection, locks, bridges, etc. The costs considered includes the initial investment costs plus operating and maintenance costs. All these were analysed to generate graphs and equations to form the inland waterways track model.

Chapter 4:

This chapter analyses a specific type and size of inland waterway carrier required to transport freight on a specific waterway route. Data were analysed to generate model which can be used to determine carrier's dimensions for a given size as well as be able to estimate the capital and various annual operating costs of the particular carrier.

Chapter 5:

The final model derived from this study is a port or/and terminal model. Specifically, dry bulk and container terminals were selected for the analysis. The study identifies the terminal facility and cargo handling equipment requirements based on future projected cargo flow in port. The model was derived for the use in the estimating of the capital development as well as the operating and maintenance cost of terminals.

Chapter 6:

The models were applied to the past developments of Sheffield and South Yorkshire Navigation (SSYN) and St Aidan Canal for validation of models. The validation indicates that the model has an acceptable level of accuracy. This chapter also discusses the consolidation of models before application of models can be considered.

Chapter 7:

The model was applied to a Malaysian case study for a proposed development of River Klang as an inland waterway transport system. This waterway is intended to provide an alternative to existing road and rail for transportation of freights to and from Klang Port through Kuala Lumpur City areas. A specific vessel type and size including a 10% cargo share assumed to be captured from the existing system were considered in the analysis.

Chapter 8:

The financial and economic analysis of the proposed waterway development was carried out. Net Present Value (NPV) technique has been selected for project evaluations. A limited economic analysis investigated the impact on congestion and fatality reduction.

Chapter 9:

This chapter discusses and summarises the work that has been undertaken.

Chapter 10:

The work is completed with conclusions and recommendations for further study.

1.8 Data collection and analysis

There were various sources of data collection. Some were obtained from literature reviews and statistics while others were obtained through personal communications or visits. Visits to several relevant organisations both in the UK and in Malaysia (see appendix 1) have been very useful for data collection, validation and application stages of this model. A flow chart diagram indicating the relationship between the data collection, construction, validation and application of the proposed model is shown in figure 1.1.

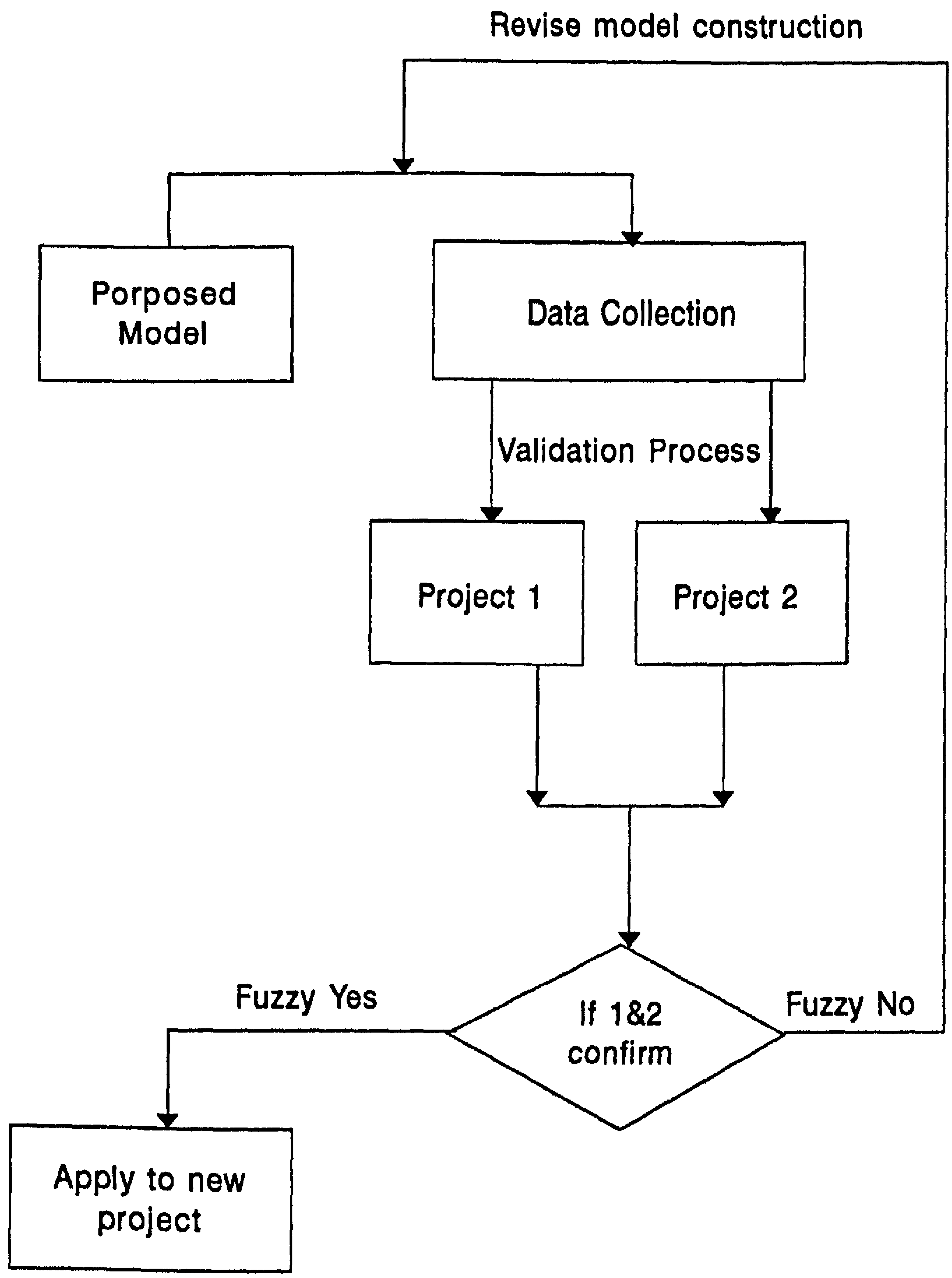

Figure 1.1: A proposed model flowchart

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CHAPTER 2

Inland waterways and their development

CHAPTER TWO

INLAND WATERWAYS AND THEIR DEVELOPMENT

2.1 Introduction

Moving around by water in maritime countries used to be a major form of inland transportation. It was a remarkable system to move not only people but a large quantity of goods over some distance both within inland areas, and between island communities and across more extensive seaways. When the populations grew and the volume of goods to be moved increased, the sizes, distances and routes of the earlier waterways need to be expanded. As the result, people began improving rivers and digging canals to link one to another to form complete inland waterway networks.

In a number of countries, which have well established and comprehensive road and rail network system, inland water transport is continuing to develop. In Europe, huge schemes for connecting the Rhine to the Rhone, the Rhine to the Danube including others have been planned and implemented successfully [1]. Significant developments have also taken place in the United States of America, USSR, China, India etc. However, in a number of riverine developing countries such as Malaysia, Sri Lanka, Bangladesh, Thailand, Vietnam and etc. inland water transport is still under-utilised due to various reasons [2].

The extensive network of canals and developed river systems in Britain for instance, was constructed predominantly in the eighteenth and nineteenth century. Canal systems were built as the first major bulk transport systems in support of industry and hence contributed to the industrial revolution in Britain. Although the subsequent emergence of railways and road transport systems have superseded inland waterway as major transport systems, there is still a significant movements of commercial goods on a small part of the system.

This chapter describes the trend of development of inland waterway transportation systems since the eighteenth century. It is followed with a brief investigation into the current state of inland waterways in the Great Britain, continent of Europe and elsewhere. It is concluded with a selective overview of the relevant transport modelling approaches in recent years.

2.2 Definition and classification

There are several definitions of inland waterway transport system. The common one being used for compilation of relevant statistics is from The Department of Transport (DOT) of the UK [*3*]. Thus:

> *An inland waterway is deemed to include all water areas available for navigation that lie inland of the "inland waterway boundary". This boundary will correspond to the most seaward point of any estuary which it would (in UK conditions) be reasonable to bridge or tunnel. Inspection of UK estuaries leads us to conclude that this is where the width of water surface area is both less than 3kms at low water and less than 5kms at high water (springs). However, vessels without load lines are legally allowed to trade anywhere within the Partially Smooth Water Area (PSWA). The summer boundaries of PSWAs are often far downstream of the inland waterway boundaries. The area between these two boundaries is defined here as "sheltered water". This approach enables tonnage and tonne kilometres to be measured for inland waterway craft along the entirety of their activities.*

In the USA, the Waterways Analysis and Management System (WAMS) has been responsible for analysing the safety and efficiency aspects of the navigable waters for 1,800 waterways for environment protection schemes [*4*]. For the purpose of these undertakings, inland waterways is defined as "*a water area providing a means of transportation from one place to another, principally a water area providing a regular route for water traffic, such as bay, channel, passage, river or regularly travelled parts of the open sea.*"

Although there are other definitions given by various authors, it is reasonable to adopt the definition from the DOT for application in this study. With this clear definition, it effectively excludes sea going traffic to and from major sea ports. However, all domestic (i.e. coastal) shipping movement of 5 km or more were separately analysed in order to avoid confusion between domestic barge traffic and domestic ship traffic [3].

In 1987, the Dutch Government set up a Committee of Waterway Administrators (CVB) to propose a new set of waterway classifications to meet the requirement for the Netherlands and the rest of Europe to which the waterways, bridges and the locks could be constructed [5]. The committee has suggested a modified classification system (see table 2.1) which shows the new lengths, heights and draughts of the inland vessels.

Table 2.1: Classification of inland waterway transport (1986)

In the UK, the waterway classification system specifically designed for the survey of the official waterborne freight statistic is classified into several categories (table 2.2). This classification was used as the framework for including or excluding short inland penetration by vessel.

Table 2.2: Waterways classification in UK

2.3 The development of the UK inland waterway system

In Great Britain, the construction of a totally new waterway did not come about until 1761 when the first phase of the Bridgewater Canal was opened mainly to carry coal. The first section opened included a stone aqueduct carrying the canal over the River Irwell at Barton. The opening of this remarkable engineering technology encouraged further developments to form a complete and viable waterway network for the carriage of goods within a developing industrial area [*6*].

At the height of the canal era in 1840, inland waterways extended to 6,000 km. Few important towns were located not more than 15 km away from the nearest waterway. The canals, although restricted to short distance haulage, still played a vital role in the growing industrial revolution. But because of the lack of co-operation between companies, lack of uniformity in sizes and locks, they left considerable scope for competition from railway and road development and made inter-operable services difficult.

The development of railway services in the early 1820's, freed the British transport from the constraint of physical geography. Railways were providing a far better movement of goods from a greater variety of areas, faster and at more regular speed. If the canal companies were to continue to operate in this competitive atmosphere, then government intervention and improvement scheme was required.

Nevertheless, by the 1880's the revival of waterways began, with the construction of Manchester Ship Canal (MSC). The MSC, approximately 58 kilometres in length, was capable of accommodating of up to 15,000 tonnes ocean vessel to inland destination. High volumes of cargo movement were secured. Contracts for tonnage were obtained from as far as Australia, Canada and USA. The success had proved the ability of an inland waterway to be competitive with other modes of transport for the right choice of cargo.

Waterways in Britain were taken into state ownership by the 1947 Transport Act, the British Transport Commission (BTC) being set up to administer all transport undertakings After taking control of the waterways in 1948, the BTC spent GBP 1.0 million on maintenance and GBP 0.5 million on equipment for nationalised waterways over a period of five years. The BTC recommended several changes towards the better future of waterways as follows:

i. Waterways to be developed, 538 kilometres
ii. Waterways to be retained, 1,591 kilometres
iii. Waterways non commercial, 1,234 kilometres

The BTC handed over the control of the national waterways to the British Waterway Board (BWB) in 1962; in 1963 the Board began looking afresh into the future of waterways and started making various proposals. Initial studies on the waterway developments were published in 1963 and 1965. These have paved the way for the new era for the British waterways with the introduction of the Transport Act of 1968.

Under the UK Transport Act 1968, waterways under the jurisdiction of British Waterways Board are divided into three main categories [7]. They are:

i. *Commercial waterways*
   Available for the commercial carriage of freight and under the control of British Waterway Board.
ii. *Cruising waterways*
   Available for cruising, fishing and other recreational purposes.
iii. *Remainder Waterways*
   To be administered as economical as possible consistent with the requirements of public safety and the preservation of amenity. Richardson and Kimber [8] estimated that over half of this waterway category is closed to navigation and used for drainage and water supply distribution from reservoirs to the cruiseways.

The commercial and cruising waterways are subject to Ministerial safeguard under the control by the British Waterways Board (BWB) whose duties include the maintenance of the commercial waterways. BWB has also been given power to provide services and facilities for amenity and recreational facilities [9].

There are only 545 km length of commercial waterways, designated as principal freight waterways, which are controlled by BWB. The rest are independent waterways which since 1948 have lost importance and therefore not been maintained. According to Baldwin [*10*], there has never been any significant details of commercial waterways properly compiled by the relevant authorities. Table 2.3 show the commercial waterways ownership.

However, in the case of the remainder waterways, the council of the Inland Waterway Amenity Advisory Council (IWAAC), in 1975 recommended that although the classification of waterways does not give priority for further development, their local leisure potential should be recognised [*11*].

<u>Table 2.3: Commercial waterways Ownership (1974)</u>

Included within the total of 1,591 km are waterways of many type and sizes. The major types of the waterways are:

i. <u>Extended docks</u>:

   Short lengths of canal or river used as transhipment sites rather than transport routes.

ii. <u>Locked waterways</u>:

   Including both totally man-made canals and rivers improved by major engineering works including locks. An example is Aire and Calder navigation (ACN)

iii. Tidal navigation:

Tidal stretches of smaller rivers where extensive engineering works may be required to provide adequate depth and width but without locks.

iv. Major estuaries:

In which most engineering work is associated with the provision of terminal facilities, though channel buoying and dredging may also be important. The estuaries themselves must be included as inland waterways as they provide routes for much of the barge traffic originating from or destined for those in the earlier groups. Table 2.4 shows the type and length of the commercial waterways in the UK.

Table 2.4: Type and length of commercial waterways (1974)

2.4 The roles and advantages of inland waterways

The accepted wisdom among transport operators has traditionally been that, per tonne of cargo movement, water craft is the cheapest mode of transportation [*12*]. Thus, every effort should be made to extend the ocean voyage as deep as possible into inland area in order to reduce land transportation costs. Although the assumption of the cost effectiveness of water transport still prevails in most cases, its validity has been made conditional.

In a publication by the Inland Waterway Association (IWA) [*7*], it was reported that resources spent on roads and rail development is vast as compared to the allocation for the development of waterways. The IWA has also published an article entitled 'Inland Shipping Group (ISG)-Its Role and Policies' [*13*], which elaborates in great detail the aims of the ISG. Amongst others, the aims of the ISG are to undertake research, to promote development of inland waterways, to promote environmental issues, to monitor planning policies at local, national and international levels.

In addition, the National Waterway Transport Association (NWTA) [*14*], suggests that there is a considerable scope for both the increased use of, and improvements to, existing waterway tracks and the new developments of waterways. It is necessary to know that there is a wide range of user markets which inland waterway systems support. The Council of NWTA [*11*] listed various aspects of non-transport benefits such as follows:

i) Leisure and recreation: These include, boating building and services, pleasure cruising, angling, camping, etc. In 1991, the British waterways network received an estimated of 150 million recreationalist and in 1992 earned GBP 8 million from such visits [*15*].

ii) Water supply: To provide water to industry, domestic and agricultural users.

iii) Water transfer: To transfer water surplus to other regions.

iv) Drainage: To remove surplus rain to safer area i.e. flood control. In 1988 a study estimated the value of drainage benefits for British Waterways canals at GBP 28 million (at 1992 prices) [*16*].

v) Hydro-electric plant: To generate power to consumers such as available on the Rhine-Main-Danube Navigation, the Rhine, Ohio River and etc.

A proper and systematic utilisation of water resources is essential to achieve the objectives of adequate energy supply, enhanced agricultural activity, creating employment opportunity, etc. There is a vital growing role in the transportation of commodities and other essential resources. In the UK, barges and towing operations have long maintained the position of the inland waterways as being suitable for the movement of large volume of bulk cargoes and other low value commodities [*17*].

Waterways link the industrial heartland of any country to the oceans and hence to the international market. Wharves and terminals alongside the waterways create 'inland ports' and are ideally placed to provide quick and effective freight transfer and storage. The deployment of barges on many waterways can also provide the answer to the storage problem if required. Barges can be used as floating warehouses when necessary to reduce congestion, storage capacity requirement as well the double handling time.

Perhaps the most distinguishing quality of waterway transport is its sheer capacity. Not only does waterway transport have the unique ability to carry irregular shaped goods, but they can also cope with a considerable sudden increase in freight movement. According to NWTA [*14*], waterway transportation is in the national interest therefore the cost of transport of goods should be kept to the minimum possible. The way to do this is through the introduction and implementation of a viable transport system undertaken by the appropriate government authorities.

Studies have shown that for certain type of bulk cargoes, water transport can be cheaper than either road and rail [*18*]. It was also argued that a pipeline can be even cheaper for moving liquid bulk, but less flexible in terms of shape and type of cargoes to move. A report on the improvement of the Sheffield and South Yorkshire Navigation (SSYN), compares the analysis of the three major transport cost as in table 2.5.

Table 2.5: Comparative rates-South Yorkshire Navigation (Sheffield area to Hull) Vs road and rail journey (in GBP/tonne at 1983 prices)

A similar study compares freight rates in the USA, in 1973 [*19*], for different modes of transport as shown in table 2.6. It is clear that rail, road and air transported are 5.5, 27.5 and 77 times respectively more expensive as compared to waterway.

Table 2.6: Comparison of freight rates in USA in 1973

Further comparison can also be seen (see table 2.7) in a number of major countries in Europe where the basis for comparison is the cargo capacity per unit of infrastructure expenditure. All the cost figures were in favour of inland waterway transport especially for commodities with low handling cost/tonne, such as bulk cargo over relatively long distance.

Table 2.7: Tonne-km of freight for each EUA (European Unit of Account) spent on infrastructure

2.5 Inland waterways and the environment

Efficient freight transportation systems can play a positive role in the economics of a country as well the quality of life of its population. While these are essential, there are growing concern on their significant negative environmental impact including pre-emption of land, disruption of topography, use of energy and resources, noise and air pollution [20]. Transportation planners and environmentalists, both recognise the problem.

On a global scale, pollution is a growing threat to both human health and environment. Commercial freight transportation, with its dependence on fuel, contributes significantly to pollution levels. Therefore, each transport mode, as an energy user, needs to evaluate both the availability of energy resources and the environment which should clearly be balanced before making a decision.

Unlike the other modes of transport however, inland waterways can contribute a number of advantages to the enhancement or improvement of the environment [21]. Waterway transport is less environmentally harmful than other mode of transport system in terms of noise and pollution and can also offer a cheap means of transport to remove waste products resulting from industrial activities. In addition, inland waterway transport offer a number of direct environmental benefits as follows:

i) Noise and vibration:

The main sources of transport noise are road, air and rail systems [22]. In general, traffic noise affects people the most particularly in the urban areas.

ii) Visual intrusion:

Waterways cause little in the way of visual intrusion and, moreover, can even enhance the appearance of an area through the clearance of derelict land. Tourism can also be promoted.

iii) Pollution:

Waterway craft do pollute the water to some slight degree. However, most water pollution comes from the irresponsible acts of industries based along the waterway.

iv) Atmospheric emissions:

Transport is a source of emissions in the UK producing 57% of nitrogen oxide, 91% of carbon monoxide, 42% of volatile organic compound [23]. A study carried out in the Netherlands in 1980 shows the levels of air emission from different modes of transport [24] (see table 2.8)

Table 2.8: Emission levels from different modes of transport

v. Safety:

The inland water transport, with its slow transit speeds is relatively safe and less vibration levels. Railways are susceptible to accidents and can result in a loss of cargo. A study on safety of transporting bulk cargo has shown that barge spills occur less often than trucks and rail cars [25].

vi. Capacity:

In term of capacity, a 1,500-tonne barge carries as much as fifteen 100-tonne rail cars or sixty 25-tonne trailer trucks. This barge is 59 metre long, the fifteen rail cars would be 250 metre long and the sixty trucks would be over 0.8 kilometre long [20]. Similarly, one 200 TEU barge is equivalent to 100 - 150 road vehicles or 3 block trains making barge transport up to three times cheaper than road, according to a study by Banks [26].

vii. Energy efficiency:

Fuel efficiency show that water transport is the most fuel efficient mode of transport for moving freight. One comprehensive study by the Congressional Budget Office (CBO) revealed the results as shown in the following table 2.9 [27]. To move one tonne of cargo by barge would require 5 litres of fuel for a distance of 500km compared to 330km by rail and 100km by road [1].

Table 2.9: Measures of freight energy efficiency (in BTUs per tonne-km)

The fact that inland waterways are capable of being integrated with road and rail services is becoming widely recognised. Water transport can contribute to future transport requirements within the concept of preservation and environmental friendliness. Concern towards environmental protection has been made mandatory in many government transport policies nowadays, thus concern over all kinds of pollution are more real than ever. The spread of road congestion is not only an environmental issue but also an economic one.

According to Doerflinger again [*21*], to develop existing commercial waterways and build new modern canals would relatively cost less than what is being spent on road transport development with reduced environmental effect. An article from the Dock and Harbour Authority (DHA) discloses some valid figures to show that the transportation of freight by fully loaded ships produces the lowest overall effect to the environment [*28*]. In addition, intrinsic safety consideration are strongly in favour of water transport, especially for the transport of dangerous goods.

Council of NWTA of UK [*29*] concerned with the carriage of dangerous goods and their effect on the environment. Road or rail transport have often caused serious accidents. They recommended that the movement of dangerous goods be made by water transport. They estimated that approximately 10 million tonnes of sewage sludge are moved annually by inland waterways with no safety issues or environmental impact arising.

In the USA, ambitious road development projects have resulted in severe environmental damage. The USA government has thus realised the long term consequences and began to revive the inland waterway development. According to Doerflinger [*21*], about 10% of total inland trade in USA is carried by means of inland waterway transport networks and the percentage is growing.

2.6 Inland waterway craft and their development

Development of inland waterway craft has taken place in parallel with the development of the waterways themselves. Craft development has been in the form of a modification to an existing craft or a brand new craft design to meet the variety and flexibility of transport demands for cargo movements which suit the carrying demands. An adoption of a successful craft design used elsewhere is a possible alternatives.

A preceding craft development in the UK was the introduction of barges (mostly self propelled ones) which were used in most parts of the rivers and canals for mainly commercial purposes. Typically they were sized about 23 metres by 3.5 metres with a minimum economic operating size of about 100 tonnes. Some of the early types of Britain's boats and barges are as follows:

i. Short boats:
   A 40 to 50 tonne boat was used to carry coal, oil, gravel, timber, grain, etc.
ii. Narrow boats:
   A 20 to 30 tonne boat was used mostly on narrow canals.
iii. Compartment boats:
   Available mainly on the Aire and Calder Navigation for carrying coal
iv. Fly-boats:
   They were express boat on most canals to carry cargo and passengers.

Over time, a variety of modernised craft types, some of them designed to carry specific type of cargo have emerged around the globe to meet the demand for craft capacities with increased efficiency and economy. They are as follows:

i. Self-propelled barges:

This is the type of craft most frequently used on inland waterways. In the UK, the minimum economic operating size is about 100 tonnes capacity. There are crafts of bigger capacities which vary in dimensions operating in UK waterways. Some of these vessels are fitted with bow thrusters to improve manoeuvrability in confined waters and carry radio communications and accommodation facilities for the crew.

ii. Lighters: (excluding push-tow):

These are unpowered craft, often referred to as *dumb barges* and are used widely in the UK mainly on the Thames and its adjoining waterways. These basic craft are used for carrying grain, general cargoes and sometimes refuse.

iii. Push-tow-system:

This uses a propulsion unit to tow one or more dumb units. The number of individual craft is linked to form a combined tow of up to 15 to 20 units. Nevertheless, push-tow systems are not possible on larger scale. In the UK, lighters of up to 140-170 tonnes are combined up to three units to carry mostly coal.

Productivity per crew for push tow increased five-fold compared with towing system. A push tow with four barges can deliver up to 1.5 million tonnes ore per year between Rotterdam and Ruhr with an average capacity of 5,000 to 11,000 tonnes per barge train [*30*].

iv. RO/RO barges:

The barges are designed to carry vehicles, tractors, excavators, cranes, etc. RO/RO is approximately 15 - 20% cheaper than direct trucking and about 30%-35% cheaper in handling operations [*31*]

v. Barge carrying vessels (BCV):

The BCV is a development of a vessel able to carry smaller barges. The cargo is carried in a barge which then carried on a mother vessel. BCVs are based on their potential for integrating inland waterway transport with deep sea shipping in the carriage of broad range of cargoes.

There are several types of BCV available. The three most dominant are LASH (Lighter Aboard Ship), SEABEE and BACAT (Barge Aboard Catamaran). Typical BCVs and their barges dimensions are shown in table 2.10 [32]. The BACAT system was in operation in Humberside between 1974/75 and proved to be technically effective but discontinued due to political problems.

Table 2.10: Barge carrying vessels and their barges

vi. Split ship:

In 1991, Marine Data International announced the development of the Split Ship, consisting of two self propelled canal barges [33]. The 60m long by 6m beam barges with about 600 tonnes deadweight are able to operate independently on a canal system. When joined together longitudinally, they can form one ocean going vessel with a total size of 1,200 tonnes.

2.7 Inland waterway freight

The inland waterways component of domestic waterborne freight in the UK has fluctuated in recent years with a peak in 1986 and reduced in 1992 (see Table 2.11). In 1991, water borne freight totalled 144 million tonnes [34]. This is made up of coastal shipping (63 million tonnes, i.e. 75% was oil and coal), one port traffic (43 million tonnes, oil-rig traffic) and inland shipping (38 million tonnes) [35]. In this year, a total of 63 million tonnes for inland shipping (including the one-port traffic) was moved. The four main categories of inland waterway traffic are described in the following section [35].

i. *Internal traffic:*

This is confined to canals, river and estuaries including the traditional lighterage activities.

ii. *One-port traffic:*

The tonnage of one-port traffic based on inland, as distinct from coastal ports.

iii. *Coastal traffic:*

Largely oil and coal which originates in coastal ports and after a coastal voyage penetrates inland waterways.

iv *Foreign traffic:*

Traffic from foreign ports by sea-going ships penetrates the inland waterway systems. In 1991, 32.5 million tonnes has been moved accounted for 53% of all inland waterway traffic. The following table 2.11 shows the UK freight statistics for different years.

Table 2.11: UK inland waterways traffic in 1990 - 1993 (million tonnes)

In Britain, waterways still play a significant role in domestic freight transport. If a more balanced transport policy were adopted in the future, more goods could be carried by water. Garratt and Hayter have been examining some of the potential commodities which can be carried in greater volumes by the UK waterways, including a freight traffic to the continent of Europe. The commodities are as the following:

i. <u>Coal, minestone and ash</u>

About five million tonnes of coal were moved on inland and coastal waterways [19]. This has been an important waterway traffic for over two centuries and is likely to continue into the future.

ii. <u>Coke and patent solid fuel</u>

These are carried in significant quantities on some of the north-east and Midland waterways, often in compartment boats. Further volume of traffic could be generated if coasters could reach the manufacturing plants alongside waterways for imports and exports.

iii. <u>Petroleum products</u>

Pipelines offer economical tonnage along particular routes. However, pipelines are less flexible and less economic than barges in transporting smaller volumes. Furthermore, many of the refining industries are mostly situated alongside the waterways such as Medway and Thames. Improving the existing waterways could lead to transferring the products by waterway networks.

iv. <u>Refuse/waste</u>

In 1980, a traffic study [19] on the lower Grand Union Canal showed that refuse would be likely to generate new traffic if the canal was further improved and enlarged. A significant annual volume of refuse is transported on the Thames.

v. <u>Grains</u>

These products can suitably be transported by barge and coaster. The nature of the product is compatible with the loading and unloading facilities on most waterways and within the waterway physical constraints.

vi. <u>Chemicals</u>

Bulk chemicals in the form of liquid, powder or pellet are ideally suited for waterway transport as handling poses no difficulties. The inherent safety of waterway transport provides good reason for the continuing use.

vii. Specific products

The industries in continental Europe have long understood the benefit of water transport in providing container feeder services. The Port of Rotterdam for instance, handled containers by regular feeder services on the Rhine. Apart from the usual LO/LO containers, there are RO/RO also on inland waterways in Europe.

2.8 Waterways today

2.8.1 UK waterways

The reasons for the current state of waterways are not technical nor topographical argued Baldwin [*37*]. If all modes of transport were treated comparably, greater use of waterways would almost certainly result. Baldwin noted that as far back as 1948, the state of inland waterway transport in Britain was more as a result of historical and political factors, than of a balanced technological appraisal. If it was given parity of treatment with other modes, its uses would increase, with a resulting benefit to the country.

A report on continental waterways [*31*] suggested that the present level of inland waterways utilisation in Britain has been determined more by negative thinking than by the potential of physical and economic geography. A publication [*19*] stated that investment in commercial waterways in Britain was based on loans while in Europe it was from direct government grants. For example, when the improvement scheme for the SSYN was accepted by central government, there was no funding available.

In the time when road development schemes were given a higher priority by the government, there were few major waterways attempting significant development. A few of the BWB's waterways which had undergone development were the Sheffield and South Yorkshire Navigation (SSYN), the Aire and Calder Navigation (ACN), the River Trent Navigation in the North East region and River Weaver in the North West of England.

According to BWB [*19*], most of the these waterways can accommodate crafts of substantial dimensions of up to 80 metres long and are capable in most cases of taking seagoing ships or estuarial craft. They have (though not equally) been improved over the years. Improvements have been in the form of enlargement and mechanisation of locks and channel improvements designed to increase the capacity of the waterway itself and the extension of the associated waterside terminal and handling facilities.

Plans to improve the SSYN were first proposed by BWB in 1966 and aimed at improving the section of the waterway to accommodate larger vessels. It was supported by the government in 1978, and a grant of 15% to the total costs were received from the European Economic Community (EEC). Work started in 1979 and was completed in 1982 at a cost of GBP16.5 million [*38*]. The 99 km of SSYN is now capable of taking craft of up to 500 tonnes.

The Aire and Calder Navigation is still commercially viable for the transportation of goods and the trend is continuing. The navigation is capable of taking craft of up to 700 deadweight tonnes. A study by Garratt and Hayter [*38*], clearly shows the economic benefits gained from the development and the existence of these two major waterways in the country. The latest in the series of continuing waterway development was the 3 km St Aidan Navigation (part of ACN) completed in 1995 to transport mainly coal. The project development costs was GBP 21.5 million.

In the north west region, the River Weaver Navigation (RWN), has seen a return of trade in 1991 to Anderton Wharf, near Northwich, 17.6 kilometres inland along the navigation. The navigation is capable of accommodating sea going ships carrying of up to 1,000 deadweight tonnes. The wharf is well equipped with a storage and distribution facility and sighted at the head of the Weaver Navigation. Figure 2.1 (inset in figure 2.2) shows the waterways network in UK with emphasised to the central regions.

The success of these waterways can be the model for further development of inland waterway networks in the future in the UK or elsewhere. The government has made it clear that it will consider any proposal for future investment in commercial waterways on the basis that each mode of transport should be economically viable in fair competition with alternative modes.

Figure 2.1: UK Freight Waterways

Figure 2.2 (inset): Part of the Uk inland waterway networks

BWB, through numerous research and publications has been very consistent in urging the government into realising the potential of waterway transport as exemplified by a number of European countries and others. Whilst road and rail development continue to progress, waterways too, should progress within their own rights. Waterways, like road and rail, will continue to contribute and serve industrial producers and consumers as long as demand for transport capacity exist.

2.8.2 Continental Europe

Clearly, topography has favoured the development of Europe's numerous waterway transport networks (of various sizes and classifications), the location of the industrial, commercial and residential centres that they served. The developments planned were aimed at improving the canal links between river navigation rather than major extension to the navigation themselves. The growth of co-operation between European nations is one of the reason for this successful development [*39*]. Figure 2.3 shows part of the waterways network in Europe.

The European Conference of Ministers for Transport (ECMT) under resolution No. 1 drew up a list of twelve development projects for inland waterways of interest in Europe including the Rhine-Main-Danube canal as in the following paragraph. After 25 years, the results concerning international waterway in Europe have been in progressed. The decisions for further improvements promised a better future for European inland waterways system. The use of larger craft and a push-tow system have been introduced. The push-tow craft represented 14.2% in 1975 from the whole fleet capacity. The deadweight capacity of self-propelled craft has also increased by 10% [*40*].

The list of the 12 waterway construction and modernisation projects in Europe is as follows:

I Improvement of the Dunkirk-Scheldt connection
ii. Improvement of Scheldt-Rhine connection
iii. Improvement of the Meuse and its international connections
iv. Meuse-Rhine link
v. Canalisation of the Moselle

Figure 2.3: Inland waterway networks in Europe

vi. Improvement of navigation on the Rhine (Strasbourg-St Goar)

vii Rhone-Rhine connection

viii. Development of the Rhine (Rheinfelden-Lake Constance)

ix. Rhine-Main-Danube

x. Development of Elbe

xi. Oder-Danube connection

xii. Lake Maggiore-The Adriatic

The completion of a number of projects and particularly the Rhine-Main-Danube (RMD) has provided a waterway artery across Europe from the North Sea to the Black Sea. This artery totalling 3,500 km, links 13 states including seven members of the ECMT. RMD is 171 km long and contains 16 locks. The total costs of the canal was 3.5 billion Duetchmark (DM) suitable for self-propelled craft of up to 2,000 tonnes and push convoys of up to 3,500 tonnes (on class iv waterway).

In 1992, total inland waterway freight in Europe was approximately 425 million tonnes per annum of which 225 million tonnes is border crossing traffic and 200 million more tonnes domestic traffic in Germany, the Netherlands, Belgium and France. Inland waterways account for 38% of all cross-border transport of goods in the EC. Road transport account for 48% and the railways 14% [*41*].

In 1985, 225,000 containers were handled by barge at Rotterdam and it was estimated that in 1990, a volume of 340,000 containers would be generated and up to 450,000-500,000 in the year 2,000 has been forecast [*42*]. Another growth freight on the Rhine was the RO/RO. The barges capable of carrying 72 x 12m trailers. Many north European ports have developed suitable facilities for efficient barge handling. Paton [*43*] argued that among the environmental advantages of the Rhine are as follows:

i. A container barge will carry the equivalent of 100 trucks or three block trains. Each barge save around 2.5 km of road space.

ii. Energy consumption by tonne/km favours the barge against rail and road with a ratio of 1:1.2:4.3.

iii. Noise pollution is very low.

iv. Safety is higher than by road or rail

v. Penta Container Liner suggest that a barge moves 4,000kg/hp compared to 500kg/hp for rail and 150kg/hp for road.

Germany is one of the countries being well served by the Rhine and its tributaries including the RMD. The industrial heartland of Germany is served by this large and wide natural waterway. The development programme of large wide beamed canals capable of supporting 1,000 tonnes barges was well planned to take full advantage of this. In France however, the main development of the waterways was to link main river navigation, namely the Seine, Rhone and Rhine giving a waterway systems of some 7,520 kilometres of commercial standard.

2.9 Potential for future inland waterway development

Many waterways world-wide are profitable and there exist a strong commercial cause for their remaining open and subject to further improvement and new development. Where similar conditions exist, in terms of geography, demand and potential development of trade, environmental enhancement, etc., the opportunity for a new development of waterways should be treated considerably.

Britain's waterways still play a significant role in domestic freight movement and wherever possible this could be enhanced to relieve pressure on congested roads. Inland transport can compete effectively in high volume markets where transhipment can be avoided to provide cheap and efficient haulage. A combined inland, estuary and coastal waterways can provide transport routes at minimal cost. Hilling [*44*] has recommended a number of factors for the success of the inland waterway systems.

Local planning authorities should encourage the use of water transport by investing in the improvement of the system to provide a more efficient and economic system. In addition, waterways still have an important role far greater than most people can appreciate [*45*]. At a time of mounting concern for the environment, their potential should be exploited to the full.

In view to the various contribution of the waterways and with the current concern for energy conservation as a stimulus, more and more riverine countries (especially the developing countries) are becoming aware of the potential for the waterways development. The demand for inland water transport has risen steadily and is likely to continue. Many countries considered modern waterways as being a vital instrument for their economic prosperity. The launching of the Transport and Communications Decade for Asia Pacific in 1985-1994 for instance, has accelerated the development of the industry [*46*].

2.10 Inland waterways modelling studies

A number of authors have attempted to produce economic models to analyse waterway development. Chowdhury and Bari [*47*] have modelled a transport network using data from transportation surveys for analyses and evaluations of country boat fleets in Bangladesh. Their main discussion was the cargo movement between major ports and transportation costs and commodity movements between ports have also been analysed. The transportation tasks specified for the model were used as the basis for the design and evaluation of an inland waterway transport system.

The fleet studied served 5,192 kilometres of waterways in dry season and 8,384 kilometres in wet season. The annual freight traffic of the fleet was estimated to be as large as 13 million tonnes. Significant use was made of linear programming techniques within their models.

The work considered all aspects of the transport system, i.e. operational characteristics, construction and operational costs of boats, the cost for the movement of cargoes, etc. The result of their analysis is to aid the decision making whether to improve the existing system or provide a new ones. If the latter is selected, the transportation task needs clear definition to the level of the requirements.

In developing countries, it is not often possible to obtain a complete data on regional cargo flow matrix. A commodity movement analysis was therefore necessary to estimate the freight flow in the transport system. Port to port flow for the model considers the closed system i.e. any inflow to any port is the outflow from one or the other port. Calculation of the required freight rates (RFR) for any transport system necessitates the calculation of the construction and operation cost of unit transport.

Bari and Chowdhury in another work [*48*] discussed the operational, construction and cost models. The RFR per tonne-mile at different discount rates and internal rate of return (IRR) were calculated for 15 categories of boat type. The result was useful for transport engineers and planners to evaluate the optimum transport system for a given task.

Bangladesh, according to Bari [*48*], possesses some 12,800 kilometres of inland waterways of which 9,000 kilometres are only navigable during the monsoon. The majority of the inland water borne freight totalling about 80% in terms of tonne-km, is carried by 75,000 privately owned craft of varying capacities. The study considered the type, construction method and possible improvement of the country boat by economic analysis. The study evaluated the status of the existing country boats and their performance in the national transport networks.

Bari in his study [*49*], undertook an analysis of a commodity movement over a core waterway network of 1,848 kilometres consisting 25 river sections and 20 selected ports. In the analysis, total transportation tasks determined the size and required fleet. The construction and operation cost model was developed together with the fleet size and RFR.

For the boat operating model, the parameters considered were transport task, unit transport capacity, loading/unloading rate, port time, waiting time, route length etc. The construction cost model comprised the cost of material and labour, while in the operational cost model, crew cost, cost of maintenance and refitting, insurance, dues charges and capital charges were considered.

The result from the study showed that the earned freight gave a return of 12% for the fleet as the whole where 14% for 5.53 tonne boat and 4% for 57.15 tonne boat. This analysis was carried out to evaluate the performance of the existing country boat fleet for a defined transportation task over a model network. It was also found that the current earnings of a boatmen are just more than the agricultural labourer but no figure was disclosed.

It was also identified that among the various modes of transport for cargo movement understudied, country boat was the costliest. Therefore, the replacement of country boat was recommended although this is difficult to achieve. The result from the analysis can be used to compare a new system with the existing ones for a decision making process within the inland waterway transportation system. Employment opportunity, congestion in port and inventory were not considered in this analysis.

Tillman [*50*] on the other hand, has also undertaken a study of the transportation system in a developing nation for future development. He stated that location and accessibility play a key role in the economic and social structure of the country. The distribution of population, the development of the natural resources and the marketing of industrial and agricultural products are tied up to the development of transportation system.

In his work entitled 'Model for Planning a Transportation System', he developed a dynamic programming model to determine the link between highways, railways, waterways and even to the extent of air lines to investigate the economic benefits to the country. He considered the cost to the links and the taxes that accrue from the past investments for future development.

The model did not consider the inland waterway transportation network specifically. However, it is still useful to provide a clear understanding towards the relationship between route links and the cost variables. This will help the planning and decision making process to be made. Although there are a number of other studies relating the transport modelling, it is beyond the scope of this work to consider in such a detail. The discussion above should be adequate in providing the basic necessary understanding of this work.

2.11 Discussion and summary

There is a large volume of literature concerning the study of inland waterways in Great Britain and other developed nations. While many tend to ignore the commercial potential the waterways can contribute, others like the British Waterways Board, Inland Waterway Association, Inland Shipping Group and others, are putting effort in convincing the appropriate relevant transport planning authorities with research findings and relevant documents to support for the development of the inland waterway system.

It is self evident that, as a country, Britain has many problems affecting transport of all modes. Not many concerned with the transport of freight on inland waterways would pretend that the waterway systems could do more than contribute to the overall solution. Indeed, the benefit which could be derived from this mode of transport must be of greatest interest to the hinterland transportation networks.

A small amount of research has been carried out in the past to identify the validity of using linear programming techniques to model inland waterway construction and operation. Given time and opportunity, the improvement or development of the waterway transportation system can be realised. The industry will be quick to respond and take advantage of a comparatively economical mode of transport, and locate itself close within that facility.

Whilst inland water transport will never supplant the ubiquitous lorry in terms of speed, efficiency and flexibility, there can be no doubt that the optimisation use of waterway system for the movement of bulk and finished products will benefit both the transport user and public at large financially and economically [2]. The important point is that the promotion of transport infrastructure should be planned, assessed, and implemented in such a way that each mode of transport is allowed the opportunity to compete on a fair basis.

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CHAPTER 3

Inland waterways track cost model

CHAPTER THREE

INLAND WATERWAYS TRACK COST MODEL

3.1 Introduction

Investment in transport infrastructure is a complex and specialised study. There is always a limited internal capability of many transport authorities and national transport planning agencies [1], and therefore there tends to be heavy reliance upon consultants in assisting project identification, initial assessment, feasibility study, detail design and implementation.

The objective of the model development in this study is to provide a simple but yet comprehensive tool to better manage the work of consultants in cost estimating for an integrated inland waterway cost model. The model is designed to be useful in the initial phases of the project to assist the initial decision making processes by highlighting the required investment cost for a given level of cargo movement activity as well as providing the likely financial and economic indicator in the project evaluation.

The project commences with specific consideration of a seven block model as a starting point. The block-model comprises of 7 basic parameters as shown in figure 3.1. The model application begins with identifying separate elements representing the seven different elements considered at this stage. These seven elements are the bases for the formation of a complete model reflecting the true elements of a real waterway transportation network system.

In the development of this model, specific details of each parameter have been identified and analysed. The details were obtained from various sources of information. Visits to several organisations, interviews and survey questions have also been undertaken to ensure that adequate and reliable data is available for the construction of the models.

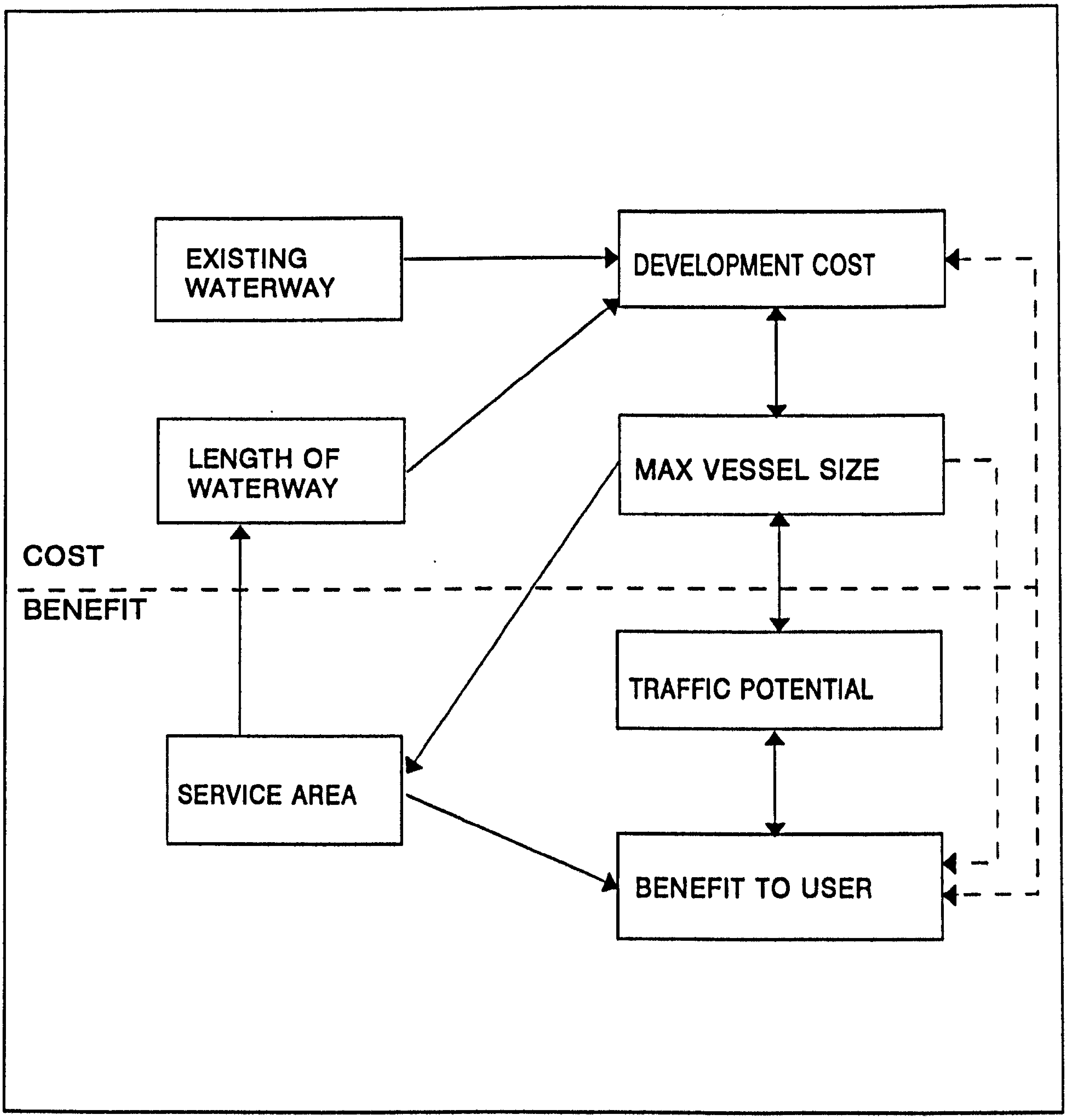


Figure 3.1: Inland waterway transport system model

The first four blocks from the model are related to the overall cost of developing or upgrading the waterways and their required facilities. The other three blocks from the bottom half of the model represent the expected benefits from the development. The model was divided into three sub-models namely inland waterway track, vessel operation and inland terminal costs. These sub-models provide a clearer way to group and to estimate direct costs. The data for the costs analysis is based on the United Kingdom and Europe inland waterway systems, and the costs were converted to a base year of 1995.

3.2 Cost estimating procedures

Most of the inland waterway track construction costs data are extracted from Spon's [2] study based on 1995 prices (base year for the project analysis). Some other costs data has been obtained from other sources for different years. These costs have been converted to GBP 1995 prices by applying the inflation rates or Consumer Price Index (CPI).

As in the case of other currencies, the costs have been adjusted to USD 1995 prices, then converted to GBP 1995 prices by an application of 1995 currency exchange rates of particular countries as shown in appendix 2. Appendix 3 shows the inflation rates for the UK, USA, Netherlands and Malaysia for which the costs analysis have been relevant to this study. Similarly, appendix 4 shows the respective CPI and economic growth rates per year of the four countries concerned.

When making comparisons of construction costs between countries, it is important to be clear about what is being compared. In terms of estimating costs, there are two main methods of comparison [3]. Firstly the comparison of the identical constructions in each country and secondly, the comparison of the identical function of the construction in each country. Apart from the obvious differences in the price of labour, materials and equipment, the comparisons are governed by many other factors [4].

An appropriate comparison of prices between countries is impracticable. Therefore, these factors will be ignored while the comparison will focus solely on considering the inflation rates, currency exchange rates and price conversion index which will be derived in this work. A brief discussion on this subject is presented in the following sections.

3.2.1 Cost of labour and materials

Typical construction costs for labour and materials are available for most countries. The cost of labour is the wage rate and this includes, where applicable, allowances and other fringe benefits. The cost of materials, on the other hand, is a delivered cost to the construction sites. In general, tax is excluded from material costs mainly because the tax rate to be levied depends on the type of work and the material to be incorporated [*3*].

3.2.2 Inflation rates

General inflation is measured by consumer or retail price indices (RPI). These reflect price changes related to a basket of goods and services weighted according to the spending patterns of typical households. General inflation indices usually rise and, in so doing, erode the purchasing power of a given currency unit. Other measures of inflation rates tend to be related to specific items. The two most commonly available for the construction industry are building cost and tender price indices as in the following section.

3.2.3 Building cost and tender price indices

Cost and tender prices measure different types of inflation which occur within the construction industry. Building costs are the costs actually incurred by a contractor in the course of his business, the major ones being labour and materials. Tender prices are the prices for which a contractor offers to erect a building. These include building costs but also take into account the prevailing market situation. When there is plenty of construction work tender prices may increase at a greater rate than building costs, while when work is scarce, tender prices may actually fall even if building costs are rising.

3.2.4 *Exchange rates*

Currency exchange rates are important when comparing costs between one country and another. While it is most useful to consider costs within a country in that country's currency, it is necessary, from time to time, to use a common currency in order to compare one country's costs with another. But exchange rates fluctuate dramatically and few currencies can be considered really stable. Therefore, it is risky to think that one country is more expensive than the other. Obviously, different rates of internal inflation affect the relative values of currencies and therefore, the rates of exchange between them.

3.3 Inland waterways track model

In this model, data collection and analysis has only considered significant costs in relation to the provision of the intended development as outlined at the beginning of the project while less significant costs have been ignored. For instance, the costs include the excavating and/or dredging the channel, construction of locks, bridges, levees, bank strengthening, bank and bottom protection, road construction, etc. A typical example of inland waterway track costs were obtained from British Waterways Board (BWB) as shown in table 3.1 and from Manchester Ship Canal Company (MSCC) in table 3.2.

<u>Table 3.1: An estimate for canal components construction cost by British Waterways, Leeds, 1995</u>

Table 3.2: Estimate of various canal costs for Manchester Ship Canal Company (1995 prices)

Based on the above data, the MSCC has also provided a data on Manchester Ship Canal Company's channel component requirements and typical construction costs based on 1995 prices as shown in appendix 5. This data will be used as general guidelines where necessary in the development of the model.

Other costs like landscaping, planting of trees, fencing and drainage have been considered as secondary components and will be treated accordingly whenever there is a necessity for so doing. Any other costs than mentioned above will be classified under contingency factors which are expressed in percentages of total development cost. The following section discusses all major inland waterway components and the development of the model as in the following section.

3.3.1 The inland waterway channel design

The various roles of inland waterways identify some of the relevant aspects that have to be taken into account when considering the design principles for the waterways. For example, air draught is very critical for commercial waterways, and hence realignment/raising of some bridges and removal of other obstructions is often necessary. In addition, the construction of various engineering structures for safe and efficient movement of cargoes is unavoidable. Figure 3.2 shows a typical UK canal owned by British Waterways Board.

The effect of vessel movements vary with seasonal patterns of use, speed of craft, the width and depth of the waterway and the type of bed material. In some waterways, silt and sediments pose some considerable problems. However, vessel designers, should be able to adopt proper design procedures in ensuring the right vessel design for the right waterway channel dimensions.

3.3.2 Channel designs criteria

When designing a waterway channel, it is most important to consider the maximum size of vessel requiring to use the waterway. Its beam, length, water draught, air draught and submerged cross-sectional area should be carefully considered [*7*]. A study by Economic and Social Commission for Asia and the Pacific (ESCAP) [*8*], the general design rule for a waterway is based on the principle that the infrastructure such as channel dimensions, bridge and lock clearances and vessel should accommodate each other. This principle leads to the distinction of infrastructure at present condition and to be constructed.

In the first situation, the maximum dimension of the vessel is completely dependent on the dimension of the existing infrastructure, while in the latter situation the dimensions of the infrastructure will be based on the present and projected vessel types. Thus the selection of a characteristic vessel design for an existing infrastructure is relatively simple and can be derived from the design rules relating to the vessel dimensions to channel and structure dimensions.

Source: British Waterways, Leeds

Figure 3.2: A typical UK canal owned by British waterways Board

There is no standard classification system for UK inland waterways, although a classification does exist for European continental waterways. In 1995 the European waterways were classified according to the typical size of vessel which plyed them and being agreed upon by the European Conference of Ministers of Transport (ECMT) [*9*]. However, this study will adopt the original 1954 classification as the basis for channel dimensions guidelines as shown in table 3.3.

<u>Table 3.3: The original classification for Western European waterways (1954)</u>

3.3.3: Channel design related to traffic density

Studies in Holland [*10*] suggest that three standards in relation to channel design may be considered, and these have been classified as follows;

i. <u>Preferred or normal cross-section</u>

   This standard allow two laden craft to meet and pass each other or overtake cautiously whilst maintaining normal service speed and should be used when traffic density is high (15,000 passages/annum or 50 passages/day).

ii. <u>Reduced or narrow cross-section</u>

   Allows the laden crafts to meet with caution and allows an unladen craft to overtake a laden craft with caution. This cross-section is suitable for medium traffic density (5,000 passages/annum or 20 passages/day).

iii. One way or single cross-section

Allows loaded craft to pass through this cross-section and applied to low traffic density (1,000 passages/annum or 5 passages/day). Figure 3.3 illustrates channel terminology for trapezoidal and rectangular cross-sections [*7*].

In 1987 the ECMT's committee [9] proposed a new international standard waterway for Europe to which waterways, bridges and locks were to be standardised. The committee has also suggested the new guidelines for Class V and VI to allow for larger craft (see table 3.4) to establish a relationship between waterway dimensions and expected traffic density on it. Figure 3.4 shows a waterway design in relation to barge dimensions and traffic expectancy [*10*].

Table 3.4: Further suggestions on barge standard dimensions

The study by ESCAP [*8*] distinguished channel cross-sectional dimensions into three broad categories as in the following paragraphs. This is important as guidelines for safe navigation design as well as for estimating the volume of the required dredging. The categories are:-

i. Depth

Too little underkeel clearance makes it difficult for steering and slow rudder response. The guidelines in table 3.5 compare the loaded craft draft (Hv) with total channel depth (Hc).

Figure 3.3: Chanel cross-sectional dimensions

Figure 3.4;Waterway designed around barge dimensions and traffic expectancy

ii. <u>Width</u>

Adequate width is required between the craft and the banks of the channel and between passing craft. Table 3.5 compares the width of the craft (Bv) to the width of the channel at keel level (Bc).

iii. <u>Cross-sectional area</u>

The ratio of cross-sectional area of the channel (Ac) compared to the wetted cross-sectional area of the craft (Av) is known as a blockage factor (Ac/Av). A low value of Ac/Av will cause higher resistance which limit the craft speed.

Table 3.5: Guidelines for channel cross-section

Factor	Parameter affected	Preferred cross-section	Guidelines	
			Reduced c-section	One-way c-section
Hc/Hv	Channel depth for keel clearances	1.4	1.3	1.3
Bc/Bv	Channel width for craft passing and overtaking	4.0	3.0	2.0
Ac/Av	Blockage factor for craft speed squatting	7.0	5.0	3.5

Source:[8]

3.4 Dredging and excavation works

The problem addressed in this section is that of determining the optimal dimensions for the channel to serve a given demand for transportation. The basic methods for improving the navigation of waterways are dredging and training [11]. There are two types of cost to be considered, the cost associated with dredging operations and the costs associated with the rise in the cost of traffic because channel dimensions are too small for particular size of vessel.

The dredging volume consist of primary volume and repair volume [11] where primary volume is the volume that must be removed from a shallow area to a required navigable depth, whereas the repair volume is the volume that must be removed over the course of the low water season. Primary volume dredging is related to the geometrical volume is calculated by taking the product of the desired channel width, the length of the channel which must be dredged to a required depth.

The cost model considered herein provides the dredging costs expressed in unit cost per cubic metre from Spon's [*2*]. The base unit cost is defined as the annual operating cost for a particular size dredger divided by its theoretical production rate under certain assumed conditions. As the factors which affect the dredging cost change, the actual unit cost vary.

Dredging can be carried out by land based equipment or by floating plant. The cost of the former can be assessed by reference to the excavation costs of the various type of plant (in the following section) suitably adjusted to take into account of the type of material to be excavated, depth and method of disposal. The cost of the latter is governed by many factors which affect the rates and leads to wide variations [*12*]. Table 3.6 indicate the estimates based on various operating conditions.

<u>Table 3.6: Dredging costs estimates by Spon's (1995 prices)</u>

Maintenance dredging however, is planned and done to remove deposited soil comprising fine sediments. Usually the material is of small thickness and low strength. When dredging is close to the quays or jetties, the sediment dredged may contain or be polluted by foreign elements such as scrap metal, ropes, rubbish, etc. The interval between maintenance dredging may be as little as a few weeks to several years. The costs have to be borne by the local owner (frequently by central government) due to the importance of the waterways to political and social circumstances [*12*].

For excavation works, the basic costs are also extracted from Spon's and divided into several categories. They are earth work, rock, reinforced concrete and unreinforced concrete. The excavation unit cost is m^3. An analysis of cost versus depth for these various excavation works generate the near linear relationships as shown in figure 3.5, the linear equations are shown in table 3.7 where y is the excavation cost while x is the total volume of dredging in m^3.

Table 3.7: Excavation costs equations

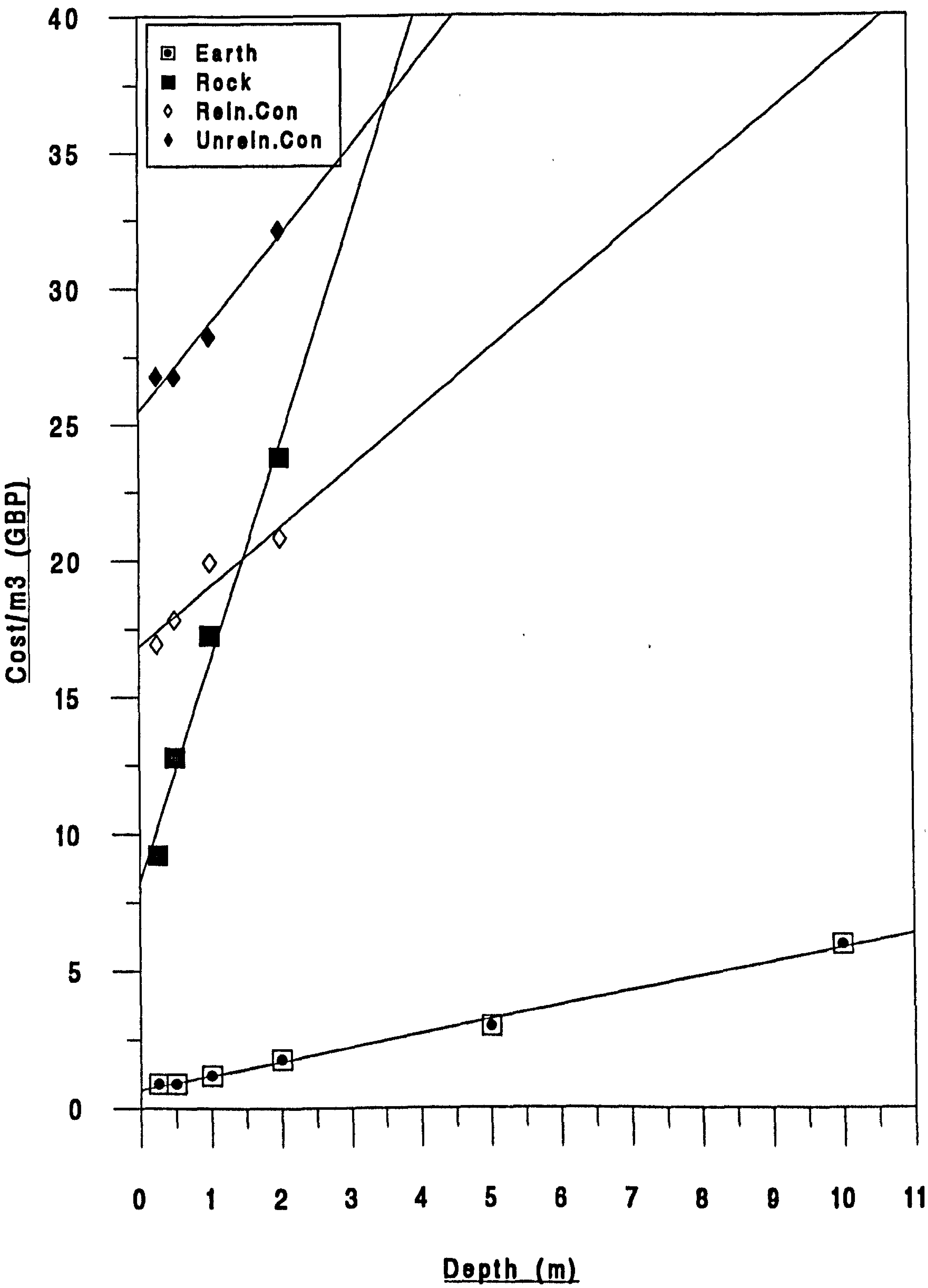
Type of excavation	Equations	R^2
Earth work	$y = 25.5 + 3.2x$	0.97
Rock	$y = 16.8 + 2.2x$	0.88
Reinforced Concrete	$y = 8.2 + 8x$	0.98
Unreinforced concrete	$y = 0.67 + 0.52x$	0.99

Similarly, the excavated material needs to be disposed of some distance away. This will incur a substantial transportation cost. Data from Spon's has been analysed to generate a relationship between the volume of material to be disposed of and the distance to disposal sites resulting in a linear relationship of $y = 1.45 + 0.0003x$ where y is the required disposal costs as a function of a distance, x (in metre).

3.5 Lock construction

Layout and general arrangement of locks are the most critical features in development of inland navigation projects. The topography, whether for rivers or canals, determines the location of locks. The location will also be determined by factors like hydrology, land cost,

Figure 3.5: Excavation depth Vs unit cost/m3



relocation of building, bridges, road, railway, water main, sewers, etc. [8]. A typical British Waterways Board narrow canal lock of St Aidan waterway is shown in figure 3.6.

No general rules govern the selection of lock sites since terrain, capacity and other elements differ from site to site. In general, selection of a maximum size of lock should be governed by the maximum size of craft, the expected amount of traffic, the economic considerations and the lock size in adjoining waterways [8]. Locks are normally designed to accommodate the traffic which can reasonably be anticipated during the economic life (usually 50 years) of the structures [8]. The maximum capacity of a lock is defined as the maximum tonnage of cargo which can be moved through the lock per unit time.

A navigation lock consists principally of a lock chamber between two set of gates mounted in lock heads. A lock facilitates craft passing between two stretches of waters of different level. The length, width and the depth of a lock are major factors in the lock design and costs. The net length of the lock should be designed to allow for stopping allowances. The depth of the lock strongly affects the construction cost because the cost of excavation and drainage increase rapidly with the increase in lock depth. Figure 3.7 shows sketch definition of lock dimensions.

According to Brandon [7], it is recommended that the minimum lock width should be 1.11 Bv (where Bv is the beam of the craft) and the minimum length of 1.05 Lv (where Lv is an overall length of the craft). Safe keel clearances should be maintained allowing for the squat (a craft's keel stuck in silt). Adequate bollards must be provided to secure craft in the lock chamber. Lock chamber (water) filling time usually takes less than 10-15 minutes. For large inland locks the total cycle time (a craft enters and leaves the lock) is approximately 60-90 minutes while for small locks the time may be less than 30 minutes. Filling systems however are often dictated by level differences of the lock.

3.5.1 Lock cost analysis

In 1980 for instance, United States Corps of Engineers (USCOE) [13], analysed data for 68 locks and 19 dams constructed in the USA to generate a relationship for lock construction

Figure 3.6: A typical narrow canal lock in UK

Figure 3.7: Definition sketch of lock dimensions

costs. The USCOE concluded that as the lift/rise of locks increases, the construction costs increases because more excavation, concrete, and cofferdam and dewatering costs increase. Filling system costs may also increase rapidly if lifts exceed 10 metres [*11*].

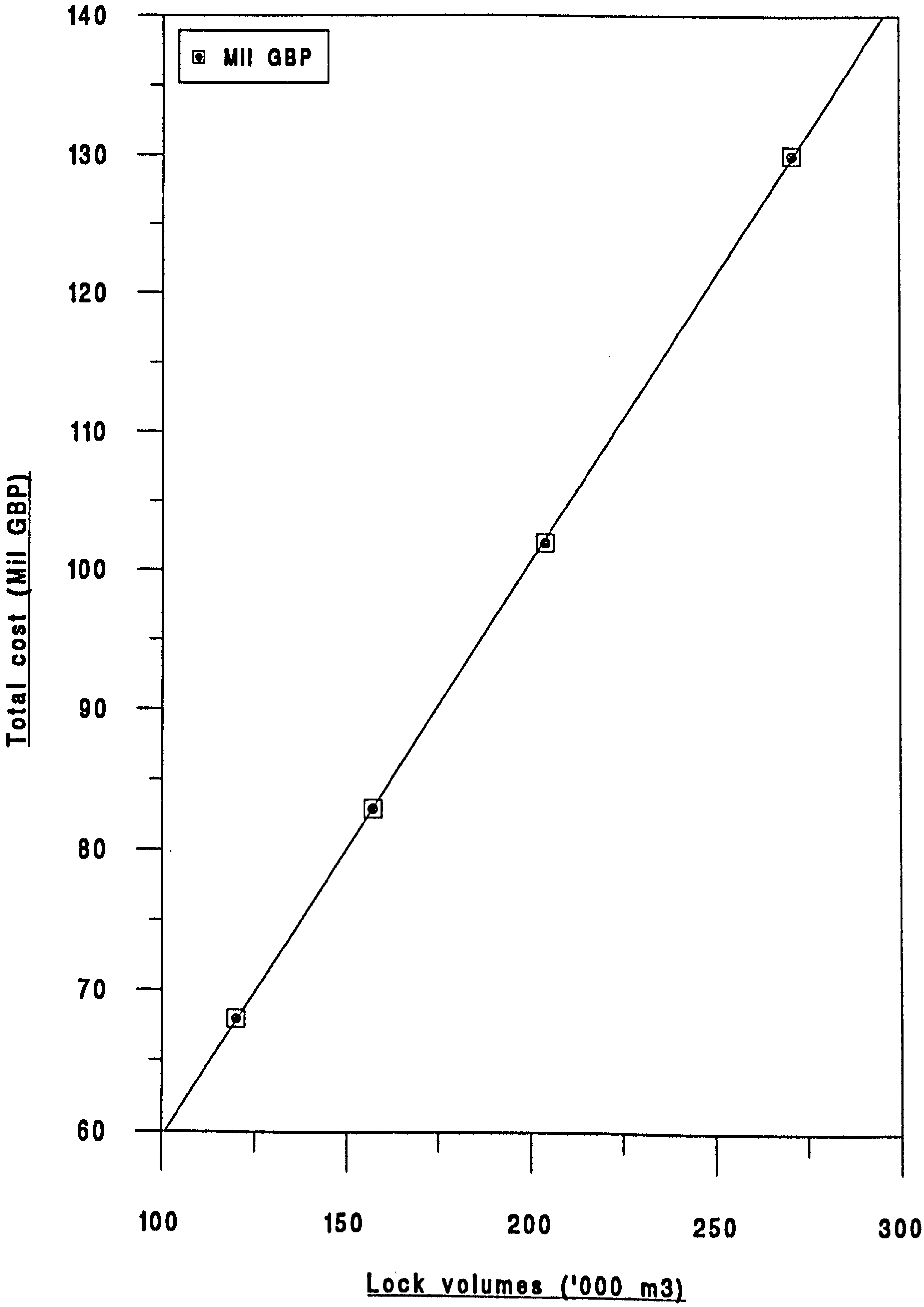
Similarly a study by National Port Council (NPC) [*14*] analysed various sizes of ocean going vessel to determine the required optimum size of locks and lock capacities using the data shown in table 3.8. By multiplying the lock capacities (m^3) to the unit cost/m^3, capital lock construction costs can be estimated. Although the costs were originally calculated in GBP 1968 prices, these costs have been adjusted to GBP 1995 prices and can be used in the lock construction cost model where applicable.

Table 3.8: Lock costs against lock capacities (m^3)

A compilation of data from the NPC study [*14*] on various lock construction costs world-wide based on GBP 1968 prices have also been analysed. Similarly, these costs have been converted to GBP 1995 prices by applying the price indices. Figure 3.8 shows graphically the total lock construction costs against the lock capacity. The analysis has produced a linear equation as follows:-

Lock construction costs, $y = 18.59 + 0.41x$,
where x is the lock capacity in m^3.

Figure 3.8: Lock volume (m3) v total cost



Another study in the UK by Mann & Dunn [*15*] on the improvement of locks on SSYN for a typical 500 tonne barges suggested that timber was used for a new set of mitre type lock gates. The frame was made of oak and the panel was from the pitch pine. The cost for the top gates was GBP 8,000 and for the taller bottom gates of GBP 12,000 (1980 prices).

3.5.2 Culvert

A culvert is to provide an access for water flowing at either the lock filling system or crossing the waterway under the channel's bed [*14*]. The size and length of the culvert depends on the lock filling system as well as the geographical conditions of the channel. In general, a typical 16 kilometre stretch of British Waterways canal has approximately 15 to 17 culverts [*16*]. Using construction cost data from Spon's [2], a relationship between culvert size and construction cost (for a required depth) has been derived and is shown in table 3.9 and graphically in figure 3.9 .

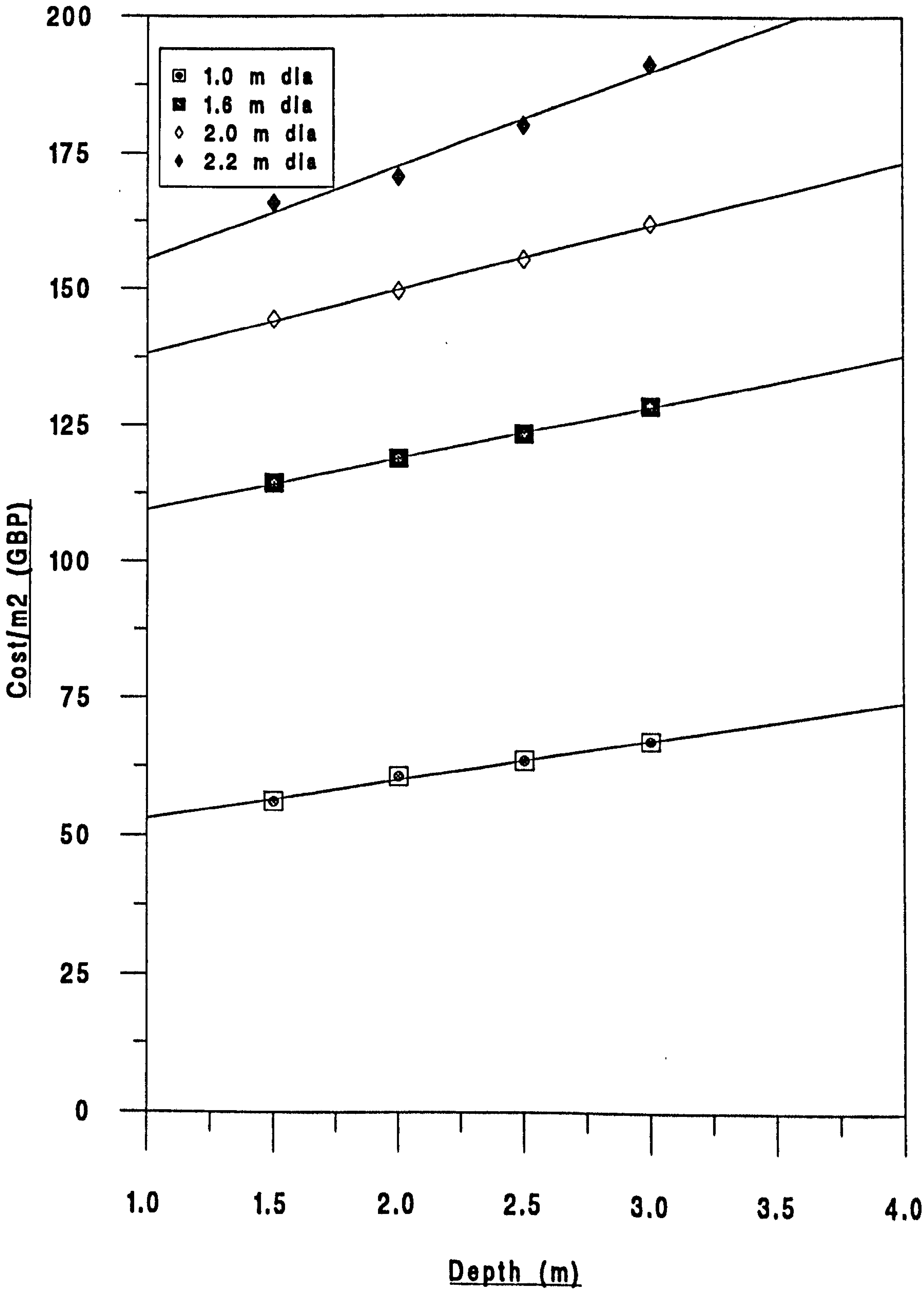
Table 3.9: Culvert depth (m) against cost/m

Diameter (mm)	Equations	R^2
1,000	$y = 46 + 7.1x$	0.99
1,600	$y = 100 + 9.4x$	0.99
2,000	$y = 126.6 + 11.7x$	0.99
2,200	$y = 138.5 + 17.1x$	0.97

3.6 Bridges construction

The construction of new waterways or improvement of existing ones frequently results in the construction or improvement of bridges. Bridge structures of several types are constructed to provide access in other social and economic activities. Some existing bridges may not require any improvement if the air draft or the height of bridge allow an uninterrupted vessel passage underneath the bridge.

Figure 3.9: Culvert depth (m) Vs cost/m2



Bridge construction cost is a function of span, the height, the type of materials used and the type of the bridge including the mechanisation system. There are various type of bridges, some of which are operated manually, electrically or even hydraulically; fixed or moveable. Thus, the bridge construction cost varies depending on the factors mentioned above. Based on British Waterways experience, a typical 16 kilometre waterway has an average of six road bridges [16].

According to Brandon [7], bridge openings should be as near to the full channel width as possible so as not to impose any restriction. However, where bridgeways exist or wide openings are impossible, a minimum width limit would be 1.3 Bv (where Bv is the beam of the craft). The width of the road bridge also has a significant impact on the bridge size and costs. Although dual two-lane carriageway for instance may be linked by dual one-lane bridge carriageway, it is however felt necessary to provide the bridge of the same width as the road to ease traffic flow. A minimum bridge headroom clearance should be in the order of 300mm above the design standard craft height. Table 3.10 indicates road bridge requirements in the UK [17].

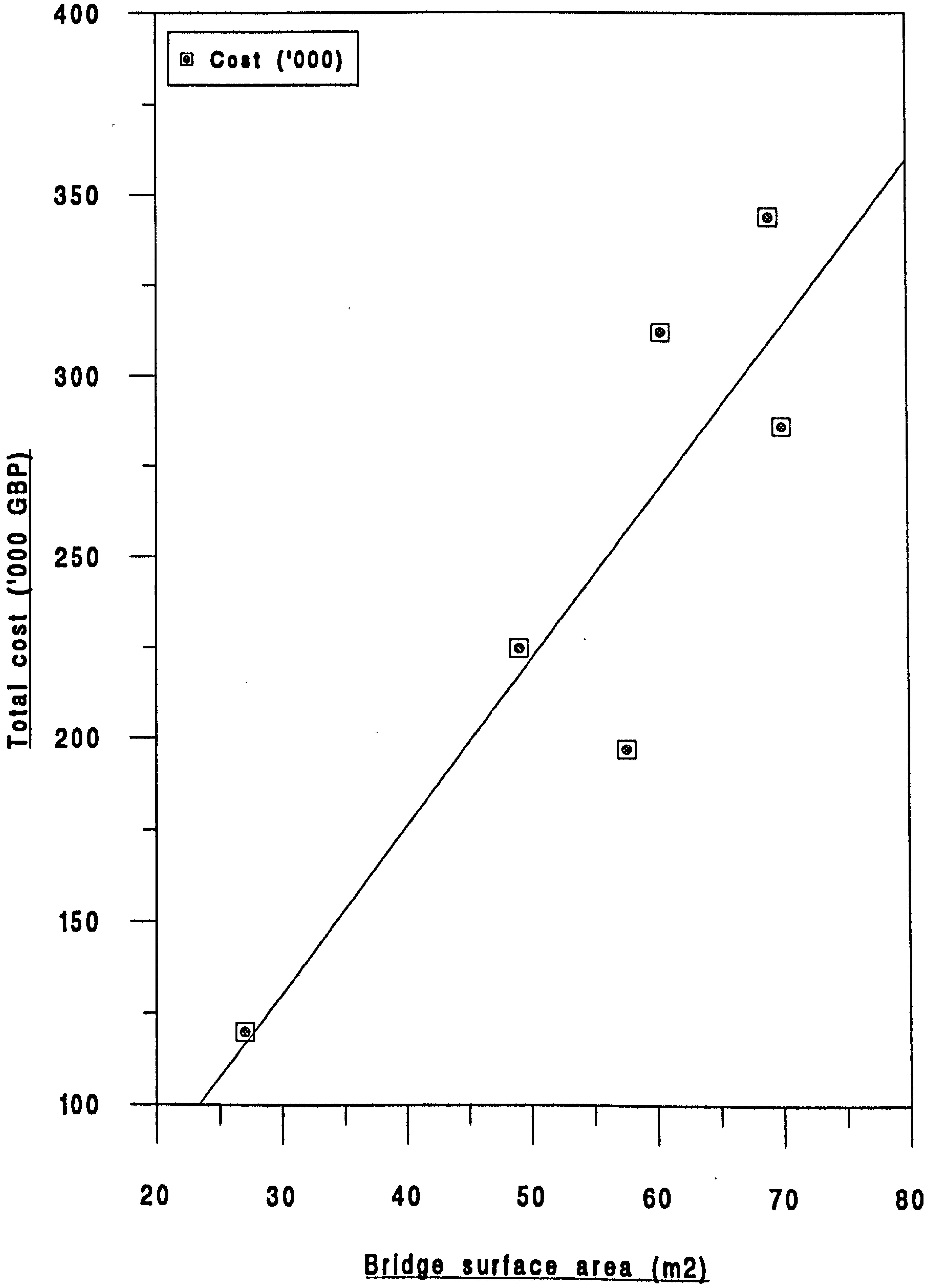
Table 3.10: UK, widths of major road formations

A data for the bridge construction costs has been obtained from the BWB [5]. The data is based on a number of typical BWB's bridges on the waterways around the UK. The data is adjusted to GBP 1995 prices using the civil engineering cost index as shown in appendix 4. The relationship between the bridge built up area and construction cost is derived linearly as shown in figure 3.10 , thus;

Bridge construction cost, $y = 4592.7x - 7586$

where x is the bridge surface built-up area in m^2.

Figure 3.10: Bridge costs V bridge surface area (m2)



3.7 Embankment (levee) construction

The construction of levees may not be necessarily required to every section of the waterway's length. Observation of the construction of the Manchester Ship Canal reveals that there are certain parts of the waterway which are of natural slopes and heights which naturally provide a prevention and protection against water overflow. In other sections, levee construction is essential.

Excavated materials from the channel can be used to form the levee on each bank. If excess material is present, this must be disposed of elsewhere incurring extra costs. Similarly, if the quantity of the material is not sufficient, the construction of levee will necessitate the importing of fill from another location and compaction and profiling of the fill to the required profile by earth moving machinery [*18*].

The height of the levee above the natural ground surface vary depending on the design requirement and the geotechnical stability. Some waterway sections may require protection along significant lengths by using rock over a graded gravel filter or geotextile fabric due to the presence of non-cohesive materials. The levee slopes will usually require protection against erosion by rainfall or other circumstances. Occasionally in the protected areas, if the fill material is of a coarse grains, the fill may be allowed to form a natural slope profile or vegetation.

There is a need to build a road surface (or tow path) on either the top of, or by the side of the embankment. This is required for maintenance and monitoring activities. A typical road width for the river embankment is approximately 4 metres [*19*]. The costs for the road construction per metre square is GBP 95.00 in 1995 prices [*19*]. However, the costs for the construction of embankment would be approximately as follows [2]:-

i. Using dredged filled material = GBP 70 -200 per m^3 (1995 prices)
ii. Using imported fill material = GBP 130-320 per m^3 (1995 prices)
iii. Generalised cost of GBP 130 per metre length of the embankment [2]

3.8 Channel bank and bed protection schemes

Channel bank retention and stabilisation schemes are important for the strengthening of the waterway's channel bank from erosion arising from wash created by waves from craft's propeller rotation and bow movement. It is recommended that the actual river bank is constructed at an angle of 1:1.5 due to strength and safety requirement [*20*]. However some banks can be kept almost vertical or deliberately steepened due to varying design requirements. Although sheet piling and concrete material are preferable, a number of other simpler and less expensive techniques for bank reinforcement can be considered. Figure 3.11 shows a typical waterways bank protection and stabilisation scheme design.

River bank protection is critical in the erosion-prone areas but will also be advantageous to other areas where it can reduce the maintenance effort. River bank reinforcement should use natural looking materials where the effect of a natural river is being achieved by other works including landscaping [*18*]. Non natural river bank reinforcement would be used where a harder channel appearance already exists. Rock bank protection is expensive and vulnerable to damage should desilting work need to be carried out. Sheet pile is also expensive and the most desirable option will be to monitor the low earthen bank in vulnerable sections and apply remedial treatment in limited areas.

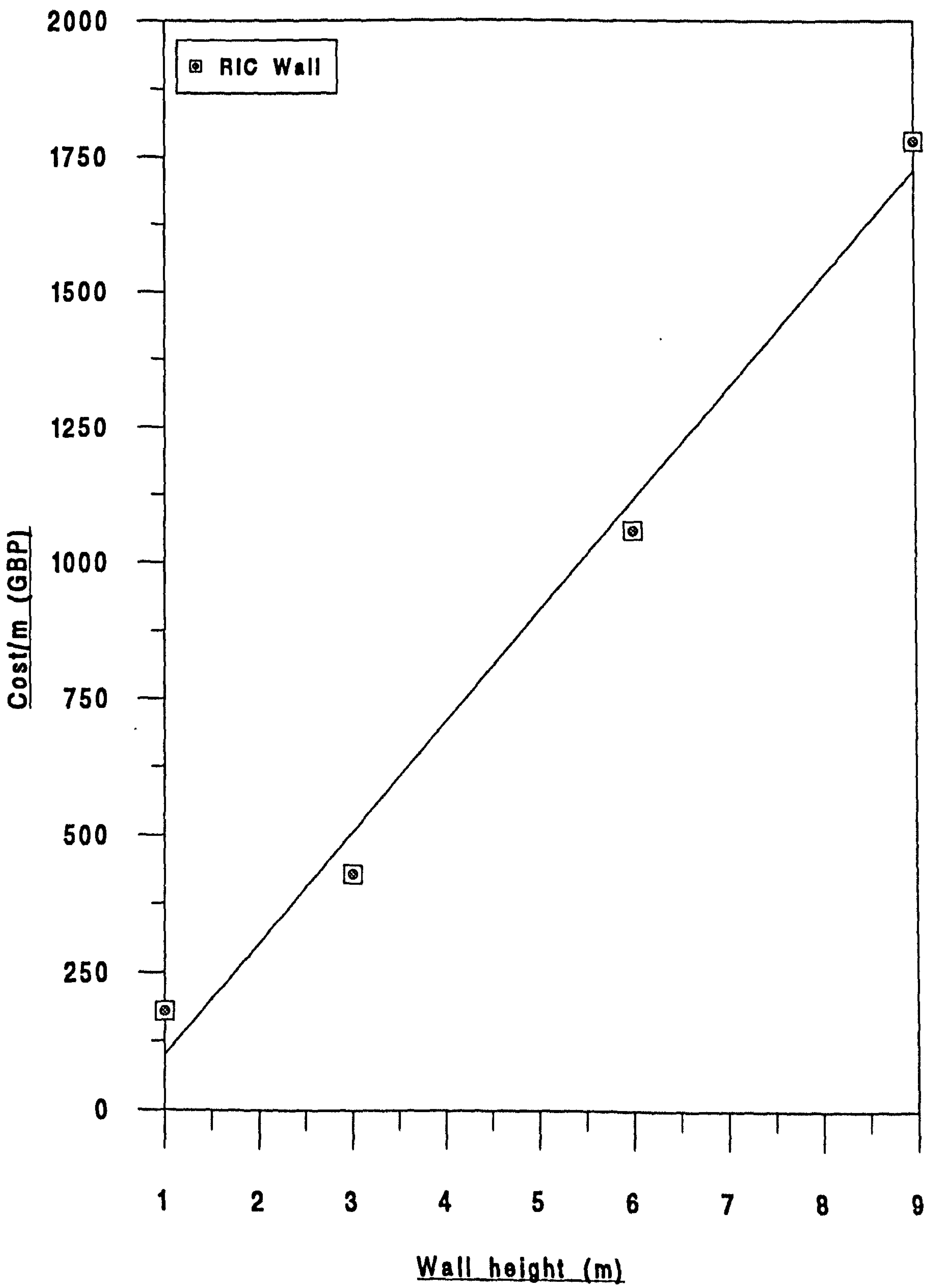
The data for retaining wall, steel sheet piles, earth retention and stabilisation schemes, and geotextile lay-up are obtained from Spons's [2] based on GBP 1995 prices. The data analysis produced graph outputs as shown in figures 3.12, 3.13 and 3.14 respectively. The equations generated from the analysis are shown in table 3.11.

Table 3.11: Equation for construction costs of various channel protection schemes

Structures	**Equations**	R^2
Retaining wall	Cost/m, $y = 203x - 102$	0.98
Steel sheet pile	Cost/m, $y = 29.2 * 10^{(-0.2315x)}$	0.65
Earth retention and stabilisation schemes	Pre-cast concrete block, cost/m^2, $y = 155 - 6.67x$ Pre-cast concrete crib, cost/m^2, $y = 100 + 13.3x$ Timber crib, cost/m^2, $y = 51.29 + 11.36x$	0.93 1.00 0.98
Geotextile lay-up	Cost/m^2, $y = 1.575 + 0.001x$, where x is the degrees of layup of geotextile (i.e. 0 -90 degrees)	0.96

Figure 3.11: Waterways bank and stabilisation schemes

Figure 3.12: Retaining wall height (m) Vs cost/m



Note: RIC=Reinforced in-situ concrete

Figure 3.13: Steel sheet length Vs cost/m

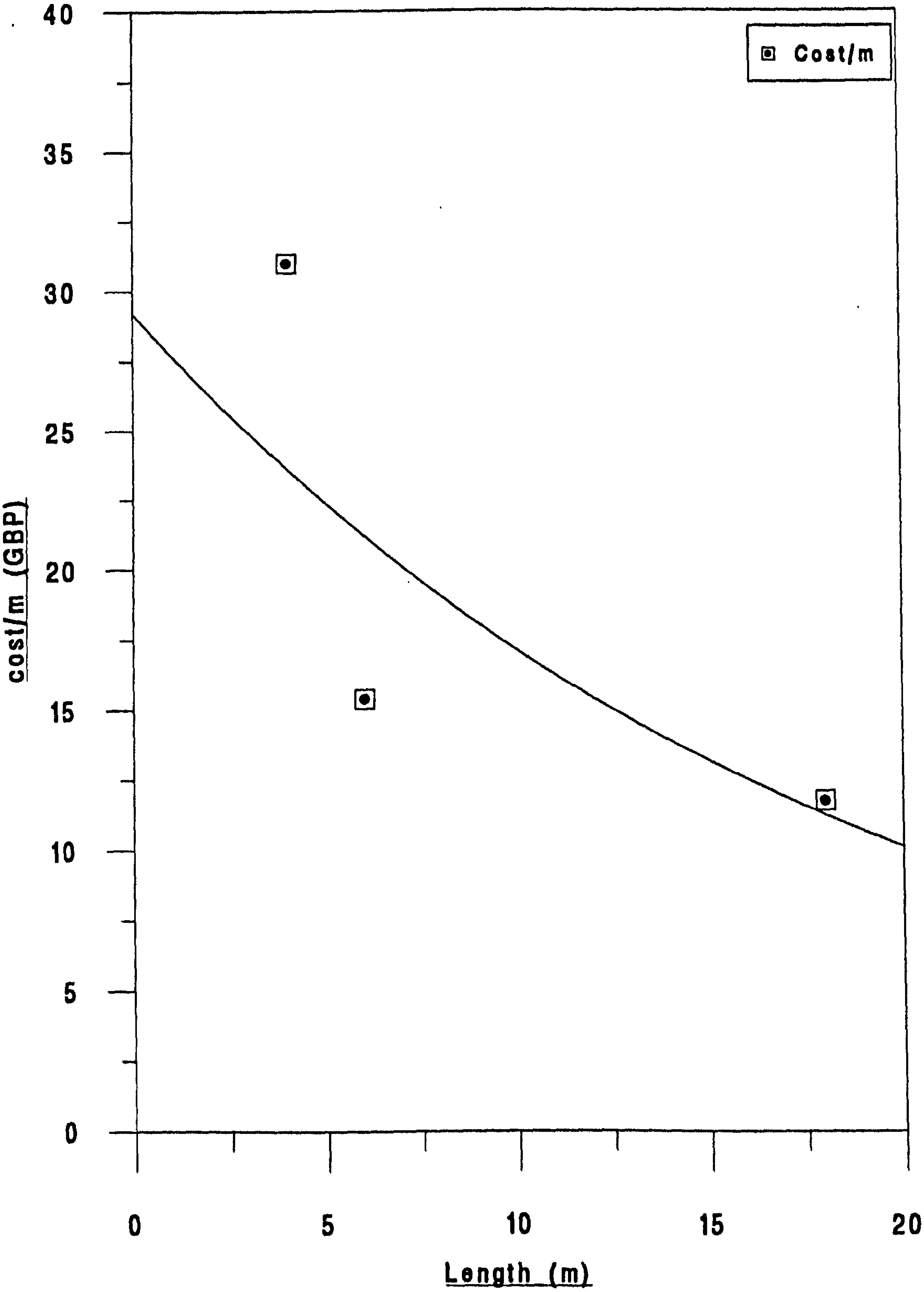
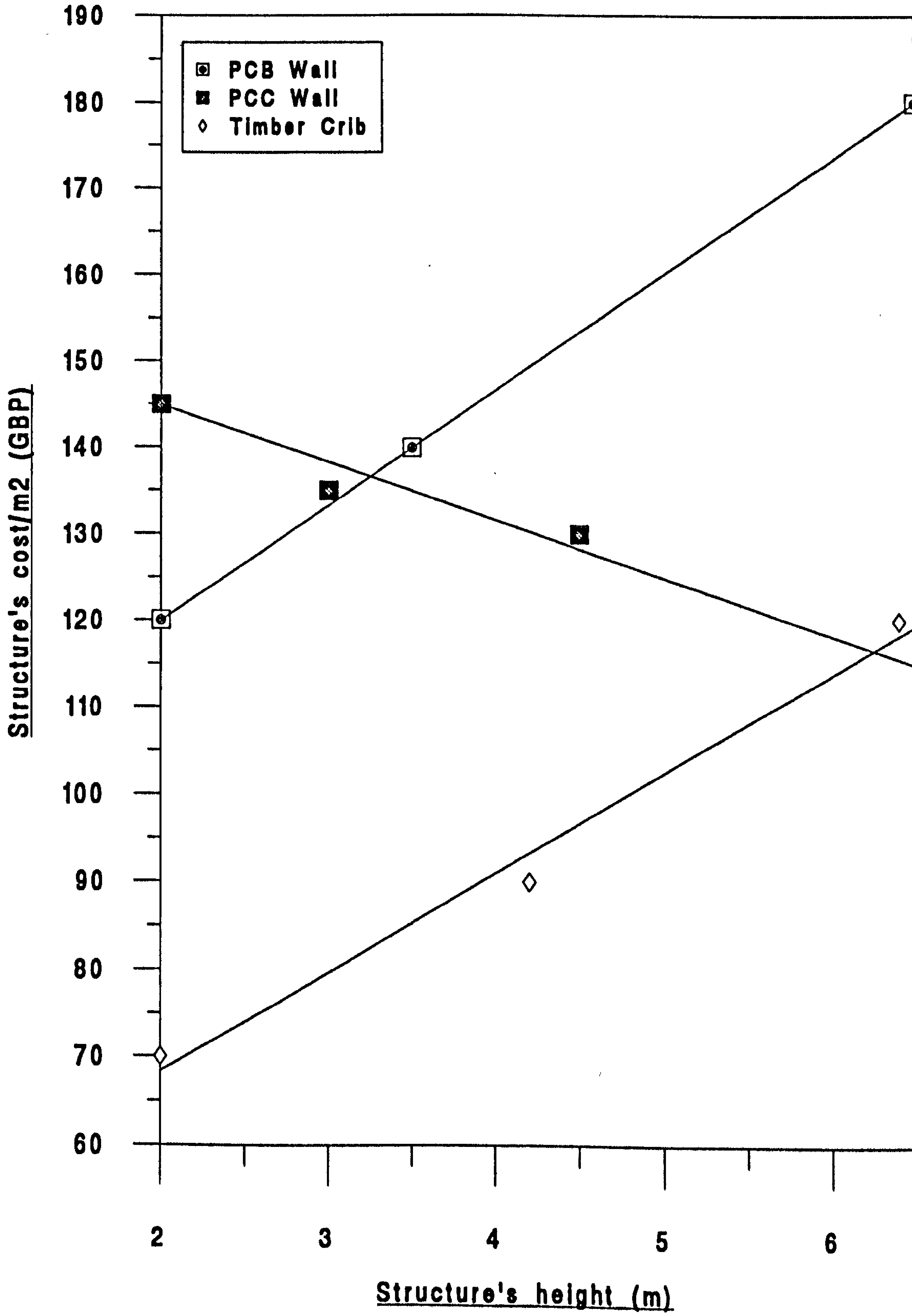


Figure 3.14: Earth retention and stabilisation costs



3.9 Drainage, landscaping and planting and fencing

Navigation authorities frequently receive applications for drainage facilities from industrial and housing. Such drainage can only increase the existing problems of water disposal and contamination. However, in the UK for instance, BWB can accept the land drainage with some compensation. Unlike rivers, canals are not designed as drainage. Even if they do, the likely costs would be approximately GBP 3.65 - GBP 9.45 per metre square of paved area for site drainage and GBP 3.65 - GBP 8.25 per metre square of gross floor area for building drainage both in 1995 prices [2]. To accept this, the authorities will need to provide extra facilities such as weirs, etc. for the additional water flows.

Landscaping is required in almost new waterway developments. The landscaped channel corridor will strengthen the earth as well as beautifying the area for environmental enhancement schemes. Landscaping cost, based on a study by BWB [*20*], was GBP 1,000 in 1983 prices for a typical narrow canal. The costs for planting and fencing was GBP 7,000 in 1983 prices.

3.10 Operating and maintenance costs

A new or existing waterway needs constant monitoring schedules to ensure its continued operation. Operating costs of a waterway can be substantial and should be kept to a minimum. Unnecessary spending should be avoided. The administration and management authorities must capable of adapting to operational requirements whenever necessary. A means of estimating and projecting the operating costs such as overhead expenses of lighting, electricity, water and fuel should be made available by the waterway authorities.

According to Baldwin [*17*], a typical 80 kilometre BWB's narrow canal needs some GBP30,000 to GBP50,000 per annum at 1969 prices with a staff of 25 to 40. The expenditure involved must be sufficient to keep water flowing regularly by essential dredging, bank protection and maintenance to towpaths, hedges, bridges, lock gates, culverts, etc. Data in previous table 3.3 provide a comparative guideline for typical annual costs of commercial waterways of relevant magnitude.

Bigger river navigations are cheaper to maintain, in general than the canals [*21*]. Operating costs of BWB's commercial waterways were GBP 721/km and GBP 868/km in 1973 and 1974 respectively. A study [22] suggests a combined annual operating and maintenance costs of GBP 5,190 per kilometre and GBP 7,953/km in 1980 and 2000 respectively (for a BACAT size canal of 104 metre length by 20.7 metre width and 5.4 metre draught). For a LASH size canal of 241-272 metre length by 30.5-32.5 metre width and 10.7-12.4 metre draught, the costs would be GBP 7,207 and GBP 11,749 respectively.

Another study by BWB [*13*] suggest that the canal maintenance alone would need GBP 3,416 per kilometre in 1973 prices. Similarly for the operating costs alone, the figure would be GBP 721 per kilometre in 1973 prices and GBP 868 per kilometre in 1974 prices. These data has been incorporated in the cost model development. However, care should be exercised in consideration to the size of the BWB canal then and the size of the proposed waterways construction. These figures should be used when necessary.

3.11 Discussion and summary

The development of a cost model for the waterway itself is not a straight forward exercises. A number of relevant and significant factors as have been discussed earlier need to be taken into consideration. In this chapter, the data has been obtained from a number of reliable sources and this enabled the analysis to progress appropriately. At this point, the model is expected to provide reliable yet comprehensive guidelines to estimate the future development cost of a waterway channel with its associated infrastructure requirements.

A number of economic factors such as price indices, inflation rates, exchange rates are subject to market fluctuations and uncertainties which needs to be applied where necessary. Due to the large number of parameters and factors for consideration in the design and construction of model, the discussion and analysis of data has been carried out as simplified a form as possible. Care has been taken to produce as reliable a model as possible. The model has been validated and applied in succeeding chapters.

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CHAPTER 4

Inland waterways vessel cost model

CHAPTER FOUR

INLAND WATERWAYS VESSEL COST MODEL

4.1 Introduction

The physical and economic planning of major investments in inland waterways transport (IWT) is a complex subject. Due to the limited capability of many transport authorities and national transport planning agencies, a simple yet comprehensive model to perform the estimating and evaluating tasks in the various phases of the project is desirable [1].

To link the multiple disciplines of transport, physical planning, financial planning and economic evaluation, the model will include the necessary planning relationships, factors and data which will be thoroughly presented and analysed. The model will increase the capability of the authorities to prepare the pre-feasibility studies i.e. the traffic flow projections together with model application giving them improved control from project specification through to implementation [2].

The model will not replace the need for competent engineering and technical personel to perform the feasibility studies and detail design, rather it will complement this work to achieve consistency in analysis and evaluation. The IWT model consist of several modules ranging from traffic projection, estimating the craft requirement and costs, and finally the financial and economic analysis as illustrated in the flowchart in figure 4.1.

A shipping module can be used to determine the vessel or barge operation characteristics for use in analysis. In a practical project analysis, all modules may be applied several times for different waterway channel's section. The expected level of accuracy increases with detail, as the amount of data and effort required. Thus the structure can be retained as components of a study report.

Figure 4.1: Vessel operating model flowchart

4.2 Inland waterway craft planning module

This module describes traffic flow projections, using typical vessels and operating data. The main outputs of the module are expected to be the actual barge/vessel requirement, annual operating time on voyage and in port. The data for vessel annual operating times and vessel number requirement will then be included for the vessel costing procedures.

The number of barges and annual operating time forms a constant cost cash flow by applying the unit cost rates, economic lives, fixed maintenance costs, fuel consumption, manpower requirements and wage disbursement. The output of this analysis will be the vessel capital requirement plus operating including maintenance costs which will be available for the financial and economic analysis.

The waterway length and route to be analysed must be clearly defined. It may be between two rivers or canals in a river network area. Only the traffic between both ends of the section and all transport activities should be taken into consideration as far as this section is concerned. Table 4.1 shows the list of vessel trip planning variables which need to be considered for a typical analysis.

Table 4.1:Vessel trip planning variables

4.2.1 Traffic flow projection

The traffic flow data for the base year and annual traffic growth rates throughout the project operation are to be projected. The traffic flow is designed to accommodate the total cargoes to be transported by all the self-propelled vessels in the project. The cargoes will specifically be categorised as all bulks and containers. For instance, table 4.2 shows the breakdown of bulk cargo components.

Table 4.2: A bulk cargo components for inland waterway transport

4.2.2 Self-propelled vessel cost model discussion

The determination of appropriate vessels and their operation are usually a key point for an inland waterway project. The user may select several options of a typical vessel and operating data and the vessel data may then be applied to determine the waterway channel and lock dimension. Finally, the total vessel annual trip requirements can be estimated. In the cross-check exercise, the user may be able to identify the optimum vessel and its operating characteristic.

The cost of a vessel depends on a number of elements some of which are not even considered by the concerned professional disciplines [*4*]. The aspects of economics, cost accountancy, planning and production control and many others need to be included for the vessel cost estimation. In this study, a self propelled vessel type is chosen for the costs analysis. A preliminary estimation of costs of the self propelled vessels by the model would be useful for both the ship builders and the shipowners.

Normally vessel size is expressed in dwt (deadweight tonnes) for the bulkers and TEUs for containers. For instance, a 500 tonne vessel can carry up to 25 containers or 50 TEU (twenty-foot equivalent unit) on one movement [5]. Typical examples of a self-propelled vessel for bulk cargo considered in the study is shown in figure 4.2.

Once the flow of commodities is known and has been assigned to specific routes, it is then necessary to project the vessel movements. These projection are used to determine fleet requirements, waterway traffic volumes and lock utilisation. The number of trips required to transport a volume of traffic between two destinations depends on the vessel capacity and utilisation rates.

According to ESCAP [2], in practical planning, inland vessels may utilise up to 95% of their dwt capacities. Load factors for return trips must be specified for each barge or vessel type which rely on both ends of the ports or terminals. For most bulk transports for instance, it is normally a fully loaded cargo for an outbound trips with either nothing or much smaller cargoes for return trips. Finally, a total number annual round trips for each vessel can be determined.

4.2.3 Self-propelled vessel operation

Operating parameters for self-propelled vessels include a number of components. They are divided into the following categories:

i. *Total vessel round trips required (TVRT)*

   The total vessel round trips calculations are based on the vessel trip planning variables as shown in earlier table 4.1.

ii. *Annual round trips per vessel (ARTV)*

   Under this item, it is necessary to consider lockage time per round trip, average

Source: Courtesy of C.C. Roberts, Liverpool John Moores University

Figure 4.2: A typical inland waterway crafts in UK

idle and repair days per year and average operating hours per day and per year for each vessel as shown in table 4.3.

Table 4.3: Self-propelled vessel operating parameters

Other elements to consider under this item include delays during the voyage due to interruption, reduced traveling speed and average days in ports per round trip. Finally, the total vessel round trips (TVRTs) and the annual possible number of round trips for each vessel can be determined as described in the following section. Hence,

$$TVRT = \frac{\text{distance/speed + delays + lockage}}{\text{operating hours per day}} + (\text{days in ports})$$

$$ARTV = \frac{\text{navigable days - repair \& idle days}}{\text{vessel days per round trip}}$$

iii. *Annual operating hours per vessel (AOHP)*

The total annual operating hours of vessel in ports (AOHP) and during voyage (AOHV) can also be determined. These are useful in the calculation of vessel operating and maintenance costs. The equations for both operating hours are;

AOHP = Days in ports/round trip x total round trips/year x operating hours/day

AOHV = Vessel days/trip x round trips/year x operating hours/day - hours in port/year

iv. *Total number of vessel required (TNVR)*

Finally, the total number of vessel required (TNVR) is as follows;

$$TNVR = \frac{\text{Total vessel round trips required}}{\text{Annual possible round trips per vessel}}$$

4.2.4 Transport revenue calculation

Most transport tariffs are measured in tonne-kilometre of transported goods and this is considered in this model. The model will convert the freight traffic data in overall tonnes (or TEUs) to tonne-kilometre (or TEUs-km) in order to calculate the transport revenues for a given freight rates. Freight rates fluctuate according to market demand and should be competitive with road and rail rates.

4.3 Self-propelled vessel dimension determination

The model is capable to determine the vessel length, beam, draught and even air draught for a given capacities (dwt or TEU) of a typical self-propelled vessel. The Europe's inland waterway vessel's data as shown in earlier table 3.1 has been analysed to produce the linear equations showing the relationship between length overall, beam, and full loaded draught, individually denoted by *y* against the vessel size (dwt) denoted by *x*. Where information on specific vessel is not available, these equations are sufficient for preliminary planning purposes. The equation for the vessel is shown in table 4.4 whereas the graphical output is shown in figure 4.3.

Table 4.4: Equations for determining vessel's dimensions

Dimensions	Equations	R^2 values
Length	$y = 30.6 + 0.0340x$	0.98
Beam	$y = 4.20 + 0.0038x$	0.98
Draught	$y = 2.23 + 0.0003x$	0.76
Air draught	$y = 2.80 + 0.0017x$	0.80

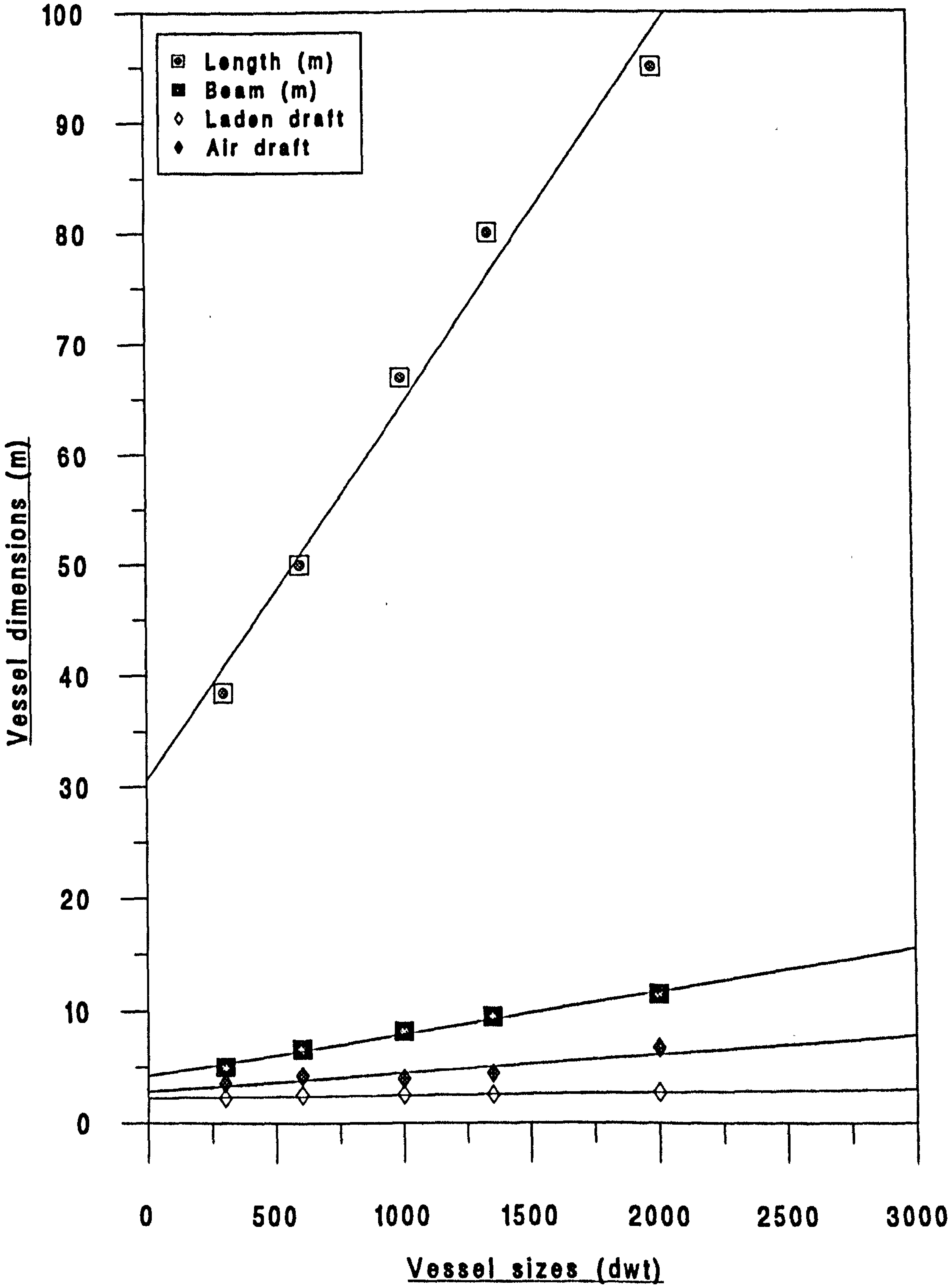


Figure 4.3: Vessel sizes Vs dimensions

4.4: Estimating vessel's capital and operating costs

Analysis of costs for inland self-propelled vessel includes the considerations of the market (new, hire or reconditioned) and transport characteristics (type, size, propulsion, etc.). The capital and operating costs of the vessel depend on the following factors [*6*]:

i. Type of vessel (size, speed, method of propulsion)
ii. Type and amount of transported goods
iii. Number of vessels and operating characteristics
iv. Transshipment time and cargo handling efficiency
v. Navigation area

The facility and the restriction along the waterway can influence the vessel operating strategies. The number of locks, the distance between locks, lockage time, bridges air draught, vessel average speed, operating hours, etc. will all influence the operating costs. The objective of the vessel operation is to ensure high level of utilisation with reduced operating costs [*1*]. There is a need to estimate the principal costs for carrying out the financial and an economic assessment [3]. The costs include a number of cost components such as capital, depreciation, operating, port and possibly toll charges.

4.4.1 Capital cost

Vessel capital cost or price estimates are needed by numerous individuals or organisations for a number of reasons. Fleet managers for instance, need the estimate for the purpose of choosing between various investment alternatives, establishing budgets or predicting charter and insurance rates. Others need the estimate for preliminary design purposes.

The initial capital costs of vessel depends on the type, capacity and possibly the design speed. Capital costs represent a high fixed cost if the vessel has been purchased using a loan with interest. If the vessel is purchased with cash, there is no mandatory payment to capital but there is an opportunity cost to be considered [7]. On the other hand, if limited capital is available, the choice may be between an old vessel (with high running costs but no debt) or a new one (with low running but bearing loan interest).

Vessel capital cost or price may be obtained from a number of sources such as vessel builders, vessel owners or from a number of past and present publications. Vessel cost is converted into annual or even daily capital cost with the consideration of vessel's economic life as shown in table 4.5.

Table 4.5: IWT vessel economic life

According to Gilman [8], There are four major vessel costs concerned: actual newbuilding price, newbuilding estimated price, second-hand price and charter rates. The first three of the prices or costs are concerned with financial and economic factors of a daily capital cost. Operating costs include insurance, maintenance, crew and fuel.

There are various methods for estimating vessel costs. A number of past studies based the estimates on the ship's functional capabilities or technical characteristics. Fleet managers however, prefer to consider the ship capital cost simply in terms of deadweight (dwt) [9]. Another study [10], estimating the costs based on ship's functional capabilities in relation to the vessel's dwt, coefficient and exponent factor of ship design and stochastic error factor.

The estimate based on technical characteristics considers a number of bases ranging from vessel's deadweight to a number of other parameters such as vessel's lightship by Benford [*11*], hull sizes and powers by Fergusson [*12*], etc. and including materials and labour components. The estimates based on material costs include the steel, outfit and machinery has also been developed by Carreyette [*13*]. However, these approaches will not be considered in this study.

A study by Mainal [*9*], whose work was dedicated to the design of offshore supply vessels, derived the relationship between capital costs with the parameters discussed above. The study suggested that this relationship is applicable to vessels and barges of identical sizes and operating condition including the inland waterway vessels. However, a study by ESCAP [*1*], suggested the price for a new inland waterway vessel including the propulsion system is slightly lower than the tug or supply boat prices.

4.4.2 Vessel operating costs

An estimation of vessel's operating costs is complex. The operating costs vary according to types, age of ship, operating pattern, trade route and others. The operating cost model in this thesis will be based on a number of studies including an analysis of appropriate data for model construction.

The term operating costs include the following definitions; [*14*]:

i. Total costs of providing a shipping service
ii. Total costs excluding the costs of vessel ownership
iii. Total costs excluding expenses directly related to the voyage

In general, typical operating costs are divided into several categories. Thus, to estimate vessel's operating costs, two specific categories are considered; i.e. fixed and variable costs. According to Chrzanowski [*15*], fixed annual operating costs include insurance, crew, repair & maintenance and stores & provisions. Variable costs include fuel, toll and port charges. Table 4.6 shows the vessel operating cost factors for consideration in the model.

Table 4.6: Vessel operating cost factors

The importance of operating costs vary with the purpose of a study. Nevertheless, it is useful to indicate the size of the costs for generalisation purposes. Heaver [14] suggests the operating costs are estimated at only one-fifth of the total costs and manning costs are about one-half of the operating costs. However, a significant difference exists in the capital and voyage costs between container and bulk vessels.

i. *Depreciation*

Depreciation is calculated as a percentage of the replacement value minus the residual value of the vessel [6]. The initial value is depreciated linearly over the remaining economic life of the vessel to the residual value of zero. Chrzanowski [15] estimates the depreciation values in within 15-30 percent of total cost which is arguably high. It would be appropriate to use the linear depreciation method in this study due to the simplification of the model. It is also the most usual method employed in a number of studies for the vessel's annual capital cost analysis as suggested by Dyson [16].

ii *Crew costs*

A number of estimates available for crew costs as a percentage of annual operating costs. However, the crew size on board a vessel is often controlled by government regulations [*6*]. The different elements of crew costs vary according to operation and employment agreement which cover factors such as basic wages, overtime, medical, training, leave pay, pension etc. For instance, a typical crew requirement for self propelled in a developing country such as Bangladesh for 500, 1,000 and 1,500 dwt vessels are 5, 6 and 7 respectively [*17*] resulting in a relationship of $y = 4.0 + 0.002x$ where y is crew requirement as a function of vessel size, x.

The developed countries of North America, North Europe, Scandinavia and Japan carry the highest crew costs due to their higher standard and cost of living. They do, however, seek to reduce costs by various means ranging from reducing crew number, etc. Chrzanowski [*15*], estimates the percentage for annual crew costs within 15 - 25 percent of the vessel's annual total operating costs.

iii. *Marine insurance costs*

The vessel will be covered by hull and machinery insurance via the insurance market with a premium based on value, operating area and past record [*19*]. The cargo will be insured separately and will not be covered in this thesis. Chrzanowski [*15*] however, estimates the costs of insurance between 6-12 percent of ship's fixed costs. In general, the older the vessel the higher the cost of insurance.

The hull and machinery cost covers the owner against damage or total loss of the vessel and is mainly dependent on the owner's past safety records. Usually such costs are expressed as a percentage of vessel's price [*19*] or as a function of machinery acquisition costs [*20*].

iv. *Repair and maintenance costs*

Repair and maintenance (R&M) costs consist of the costs associated with the docking of the vessel, maintenance of engines, repair to damage, part replacements etc. R&M costs is divided into hull and outfit maintenance and machinery maintenance. Machinery maintenance depend on the type of engine. The hull and outfit R&M costs comprise mainly docking. A study by Sen [*21*] stated that such costs are functions of vessel capacity of length (L), breadth (B) and draught (D).

Annual machinery R&M costs form a substantial part of the total R&M costs particularly for diesel power plant. The costs are usually expressed as a function of the brake horse power (BHP) [*24*]. Chrzanowski [*15*] however, estimates the overall repair and maintenance costs between 10-15 percent.

v. *Stores and provisions (S&P) costs*

This category includes items such as paint, cleaning materials and cabin stores. It may also includes deck stores such as mooring lines. such costs are usually taken as a function of crew number [*23*].

vi. *Fuel costs*

Fuel costs are divided into heavy fuel oil (HFO), marine diesel oil (MDO), and Lubricating oil (LO). Fuel costs are determined by a number of factors such as the type of the engine, horsepower, type of fuel and its price. A daily consumption is the basis for calculation of fuel costs. It is determined by the total horsepower times the consumption per one horsepower. There is a different fuel consumption of approximately 6 percent for laden and unladen vessel. In general, it is estimated the costs of fuel and lubricant of 12-25 percent of the total annual operating costs [*15*]. A fuel consumption of 150 grams per BHP is assumed [*4*] on the basis that the required (installed) power of ship's machinery can be derived by the following equation:

$$BHP = C \times (\text{TEU capacity})^{0.5} \times (\text{service speed})^3$$

where C is a constant of value 0.08 for LO/LO vessels

For illustration, a typical fuel consumption model for an offshore supply vessel operating in the North Sea is shown below [*24*]. Two generators of 500kW each were assumed to have been used at sea and in port for generating electricity, running the ventilation plant, etc. where the engine operates at 75% of the maximum continuous rating (at sea) at an efficiency of 95%.

a. Heavy fuel oil (HFO) consumed per day in tonnes
$= 204 \times 0.90 \times BHP \times 1.10 \times 24/10^6$

b. Diesel oil (DO) consumed per day in tonnes
$= 204 \times kW \times (0.50/0.95) \times 24/10^6$

c. Diesel oil (DO) consumed in port/day in tonnes
$= 204 \times kW \times (0.75/0.95) \times 24/10^6$

vii. *Miscellaneous costs*

These include the costs to cover crew recruitment, communications, standby, medical, sundries and administration. This is usually expressed as a percentage of fixed costs [25] which have not been considered in this study.

4.5 Vessel capital and operating cost data analysis

In order to validate the various detailed costs expressed in this section; vessels cost data has been obtained from the Port of Rotterdam Authority [26]. The data applies to a number of vessel types including self-propelled, tankers and push-tow systems. A self-propelled cost data based on daily rates for capital and operating costs has been selected for analysis as shown in table 4.7. The costs were adjusted to annual rates based on GBP 1995 prices, by the application of cost index as shown in appendix 6.

Table 4.7: Barge dwt, capital & annual operating costs ('000 GBP 1995 prices)

These data were analysed to produce the vessel's capital costs as shown in the graph in figure 4.4 and the annual total operating costs as shown in the graph as shown figure 4.5. The equations for each of the vessel cost components derived from the analysis are tabulated in table 4.8 where *y* is the vessel capital and annual costs as a function of *x*, the vessel's dwt.

Table 4.8: Vessel capital and annual operating cost equations

Cost components	Equations derived	R^2 values
Capital (price)	$y = 0.79 + 0.0013x^2 - 107.8$	0.97
Depreciation	$y = 0.14x - 34.1$	0.97
Crew	$y = 66.51 + 0.034x$	0.99
Insurance	$y = 0.018x - 1.38$	0.99
Repair & maintenance	$y = 1.76 + 0.03x$	0.86
Fuel	$y = 0.19x - 12.9$	0.99
Total annual operating costs	$y = 21.33 + 0.45x$	0.99

Additional vessel capital and annual costs data from Garratt [26] was obtained and shown in table 4.9. This typical UK inland vessel cost data provides valid and useful comparison with Rotterdam data. While Rotterdam data considers crew and fuel cost based on lump sum per annum, Garratt expressed crew and fuel cost in terms of per hour and per km respectively. Garratt data representing total annual operating cost, crew cost/hour and fuel cost/km were analysed and the results are shown in table 4.10.

Table 4.9: Vessel capital and annual operating costs

Operating parameters	500 dwt ('000 GBP) (2 crews)	1,250 dwt ('000 GBP) (3 crews)
Capital	1,250.00	2,500.00
Depreciation (20 years at 10% interest)	187.50	375.00
Insurance (2.5%)	31.25	62,50
R & M (2%)	25.00	50.00
Total annual operating costs (fixed)	243.75	487.50
Crew (48hour/week, 46 weeks)	34.00	51.00
Fuel	GBP 5/h or GBP2.13/km	GBP 10/h or GBP 3.44/km

Source: Garratt [26]

Figure 4.4: Vessel capital and annual operating costs

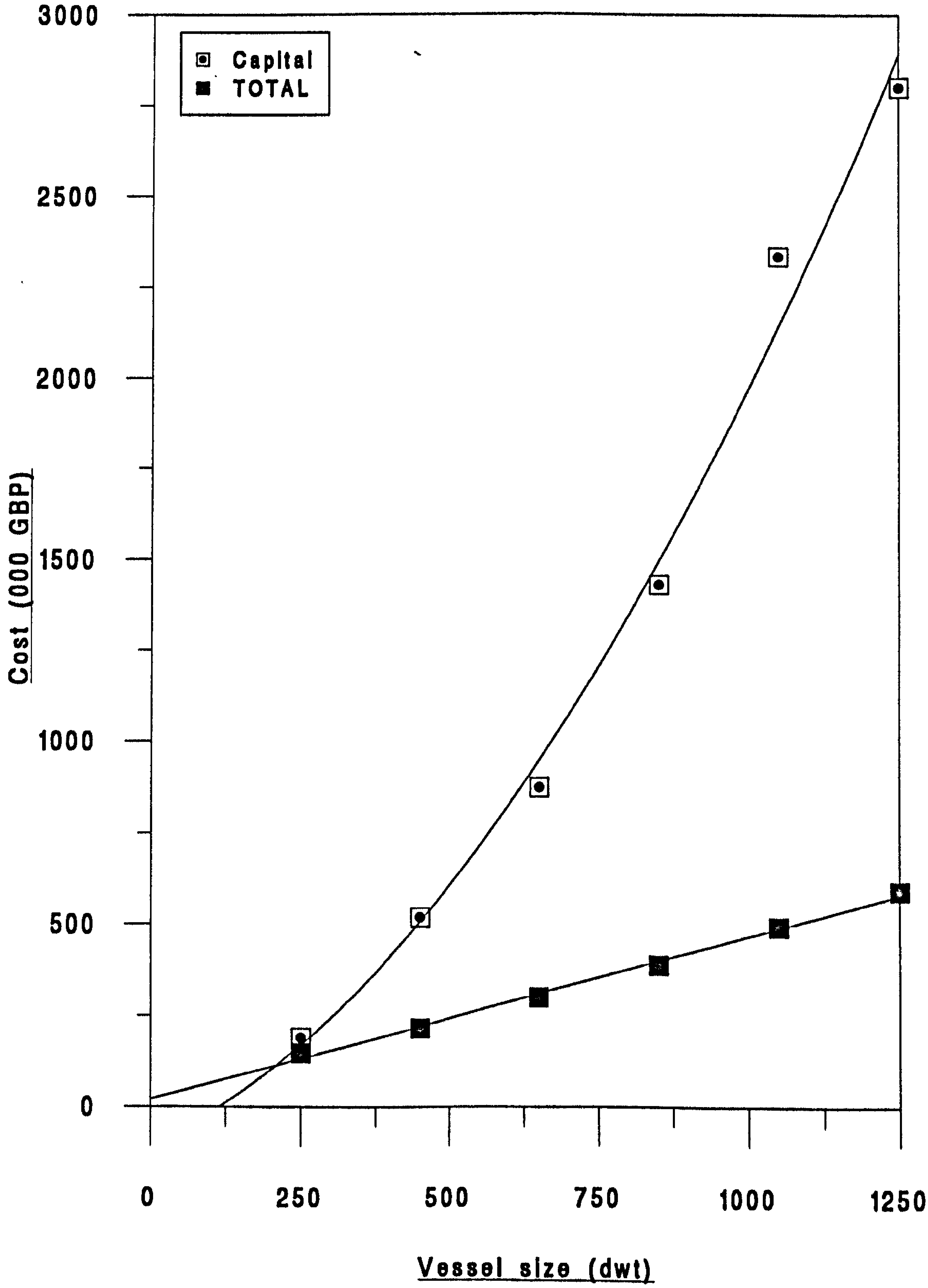


Figure 4.5: Vessel annual operating costs

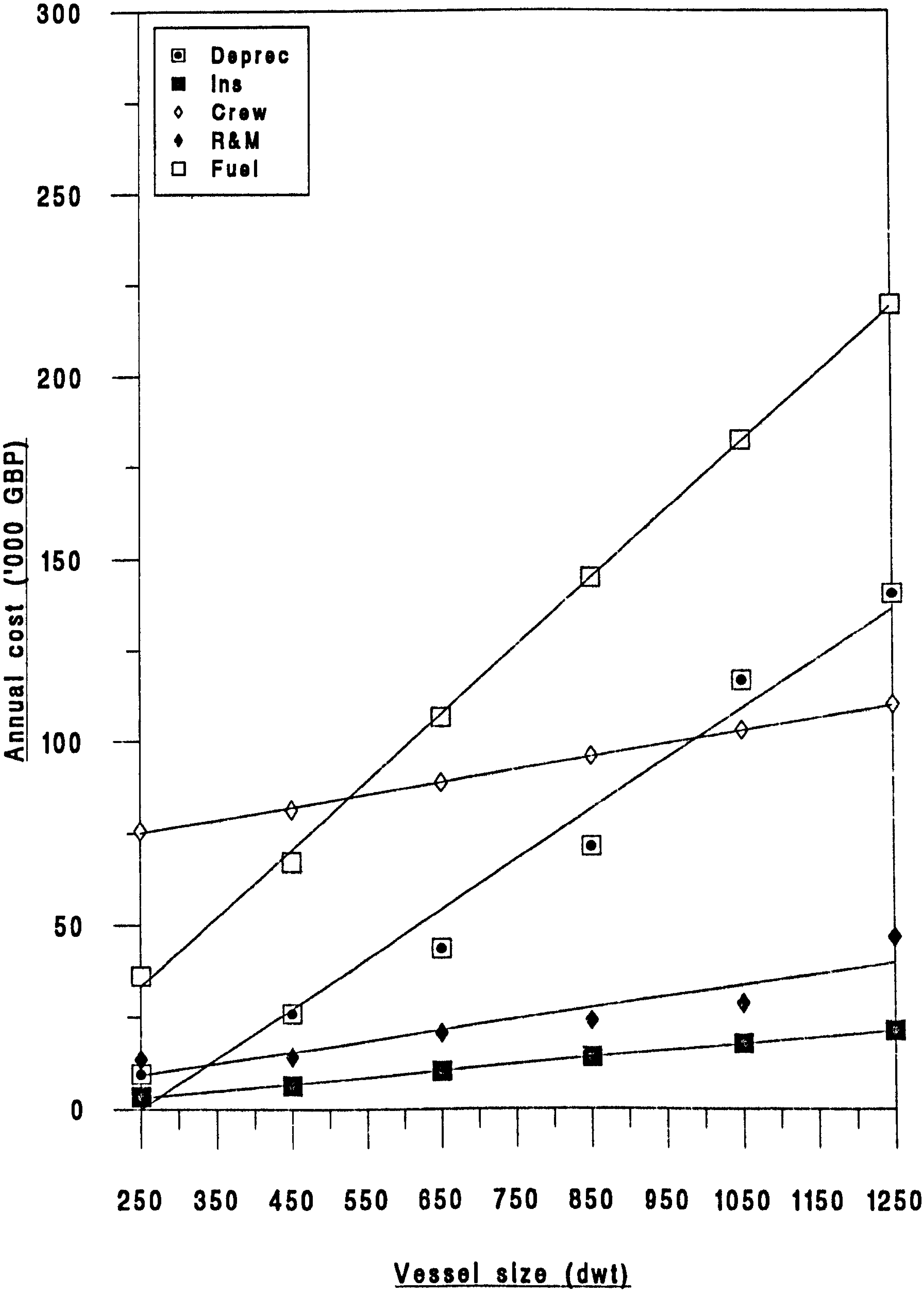


Table 4.10: Self-propelled vessel's annual fixed, fuel/km and crew/hour

Cost parameters	**Equations derived**
Capital	$y = 417 + 1.67x$
Total annual operating costs	$y = 81.3 + 0.33x$
Crew cost/hour	$y = 10.33 + 0.01x$
Fuel cost/km	$y = 1.26 + 0.0018x$

In addition to both sources of data, another information regarding vessel annual costs can be further enhanced with information from PIANC [27]. This data representing a percentages of total annual for capital, crew (labour), fuel and other cost providing a useful guidelines for an estimate to the particular cost for a known vessel capital cost. The vessel capital cost or price can be obtained or even estimated using the models developed in the earlier analysis). PIANC data was analysed and shown in table 4.11.

Table 4.11 :Inland shipping as percentage of total annual cost by vessel size

4.6 Voyage Costs

There are costs related to running the vessel under normal operating conditions. They include the following;

i. Fuel costs: in transit and in port in tonne per hour and day. Fuel consumption in port is approximately one-fifth of consumption in transit.

ii. Port dues and charges: these include harbour dues, wharf dues, lighthouse and buoys, pilotage and towage, port authorities, et.

iii. Toll or canal dues: charged on the basis of vessel capacity (dwt).

Voyage costs are largely comprised of fuel expenses which vary from one vessel to another, the number of days spent during any voyage (inland waterway, lake or at sea) and in port. The importance of fuel costs as a major operating cost factor is clear as described in the following sections. The price of oil at present is much less than in 1986 when the oil price fell significantly [*3*]. Fuel economy depends on the following factors;

i. Speed of vessel
ii. Quality of fuel
iii. Specific fuel consumption
iv. Propulsive efficiency
v. Maintenance of hull and propellers

4.6.1 Fuel costs (voyage and in port)

Clearly, for any round trip, even without back loading, the voyage cost of fuel and possible tolls (if applicable) for both directions will have to be incurred. To calculate the cost of delivering a full cargo, one must add the costs of the two trips. However, for a light return journey, there will be some saving on fuel costs.

An assumption of barge daily operating hours and annual operating days have to be established for data analysis purposes. The average navigation speed of a barge over the waterway section depends on a number of factors such as tide variations, lock transit times and currents. Speed is by far the most important determinant of fuel costs. Empirical data indicate that fuel consumption related to speed increases geometrically due to increased resistance of water [*15*].

4.6.2 Toll or canal dues

In a number of inland waterway systems, particularly estuarial waters are free for navigation and no tolls are charged. However, where tolls are chargeable, the rates depend on the type of commodity carried. Canal dues must be added where applicable, calculated per net tonne (NRT) [3]. For instance, the dues charged per NRT are approximately USD 1.83 laden and USD 1.46 ballast for Panama. This information can be obtained from the port and waterway authorities. Table 4.12 shows the toll rates of MSCC and BWB, both through private communications.

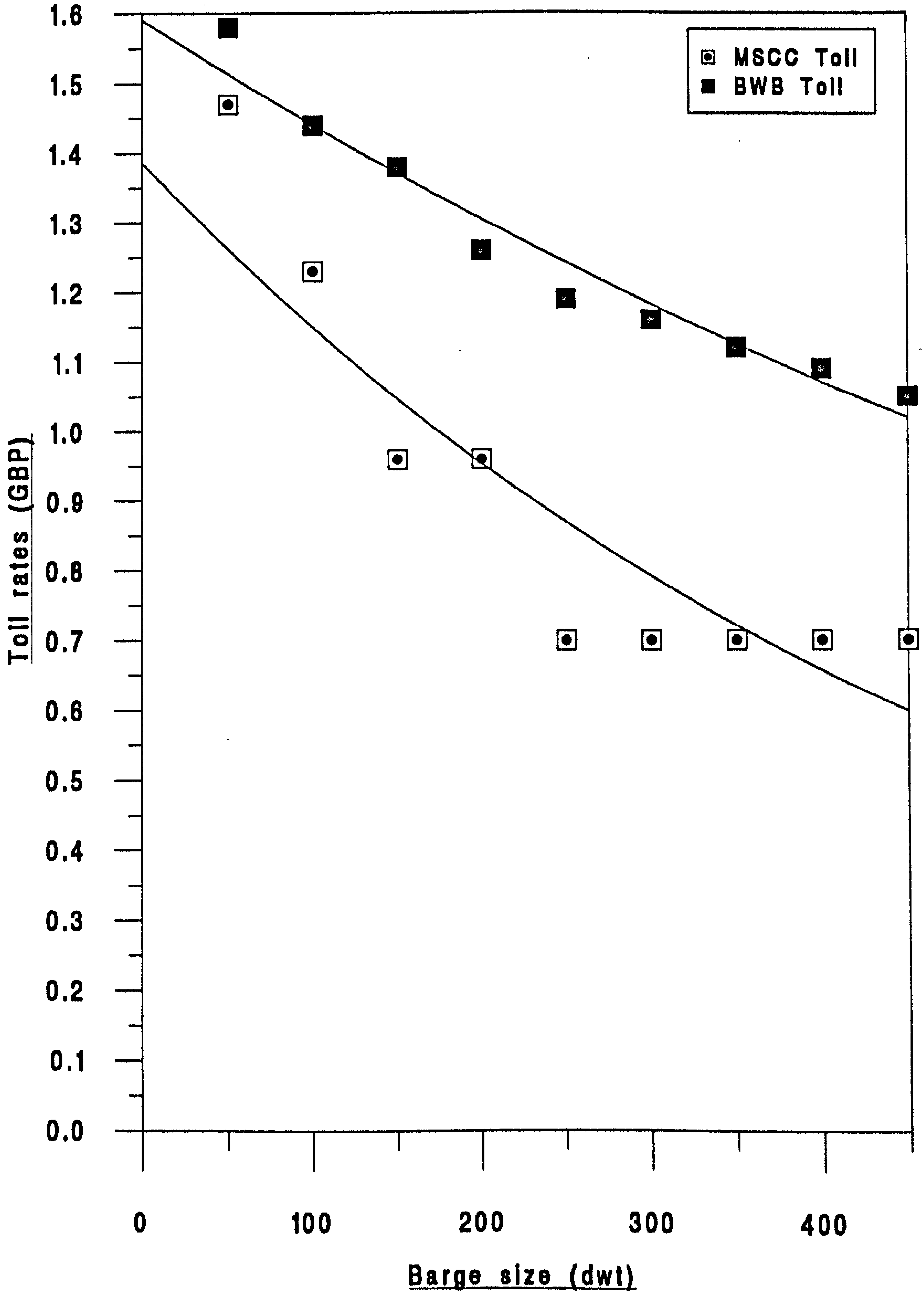
Table 4.12: Toll rates per vessel dwt

A decision to charge a toll depend on many aspect of the investment. Normally, for a public waterway, the toll may not be charged (to attract the use of waterways to relieve road congestion). Private waterway owners such as the Manchester Ship Canal Company (MSCC) for instance needed to cover the capital investment costs by imposing tolls at an appropriate rate. A graph in figure 4.6 shows the toll dues imposed by the MSCC in comparison to British Waterways toll rates, y as the function of the vessel size in dwt, x. It is appropriate to use the rates in the model at preliminary stage of the feasibility study as follows;

MSCC toll rate, $y = 1.39 * 10^{(-0.00081x)}$ $(R^2 = 0.81)$

BWB toll rate, $y = 1.59 * 10^{(-0.00043x)}$ $(R^2 = 0.96)$

Figure 4.6: Toll rates Vs vessel size (dwt)



4.6.3 Port Costs

Port charges comprise expenses such as pilotage (if necessary), anchorage/mooring, berthing/wharfage, port dues, light dues depending on terminal or port charging procedures. Charges are based on either the type of craft/vessel (per dwt/nrt) calling at port or the type of cargo handled (per tonne). In general, it is estimated at 8-12 percent of the total costs [*15*]. Buxton [3] suggested that great accuracy is not necessary at the feasibility study stage of port costs.

Port related charges represent a major component in voyage cost and include a wide range of fees levied against the vessel and/or cargo for the use of the facilities and services provided by the port [7]. The charges are divided into two general categories. Firstly the port dues, levied for the general use of port facilities. Secondly, service charge covers the services that the uses in port including pilotage, towage and cargo handling.

The charges vary from port to port. The shipowner or operator can do little about this cost but alternative ports remain an option. However, a faster turnaround time due to reliable service may reduce the port charges and improve vessel productivity in long term operation. A Study by Sen [*21*] expressed the port charges based on cargo tonnage while Buxton [28] expressed the charges based on cargo net or gross tonnage per port call.

However, a study by ESCAP [*19*] provides a much more comprehensive data as general guidelines on charges for dry bulk and container vessel which will be appropriately adopted in the model where applicable. This data based in 1989 prices was converted to Ringgit Malaysia (RM) based on 1995 prices for the application.

4.6.4 Cargo handling costs in port

The cost of loading and discharging cargo represents a significant component in the total costs equation [7]. A traditional liner for instance, can easily spend half of its time in port. The relationship of this cost simply represented by the sum of loading and discharging cost. The level of these costs may be reduced by investment in improved ship design to facilitate rapid cargo handling operation.

Loading and unloading in a port with low labour costs (especially in the Far East), may cost as little as GBP4 - 5 per tonne, to as much as GBP30 - 40 per tonne in the North America. A realistic average to use depends on the range of ports served and the range of the cargo carried. A container can vary between GBP50 - 120 ship to quay or vice versa. Bulk cargo handling costs however, accounted for GBP0.3 to GBP1 per tonne while unloading accounted for GBP1 - 2 per tonne, all based on 1990 prices [*3*].

Similarly, a study by ESCAP [*19*] provides a much more comprehensive data as general guidelines on charges for cargo handling for dry bulk and container which will be appropriately adopted in the model where applicable. This data based in 1989 prices was converted to Ringgit Malaysia (RM) based on 1995 prices for application.

4.7 Freight charges

Required freight rates (RFR) is a rate needed per unit of cargo to cover the minimum annual vessel operating to a break-even costs. Thus, freight rates is simply a RFR plus some percentages of reasonable profit required for the cargo movement. It is useful when comparing alternative ship sizes, as single freight rate cannot be applied to all ship sizes hence,

$$\text{RFR (per tonne)} = \frac{\text{Annual capital costs + Annual operating costs}}{\text{Annual cargo volume (tonnes)}}$$

The freight rates charged by vessel operators typically depend on route and type of commodity [*1*]. The rate is usually formulated by taking the average costs per tonne-kilometre as a function of commodity type, and multiplying by the distance traveled. A typical freight rate for bulk cargo was GBP15 per tonne based on 1990 prices [*3*]. Freight rates are regularly published in the shipping press, shipbrokers' reports, etc.

4.8 Discussion and summary

The operating costs of specific vessels vary according to its portfolio of movement. Furthermore, it must be noted that the total operating costs are influenced by the assumptions that were established concerning the operating hours. The cost per tonne varies according to upstream and downstream movement, navigation area, distance of movement, rate of capacity utilisation and waterways channel characteristics.

It can be summarised that craft/vessel/ship costs are often difficult to estimate. Accurate information on vessel costs are confidential to most shipbuilders or even shipowners. It would be an added advantage if access to the data required can be gained for the analysis. Although some information is available from various individuals, learned journals and publications, very little relates to specifically inland waterway vessels which are required for the model in this study.

Similarly, accurate ship operating cost model experienced similar setbacks where most shipowners are reluctant to provide the information. Although a number of vessel operating data are available, they are insufficient and do not reflect the inland waterway vessel operation. Equations from a number of past studies are also available, but require an adjustment to the present (1995) prices. These equations can be used when necessary and wherever appropriate. The reason being that most of the equations reflected a bigger scale of vessel sizes and different operating conditions.

Comparison between the costs of inland waterway transport with other modes is difficult due to a complexity in their charging practices, thus not included in the scope of this study. In addition, the total costs of moving goods from place of origin to place of destination vary substantially between or within the systems. Although it has not been proved in this study, a number of past studies however has proved that the waterway transport is much cheaper that its competitors based on the facts discussed earlier [*6*].

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CHAPTER 5

Inland waterways terminal cost model

CHAPTER FIVE

INLAND WATERWAYS TERMINAL COST MODEL

5.1 Introduction

The physical development of a port or terminal is a major investment, which is complex and requires a specialised study. For a project feasibility study, the user can avoid a number of detailed and lengthy calculations by using various general planning factors as discussed in the preceding sections [*1*]. For a more thorough analysis, the user can use the full model and, if necessary, include some necessary expansions. In addition, a selected portion of the model may be used independently for specific analysis such as berth occupancy, cargo handling equipment requirement, etc.

A general flowchart indicating the overall model plan is shown in figure 5.1. While the model provides a continuous logic all the way from cargo projection to economic analysis, selected portions of the planning model may be used independently for special application. However, for overall project analysis, it is recommended to maintain the integrity of the overall planning strategies. A comprehensive list of planning phases is as follows:-

i. Cargo: tonnes for dry bulk, and TEU for container per annum
ii. Ship working productivity and ship dimensions
iii. Shipping profile:Tonnage of cargo to be moved on each ship
iv. Berth occupancy or berth requirement
v. Ship waiting time and berth-time costs
vi. Terminal revenues
vii. Terminal requirement and costs
viii. Cargo handling equipment requirement and costs
ix. Operating costs
x. Maintenance costs

Figure 5.1: Inland terminal cost model flowchart

5.2: Inland terminal planning characteristics

Inland terminals have been developed as part of the overall development of successful inland waterway systems [*3*]. These have been accomplished by both private enterprises, port authorities or through joint ventures. It is important to ensure the correct allocation of land for the industrial base alongside the waterways. A major benefit is that the demands for heavy road traffic to serve the industry can be diminished with consequent improvement to amenities.

Planning for a new terminal or an extension to an existing one differ in the planning strategy from one another [*4*]. In the case of a new inland port development along the existing or proposed waterway, the justification of the investment can be determined through several assessments. Physical characteristics and limitations, growth of traffic, technological changes and managerial expertise all influence the terminal planning and investment decision making processes.

The cost of a port can be categorised into two fundamental groups. Firstly it is a fixed cost that is independent of throughput and covers mainly the capital investment cost [*4*]. This includes the capital costs of quays, sheds, administration buildings, warehouses, etc. [*5*]. Secondly is the variable cost that depends on the level of terminal operation. This includes labour, fuel, electricity, maintenance costs, etc. As the tonnage handled at terminal increases, so the fixed component, when expressed as cost per tonne, decreases [*5*]. Figure 5.2 illustrates the relationship between port cost per tonne in relation to increasing traffic volume.

5.2.1 Costs and benefits

Costs are the total costs of fixed facilities and equipment, their operation and maintenance, less all domestic customs duties and taxes associated to the project. Capital costs are the costs of construction and equipment, as well as the costs of replacement required during the life of the project. Normally the replacement will only be needed for port operating equipment. Depreciation and interest costs should not be included as the full initial costs

Figure 5.2: Port Costs Per Tonne of Annual Cargo Throughput

and replacement costs are capital costs. Operating and maintenance costs are the costs of staff, fuel, electric power, spare parts and other supplies for additional facilities.

In general, all benefits result from avoidance or reduction of costs, which would be incurred if the project in question is not implemented. It is important to attempt to determine who the actual beneficiaries are. However, it is much simpler to identify the categories of benefit, rather than the actual beneficiaries directly, and these are listed below [6].

i. Reduction of waiting and service time for ships/cargoes to increase port revenue
ii. Reduction of cargo handling costs to attract more traffic
iii. Reduction of cargo damage/losses result in lower insurance rates
iv. Diversion of cargo from other ports to generate more traffic
v. Recovery costs for the development to generate greater overall profit

The main economic benefit of the investment is expected to be the ability of the terminal to reduce terminal time, hence ship-turnaround time. This is often the determining factor in setting the optimum economic benefit [5]. There are two aspects of considerations in making the investment decisions. Firstly, the immediate benefit from the investment to the user of the terminal and, in the long run, to the terminal authority and country. Secondly, the practical implications of the average ship waiting time as the result of the investment.

5.3 Inland terminal waterfront facility

For cargo handling operation, some form of wharf is required. It may be in the form of a very simple structure possibly without fixed buildings or plant, to a group of basins off the navigation channel, with warehousing and the distribution facilities as well as mechanical handling equipment. In a typical riverine developing country, a majority of wharf may be a simple wooden staging, either marginal to the river bank, a wharf or quay, or projecting from the bank in to the river, a pier, cater for a relatively small volume of cargo throughput [7]. The level of development of an inland terminal clearly depends on the level of cargo throughput and size of barge servicing the terminal area.

On some riverine developing country like China for instance, The change in water level is huge making it necessary to design the wharf which could accommodate such changes. In places where cargo volume increase rapidly, sophisticated cargo handling methods were necessary. It is desirable to develop wharf that allow unhindered use of terminal facilities at all levels of water. According to Hilling [7], there are five main types of wharf (Figure 5.3) that need to be considered when planning for wharf development particularly in developing countries which clearly has costs implication. They are;

i. *Vertical*

   Flexible for bulk cargo and multi purpose terminal.

ii. *Inclined*

   Most common type. Cargo handling could be a problem if the slopes are too steep.

iii. *Floating*

   Automatically adjusts to changing water level and more efficient.

iv. *Double step*

   Used in an area where water level changes are huge.

v. *Dredged/dock basin*

   Used in an area of heavy rain to ensure no disruption to cargo handling operation.

It is important to note that in any terminal development, engineering cost estimates and subsequent investment decisions must be based on detailed civil engineering studies by the appropriate authority [5]. The development potential of several alternatives, the costs of engineering proposals which meet the water and land area, need broad estimates to provide the basis for investment appraisal and the project decision. Although broad, the estimate should be as realistic as possible.

5.3.1 New and existing sites

The need to construct or develop an inland terminal arises as a result of the new development of a new waterway or a section of it or the growth in traffic which require an extension on existing facilities [8]. In most of the developed countries, the inland waterway

Figure 5.3: Chinese river quay design

systems have been used for a long time with established terminal sites. In fact, the origin of many big cities along the waterways resulted from the existence of inland terminals. If a new site is to be developed, it is important to consider its relation to industrial locations.

The fundamental consideration which guides the terminal selection process is to minimise the economic and social cost of terminal services to be provided. In a market driven situation however, the consideration is based on the commercial consideration i.e. maximise profitability. Another consideration is political, usually relating to regional development, including environmental considerations.

A decision making process for terminal sites is tedious and time consuming [8]. This effort can be quite costly if there is a need to review a large number of sites. Consequently, the selection process should be both comprehensive and economical. A logical approach is to divide the process into several sequential stages, whereby the number of sites and the amount of information required per site are evaluated.

5.3.2 Channel-area requirements

The improvement to, or construction of, a new channel is inter-related to the required cargo and barge capacity moving along the channel approaching the terminal area for cargo handling operation. It is basically involved with several stages of works such as site investigation, conceptual design of channel, width of channel, depth of channel, channel alignment, mooring structures, navigational etc.

The inland terminal development is almost identical in part to the construction or improvement of the waterway track channel. Works such as dredging, reclamation, bank protection and sometimes embankment and bank retaining wall would be required. Hence, a number of equations in the waterway track model can be applied to estimate the construction cost for terminal development.

5.4 Inland terminal infrastructure design requirement

Inland terminals tend to be classified under several types and categories. However, this study will consider only bulk cargo and container terminals as outlined in the scope of the study. Branch [9], suggests a number of factors in relation to terminal requirement. This includes the type and size of vessel using the berth, availability of land, depth of water serving the berth, type/classification of cargo to be handled, volume of cargo to be handled, inland transport system serving the berth and the nature of cargo handling equipment

Terminal layout designs for the present study will consider major land based facilities or structures including handling equipment. This includes the dredging if necessary, quay wall or jetty, transit sheds, warehouses, administration and customs buildings. The cargoes which are stored in terminal yard facilities differ greatly in their sensitivity to moisture and changes in temperature [9] and should be taken into consideration.

5.4.1 Terminal requirement and costs

In a feasibility study of a proposed new terminal system design, there should be an idea of the land availability, general lay-out, number, type and dimension of berth required. The requirement for facilities and equipment and the costs to be borne can be estimated using a model developed in this study. ESCAP has provided the construction cost data for deep sea container and bulk terminals as shown in tables 5.1 and table 5.2. However, the application of the data in the model is only considered additionally when necessary.

Table 5.1: Container terminal construction costs (USD 1988 prices)

Table 5.2:: Bulk terminal construction costs (USD 1988 prices)

The construction cost estimates should be carried out in considerable detail for major works. This ensures that the appropriate cost factor can be applied to estimate annual maintenance costs for the different facilities. Although a data base from the ESCAP study is reliable for most of the estimates, it is however felt that it would be significant to associate this with data from other studies too. The maintenance cost factors from a study by National Port Council (NPC) [*11*] are shown in table 5.3.

Table 5.3: Maintenance cost planning factors (annual maintenance cost as % of replacement cost)

A model for dredging and construction costs for quay has been established in earlier chapter three and may be applied in the case of the terminal development when necessary. However, the unit requirement and construction costs for transit sheds and warehouses will be based on a study by the UK National Planning Council (NPC) [*12*].

i. <u>*Dredging*</u>

(a) *Capital dredging costs*

A capital dredging cost is an initial cost of deepening the harbour bed and its approaches, if necessary. The cost of the work is the total volume of dredged material multiplied by the unit cost per cubic metre. The dredging cost is extracted from the Spon's study [*13*] as shown in table 3.6 of chapter 3.

(b) *Maintenance dredging costs*

Maintenance dredging costs include the operating costs of the dredging fleet. This allows the user to estimate the cost of operating dredging equipment separately and then sum them up [*14*]. A typical 600hp dredging barge and equipment (owned by terminal or waterway authorities incurs a cost of USD 282.2 per day. Likewise, a 1,200hp incur a cost of USD 548.00 per day both based on 1986 prices [*15*].

ii. <u>*Terminal requirement and costs*</u>

Factors affecting terminal layout are mainly related to the operation of ships and equipment. However, under certain circumstances, storage area requirement is also an important consideration [*16*]. A terminal should always provide sufficient space for consolidation of cargo. A reasonably good road and rail connection should also be provided to ensure terminal efficiency. A typical small modern coastal or inland terminal is shown in figure 5.4.

Discharge could be direct to land transport, although this could result in congestion and delay [*17*]. For a LO/LO operation, direct handling should be avoided in favour of the use of transit sheds and storage facilities in order to shorten port time per visit. This can lead to an increase of vessel annual turnaround time i.e. vessel productivity. The terminal land area requirement planning should consider this aspect too.

Figure 5.4: Typical small modern coastal or inland terminal

Data from the following table 5.4 for dry bulk terminal requirement was analysed resulting in a linear relationship of $y = 0.08x$ where y is the required terminal area as a function of cargo throughput, x. Nevertheless, this relationship may differ from one port to another depending on handling equipment productivity and method of handling operation, direct or indirect transfer.

Table 5.4: Bulk terminal costs (throughput of 250,000 tonnes/annum) and
Container terminal costs (throughput of 50,000 containers/annum)

Similarly, data for container terminal area requirement as shown in table 5.5 was analysed resulting in a linear equation of $y = 2.073 + 0.89x$ (with a correlation coefficient, R^2 of 0.51) where y is terminal area requirement as a function of cargo throughput, x in TEU/annum. The graphical output of the analysis is shown in figure 5.5. For both type of terminals, the land unit cost of GBP 25 per m^2 based on 1995 prices is used in the model [*18*].

Figure 5.5: Terminal area requirement

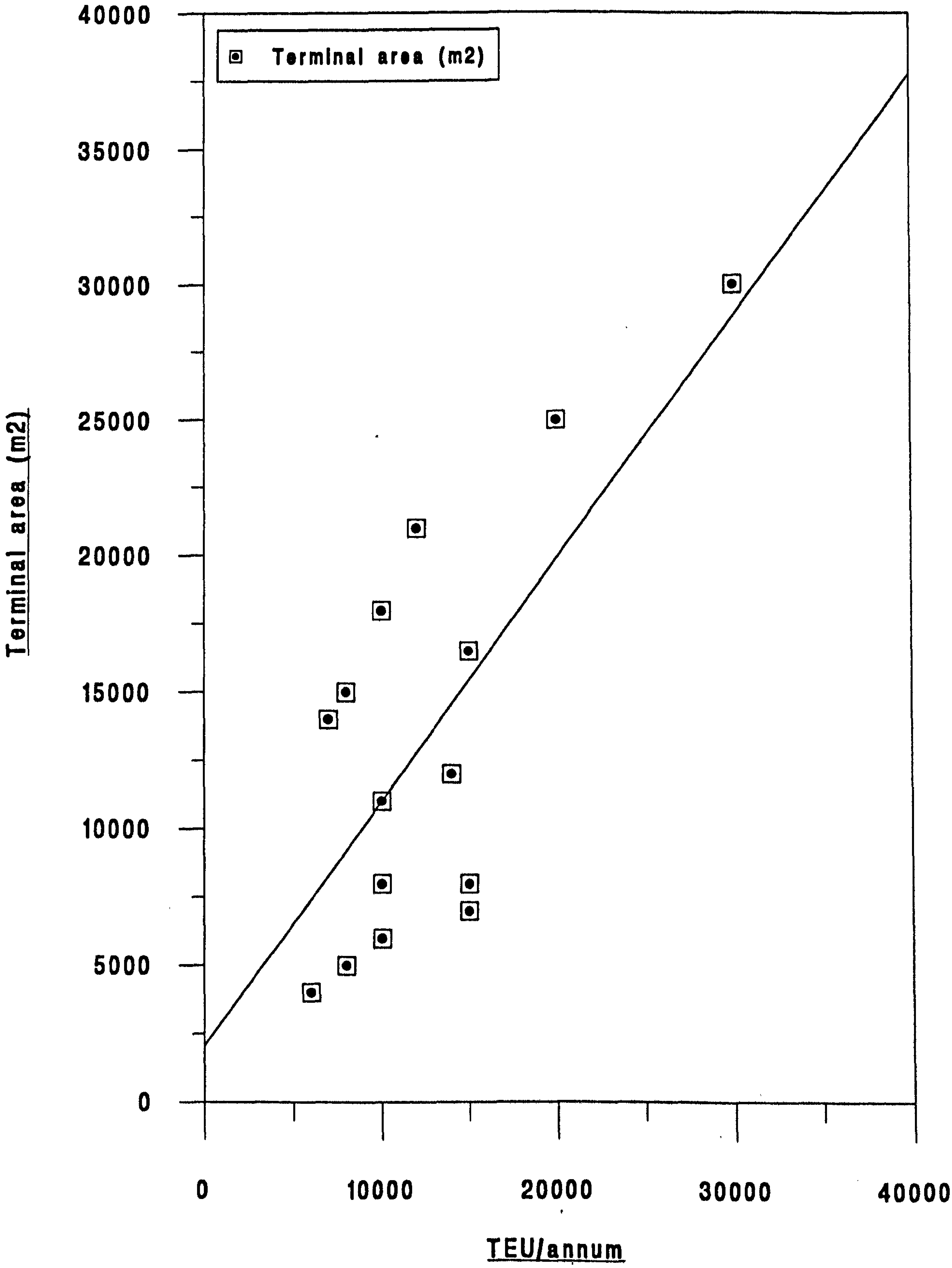


Table 5.5: Rhine container terminal area provision

iii. *Berth or quay requirement and costs*

There are two basic ship berthing facilities. One is called finger pier or quay and secondly called wharf [*20*]. A pier is a structure extending outward at an angle from the shore into navigable waters. A wharf is a structure extending parallel to the shore line. A typical wharf, classified as open or solid filled type is shown in figure 5.6.

The length of berth required varies with the size of vessels. A typical vessel of 1,500 dwt for instance, requires a berth length of 75 to 80 metres [*16*]. An allowance of berth length between 10 to 20 metres is recommended for normal berthing operation. In Japan, a generalised figure of 1,000 tonnes per metre of berth length per annum is employed for a rough estimate for berth requirement [*21*]. In Rotterdam however, the figures are estimated at 400 containers per metre of quay wall length per year, an average of 1,750 tonnes for

Figure 5.6: A typical type of quay structure

multi-purpose berth and 700 tonnes for a general cargo [22] where *y* is the required quay length in metre as a function of cargo throughput *x*, tonnes/annum.

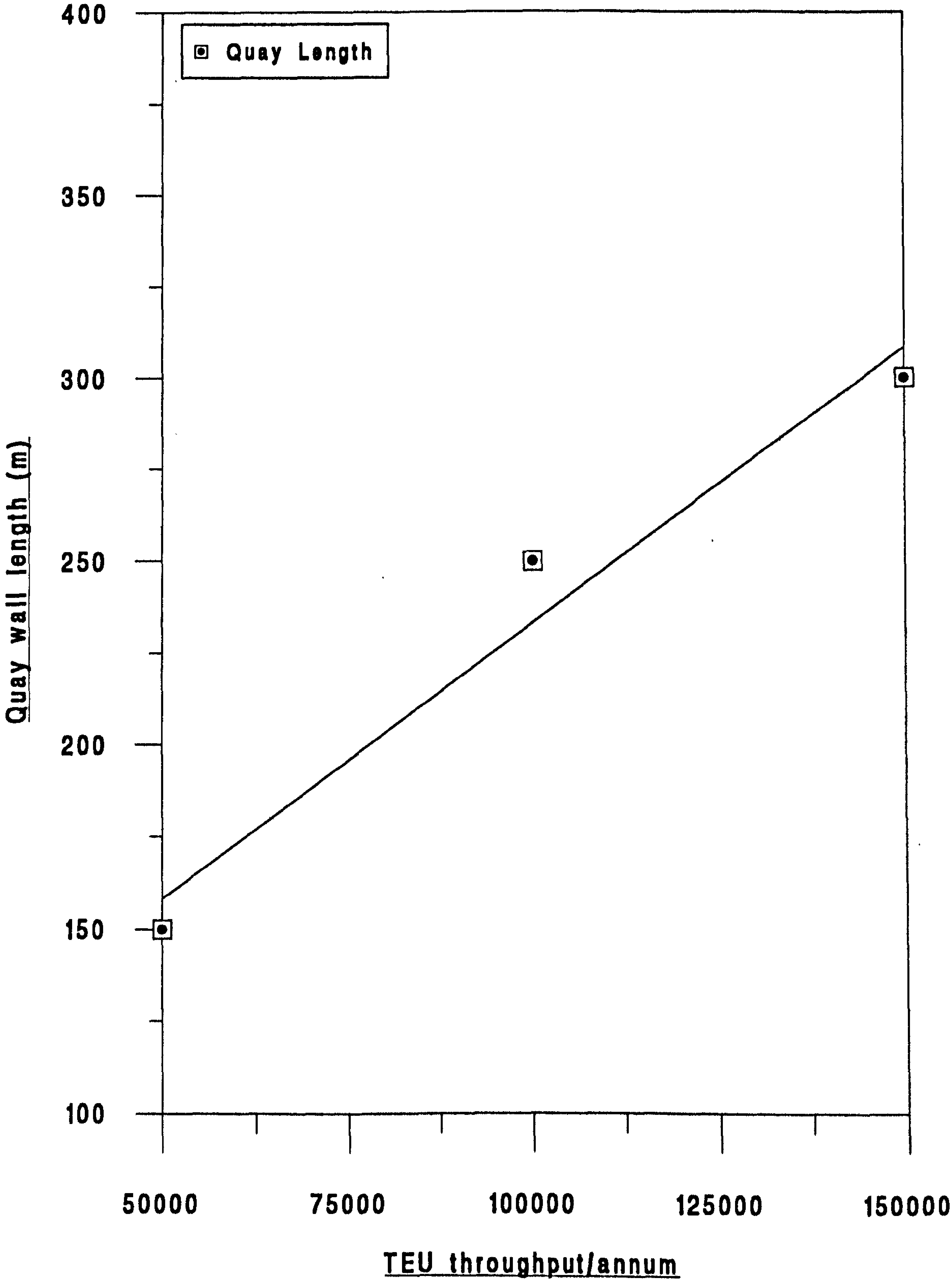
In the UK, the estimates from the Manchester Ship Canal Company (MSCC) for quay wall, transit shed and administration building requirements for both container and bulk terminals are shown in table 5.6, as general guidelines. The analysis produced a graph of the quay length requirement for container terminal as shown in the following figure 5.7 giving an equation of $y = 83.3 + 0.0015x$ (R^2 0.96) where *y* is the required quay length in metre as a function of cargo throughput *x*, TEUs/annum. The cost of constructing the quay wall or berth per metre length was obtained from a data supplied by MSCC being GBP10,000 per metre in 1995 prices as shown in appendix 5.

Table 5.6: Container and bulk terminal requirement for quay, transit shed, warehouse and administration building

iv. Transit shed requirement and cost

The decision on the type and size of transit shed required depends on the type, volume and the properties of the material to be stored and the cargo handling equipment in operation. Cargoes carried on open barges can be stored in an open yard. Coal, ore, sand and gravel, scrap and to some extent iron steel and lumber can be stored outdoor while the rest requires weather protection. In some cases, indoor cargoes can also be stored outdoor by using waterproof covers.

Figure 5.7: TEU/annum Vs quay wall requirement



Indirect cargo handling operation gives rise to a need for transit sheds [*17*]. An inexpensive one-storey shed is the most popular [*16*]. The number of doors depend on the length of shed. The shed can have a height of approximately 6 metres and above. When sheds with more than one floor are built, it should be possible to lift the cargo by using a standard indoor cranes. A typical design of transit shed is shown in figure 5.8.

Data for dry bulk transit shed requirement in table 5.4 was analysed resulting in a linear relationship of $\underline{y = 0.04x}$ where y is the required area in m^2 as a function of cargo throughput in x, in tonnes/annum [*16*]. For container transit shed requirement, data in table 5.6 has generated a linear relationship of $\underline{y = 0.4x}$ where y is the required area in m^2 as a function of container throughput x, in TEUs/annum. A unit cost of providing the shed is also obtained from data in table 5.4 i.e. GBP150/m^2 in 1995 prices and used in the model.

v. *Warehouses requirement and costs*

Warehouses should be located away from the berth apron to avoid congestion and terminal operation [*16*]. An estimate by MSCC (see table 5.7) for warehouse requirement is 30,000m^2 for a typical 1,000,000 tonnes throughput of bulk cargo giving a linear relationship of $\underline{y = 0.03x}$ where y is the required warehouse area (m^2) as a function of cargo throughput x, in tonnes/year [23]. A unit cost for the provision of the warehouses is on average at GBP 182.50/m^2 in 1995 prices [*13*]. A typical design of warehouse is shown in figure 5.9.

vi. *Administration building*

Administration building requirement is not very critical. It is not influenced by cargo throughput per year. Data obtained from MSCC [23] as shown in table 5.7 indicates that the average administration building requirement is 300m^2 regardless of cargo throughput. The unit construction cost however, is GBP 775/m^2 based on 1995 prices [*13*].

Figure 5.8: A typical type. of transit sheds

Figure 5.9: A typical type of warehouse design

5.4.2 Terminal maintenance costs

With the exception of maintenance dredging, the maintenance costs are based on annual maintenance cost factors as a percentage of cumulative initial investment costs by type of major port or terminal construction work. The following table 5.7 shows the typical maintenance costs per annum for container and bulk terminals respectively.

Table 5.7: Inland terminals maintenance factors

5.5 Bulk cargo handling equipment requirement

The terminals are usually classified by their type of cargo handling activities. A common division of cargoes handled by inland ports depend on their operational forms. In general, there are numerous cargo groups representing general, bulk, container, etc. Hence cargo handling equipment can be categorised by several distinct groups. However, the focus of this work as outlined in the scope of study are dry bulk cargo and container terminals.

Bulk cargoes such grain, ore, coal etc. are composed of a multitude of small and homogeneous units. Their main handling methods are based on conveyors. The volume handled by bulk terminals justifies the design of the entire terminal as one big cargo handling equipment. This is to ensure efficient flow of cargo and to optimise investment in equipment. In many terminals, the handling equipment are already physically connected together through a network of conveyors and elevators [8].

Most bulk terminals are single commodity terminal. The concentration on one type of commodity reflects the fact that each commodity has its own properties which require specialised machinery and equipment. However, terminals may be designed for multi purpose handling operation. An example is, a coal terminal can also handle grain and vice versa. A typical cost for bulk cargo handling equipment in the UK, estimated by Garratt [18] is shown in earlier table 5.7.

In general, cargo handling equipment (or multi purpose equipment) geared towards low handling rates for typical small volume terminals requires one of two equipment, as follows.

i. *Grab crane:*

Grabs can be attached to any crane system but commonly they are used with gantry crane. A gantry crane is however, usually limited to the unloading operation only. A typical grab crane with a handling capacity of 100t/hour was estimated by ABP [24] to cost GBP 0.2 million compared to GBP 90,000 for a handling capacity of 40t/hour quoted by Transport and Road Research Laboratory (TRRL) [25] in 1995 prices.

ii. *Hopper truck and front loader*

These machines are probably the most basic machines utilised in batch handling of bulk cargo. A simple inland waterway terminal may only require hopper truck.

Based on a specialised bulk handling operation, this equipment is geared toward the higher volume terminals up to several million tonnes a year. There is a wide range of materials included the bulk group based on basic characteristics such as density, size of particles and flowability. A continuous bulk handling system tends to service one type of commodity only. Though different in detail, a few basic components can be identified in most of the terminals. These include:

i. *Belt conveyors:*

Used mainly for the horizontal movement of cargo. An estimated cost of GBP 362,000 at 1995 prices for a capacity of 300t/hour [25].

ii. *Elevators:*

Used mainly for the vertical movement of cargo.

iii. *Slopes, chutes and dumps:*

Used by gravity lowering or dumping

iv. *Bucket wheel:*

Use to dig up cargo for feeding the other machines

Belt conveyors are probably the most common equipment for bulk cargo handling. The main advantage of this machine is that it is the lowest cost alternative for horizontal movement of cargo. The main disadvantages however, are that they provide point to point connection and in most designs, require a fixed structure for support. The handling capacity of the conveyor varies according to a number of considerations such as the cargo annual throughput, speed, type of cargo, etc.

5.5.1 Bulk handling equipment requirement and costs

Bulk terminals are either conventional type or a less costly structure consisting of two berthing dolphins, mooring dolphins and a stand alone handling platform [26]. The cost of providing the bulk cargo handling equipment varies with the type of cargo and annual throughput.

For a berth with quay-side handling equipment, the capacity and type of equipment should be determined to yield a quick vessel service time for a new design of high-volume bulk capacities. Equipment capacity is usually specified in m^3/hour or tonnes/hour. Planning factors for tonnes/hour can be obtained from the UNCTAD Port Planning handbook [5]. The following pages list typical types of bulk handling equipment and the financial factors which must be considered at the planning stage.

i. *Loaders/unloaders*

Type, quantities and unit cost of equipment should be known including the major replacement costs. The replacement should include replacement of conveyors, motor drives, grab buckets and other items which are not covered by typical maintenance schemes.

ii. *Horizontal transport*

This includes conveyor systems between quay and storage. The cost is estimated by the length of the belt and the effective capacity required.

iii. *Stackers/reclaimers*

For high volume loading operations, the capacity of reclaimers is often the limiting factor and should be adequately planned such that the effective capacity of the reclaimers can match the peak capacity of the loaders [26]. Low volume facilities often use the combination of stacker/reclaimer. Table 5.8 shows the rated capacity and costs for stackers and reclaimers including other dry bulk handling equipment.

Table 5.8: Bulk handling equipment planning factors and costs

Unloaders	**Rated Capacity (tonne/hour)-50%**	**Approx. USD 1989 prices**
Grabs		
overhead type	250	3,400
revolving type	250	1,600-3,000
mobile port tower	250	2,300
Continuous unloader		
bucket	500	4,000-5,300
scraper chain	250	1,800-3,100
screw digger	250	2,500
Pneumatic System		
elevator	100	2,000
portable unit	25	500
Loaders	**Rated Capacity (tonne/hour)-80%**	**Approx. USD 1989 prices**
Continuous		
travelling	800	1,800-2,100
slewing	800	2,500
fixed	400	1,500
Horizontal Transport		
belt conveyor 800mm	480	1,360
1000mm	720	1,800
1200mm	960	2,400
Stacker/reclaimers		
stackers	800	1,200-1,600
reclaimers	500	2,500-3,200

Notes: The percentages of rated capacities for equipment were estimated by ESCAP [26]

5.5.2 *Handling equipment maintenance*

The annual maintenance cost can be considered to be of some percentages of capital costs for all dry bulk cargo handling equipment in service [*26*]. This maintenance does not include the replacement costs of major system (conveyor belt, drive motor, grab bucket, etc.). Table 5.9 shows a typical bulk cargo handling equipment maintenance.

Table 5.9: Bulk cargo handling equipment maintenance costs

5.5.3 *Manpower requirements and costs*

Terminal manpower includes its management, engineering, harbour service, security and general services. A typical manpower requirement for a moderate size of an inland waterway terminal is estimated at approximately 70 staff of all levels [*26*]. Garratt [*18*] on the other hand, estimated the approximate manpower costs of GBP 200,000 per annum for a cargo throughput of 250,000 tonnes. This gives a relationship of GBP 0.8/tonne of cargo throughput per annum.

5.5.4 *Operating costs*

Operating costs are unique to the particular port and scope of port management functions. Reasonable assumptions will have to be established from a number of sources. A study by ESCAP [*30*] estimated the operating costs of approximately 38% of total capital costs per year.

5.6 Container handling equipment requirement

A knowledge of characteristics of different types of container equipment is important. The problem of equipment management in developing countries is becoming more serious [*28*]. Often the wrong type of equipment is purchased. There is an imbalance of mix of units causing operating and maintenance problems. Container (LO/LO) terminals require a quay, paved area for container stacking and manoeuvring and servicing inland haulage and some administrative and customs buildings. There is however some variety in their modes of operation. Container handling operations can be distinguished by four major systems as follows [*29*]:

i. *The gantry crane and straddle carrier system*

This system using a straddle carrier (GBP 150,000 each in 1980) pick up containers on the quay, carry them to stacking areas [*29*]. Straddle carriers have developed reputations for being unreliable and a large number of spare carriers are normally kept in service. A typical designs of gantry crane and straddle carrier are shown in figure 5.10.

ii. *The gantry and park crane system*

The gantry crane directly loads a tractor and trailer unit (GBP 25,000 each in 1980) which travels to stacking area to be handled by a park crane (GBP 500,000 each in 1980). The tractor or trailer units can be dispensed with if the stack is close enough to the gantry crane. The advantage of this system is that the process of lifting and carrying are separated thereby economising the capital outlay.

iii. *The all purpose gantry system*

Suitable for medium level container throughput. The number of containers is small enough to be stacked on the quay within reach of a single ship to shore gantry crane (GBP 1.5 million in 1980) [*29*]. It eliminates the need for park cranes or straddle carriers.

Figure 5.10: A typical gantry crane (top) and straddle carrier (bottom)

iv. *The non-gantry system*

30 to 35 tonne Scotch Derricks have been found to be capable of handling of up to 15 to 20 units per hour (60%-80% of gantry cranes). Limited reach will normally mean that other equipment is required for stack access and inland haulage.

In relation to the above four systems, Champion [*28*] indicates that there are several other systems for container handling. These systems are chassis, tractor-trailer, straddle carrier direct, rubber-tyred gantry and finally the combination system of all mentioned. However, due to their complicated operation, they will not be included in the study. A rather simpler method based on data obtained through personal communications from various sources has been considered and included.

Terminal operators may decide whether to operate his own terminal and equipment or use a common user facility within the same port. This alternative will largely be determined by the expected traffic throughput. Exclusive terminal rights provide dual attraction to the barge operator. Firstly, the potential of queuing delays can be avoided and secondly, the benefit of economies of scale can be obtained.

5.6.1 Container handling equipment requirement and costs

The calculation for equipment requirement will be obtained from ESCAP study [*1*] & [*26*]. These calculations based on the cargo projections and the productivity level assumptions for major equipment (quay cranes, straddle carriers, rubber-tyred gantries, rail-mounted gantries, tractors/trailers, fork-lift trucks) as follows:

i. *Quay-crane (QC)*

The annual throughput of a quay crane depends on its productivity and the level of berth occupancy [*1*]. Port operators often use an assumption of around 70,000 -75,000 boxes per crane per year for three shifts quay crane operations. For example;

Container throughput/year = (Box/hour) * (Hours/day) * (Days/year) * AF x * CUF

where:
AF is the crane availability factor estimated by ESCAP [1] at 0.95
CUF is the crane utilisation factor estimated by ESCAP [1] at 0.45, hence

$$QC\ required = \frac{\text{Container throughput per year}}{\text{Quay crane standard annual throughput}}$$

ii. *Straddle carriers required/quay crane (SC)*

For a standard operation, a typical maximum annual lift is around 35,000 lifts/year [1] with 6 straddle carrier (SC) units required per quay crane giving a relationship of;

SC required = QC required x (straddle carriers required per QC)

iii. *Rubber-tyred gantries (RTG) required/quay crane*

For a standard operation, a typical 3 units per quay crane are required per annum with a lifts of around 65,000 lifts per year [1] giving a relationship of:

RTG required = QC required x (rubber-tyred gantries required per QC)

iv. *Rail-mounted gantries (RMG) required/quay crane*

For a standard operation, a typical 3 units are required per two quay cranes. This is equivalent of around 130,000 lifts per year [1] (or a factor of 1.5 per quay crane) giving a relationship of:

RMG required = QC required x (Rail-mounted gantries required per QC)

v. *Tractors/trailers*

a. Ship-side: For straddle carrier relay, RTG and RMG systems, 3-5 units per quay crane are required. For a straddle carrier direct system, no units are required.
b. Container Freight Station (CFS) area: Tractors and trailers for CFS based on total CFS throughput. A typical 2,400TEU per year [1] for 1 tractor and 600TEU/year for 1 trailer giving a relationship of:

Tractors = (QC required) x (ship-side tractors per QC)

$$Trailers = \frac{\text{Total CFS throughput in TEU}}{\text{CFS throughput in TEU per tractor}}$$

vi. *CFS Forklifts trucks (FLT)*

The requirement of one FLT for 1,200TEU per year [*1*] through the is assumed giving a relationship of: $FLT = \frac{\text{Total CFS throughput in TEU}}{\text{CFS throughput in TEU per FLT}}$

The following table 5.10 provides general planning factors and capital cost data for various types of equipment obtained from ESCAP [*1*] However, for simplification purposes, the earlier data in tables 5.8 will be used in the model to determine the capital acquisition costs of container handling equipment.

Table 5.10: Container handling equipment capital costs

5.6.2 Handling equipment maintenance

The annual maintenance cost is calculated as a percentage of initial capital costs for all container handling equipment in service. This maintenance does not include the replacement costs of whole equipment such as quay crane, straddle carrier, rubber-tyred gantry, etc. Table 5.11 shows the container handling equipment maintenance per annum.

Table 5.11: Container handling equipment maintenance costs

5.6.3 Manpower requirements

Total terminal manpower includes its management, engineering, harbour service, security and general services, the container terminal operations and any other facilities. A typical manpower requirement for a moderate size of a new inland waterway terminal is estimated at approximately 90 staff of all levels [*1*].

5.6.4 Operating costs

Operating costs vary to the particular port and scope of port management functions. A study by ESCAP [*1*] estimated annual operating costs of approximately 35% of capital costs per annum. Typically, the annual operating costs for container handling equipment obtained from a study by Champion [*28*] are shown in table 5.12.

Table 5.12: Annual operating costs (USD'000 Sept 1987 prices)

5.7 Discussion and summary

Planning the development of port or terminal system is not straightforward subject. It involves many factors and strategies. Although the cargo type and projected annual volume may be the major determining factors, the overall level of investment and management system may vary significantly between terminals.

It has been shown that a simplified model may be derived based on past experience. The elements may be bound together to provide guidelines and methodologies to assist in dealing with a project's financial assessment. This model has been formulated from a number of typical real life examples from the competitive port and terminal sectors. It is hoped that the model can be used to provide rapid approximations of terminal development project costs which may then be used in financial and economic appraisal.

The user of the model would be required to exercise cautions with regard to the dates and locations of the data used in deriving the model and apply appropriate conversion factors when necessary to obtain acceptable and reliable estimates.

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CHAPTER 6

The validation and consolidation of models

CHAPTER SIX

THE VALIDATION AND CONSOLIDATION OF MODELS

6.1 Introduction

The models developed in this study were validated with a number of case studies. This is done to check the validity of the model by comparing the estimated costs using the models to the actual costs of past development projects. Errors and inaccuracies are inevitable but have been kept to the minimum possible. Where errors were found to be significant, the variables of the model were reviewed and adjusted accordingly.

The inland waterway track cost model was validated against the improvement scheme of the Sheffield and South Yorkshire Navigation (SSYN) [*1*] which was completed in 1983, and against a new development of St Aidan waterway in 1995. The inland vessel and terminal model was validated against the vessel costs in the Port of Rotterdam (POR) [*2*] as well from the UK [*3*]. Finally the inland terminal model was validated against the development of inland terminal by the Associated British Port of Immingham (ABP) [*4*]. Modification and improvement of the models were constantly reviewed to ensure the models reflect the actual cost structures of particular project.

The inland waterway track model, comprising a number of components as discussed in chapter three, was generated using the first principle data gathered for various civil engineering construction prices from Spon's manual [*5*]. In addition, data from the UK's National Port Council (NPC) [*6*], British Waterways Board (BWB) [*7*] and Manchester Ship Canal Company (MSCC) [*8*] were also included.

The vessel cost model was generated based from actual vessel size and costs data obtained from the Port of Rotterdam Authority [*2*]. Vessel size, its capital and annual operating costs are primarily influenced by the existing inland waterway channel dimensions and navigational restrictions. Similarly, the channel construction can also be influenced by the proposed vessel dimensions.

A comparison between estimated vessel costs using the model to the actual one operating elsewhere would be preferred. Unfortunately, such data have not been obtained. However, even if they are available, it is expected that the vessel's costs, particularly the capital costs, will differ from one estimate to another due to a number of factors. These can be summarised as, design factors, labour and material costs, taxation, etc., as discussed in chapter four of this thesis, and clearly need adjustments.

Terminal model validation process is considerably difficult to achieve. The reason is that the terminal operators were unwilling to disclose the comprehensive cost data on the previous financial investment of their terminal development projects. Nevertheless, terminal design and requirement distinct substantially from one to another. For this reason, a generalised cost data on the expansion scheme of a RO/RO terminal at the Port of Immingham [*4*] has been applied for the validation.

There are no straightforward method in determining the actual costs of terminal or port development projects due to a number of factors involved in the project's development phases. Reasonable assumptions have to be established and included wherever necessary in order to generate a reliable model. However, the cost data supplied by ABP [*4*] are reasonably sufficient for this validation purposes.

6.2 Validation 1: The Sheffield and South Yorkshire Navigation (SSYN)

6.2.1 Background of SSYN

The SSYN is one of the major commercial waterways in Britain under the control of the British Waterways Board (BWB). It provides waterborne freight transport facilities between places as Leeds via the Aire and Calder Navigation (ACN), Nottingham via The Trent Navigation, Rotherham and Doncaster via SSYN and the Humber. This direct link with the Humber Ports is the gateway to Europe and the international sea routes (figure 6.1).

Figure 6.1: The map of Sheffield and South Yorkshire Navigation

Up to 1979, the SSYN has been utilised for the movement of freight in conventional barges carrying up to 500 tonnes to Doncaster only and 90 tonnes beyond there to Rotherham and Sheffield area. Each year over one-third of a million tonnes of bulk cargoes were carried on this waterway. The scheme was designed to provide a new trunk transport route for Yorkshire to link the industrial areas of Sheffield and Rotherham with the Humber Ports. It would provide an attractive transport route for freight of 700 tonne craft. It would reduce congestion on existing roads and environmental hazards such as noise and pollution.

The proposed improvement scheme was the lengthening, improvement or reconstruction of 10 locks, the widening or removal of 5 bridges, the realignment of navigational channels at four sites, reducing sharp curves and other restrictions of larger craft between Doncaster and Rotherham. Swinging bays at Mexborough were constructed to allow larger inland craft to pass through the railway bridges. Table 6.1 shows a complete list of the proposed improvements.

In addition to the improvement of the channel, other facilities were also planned for the handling and storage of import and export goods as well as a new industrial complex of 32.4 hectares comprising a new inland terminal at Rotherham. This terminal would provide a fully integrated transport service including facilities for the storage of dry goods, liquids and bulk cargoes. These facilities were financed by private firms and not included in the project costs of GBP 16.0 millions (1980 prices) thus not considered in this study.

Table 6.1: SSYN - construction components

The capital cost of improving the navigation to a modem standards was GBP 3.2 million (1980 prices). Conventional barges with a capacity of 500 tonnes were then able to navigate the canal to Doncaster. Before the improvement, it was only possible to take barges of maximum of approximately 90 tonnes beyond Doncaster in the direction of Rotherham. In 1979, a GBP 16.0 million scheme to modernise the SSYN between Bramwith Junction and Rotherham, a distance of 35 km and with New Junction Canal was implemented [*11*]. The appraisal for the improvement proposals was prepared by the British Waterways Board and the South Yorkshire County Council in 1977.

The first new traffic for the improved SSYN was a 500 tonne tanker with oil products from Goole to Kilnhurst in June 1983. Large capacity vessels carrying cargoes to destinations on the improved section of the SSYN must use the ACN for the first seven miles of their journey inland, as well as the New Junction Canal. Over the years, the success of the scheme has resulted in extra traffic for the ACN and the New Junction Canal.

6.2.2 The improvement project of SSYN

Several improvement projects on the waterway's channel has taken place includes the following:

I) <u>*Locks*</u>

Lengthening, improvement and reconstruction of locks have been undertaken by BWB to upgrade the dimensions to allow bigger barges to move along the navigation. Tables 6.2 and 6.3 provide data on the distance between channel sections and craft dimensions before and after channel improvement scheme respectively. Whereas the locks improvement schemes and costs are shown in table 6.4 and 6.5. These costs were estimated using the model as a function of lock volumes expansion, x in m^3. Figures 6.2 and 6.3 show the layouts of the locks involved in the improvement schemes.

Figure 6.2: SSYN - Locks layout at northern section

Figure 6.3: SSYN - Locks layout at southern section

Table 6.2: SSYN - Distance and maximum craft dimensions

Table 6.3: SSYN - Barge dimension before and after the improvement

Table 6.4: Locks improvement scheme and costs on SSYN project

Locks	Original dimensions (m)	New dimensions (m)	Lock volume expansion (m^3)
Sykehouse Lock	60 x 5.8 x 2.5	71.25 x 5.8 x 8.5	2,643
Long Sandal	60 x 5.8 x 2.5	71.25 x 5.8 x 8.5	2,643
Doncaster	60 x 5.8 x 2.5	71.25 x 7.0 x 8.5	2,643 (a)
Sprotborough	18 x 4.5 x 2.5	71.25 x 7.0 x 8.5	3,310 (a)
Mexborough Low	18 x 4.5 x 2.5	71.25 x 5.8 x 8.5	3,310 (a&b)
Mexborough Top and Swinton	18 x 4.5 x 2.5 18 x 4.5 x 2.5	71.25 x 5.8 x 8.5 71.25 x 7.0 x 8.5	3,310 3,310 (a)
Kilnhurst	18 x 4.5 x 2.5	71.25 x 7.0 x 8.5	3,310 (a)
Aldwarke	18 x 4.5 x 2.5	71.25 x 7.0 x 8.5	3,310 (a)
Eastwood	18 x 4.5 x 2.5	71.25 x 7.0 x 8.5	3,310 (a&b&c)

Notes: Mexborough Top lock and Swinton lock have been combined together
(a) lock cost to include 30% adjustment factor
(b) lock cost to include 10% extra quay wall filling cost
(c) lock cost to include 10% mooring basin

Table 6.5: Comparison between the estimated (model) and actual costs

Lock names	1980 prices (GBP)	Adjusted to GBP 1995	Model estimate (GBP) $y = 18.6 + 0.41x$	Errors (%)
Sykehouse	446,000	990,120	1,102,230	11.3
Long Sandal	429,000	952,380	1,102,230	15.7
Doncaster	866,000	1,922,520	1,820,390	5.3
Spotborough	1,096,000	2,433,120	2,176,434	10.5
Mexborough Low	1,210,000	2,686,200	2,343,852	12.7
Mexborough Top[a]				
Swinton[a]	2,239,000	4,970,580	4,352,868	12.4
Kilnhurst	987,000	2,191,140	2,176,434	0.7
Aldwarke	929,000	2,062,380	2,176,434	5.5
Eastwood	1,330,000	2,952,600	2,511,270	15.0
Total	9,532,000	21,161,040	19,762,142	9.3

Notes:
i. Mexborough Top lock and Swinton lock have been combined together
ii. Figures were adjusted by application of Civil Engineering Construction Cost Index
iii.The locks undergoing the improvement scheme are presented in figure a and b.
iv.The 1980 prices was obtained from original study by Mann and Dunn [1]

The detail of the estimates and validating of the model has been carried out with assistance from British Waterways Technical Department in Leeds [7] and also from a study by Mann and Dunn [1]. It is worth noting that a 30% adjustment factor has been applied to some of the lock costs due to the extra works necessary for new cuts, extra retaining walls and filling (eliminating existing channels).

It is observed from the analysis that the model estimate produced an error of between 0.07% to 15.7% for each individual lock. The overall estimated lock costs however, produced a result with an error of 9.3% which is well within the limiting figure of normally 10-15% [7]. It has been anticipated that the big difference between the estimated to the actual costs due to economic fluctuation over the years.

ii) <u>Bridges</u>

According to information from BWB Leeds [7], the approximate cost of improving the five bridges on the SSYN was GBP 500,000 (1980 prices). Using a civil engineering cost index for the two particular years [5], the adjusted values for 1995 was approximately GBP1.11 million. All the five bridges which underwent improvement in the project are detailed in the following paragraph. The estimated costs, using model application, are shown in table 6.6. Figure 6.4 shows a photograph of one of the five bridges following the improvement;

i. Single carriageway road bridge 7m x 4m
ii. Dual carriageway road bridge 8m x 8.5m
iii. Kilnest railway bridge 8m x 3m
iv. Doncaster road bridge 20m x 3.5m
v. Doncaster rail bridge 20m x 3m

<u>Table 6.6: The estimated bridge cost using a model (SSYN)</u>

Bridge number	**Bridge area (m^2)**	**Model estimate (GBP) $y = -7586 + 4593x$**
Bridge 1	$x = 7x4 = 28m^2$	121,000
Bridge 2	$x = 8x8.5 = 68m^2$	304,718
Bridge 3	$x = 8x3 = 24m^2$	102,639
Bridge 4	$x = 20x3.5 = 70m^2$	313,903
Bridge 5	$x = 20x3 = 60m^2$	267,976
Total		1,110,246

Looking from the model estimated costs of GBP 1,110,246, there is only a difference of GBP 246 (GBP1,110,246 - GBP1,110,000) or 0.02%. The small error has indicated that the model is particularly applicable for this bridge construction. It is hoped the model will also be applicable to other bridge construction with an acceptable level of accuracy. However, caution has been exercised for reasons similar the lock model,

Figure 6.4: A typical inland waterway bridges in UK

namely the economic fluctuations. Wherever necessary, adjustment to model parameters has to be made to suit various application.

iii) <u>*Channel improvement*</u>

There are no detailed published materials available for the SSYN's channel improvement works in 1980. Nevertheless, a private communication at BWB Leeds provided some useful data and figures. Based on this information, the validation of the channel model has been carried out. A number of reasonable assumptions have been established to assist the validation.

A report by BWB [9] indicated that the work involved in the project consisted of an alignment of navigation channels at four sites, a reduction of the sharp bends and curves and the removal of channel obstructions. All of these involved cutting, excavating and dredging operations only resulting in the removal and disposal of surplus dredged material combined with the construction of channel bank protection schemes.

Based on data in table 6.3 and the rules governing the determination of required channel dimension as shown in figure 3.4 in chapter 3, the depth and width of old and new channel were determined. Based on the calculation, the required extension for channel depth and width were 0.63 metre and 7.23 metre respectively. For a given channel section of 35 km underwent the improvement, the total volume of dredging required were estimated at 175,000 m^3 including 10% contingency factor.

The total cost of channel improvement works was GBP 5,968,000 (GBP 16.0 millions less GBP 9,532,000 for lock costs and less GBP 500,000 for bridge costs at 1980 prices. By applying the construction cost index, the channel improvement cost was adjusted to GBP 1995 prices giving a value GBP 13,248,960. This cost is compared to the required channel improvement cost estimated by the model based on 1995 prices as shown in the following table 6.7.

Table 6.7: The estimated channel improvement costs using the model (SSYN)

Work undertaken	Model estimates (GBP1995 prices)
I. Cut,excavate and dredge of 175,000m^3 @ GBP 4.78/m^3 (table 3.6)	836,500
ii. Disposal of dredged aggregate 175,000m^3 @ GBP 5.5/m^3 [2]	962,500
iii.Landscaping, planting and fencing (appendix 6)	1,400,000
iv.Bank protection (35.0km of steel sheet on both side of the banks) (table 3.11)	2,380,000
v.Bed protection (35.0km of geotextile) (table 3.11)	2,088,450
vi.Weir (for a 27.6m channel width) (a)	400,000
Total	8,067,450
20% contractors tender prices	1,613,490
10% design and specifications	806,745
10% contingencies	806,745
Grand Total	11,294,430
Difference from adjusted 1995 prices of GBP 13,248,960	1,954,530
% of difference	14.8%

Notes: (a) Figure obtained from MSCC estimates by extrapolation (appendix 5)
Contingency factors were included to reflect the real development costs of any civil engineering construction project [7]

The output result of the analysis indicates that the channel development model has generated an error of 14.8%. This is acceptable considering the estimates on some elements of the work cannot be done due to a lack of information. With the additional costs of the other works the total cost will increase hence improving the error. Nevertheless, these works are considered as minor works which should not in most cases exceed the dredging, locks and bridge costs. The difference of the estimated costs to the actual ones could be due to additional works which have not been considered in the model.

6.3 Validation 2: The St Aidan waterway

It is appropriate to enhance the validity of the model by applying it to a canal construction project. The cost structure for new and improved waterways are similar. However, within the model, it may be necessary to apply certain adjustment factors. The next validation is an application of the model developed in this work to the newly developed St Aidan canal at ACN in the North East of the UK. Figure 6.5 shows a typical bank and bed protection scheme for the St Aidan waterways channel.

6.3.1 Background of St Aidan waterway

St Aidan is a newly built 3.5 km stretch of the Aire and Calder Navigation [*13*]. The work has involved the building of a new lock which is 4.6m deep with a capacity of over 2.27 million litres of water, two lock keeper's cottages, a weir, mooring basin, three bridges and some environmental enhancement. It is the most comprehensive canal built in the UK since the New Junction Canal in 1905 and the Manchester Ship Canal in 1894.

This GBP 20 millions scheme (GBP 14.5 millions for the channel, GBP 3.0 millions for the lock and GBP 2.5 millions for bridges) is intended to enhance the freight carrying potential of the Aire and Calder Navigation (ACN). The ACN moved 2.5 million tonnes of freight mainly coal, oil, sand and gravel every year at the time this project was completed in 1995. It was estimated that 3 million tonnes of coal will be transported on ACN within the next five years.

500 tonne barge trains carrying coal to Ferrybridge power station along part of the ACN relieved the strain off the region's roads. Around 12,000 tonnes of coal a week will be moved by the mining company from four seams of approximately 1.5 metre thick. The largest dragline will scoop up to 50-tonne bucketful, while dump trucks move 170 tonnes of earth at any one time. One barge load is equivalent to 20 trucks which makes moving freight environmentally friendly.

Figure 6.5: St. Aidan waterways bank and bed protection schemes

A lock chamber, gate installation, approach moorings and mooring basin were major components of the lock system. Mechanical and electrical works have also been carried out. The cabin which was constructed alongside the new Lemonroyd Lock has two storey structure finished with traditional materials. It has brickwork perimeter walls, steel first floor balconies, timber windows and doors all under a natural slated roof.

Rip-rap which is a loose stone, has been used for bank protection against erosion due to vessel wash, waves and currents. A submerged berm of 2,500 metre length and width between 2 metres and 5 metres underwater has been put in place. Three culverts have also been created in the bed of the channel. These 1 metre deep, 75 metres long and 3 metres wide troughs were infilled by several clusters of stones varying between 0.6 metre and 1 metre diameter. A new crump weir (flat top with well defined slope on upstream and downstream side) with a 25 metres wide crest and a 1.47 metres drop.

6.3.2 The new development of St Aidan waterway

Several development on the waterway's channel has taken place includes the structures as follows:

a. Lemonroyd lock

i) Lock dimensions: 71.25m x 7.0m x 8.5m

ii) Lock Volume (x): 4,240 m^3

iii) Actual Total Cost 1995 : GBP 3.5 millions [6]
(Total lock cost consisted of estimated 1/4 of mooring basin, 1/4 of control cabin and 1/2 of lock structure) [6]

iv) Lock structure cost = 1/2 x 3.5 mil = GBP 1.750 mil

v) Using a model, the cost, $y = 18.6 + 0.41x$ = GBP 1.757 mil

vi) Error of estimate = $\frac{1.757 - 1.750}{1.750}$ = <1%

b. *Bridge construction*

There were two footbridges and one road bridge with a total construction cost of GBP 2.5 millions 1995 prices. Assuming that the bridge span would be in the region of 50 metre to cross the 40 metres width canal, the width of the footbridge is assumed to be 3 metres, whereas the width for the road bridge is estimated at 4 metres for a rural two way single lane [5]. Hence the estimated costs of the three bridges using the model are as in the following table 6.8.

Table 6.8: The estimated bridge construction costs using the model (St Aidan)

Bridge parameters	**Bridge surface area, x (m^2)**	**Cost (1995 prices) $y = -7586+4592.7x$**
Footbridge No.1	$x = 50m \times 3m = 150m^2$	y = GBP 681,319
Footbridge No.2	$x = 50m \times 3m = 150m^2$	y = GBP 681,319
Road bridge	$x = 50m \times 4m = 200m^2$	y = GBP 910,954
Total Bridge Cost		GBP 2,273,592
Total Cost difference		GBP 226,408
Error of estimate		9.1%

c. *Waterway channel (watercourse)*

Waterway dimensions : 3,500m x 40m x 3.5m

Development Cost : GBP 14.5 millions (1995 prices)

The components of construction are as the following:

i. Excavation and disposal of dredged material = $490,000m^3$
ii. Bailey bridge: 1 unit
iii. Geotextile lay-up: 2 layers
vi. Crump weir: 1 unit @ 25m x 1.47m
v. Culvert: 3 unit @ 75m x 3m (1m deep)
vi. Landscaping
vii. Planting and fencing
viii. Others

The BWB Technical Department in Leeds [7] have been consulted for the model validation exercises. Based on their vast knowledge and experience, they felt that the model was quite reliable in providing the cost estimates. Nevertheless, the following factors should also be considered, namely: 20% contractors cost margins, 10% design and supervisory fees and 10% as a contingency allowance. Taking all these into account, the inland waterway channel development costs estimate are shown in the following table 6.9.

Table 6.9: The estimated channel development costs using the model (St Aidan)

Excavation Excavation costs, y	$y = 25.46 + 3.22x$, where $x = 490{,}000\ m^3$ = 1,577,825
Disposal Disposal Cost, y	$y = 5.5x$ (15km or more) = 2,695,000
Rock Channel lining Channel lining cost	$y = 90x$ y = 3,500m x 90 = 315,000
Geotextile Geotextile cost (2 layers)	$y = 4.50x$ = 3,500 x (3.5 x 2+40) y = 1,480,500
Crump Weir Weir cost	y = 1,000,000 (a)
Culvert Culvert cost	$y = 138.5 + 17.12x$, x=75m = 14,260
Bank protection (berm) Bank protection cost	$y = 100x$ = (3,500 x 2 x 100) = 700,000
Landscaping Landscaping cost	$y = 75x$ = (3,500 x 2) x 75 = 525,000
Planting and Fencing Planting cost	$y = 200x$ = (3,500 x 2) x 200 = 1,400,000
Total 20% Contractor's price 10% Design and supervision 10% Contingencies Grand Total Total cost difference Error of estimates (%)	= 9,707,585 = 1,941,517 = 970,758 = 970,758 =13,590,620 = 909,380 = 6.3%

Notes: (a) Figures obtained from MSCC data (see appendix 5)

The comparison of estimated costs using a model and the actual ones resulted with an error of 6.3% for the channel development costs. This is acceptable especially when the estimated costs for culvert construction is relatively low. It is anticipated that the total costs difference would have been lower. Nevertheless, the model through two case studies have proven acceptable for future applications of channel development cost estimates.

It is concluded that the validation of the inland waterway track model has covered quite an extensive range of construction works that may be required and the result showed that the model is acceptable and can be considered for application in future in other location with consideration to the variation of cost indices including labour, material, plant and currency exchange rates.

6.4 Validation 3: Inland self-propelled vessel cost model

The Port of Rotterdam Authority has supplied costs for several types of inland waterway vessel of different deadweight capacities. The annual cost of capital, crew, insurance, repair and maintenance, fixed overhead and fuel have been available on hourly basis based on Netherlands's Guilder 1986 prices [2]. In accordance to the scope of the study, only self propelled vessel's capital and annual operating cost data were selected for the analysis.

These hourly costs were adjusted to GBP 1995 prices on annual basis as discussed in chapter 4 of this study by an application of cost index. The data analysis has produced equations as shown in table 4.8 to represent Europe's model. This has been compared to the UK model by Garratt [3]. Both analyses are based on GBP 1995 prices. Europe's (Rotterdam) model has been selected to be used in this study because the data was more comprehensive compared to Garratt's data for the UK model. In addition, the size of the waterway in Rotterdam (Class IV) is more relevant to the waterway channel to be developed in Malaysia.

Before any attempt of using the Europe's model for the vessel capital and annual operating costs, can become a reality, this model will have to validated with other data. It would be appropriate to validate the model against the actual vessel capital and operating costs from elsewhere. However, since there is no such data available, the Europe's model will be validated against estimates from Garratt's model of UK.

Even this validation or comparison cannot guarantee the validity of the model. The vessel costs vary from one instance to another, sometimes vary greatly even within the same country due to numerous factors.

The results of the validation or comparison between Europe's and the UK model representing capital and overall vessel annual operating costs are shown in the following table 6.10, 6.11, and 6.12.

Table 6.10: Capital costs estimate against actual capital costs

Vessel Size (dwt)	Europe model $y = 0.79x + 0.0013x^2 - 107.8$	UK model $y = 417 + 1.67x$	Rotterdam Actual Costs (GBP)	Diff (%)
450	510,950	1,168,500	520,500	56.3
650	954,950	1,502,500	874,000	36.4
850	1,502,950	1,836,500	1,430,000	18.2
1,050	2,154,950	2,170,500	2,330,000	0.7
1,250	2,910,950	2,504,500	2,800,000	16.2
Mean value				25.6

Notes: Difference: Europe model Vs UK model (all costs are in GBP 1995 prices)

Table 6.11: Annual crew costs estimate against actual crew costs

Vessel Size (dwt)	Europe model $y = 66.51 + 0.0034x$	UK model $y = 10.33 + 0.01x$ (a)	Rotterdam Actual Costs (GBP)	Diff. (%)
450	81,810	83,048	81,450	1.5
650	88,610	92,248	88,720	3.9
850	95,410	105,448	95,810	9.5
1,050	102,210	116,648	102,710	12.4
1,250	109,010	127,848	109,660	14.7
Mean value				8.4

Notes: Difference: Europe model Vs UK model (all costs are in GBP 1995 prices)
(a) 16 hours/day, 350 days/year (similar to Rotterdam model assumption)

Table 6.12: Annual total operating costs estimate against actual costs

Vessel Size (dwt)	Europe model $y = 21.33 + 0.45x$	UK model $y = 81.33 + 0.33x$	Actual Rotterdam Costs (GBP)	Diff. (%)
450	223,830	229,830	216,810	2.6
650	313,830	295,830	300,360	6.1
850	403,830	361,830	388,300	11.6
1,050	493,830	427,830	493,460	15.4
1,250	583,830	493,830	589,730	18.2
Mean value				10.8

Notes: Difference:Europe model Vs UK model (all costs are in GBP 1995 prices)
Operating costs include annual capital cost

The comparison between the estimated vessel capital and annual operating costs against the UK model shows that the difference vary considerably indicating that shipping costs between one organisation to the other differ in variety of ways reflecting the adoption of different operating strategies and costing practices of the particular organisation.

From the analysis, it is concluded that vessel capital costs are expensive in the UK compared to Europe whereas annual crew costs are much more expensive in Europe than in the UK. However, for total annual operating costs, the differences are comparatively small between both models indicating that the models are balanced in one way or another. Afterall, the total annual operating costs model including the annual capital cost will be the one that applied in the assessment of the inland waterway development project to determine the impact of using a particular size of vessel on particular waterways.

6.5 Validation 4: Inland terminal cost model

The costs of terminal or port development, whether new or improved, depend on the terminal's annual cargo throughput. For a port improvement or extension scheme, the likely expenditure will be proportion to the increase in the cargo throughput. To start from scratch for a new terminal often requires with a much bigger expenditure including land acquisition, foundation lay-up, etc.

By comparison with LO/LO terminals, RO/RO terminals are technological more straightforward [*15*]. The essential components of RO/RO terminals are a large paved area and ship to shore linkspan i.e. ramp. Accompanied vehicles clearly load and unload using their own power and impose no incremental handling costs. RO/RO terminal would only require gatekeepers, checkers, park controllers and mooring staff. Apart from the need for good access and suitable storage areas, RO/RO operations place little demand on a port's specialised facilities and can be fully self supporting in smaller ports [*16*].

6.5.1 The Port of Immingham case study

A model can be used to estimate the terminal requirement and costs too. However, to compare the estimated terminal development costs to the actual ones is difficult. In this study, data for the recently improved RO/RO terminal at ABP Immingham [*4*] will be used for the validation of the model as shown in appendix 8. The following section summarised the facilities provided in the improvement scheme of ABP Immingham to cater for the annual throughput of 420,000 TEUs.

According to Kent [*4*], the port has recently completed a brand new four-berth RO/RO terminal from scratch at a total costs of GBP 20 millions (1995 prices). The development includes 16.2 hectares of pavement, handling equipment, maintenance facilities, security provisions, a dock basin (200m x 100m x 11m), roadways, railways and alteration to existing tenancy boundaries. The port built a 17,000 m^2 storage compartment costing an extra GBP 2 millions (1995 prices).

Although the model was developed for the LO/LO terminal only, it can still be applied to RO/RO terminal because the majority of the equipment and facilities are of a common designs and characteristics. The main different is the linkspan which was not required in the case of LO/LO. Likewise, no crane would be required because the containers are carried by accompanied trailers on board the RO/RO vessels. Table 6.13 summarises the estimated total costs for the terminal development using the model.

Table 6.13: The estimated terminal development cost using the model

Equipment/facility	Model equations	GBP 1995 prices
16.188 hectares	= 161,880m^2 @ GBP 20/m^2 (1980 prices) = GBP 3,237,600 (1980 prices)	7,187,472
4 berths	1 berth @ 120m length [*11*] 4 berths = 480m @ GBP 4,000/m = GBP 1.92 mil (1980 prices)	4,262,400
Handling equipment	not available	
Maintenance facility	not available	
Dock Basin: 200m x 100m x 11m (220,000 m^3)	Excavation @ GBP 3.85/m^3 Disposal @ GBP 5.5/m^3 Retaining Wall, $y = 203x-102$	847,000 1,210,000 1,339,700
Roadway:(assumption) Length (m):400m width (m):8m	Road area = 3,200m^2 Cost 3,200 @ GBP 95/m^2 =	304,000
Railway:0.5km	GBP 375,000/km [*13*] (1994 prices)	188,156
Total Costs 20% tender prices 10% design and specs 10% contingencies		15,338,728 3,067,746 1,533,873 1,533,873
Total Costs Original Costs Difference Error		21,474,220 20,000,000 1,474,220 7.4%

The cost estimated by the model is compared to the actual ones, results in an error of 7.4% which is well below 10-15% limiting errors. The reason for this error may be that there was no accurate data on a number and size of equipment and facilities available. Reasonable assumptions have to be made in order to estimate the likely costs using the model.

Development costs vary greatly between terminal developments. They are affected by factors other than just the annual cargo throughput and cargo handling rates alone. Government or private owners policy, geography and the economy must be considered together to provide the basis for a decision to be made involving different level of financial responsibility.

6.6 Consolidation of models

The main aim of the study was to generate a generalised cost model capable of estimating the complete costs of developing and operating an integrated inland waterway transport system, either canal or river navigation. The ability of the model in estimating the required initial investment costs of a project is vital to measure the overall financial and other benefits which are predicted for the proposed development before any real decision can be made. A number of options and alternatives can be examined to enable the optimum costs and benefits to be achieved. Often, the benefit will include the social and environmental benefits as expressed in monetary terms.

In principle, the canal or river navigation are almost identical in a number of infrastructures available within the system. However, within this system itself, there are other sub-systems which operate interdependently according to the overall objective of the whole system. Although in a number of cases, these sub-systems may be operated by different entities, namely channel navigation authorities, vessel and terminal owners, the ultimate aim is nevertheless to provide the framework for a fully operational, integrated system. It is important that the three sub-systems can co-exist in carrying out the task of providing a reliable, efficient and economical cargo movement through an inland waterway transport system in a competitive manner compared to the existing road and rail.

The three models developed in this study were firstly analysed and derived individually from a number of sources of data and information collected mostly in the UK. The models were produced in isolation from each other after having identified the required parameters to be included in the particular model to exist as individual independent system. Each individual model is valid within its own application and this has been proven reliable as shown in the model validation process.

Although each model can be applied to accomplish certain tasks individually, for a complete and comprehensively integrated inland waterway transport system, the models need to be applied together. The individual model parameters will influence one another in reaching the optimum consideration of the system. This can only be realised in the real application of the model where a number of alternatives under consideration can be assessed to decide on the most attractive ones.

6.6.1 Inland waterway track model

Inland waterway channel comprises of a number of construction variables namely dredging, cutting for channel width, bank protection, embankment, bridges, lock structures etc. which are determined in relation to a vessel size selected for the system. The development cost of the channel track will be influenced by vessel dimension, in particular the dredging depth required to accommodate the vessel's draught as well as channel width in relation to vessel's beam.

The need for navigation lock in terms of particular layout will also be determined by the vessel dimensions. Similarly, additional lock requirement at similar location can also be determined once the vessel's fleet is expanded. Even with similar amount of cargo throughput to be served on the channel, the vessel size and dimensions can be varied to achieve the optimum costs of developing the channel section. A bigger vessel employed on the waterway will not necessarily result in optimum cost and benefit.

Although it is known that there is an element of economies of scale for employing a bigger vessel, this can only be determined by an optimisation analysis through a repetitive exercises using the model.

A smaller size of vessel tends to generate a greater number of vessel required in the fleet to carry the cargo. This would mean a heavy burden on vessel owner to provide capital cost for greater number of vessels to be employed. Similarly, there will be higher annual operating and toll costs due to higher turn-round trip per year. Although this may favourably increase the toll revenues to the waterway authority, it will be the interest of all parties to balance the responsibility of providing the required system and the finance which the party or parties need to provide. In determining the optimum channel size and dimensions, it is important to relate this to vessel size and vice versa in terms of costs and benefits of the proposed system.

6.6.2 Inland waterway vessel model

Inland vessel dimensions can be determined based on two fundamental considerations. Firstly, in an existing system it may be prudent to add vessels of similar size to those already in operation. This may result in congestion due to an increased number of vessels in the fleet required to carry the increased cargo throughput. The waterway authority may still be required to spend on the cost of improving the channel width to provide a dual ways or safe navigation for the vessel operation. Similarly, the lock sizes will have to be improved perhaps to the extent of providing additional locks to prevent delays and congestion in the channel navigation.

To increase the vessel size at this stage would also mean involving extra expenses for both shipowners and waterway authority which could be costly. This is because all infrastructures within the existing system including channel dredging and cutting, locks, bridges, etc. need to be upgraded to accommodate the increase size of the vessel. It may be or may not be economically feasible. Similarly, the answer can only be determined through an optimisation analysis using the model. However, if the number of vessel is small, it is wise to provide additional vessels of similar size without having to redevelop the whole infrastructure system. The provision of extra vessel capacity will be off set from a revenues generated through freight charges.

Any option will consequently affect the terminal operation and its infrastructure and equipment requirement. Even without any major channel development, the additional vessels giving berth at the terminal will result in the berth extension requirement in order to enhance or even improve the efficient and uninterrupted cargo handling operation. The terminal area, transit shed as well as warehouse facilities are all need to be considered for further expansion too in accordance to vessel berthing operation.

Secondly, if the waterway system is a new system waiting for development, there are choices between starting the design process with a consideration based on the size and dimension of the existing waterway channel, or to start with a pre-determined size of vessel which is required to carry the amount of the projected cargo throughput throughout the life of the proposed waterway project.

In principle, it is economically advantageous to employ the biggest vessel possible. Whilst this may be applicable with most sea trades, on waterways there are a considerable factors such as land gradient, water sources and flow, waterway depth, fixed structures, bank strengthening scheme which need to be examined and assessed appropriately. All these factors need to be considered and balanced equally to achieve the optimum investment strategies resulting in optimum costs.

It would not be appropriate to suggest that it is wrong to start the whole design process with a predetermination of vessel size rather than the channel dimensions. This situation depends on a number of factors and alternatives within the system to be developed. The model is applied to assist this task by adjusting the model parameters. When one parameter changed, the other will affected forming the relationship of a 'cause and effect' situation i.e. changing independent variable will change the dependent variable. Until the optimum situation is achieved, the model will be used to repeat the task.

Based on the projected annual cargo throughput and the year 25 of the project life, it is anticipated that no major improvement would be required for the channel development as well as no major disruption occurring with the employment of the size of the vessel. This includes, the congestion in terms of delay at locks and at terminals in port. Of course, the proposed size has to be sensible in relation to the existing channel dimension as well as a consideration to the minimum cost of developing the channel including dredging, cutting, lock, bridges, and etc.

When the actual cargo flow during the operational life of the system differ from the projected one, then clearly there is a need to adjust the situation with emergency planning including expansion of vessel size or/and channel track too. Otherwise, after 25 years, the project can be reviewed for further assessment for a new decision to be made and implemented. At this stage, the model will have to be reviewed too in the light of the latest technology and cost minimising techniques which may then be available for consideration.

6.6.3 Inland terminal model

An inland terminal is developed purely to provide an interface for transhipment of cargo from water to shore. Clearly, there is a need to design the required space, infrastructure and facilities based on both the size of vessel calling at the terminal as well as the projected cargo throughput throughout the life of the project. If the determination of vessel and channel size and dimensions determine each other, it is a different case with terminal requirement the cost of its development.

While part of the terminal system is determined based on cargo throughput, the other part is determined based on vessel size. The former includes terminal area, warehouses and cargo handling equipment. On the other hand, the latter includes quay material and length, terminal water depth and also cargo handling equipment in terms of types, capacities and quantities plus contingencies.

It should be noted that, in terminal development, the infrastructures are designed and planned years ahead according to the life of the project. This includes all necessary infrastructures such as quay, land acquisition, warehouses, transit shed and etc. On the other hand, the handling equipment is planned annually based on the requirement for a sufficient types and number of cargo handling equipment to fulfil the cargo handling operation.

Clearly changing one parameter of the model will affect others. Therefore, it is important that the model is applied and assessed holistically in determining the optimum economic return in term of financial as well as economic ones. The integrated inland waterway transport system exist to provide the service for the movement of cargo and in direct competition with road transport system. To be competitive, it is inevitable that the three sub-systems, through the model application, will have to co-exist in determining the acceptable level of investment that need to be considered and the benefits arising from such a development.

6.7 Summary

The three models developed in this work have been validated using a number of different UK case studies. This has been done to ensure that the model is valid and reliable for future use in estimating the development costs of inland waterway channel track, barge operating and inland terminal development schemes. Although there a number of equations derived for the models in this study, it is however important to note that some applications require additional data which may not be suitable or available from the study. This has been indicated as being the case in the validation process of the models.

From the very beginning of this study, the models have shown that the development of inland waterway systems, whether river or canal, considers common development parameters. Using this model, it is possible to estimate the cost of developing a waterway in other parts of the world with some adjustment according to various economic factors.

The validation of inland waterway channel track based on the SSYN improvement scheme in the UK has resulted in an acceptable accuracy using the model. Likewise, barge model posed no difficulties in the validation where the equations have proven reliable judging from the moderately small errors when both the estimated costs and actual ones were compared.

However, terminal model is difficult to validate owing to the complexity of development strategies involving the consideration of many financial and economic factors. Nevertheless, having limited data on the development requirement and costs for the RO/RO terminal development in ABP Immingham, it is considered that the differences between the estimated costs and the actual ones were within acceptable limits.

It is concluded that the work have been successful in developing a simple yet comprehensive models. They can be used by a number of relevant planning authorities in the initial stage of an inland waterway development. This will provide them with adequate information on the overall costs before further action can be taken. There is ample room for improvement for the models to suit various applications on a project specific basis.

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CHAPTER 7

Model application to the development of inland waterways transport system in Malaysia: A case study

CHAPTER SEVEN

MODEL APPLICATION TO THE DEVELOPMENT OF INLAND WATERWAYS TRANSPORT SYSTEM IN MALAYSIA: A CASE STUDY

7.1 Introduction

Many countries in Europe, USA and other continents have planned and developed inland waterway systems, mainly for the transportation of commercial goods, but able to include leisure and tourism activities. The undoubted convenience of road transport has tended to limit many recent developments in inland waterways and caused the lack of use of all but the most economically viable and strategic part of networks. However, as an environmentally friendly alternative with good economic potential, inland waterway systems deserve careful appraisal even in highly developed countries.

Thriving systems such as the Rhine and the Danube in continent of Europe and the Manchester Ship Canal in the UK confirm the possibilities for developing and extending river and canal for freight transport. Malaysia too, owing to the present need of a much bigger transport capacity can learn and benefit from the experience of these countries.

In this chapter, the present state of inland waterways in Malaysia will be examined and discussed. The development of a selected river navigation will be carried out using the model developed in this study. The model is expected to be able to estimate the total investment costs for an evaluation of the economic benefit arising from the investment in the proposed development.

The need for developing inland waterway transportation systems in Malaysia particularly River Klang in the Federal Territory and River Rajang in the state of Sarawak in the North Borneo has been stated by various authors through several publications [1], [2], [3] & [4]. All have indicated that the proposed developments are feasible undertakings, providing various transport benefits as well as leisure and tourism opportunities.

The transport system in Peninsular Malaysia today, in particular, is going through a period of heavy demand for increased capacity [1]. More passengers and more commercial goods are being moved by all modes of transport, but mainly by road and rail, reflecting the financial investment which has been provided for road and rail expansion programmes.

Inland waterways of river and/or canal navigation have been neglected in Peninsula except in Sarawak whereby the Sarawak Rivers Board (SRB) was established in 1993 to research and promote the development of commercial waterways for both passengers and goods transportation [3]. The case study will examine the proposed development of Klang River as an inland waterway transport system between Klang Port and Kuala Lumpur city centre (see figure 7.1 and inset in figure 7.2).

7.2 Physical and economic features of Malaysia

7.2.1 *Geography*

Malaysia is situated in the region of the international shipping routes through the Straits of Malacca and the South China Sea provides a natural maritime hub to link with other part of the world (figure 7.3). Malaysia also possesses numerous strategically located coastal ports which handle both domestic and international cargoes.

A significant proportion of Malaysia import and export are handled through the Port of Singapore, with transport to and from Malaysia being predominantly by road. Development of an inland waterway network would perhaps allow a modal shift away from road and provide an increasing role for Malaysia's ports in competition with Singapore for direct international trade.

Figure 7.1: Rivers in Peninsula Malaysia

Figure 7.2 (inset): Klang River in Klang Valley region

Figure 7.3: Malaysia's location in South East Asia

7.2.2 *Economy*

The Malaysian economy has been expected to grow by an average of 7% per annum to the year 2000 [5]. The share of manufacturing in Gross Domestic Product (GDP) is projected to increase from 27% in 1990 to about 37% in the year 2000, making Malaysia an industrially oriented economy, increasingly dependent on manufacturing exports for the growth of incomes. Manufacturing exports are projected to account for about 81% of total export value by the year 2000 (table 7.1). The trend will generate a requirement for a bigger transport capacity to transport the raw and finished products to the international markets.

Table 7.1: Sources of growth by industry of origin and structure of production

7.3 Inland waterway systems in Malaysia

Both Peninsular Malaysia and East Malaysia (consisting Sarawak and Sabah on North Borneo) possess a number of inland waterways being utilised commercially at present. In Sarawak and Sabah, with their large territorial areas with relatively small population, rivers have always been a major mode of transport for passengers and commercial goods. The development of an extensive road and rail network to serve a relatively small population is likely to be uneconomical in the immediate or medium term future.

The large urban areas in East Malaysia have developed around rivers which provide water supply, fishing and irrigation as well moving people and cargoes around the area. As the population grows, so does the need for larger transport capacity. Experience suggests that growth in economic activity leads to river congestion, pollution and siltation causing passage difficulty for vessels using them. Hence inevitably, the need for river development or improvement of strategic rivers is necessary in order to provide a bigger and more efficient inland waterway transportation system.

Peninsular Malaysia is endowed with an excellent network of rivers, most of which were navigable in the past (see figure 7.1). The total length of the main rivers can be estimated to be about 5,000km [*1*], although at present only a few rivers are used for the navigation of small boats.

River Tembeling in the state of Pahang is one of the longest in the Peninsula (approximately 144 kilometres), although it only caters for a limited amount of inland transport activities. Coastal shipping also uses certain rivers for a few kilometres upstream. Teluk Intan which is located on the River Perak in the state of Perak is an old inland port still operational for coastal ships on a small scale basis. Typically there are few rivers, however, presently capable of taking small boats upstream. They are as follows [*6*];

i. River Perak: permitting 50 dwt boat moving upstream to Teluk Intan for a distance of 58 km from estuarial area.
ii. River Muar: permitting 30 dwt boat moving upstream for a distance 97 km from the estuarial area.
iii. River Johor: permitting 37.5 dwt boat moving upstream for a distance of 64 km from its estuary.

7.4 Klang Valley region and Klang River

Urban transportation programmes have been implemented within the Klang Valley area, aimed at meeting the rapid increase in urban traffic through traffic dispersal schemes and improvement in public transportation. This is mainly because higher income levels and vehicle ownership have created congestion problems. The congestion problem was most serious in the Federal Territory where car sales accounted for nearly 43 percent of the country [7].

Road and interchange projects were implemented within the city areas of Kuala Lumpur. The major projects included the New Klang Valley Expressway (NKVE), Shah Alam Expressway and the development of a rail based commuter system for the greater Klang Valley. All these were aimed at easing congestion so as to enhance the economic productivity. Unfortunately, the congestion problems remain and still demand serious attention.

The existence of trailers and HGVs to carry cargo on federal highways to and from Klang Port created congestion, noise and pollution, resulted in serious economic and financial losses. According to the Traffic Department of Kuala Lumpur City Council [8] for 1991, the number of trucks and HGVs entering Kuala Lumpur City Centre from the Port Klang area per day was estimated at 6,799 units for small lorries and 368 units for the bigger ones. Data from the Ministry reveals that the average daily traffic flow from Port Klang to Klang Town was 31,600 vehicles as shown in figure 7.4 [9].

The Federal Government developed several more new highways to reduce the congestion. This has proven to be unsuccessful for two main reasons. Firstly, the new government policy to upgrade Klang Port to encourage Malaysian cargo to be moved through Port Klang means more cargo is carried in the Klang Valley Federal Highway. Secondly, the economic growth has contributed to the increased number of vehicles on road, and hence congestion. By virtue of it's nature and geographical location, Klang River is expected to provide a reliable transport network system for the movement of commercial goods in the Klang Valley once developed.

Figure 7.4: Average daily traffic in Peninsula Malaysia (1986)

7.4.1 Background of Klang River

The Klang River lies within the Klang Valley area of approximately 128,000 hectares as shown in the map in figure 7.5 which details of the river sections are highlighted in appendices 9-14. The total population in 1991 was recorded at 2.95 million with 39% residing in the Federal territory of Kuala Lumpur [*10*]. The agricultural based activities have greatly declined in favour of the rapid industrialisation and urbanisation activities for the period indicated in table 7.1. The river channels north of the city area are quite narrow and steep with the channel gradient falls between 3 to 2 metres/kilometre (0.3% - 0.2%), 1 metre/1km in the city centre, 1 metre/1.5km and finally 1 metre/10km towards the river mouth at Klang River estuary [*11*].

The Klang River consist generally of unobstructed channels. Low level bridges cross all three tributary rivers. Downstream of the city the channel has a concrete wall until the Federal Highway bridges (figure 7.5) with steep banks which have been rock protected. Puchong Drop weir (figure 7.5) is the main obstruction. Below this weir, the river is wider and deeper. There are several bridges with low air draughts.

Although the lower reaches of the river have been used to transport goods and passengers in the past, it is no longer the case now. However, river boats could probably take tourists between Port Klang to about 35km upstream [*11*]. Upstream of the Shah Alam bridge (figure 7.5), the channel becomes too narrow and shallow for navigation except for small craft. Further upstream beyond the Puchong Drop, the river gradient, rock bars, the shallow water depth and the high banks tend to make navigation even more difficult even for small craft.

The concrete channels of the river between the Federal Highway Bridges and upstream into the city centre are not suitable for navigation. This is due to the steep gradient, strong current, rock bars, cascade weirs and high concrete walls. Upstream of the city areas, the river could be used for shallow draft craft. This could be improved in the natural channel sections of the Klang and Gombak Rivers. This is seen as having potential for future improvement for transportation arteries.

Figure 7.5: Klang River in Klang Valley Region

The Klang River above the Klang Gates is still in a natural state (figure 7.5). Although small reaches of the Klang River immediately below the Klang Gates Dam may still be in the untouched state, the River occupies an improved channel from Klang Gates Dam to Shah Alam area (figure 7.5), a distance of approximately 55 kilometres.

The authorities have completed an improvement project which included:

i. Major alignment, bend cutting and straightening of the channel
ii. Channel enlargement, both widening, deepening and creating embankments
iii. Bank protection using steel sheet piles/concrete walls
iv. Replacement of bridges wherever necessary
v. The development of newly proposed inland terminal
vi. The construction of lock structures
vii. Landscaping, planting and fencing

Table 7.2 shows the preliminary bank material and height for design guidelines of the required waterway channel and embankment of the Klang River.

Table 7.2: Preliminary bank materials and height of Klang River

7.5 Cargo throughput on Klang River

The development or improvement cost associated with adapting this river to become a commercial inland waterway transport network is estimated using the model developed in this study. The costs are calculated as waterway track channel, barge operating and inland terminal development cost. The three sub models are interrelated and interdependent with one another.

Estimated costs using the models will mainly depend on the availability and the projected or allocated amount of cargo throughput to be captured by this waterway. While the project concentrates on the application of the model to determine these costs, data, information, figures etc. from a number of past studies will be referred to. Amongst those are Chin [*4*], and others.

7.5.1 Expected type of cargo and its annual throughput

The rapid expansion of trade and industry has led to increase the demand for port facilities and related maritime services. Increasing emphasis has been placed upon port efficiency and productivity to stimulate the port's and maritime activities. The throughput handled grew by 8.9% per annum, increasing from 52.2 million tonnes in 1985 to 80 million tonnes by 1990 and to 125 million tonnes by 1995 [7]. Container throughput recorded an impressive 13.1% increase from 1985 to register 739,880 TEU by 1990 and by approximately 130% to almost 1.5 million TEUs by 1995 [7].

Although it is difficult to estimate the future throughput for dry bulk and containers which could use this proposed waterway, a possible alternative is to base the projection on the typical cargo throughput handled at Klang Port. At present the majority of this throughput is transported by road transport on the Federal Highway which is almost parallel to the proposed inland waterway route via the Klang River. A proportion of this could then be used as a parameter to gauge the benefits of developing the waterway. A percentage of cargo passing through Port Klang is distributed by means of a coastal feeder service to other coastal ports.

It is therefore reasonable to make estimates based on the throughput data at Klang Port and then to transfer some percentage of cargo from road transport into barges on the waterway for delivery to and from Klang Port. The throughput at the five major ports (including Klang Port) has doubled from 31 million tonnes in 1985 to more than 62 million tonnes in 1991 [*12*]. For Klang Port, table 7.3 shows the annual total cargo throughput by type for 1985 to 1991.

Table 7.3: Total cargo throughput by type at Klang Port 1985 - 1991 (Mil tonnes)

From table 7.3, the growth rates for dry bulk of 18% per annum and for containers 16% per annum is highly unlikely to be sustained over 25 year period. The projection for both cargo types in 25 years results in a very high throughput. Although it may be correct theoretically, it may not be the case in reality where growth rates may not be sustained over such a long period of time due to a number of economic and political factors. Better estimate, given the potential growth in Malaysia economy, by linear method, results in the equation as follows;

i. Bulk cargo, $y = 6274 + 509x$

   where y is the projected cargo throughput in tonnes and x is the increment of year where 1995 is year 0

ii. Container, $y = 797 + 61x$

   where y is the projected cargo throughput in TEUs and x is the increment of year where 1995 is year 0

Using these equations, the cargo throughput for both the dry bulk and container for *n* year are projected and tabulated in table 7.4. When these estimates are compared to the real cargo throughput in Klang Port as in table 7.3, the results give better correlation.

Table 7.4: Projected throughput for bulk and container at Klang Port

No.	Year	Bulk cargo ('000 tonnes)	Container ('000 TEUs)
0	1995	6,274	797
5	2000	8,819	1,102
10	2005	11,364	1,407
15	2010	13,909	1,712
20	2015	16,454	2,017
25	2020	19,000	2,322

From the Klang Port, cargo is carried out via the three transportation modes. It is clear that road transport has a significant majority of the market. From the previous table 7.3, 10% of dry bulk and 10% of containers moving on road transport at present is assumed to be captured by or allocated to a newly operated waterway. Although the figure may change in future years, it is assumed that for the first 25 years of operation, the 10% share will be maintained.

7.5.2 Anticipated size and dimensions of inland vessel

There are several ways of determining the appropriate size of barges to carry both types of commodities on the inland waterway. An existing waterway with its infrastructure support such as locks, bridges, etc. could be used to determine the permissible size of barge for navigation. Projected cargo throughput over the remaining life of the navigation can be used to determine the number of barges required in the fleet.

For a new inland waterway development, the channel can be designed based upon a vessel size to be employed on the waterway. The vessel size can be determined based on the present model succeeded elsewhere or in relation to the projected cargo throughput to be carried on the waterway. The experience in Europe suggest that Class IV waterway able to link international boundaries of different countries can be considered as the barge size for the Klang River case study to test its economic feasibility. In addition, the present dimensions of the Klang River is compatible with the European Class IV waterway. Table 7.5 shows the Class IV barge dimensions.

Table 7.5: Vessel size and dimensions for the Klang River

Barge parameters	Barge dimensions
Length (m), L	80.00
Breadth (m), B	9.50
draught (m), d	2.50
Depth (m), D	4.40
Tonnage, Dwt	1,350.00

Since the size of barge has been predetermined in the initial stage of this study, it is expected that the channel will be able to provide access for two way traffic avoiding an unnecessary delay to navigation. Using the channel design principle discussed in chapter 3, the estimated width required would be 43 metres while the channel depth would be 3.5 metres as shown in the following table 7.6.

Table 7.6: Estimated waterway channel dimensions

	Dimensions (m)
Channel depth = 4 x B + (13% side wind allowance)	43.00
Channel depth = 1.4 x vessel draft of 2.5m	3.50
Channel Length= 70 km (the distance between the proposed inland terminal and the Klang River estuary)	70,000.00

7.6 The Klang Valley Water Highway (KVWH) development cost estimate

The proposed development of the river section to become an inland waterway transportation network will be primarily based on the movement of commercial goods only. Any other facilities relating to the leisure and tourism scheme will not be discussed. Upon planning for the development as discussed earlier, the waterways system model will be divided into three major categories. They are namely the waterway channel track, the inland terminal development and the self-propelled vessels to be used on the system.

The model derived in this study are applied to estimate the development costs of KVWH. The outcome from the application of the model will generate the estimated investment costs of the proposed project based on UK 1995 prices. These costs will be transferred to Malaysian currency by applying the exchange rate as shown in appendix 2 and the Cost Index (CI) which has been derived in this study as shown in appendix 7. The application of CI is necessary to reflex the real cost and standard of living of Malaysia.

7.6.1 The scope of proposed development for the Klang River

The proposed development is that the river is to become an inland waterway transport route for the movement of specific type of commodities, namely dry bulk cargoes and containers. Due to the nature of the river i.e. narrow and with a lot of sharp bends, it is suggested that only self propelled barges both for dry bulk cargo and containers will be considered. Thus, the push-tow system will not be considered for this analysis due to the physical constraints.

This development has been proposed in consideration of the anticipated benefits in the reduction of road congestion, noise and pollution and to keep the transport cost per tonne-kilometre as minimum as possible. Similarly, some forms of social benefit are likely to be realised, namely leisure and tourism.

7.6.2 The waterway channel development

The development of the waterway channel will cover the river section from the Federal Highway bridge to the Klang River estuary for a distance of 70 kilometres. The proposed route will link the waterway to the existing Klang North and South Ports. At present, the cross-section of the river channel's width, depth and distances between river sections are as shown in the following table 7.7. The cross-section of the river for the various sections is shown in figures 7.6 and 7.7.

Table 7.7: Width, depth and distance of Klang River sections at present

Following the standard practices of earlier inland waterway developments, the following types of construction works have been identified. Some or all of these will be necessary in the proposed Klang River development. In addition, channel construction cost data for the recent flood mitigation project for Klang River (in Ringgit Malaysia) is shown in appendix 8 for information and could be used when necessary.

i) Land acquisition

In a number of circumstances, land take is critical because not only it is expensive but also because of a land scarcity. It is a policy of the Kuala Lumpur City Council (DBKL) and other local authorities to reserve land corridor along the river section for various circumstances. In the meantime, the corridor is used for planting and beautification, river bank strengthening, flood mitigation, building for leisure, recreational and tourism facilities as well as possibility of future expansion or redevelopment programmes.

Figure 7.6: Klang River channel cross-section: Federal Highway Bridge to Puchong Drop

Figure 7.7: Klang River channel cross-section: Puchong Drop to Damansara River Junction

However, it is assumed that there will be no land acquisition cost involved in this development, mainly because this project is proposed to the government for its development which will generate social benefit into the region in particular and the country in general for the delivery of goods at presumably low transport cost. If the private sector is involved however, the land cost can be negotiated based on market price, perhaps with some subsidies to be granted.

ii) *Excavating, cutting (for alignment) or dredging*

Clearly, the volume of dredging will have to be determined before any costs in these areas can be estimated. Fortunately, for this development in particular, a large section of the intended development has been widened recently under the flood mitigation project. Hence, the required volume of excavating and dredging of the channel will clearly be less, resulting in lower initial cost. Table 7.8 shows the required volume of dredging in cubic metres for the channel expansion programme.

Table 7.8: The volume of channel materials to be dredged

Named Section	Volume of dredged materials required
AA	Original cross-section: 35m (w) by 2.0m (d) Required cross-section:43m (w) by 3.5m (d) Volume to dredge: (43-35)x(3.5-2.0)*1,500m = 18,000m^3
BB	Original cross-section: 40m (w) by 2.0m (d) Required cross section:43m (w) by 3.5m (d) Volume to dredge: (43-40)*(3.5-2)*4,500m = 20,250m^3
CC	Original cross-section: 42m (w) by 2.0m (d) Required cross-section:43m (w) by 3.5m (d) Volume to dredge: (43-42)*(3.5-2)*3,500m = 5,250m^3
DD	Original cross-section: 50m (w) by 2.0m (d) Required cross-section:43m (w) by 3.5m (d) Volume to dredge: (3.5-2)*6,500m = 9,750 m^3
EE	Original cross-section: 70m (w) by 3.0m (d) Required cross-section:43m (w) by 3.5m (d) Volume to dredge: (3.5-3)*54,000m = 27,000m^3
Total volume, x	= 80,250m^3
Total cost, y	y =GBP 4.78/m^3, y =4.78*80,250 =GBP 383,595

iii) *River bank and bed protection*

It is expected that channel bed protection is required to cover certain section of the river whereby porosity is prominent due to channel bed dredging and levelling works. However, extreme care is exercised to ensure the channel bed is safe from any leakage and absorption. If this is unavoidable, layers of geotextile material including sealing sheets and protection schemes are needed to cover the channel bed for water retaining purposes.

In this project, the river bed is assumed to be stable without any damage occurring during the dredging works. However, the river banks still need to be stabilised and strengthened by geotextile materials, rocks or stone pitch. Using equations derived in chapter three, table 7.9 illustrates the quantity and cost of bank and bed protection required for the river channel.

Table 7.9: River bank and bed protection costs

16km (from Federal Highway Bridge to Puchong Drop only)	**Total cost (GBP 1995 prices)**
i. Close turfing berm, x = 16km @ 16,000m	y = 100/m =1,600,000
ii. Geotextile, x = 16km @ 16,000m @ 112,000m^2	y = 4.5/m^2 = 504,000
iii. Rock, x = 16km @ 16,000m	y = 95/m =1,520,000
Total cost	3,624,000

iv) *Planting (and fencing)*

The main purpose for using plants in this category is to stabilise the bank. It also improves the aesthetics of the area. The provision of basic planting will include ground cover, shrubs and also the appropriate planting as to transform or maintain the river corridor. The basic planting may be a combination of aesthetic planting, reinforcement planting, the available area and future use for the planted area. Similarly, equations in chapter three are used and the following table 7.10 presents the estimate of planting, and associated fencing costs.

Table 7.10: Planting and fencing cost

16km (from Federal Highway Bridge to Puchong Drop only)	Total cost (GBP 1995 prices)
x = 16km @ 16,000m Total planting and fencing cost	y = 200/m = 3,200,000

v) *Landscaping (river bank reinforcement) and drainage*

This is done by removing the obstructions detrimental to landscaping work such as illegal structures and rubbish. This will also clear the river-edges of wild plants that disrupt the water flow as well as degrading the visual quality of the river corridor. River bank reinforcement should use natural looking materials where the effect of a natural river is being achieved by other work, including landscaping. Likewise, equations in chapter three are applied and the following table 7.11 presents the cost of landscaping.

Table 7.11: The landscaping cost

From Federal Highway Bridge to Puchong Drop only	Total cost (GBP 1995 prices)
x = 16km @ 16,000m	y = 75/m = 1,200,000

vi) *Culvert*

Culverts are usually required as part of canal construction schemes. Based on the UK model, a typical rural canal will need some 17 culverts per 16 kilometres as a general guideline. However, river channels rarely require culverts and this is assumed to be the case for the River Klang because all the land origin water flow will discharge direct into the river channel [*13*]. Therefore, culvert construction cost does not require inclusion in this application.

vii) *Outlet structure or tidal flood gates*

Based on the past flood mitigation project on the Klang River, tidal gates are necessary because originally the river has been functional as the flood relief scheme. A typical one unit tidal gate is required for every half kilometre length of waterway. For 16 kilometres length of the channel section, 32 gates will be required. One unit will cost RM100,000 [*13*] or GBP 42,500 expressed in 1995 prices. Therefore, 32 units outlet structures require a total of GBP 1,360,000.

viii) *Embankment*

The design for the embankment or levee will be based on the flood mitigation study in recent years. The cross sectional profile of the levee is shown in figure 7.8. There are two type of levees to be constructed. Firstly a levee with side access road and secondly a levee with top side access road (figure 7.8). Raising low levees is less costly and more effective than trying to excavate the channel wider and deeper than the optimum design requirement. This method will also be less damaging to the river bank vegetation.

The cross-section adopted for the levee is an arbitrary one and can be reduced when necessary. The construction of levees for the river bank downstream of the Connaught Road bridge a distance of approximately 22.5 km from River Klang estuary will be 9.5 km only. This is because a total of 35.0 km (on both side of banks) of levees have been constructed in the recent project.

The rest of the river section from Federal Highway Bridge (location of the proposed inland terminal) to the Connaught Bridge, a distance of 47.5 km, only needs one levee on one side of the bank because construction of levee for the other river bank has been carried out recently. Using the equations derived in chapter three, the cost for the construction of the levee is shown in table 7.12.

Figure 7.8: Levee construction for Klang River development

Table 7.12: Embankment/levee estimated construction costs

Levee section	Estimated volume m^3	Cost GBP 1995 prices
Levee 1 = 47.5km -With top access road	x =(4.5*3.5)+(4.5*3.5)*47,500 = 1,480,500m^3	
Levee 2 = 9.5km (22.5*2) - (35.0)	x =(3*3.5)+(4.5*3.5)*9,500 = 249,375m^3	
Total levee material required	= 1,729,875m^3	
Generalised dredging cost/m) Total cost (levee 1)	= 130/m (see appendix 10) = 130*47,500	 6,175,000
The costs (levee 2)	= 130* 9,500	1,235,000
Total cost		7,410,000

ix) *Road construction*

A road will have to be constructed on top of or by the side of the levee to provide access for maintenance or other activities. Based on the previous study [*13*], a road width of 4m is sufficient, paved with bitumen materials. The estimated cost per metre for the road construction is estimated at RM 222/m [*10*] or GBP 95/m in 1995 prices. Hence, the total road construction costs for 70 km is estimated at GBP 6,650,000.

x) *Lock construction*

In the recent flood mitigation project, it has been proposed that Puchong Drop will be removed and replaced with a slope. However, this is not feasible in relation to the movement of barges or other inland water craft. It is necessary to build a lock structure for a drop of about 3.6 metre. Fortunately only one lock is required for the 70 km stretch of this proposed waterway.

Based on the projected cargo movement, it is recommended that the lock should be able to take in two Class IV barges of European standard of 1,350 dwt. at once, or one barge with one other type of inland craft. It is anticipated that one lock structure will be sufficient for the 25 years projected cargo throughput. Second lock would not be necessary as it will increase capital and operating costs of the project. With the barge size of 80m length, 9.5m width and 2.5m draught, the dimensions of the lock can be determined. Using the equation derived in chapter three, section 3.5, the result is shown in table 7.13.

Table 7.13: A proposed lock dimension for the KVWH

Lock structure	Required dimension
Net length (m)	1.15*80m*2 = 184.00m
Net width (m)	1.15*9.5m = 10.93m
Net depth (m)	1.25*2.5m = 3.13m
Lock volume	x = 185*11*3.2 = 6,512m^3
Lock cost (GBP 1995 prices)	y = 18.6+0.41x = 2,688,520

xi) Bridge construction

The benefit of the channel improvement works is to enable and ensure the movement of barges and other water craft along the waterway. Most of the existing bridges available on the proposed section of the waterway development are restricted by the bridge air draught. With small clearances, the bridges may obstruct the movement of barges underneath, particularly during the flood season, resulting in traffic disruptions.

Puchong Drop Bridge should not present any obstruction to the river traffic and due to its recent improvement (figure 7.9). With a span of 100m and height of 12m and interval pier spacing of 20m, a barge of 9.5m width can pass through safely underneath the bridge. The slope section of the river bank underneath the bridge structure should be cut vertically and protected with concrete retaining wall to provide bigger navigational width. Barges waiting to enter the lock can moor at a nearby mooring bay which need to be constructed.

A four lane road bridge with 3.8m each direction is expected to be sufficient for the movement of traffic to the year 2020 when the KVWH system will be further reviewed

Figure 7.9: Puchong Drop Bridge typical cross-section

for redevelopment programme especially to the fixed structure such as bridges and locks to accommodate a bigger freight capacity in future. There are currently 9 major bridges exist on the 70 km section of the proposed navigation. Excluding the Puchong Drop bridge, the remaining 8 other bridges need to be improved or replaced with new ones. Using the model generated in this study in earlier chapter three, the estimated bridge construction cost is shown in the following table 7.14.

Table 7.14: Road bridge construction cost

Bridge specifications	**Bridge cost (1995 prices)**
Bridge area= 70m*15.2m = 1,064m^2	
Bridge costs (1 bridge) The cost for 8 bridges	y = GBP 1,704/m^2 (appendix 10) = GBP 1,813,056 = GBP 14,504,448

7.6.3 Cost estimating discussion

The inland waterway track development estimates have principally used the model derived in this study. However, there are circumstances (in case UK data is inadequate) where data from the recent River Klang flood mitigation project is applied. As discussed in previous chapter three, the development costs in GBP 1995 has to be adjusted to the tender prices by additional 15-20% contractor's cost, 10% design and supervision and 10% contingencies. The final costs are then converted to Ringgit Malaysia (RM) by the application of price indices, also derived in this study. The total estimated capital investment cost for the KVWH using the model is summarised in the following table 7.15.

Looking at the cost estimates, it shows that the bulk of the investment cost derives from the replacement cost of eight existing bridges and embankments. However, it is notable that even with this total cost, it is still very much cheaper than developing a similar project in the UK in the same year, for example GBP 21.5 million (1995 prices) for the 3.5km St Aidan waterway [*14*]. This due to the higher cost of living and hence higher labour and material costs.

Table 7.15: A summary of the development of the Klang Valley Water Highway (in Ringgit Malaysia 1995 prices)

Development parameters	GBP ('000 1995 prices)
Excavating/cutting/dredging	385
Bed (bottom) and bank protection	3,624
Embankment/levee	7,410
Lock construction	2,689
Tidal gates	1,360
Landscaping and drainage	1,200
Planting and fencing	3,200
Bridge construction	14,504
Road construction	6,650
Total cost	41,022
20% contractor's price	8,204
10% design and supervision	4,102
10% contingencies	4,102
Grand Total	57,431
Adjusted to Ringgit Malaysia ('000 RM)	
@ 3.85 (1995 currency exchange rate)	221,110
@ 0.60 (cost index)	132,666
Development cost per kilometre	132,666/70=RM 1,895/km

It is also important to have some knowledge of the likely amount of operating and maintenance cost. The British Waterways Board (BWB) estimates the operating and maintenance costs of GBP 21,848 per kilometre in 1995 prices [*15*]. Similarly, the BWB model for human resource requirement is 0.5 person/km. The average cost per staff is GBP19,000 per annum (1995 prices) includes all the fringe benefits of approximately 30% of the gross annual salary.

In a number of project analysis, the operating and maintenance cost is appropriately expressed in percentage of capital cost of per kilometre of waterway length. Although there is no specific rule of thumb to be used in deciding the appropriate costing method, experience from past relevant work of organisation such as British Waterways, Manchester Ship Canal Company, ESCAP study, etc. will certainly be adopted as general guidelines.

7.7 The KVWH self-propelled vessel cost estimates using the model

It has been the aim of this work to use the model to provide general guidelines on the development costs of an inland waterway transport system before more detailed planning. Influenced by channel configuration, and in particular the lock dimensions, the size of vessels and hence capital and operating costs can be estimated. The interdependence of these factors is noted, and may ultimately result in some revision of the channel parameters.

The number of vessels to be provided depend on a number of factors as discussed in chapter 4. Amongst other things are the type and throughput of cargo to be carried, distance, speed, lockage time, voyage time, port time as well as weather factors. In this work, a self-propelled vessel of 1,350 dwt for bulk cargo and 126 TEU for container (LO/LO) will be considered for the proposed development. A number of assumptions have been made, as listed in table 7.16.

Once the barge dimension is known, the daily movement of cargo and the likely number of trips required can be estimated. This figure will be used to forecast the number of barges required as a function of barge speed and return trip time. However, the vessel's turnaround time depend on factors such as lock transit times (whenever applicable) and particularly port time. Time in port (or terminal) depends on the cargo equipment's handling rate as well as the number of equipment available.

Assuming the annual operating time of 350 days, a vessel with a turnaround time of 2 days per trip can perform 175 trips per year. The vessel's capacity utilisation factor can achieve 0.95 [*16*]. Thus a 1,350 dwt vessel can accommodate 1,280 tonnes for every trip giving a total capacity of 224,000 tonnes per vessel per year. This will be the basis for determining the number of vessels required per year to carry the projected annual cargo throughput.

Table 7.16: Assumptions for the operating time of the self-propelled vessels

Type of operations	Operating hours (one way)
Vessel speed = 10 kmh Distance = 70 kilometre, hence *Voyage time (VT)*	7 hours
Lockage time (LT)	1 hour
Assumed 1 hours waiting time Assumed 4 hours handling time (a) (loading or unloading) Assumed 3 hours berthing time *Port time (PT)*	8 hours
Navigation daily operating time (NDOT) (6.00 am to 10.00 p.m.)	16 hours/day
One way (Port A-B) Two ways (one trip A-B-A)	(7+1+8)=16hours (1 day) 1 day x 2 trips = 2 days

Notes: (a) Crane gross productivity = 300 t/h, vessel capacity = 1,350 dwt
Port time = approximately = 1,350* 0.8 (load factor)/300 t/h = 4 hours
Berthing and unberthing time of approximately 3 hours

For a container vessel, the utilisation factor is assumed to be 0.95 considering that the vessel have been designed to accommodate high percentage of the container boxes. For example, the 126 TEU container (equivalent to 1,350 dwt of self-propelled bulk vessel) will accommodate containers, 3 boxes wide, 7 boxes length and 3 boxes high of stacking arrangement resulting in 63 forty foot containers carried in one movement. With a vessel turnaround of 2 days per trip, 175 trips per year result in one vessel able to move 21,000 TEUs as the basis for determining the number of vessels required for a given throughput per year.

Based on the amount of projected cargo throughput per year and 10% share of cargo to be moved on the proposed KVWH, the required number of self-propelled vessel needed for each year to accomplish the transportation can be determined. The market shares is assumed to be acceptable in comparison to the inland waterways shares for other maritime developing nations of China 17%, Bangladesh 44%, Burma 50%. This compares with USA 11% and Western Europe 28% [*17*].

Using the model developed in chapter 4, the capital cost of a 1,350 dwt vessel is estimated at GBP 3.3 millions. Similarly, the model for the vessel operating cost per annum is estimated at GBP 0.63 million both in 1995 prices. Using the cost index, these costs (based on Netherlands data) are adjusted to GBP 2.78 million and GBP 0.53 million for capital and operating costs respectively using cost index (appendix 6). These costs in Malaysia currency were RM6.5 million and RM1.22 million respectively.

Likewise, the number of additional vessels needed for the following year can also be determined. The following two tables, 7.17 and 7.18 show the typical capital and operating costs of the vessels for the transportation of bulk cargo and containers respectively between Port Klang to the newly proposed inland cargo terminal at a distance of 70 kilometres for an anticipated life time of 25 years.

Table 7.17: Bulk Cargo movement on KVWH (1995-2020)

n	Year	Dry bulk throughput ('000 t)	Total number of vessel operating	Additional vessel required	Capital cost of vessels (RM million)	Operating cost per year (RM)
0	1995	627	3		19.50	3.66
5	2000	882	4	1	6.50	4.88
10	2005	1,136	5	1	6.50	6.10
15	2010	1,391	7	2	13.00	8.54
20	2015	1,645	8	1	6.50	9.76
25	2020	1,900	9	1	6.50	10.98

Notes: *n* is a number of year of the project
operating cost is calculated based on the number of vessels in operation at any time

Table 7.18: Containers movement on KVWH (1995-2020)

n	Year	Container t'put ('000 TEUs)	Total number of vessel operating	Additional vessel required	Capital cost of vessels (RM million)	Operating cost per year (RM)
0	1995	80	4		26.00	4.88
5	2000	110	6	2	13.00	7.32
10	2005	141	7	1	6.50	8.54
15	2010	171	8	1	6.50	9.76
20	2015	202	10	2	13.00	12.20
25	2020	232	11	1	6.50	13.42

Notes: *n* is a number of year of the project
operating cost is calculated based on the number of vessels in operation at any time

The result in tables 7.17 and 7.18 above show the capital and operating costs of vessels at 5 years interval for 25 years. Based on the future projected growth of cargo throughput per annum, additional transport capacity would be required and this could result in additional capital and operating costs. However, the annual capital and operating cost of the vessels can be interpolated from the tables for financial appraisal purposes.

The small number of vessels in the fleet operating on the waterways is assumed not to pose serious congestion problems for at least to the next 25 years of the project life. Therefore, the waterway is expected not to undergo any major improvement programme such as the expansion of channel's width and depth, the employment of bigger vessels, the enlargement of the existing lock or the construction of additional ones or the construction of more inland cargo terminals with additional handling equipment with their cost implications.

The level of waterborne cargo movement should be monitored to ensure the system runs efficiently and economically to the benefit of the operators, and users as well as the country at large. This means, on one hand, further financial investment could result in more cargo being captured and moved on the waterway. Conversely, a restriction on financial investment will place an upper limit cargo throughput. The best option will only be determined by financial and economic appraisal in relation to the success of the waterway in generating traffic.

7.8 Klang Valley inland terminal cost estimates

The proposed inland terminal for both the dry bulk and container is approximately 70 kilometres from the river mouth and situated within the city of Kuala Lumpur. There was no extensive information available regarding the status of the proposed site in terms of current social and economic usage and development. For the purpose of model application and feasibility evaluation, it is assumed that an appropriate site is available.

The terminal size, including the requirement for berth facility and cargo handling equipment which is the function of cargo throughput, was determined using the model. The model was also used to estimate the cost of the development as well as operating and maintenance cost.

During the data collected for the terminal model construction, one of major Malaysian ports i.e. Johor Port was visited. Personal communication with one of the principal engineers resulted in the data tabulated in tables 7.19 and 7.20. This data is used in the model whenever necessary. The model forms the basis for the determination of the proposed terminal characteristic and requirement.

Table 7.19: Container terminal cost estimates by Johor Port Authority (1995 prices)

Table 7.20: Bulk terminal cost estimates by Johor Port Authority (1995 prices)

The model derived in this work have been used in estimating terminal infrastructure facility and equipment requirement as well as costs. These estimates can then be compared to the Johor Port's figures. Whenever necessary, the figures from Johor Port can be supplemented in the model for application. In this way, the reliability of the model can be maintained throughout the application.

7.8.1 Bulk cargo terminal

The model is firstly applied in determining the terminal facility requirement such as terminal land acquisition, berth, transit shed, warehouse and administration building. Secondly, the suitable type of equipment is determined in parallel with the number of units required. The model then estimates the costs ranging from capital, operating and maintaining the terminal

The estimate will be based on the cargo throughput per year as well as the size and number of vessels using the terminals. The projected cargo throughput as shown in previous table 7.7 will be used as the basis of the estimate. The cost for terminal infrastructure requirement will be estimated for 25 years. However, the cost for equipment requirement will be estimated on five yearly basis in order to avoid unnecessary spending on redundant equipment. The following are the results of the analysis for dry bulk and container terminal development costs, using relationship derived in chapter 4.

7.8.2 Capital investment costs for bulk and container handling equipment

Although several types of cargo handling equipment are available for bulk and containers handling, only specific types are employed based on the system considered. A typical Malaysian experience of Johor Port in the selection of equipment has been adopted in this study for both terminals. Using the model developed in this study, the results of the analysis are shown in table 7.23. All major equipment for both type of cargo and terminals are evaluated to provide options for the favoured handling system as in the following sections.

Table 7.21 : Inland bulk terminal development cost

	Area/length required	Costs (million)
Terminal area required = 1,900,000 tonnes x 0.08 Cost = 152,000 x GBP 25/m^2	152,000 m^2	GBP 3.8
Transit shed required = 1,900,000 tonnes x 0.04 Cost = 76,000m^2 x GBP 150/m^2	76,000 m^2	GBP 11.4
Quay wall required = No.of ship in fleet in year 2020 = 5 calls/day return trip time per vessel = 5 x 80m (vessel length)+20% allowance Cost = 480m x GBP 10,000/m	480 m	GBP 4.8
Warehouses required = 1,900,000 tonnes x 0.03 Cost = 57,000m^2 x GBP 182.5/m^2 [Spon's]	57,000 m^2	GBP 10.4
Administration area required Cost = 300 m^2 x 775/m^2	300 m^2	GBP 0.233
Total Cost Plus 15% contingencies factor Total investment cost Cost in Ringgit Malaysia		GBP 30.6 GBP 4.6 GBP 35.2 RM 82.7

Table 7.22: Inland container terminal development cost

	Area/length required	Costs (million)
Terminal area required, $y = 2,073 + 0.89x$, where x = 232,000 TEUs Cost = 208,553 x GBP 25/m^2 =	208,553 m^2	GBP 5.2
Transit shed required = 232,000 TEUs x 0.4 Cost = 92,800 x GBP 150/m^2	92,800 m^2	GBP 13.9
Quay wall required = No.of ship in fleet in year 2020 = 6 calls/day return trip time per vessel = 6 x 80m (vessel length) +20% allowance Cost = 576m x GBP 10,000/m	576 m	GBP 5.8
Warehouses required = not required		
Administration area required Cost = 300 m^2 x 775	300 m^2	GBP 0.233
Total Cost Plus 15% contingencies factor Total investment cost Cost in Ringgit Malaysia		GBP 25.1 GBP 3.8 GBP 28.9 RM 68.0

i. Bulk cargo handling equipment

Based on Johor Port experience, the choice is between grabbing crane, unloader or belt conveyor for the handling of bulk cargo. The costs for providing the three equipment types above has been estimated and the cheapest one selected for application to the newly developed inland bulk terminal. The estimated cost are shown in table 7.23. Although the analysis is made for three major types of equipment, only one type would be required and this clearly need to be selected appropriately.

Table 7.23: Estimated costs of bulk cargo handling equipment

The choices of equipment are largely influenced by the local operating practices as exemplified by Johor Port. Based on the projected container throughput, the model determines the terminal equipment requirement and costs. A study by Champion [20] suggests that a typical 100,000 container movements require 2 quay cranes in comparison to 4 units for a 250,000 movements per year indicating the economies of scale. In practice however, a number of assumptions are necessary in estimating the equipment requirement and costs. Table 7.24 show the result of the model analysis.

Table 7.24: Estimated costs of container handling equipment

For the container terminal equipment requirement, a number of options can be considered. However, for simplification and cost effective measures, the straddle carrier direct system is preferred. The type of equipment required under this system would be quay cranes and straddle carriers only. Clearly, there is a need to estimate the annual capital and running costs to be input in the financial appraisal in the project life of 25 years. Data in previous table 5.15 in chapter 5 is used in further analysis.

7.9 Summary

Inland terminal design are influenced both by the characteristics of the cargo types and annual throughput as well as the vessel type and size. Inland terminal infrastructures and handling equipment are expensive to provide. These infrastructures and equipment have a wide variety of life cycles and maintenance cost structures, making it difficult to estimate the costs.

Terminals rarely adopt the same policy in their development and operation. This is mainly due to a clear distinction between one terminal operator's choices as compared to the other. Where profitability and benefits are generally the main determinant for selecting the terminal system, other factors can be of significant important too.

In this analysis, design and planning for terminal infrastructure and equipment requirement have been carried out according to recommendation made by ESCAP studies for mainly developing countries. The infrastructures and equipment are determined according to the optimum requirement. This is done to ensure the costs estimated using a number of costs data from various sources can be justified for further analysis in the financial and economic assessment in the preceding chapter. It is important to note that unnecessary provision or equipment redundancy due to over purchased are uneconomic.

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CHAPTER 8

Financial appraisal and cost benefit analysis

CHAPTER EIGHT

FINANCIAL APPRAISAL AND COST BENEFIT ANALYSIS

8.1 Project evaluation theory and principle

A project evaluation is treated in accordance with the objective of its development. Apart from the financial capability, political stability and the demand for quality of transport and a priority scheme which is mainly based on economic benefits, are always an important consideration. The principle of public or private project appraisal requires the estimation of the costs and benefits associated with the project, the choice of discount rate [1] and the typical project life of a particular project as an example shown in table 8.1.

Table 8.1: Typical range of physical lives of selected projects

It is often difficult to attach a money value to all costs and benefits. Difficulty also arises in the choice of a discount rate. An assessment of the benefit should consider the effect of future growth in the area both with and without the project. This should be carried out with a wide understanding of the social and economic problems of the country concerned. When there is a lack of accurate information and statistics, good judgement and experience in the evaluation of data is important [1].

Those costs and benefits which can be valued in money terms should be set out against the time when they are expected to occur. Although there are different implications between commercial and public project, in general they normally are [2]:

i. Capital cost including buildings, equipment and land
ii. Running costs over the whole life of the option
iii. Significant costs and benefits which affect part of the public or private sector
iv. Benefits in the form of revenues, cost savings or other outputs

In transport infrastructure projects, a series of financial packages are possible, ranging from those financed by government or entirely private fund. The financing of major transport infrastructure projects comes under the broader category of project financing which is generally defined as "*The financing of an economic entity which is viable from the technical, commercial and financial viewpoint and which will generate a cash flow considered sufficient to ensure, with a safety margin for uncertainties, the debt service, the coverage of operating costs and a fair return on capital*" [3]. The financial analysis must evaluate the financial viability of the project and the impact of the investment [4].

Both a financial appraisal and economic evaluation are generally required before an investment project is approved [4]. The two criteria are identical in many respects. They take into account the time-value for money. For instance, there are various different measures of merit used to evaluate investments as shown in table 8.2.

Table 8.2: Project investment evaluation criteria

8.2 Introduction to cost and financial theory

There are a number of costs to be considered in project evaluation namely;

8.2.1 Opportunity cost

Most resources have alternative uses in the economy. The cost of using them is an alternative use that is foregone. This is called opportunity cost [2]. It is this opportunity cost that is used to value resources in investment appraisal. Resources should be financially assessed at their full value in the best alternative use. To be acceptable, a project must earn a minimum return equal to that being invested and it must earn at least as great a return as could be earned on any project which it displaces [*1*].

8.2.2 Shadow prices

The internal opportunity cost of capital is called shadow price of finance [*1*]. Any resource may have a shadow price if it is scarce in the sense of being absolutely limited in amount. It restricts an organisation's ability to accept projects and a choice has to be made between different alternatives.

8.2.3 External financial considerations

i. <u>*Interest:*</u>

Investments are made to earn money and their costs can be measured in terms of the required future earning. In addition to direct outlay there is a financial interest which is forgone on the invested principal. The eventual earning should cover both the cost of regaining the money invested and the forgone interest on that money until it is recovered. The cost of repaying the borrowed money is the instalments that repay capital and interest to the lenders.

ii) *Inflation*

Evaluations can either be carried out in real terms (that is with constant purchasing power excluding the inflation consideration) or in money terms (that is including an allowance for inflation) [*1*]. The former method appears to be less realistic although it generates acceptable results as long as the appropriate discount rate is applied [*5*]. However, some appraisals ignore the inclusion of inflation rate since the opportunity cost of capital has been expressed without inflation rate too. This is called 'working in real terms approach' [*6*].

iii) *Depreciation*

There are straight line, declining balance and free depreciation [*5*]. Straight-line depreciation may be assessed as the cost over expected life of a project. The declining balance depreciation which is now used in the UK, makes the annual allowance for depreciation to be a percentage of the residual value each year. Free depreciation allows the cost to be written off against tax as fast as profits permit [*5*].

iv) *Taxation*

Special considerations of the effect of taxes may apply to certain government projects. In other cases, the accepted rule is to treat a payment of taxation as a negative component of the cash flow. The discounting rate to be used must be similarly net of tax and should reflect the rate of return on the best alternative use of finance.

8.3 Cost and benefit analysis (CBA)

Cost benefit analysis is an aid to decision making which differs from ordinary calculations of profitability [*6*]. Cost benefit analysis attempts to go more widely so as to include all effects, costs and benefits which can be expressed in economic terms. CBA is a method used to recommend policy actions based on a comprehensive evaluation of all costs and benefits associated with public or private projects [*7*]. The task involved in conducting the CBA is summarised in the following table 8.3.

Table 8.3: Tasks in cost benefit analysis

The precise method of project appraisal chosen depends not only upon available techniques but also upon how the choice is characterised [*8*]. An expenditure is to be judged potentially worthwhile if its benefits exceed its costs, where benefits and costs are defined to include any gain and losses which occurs because of the expenditure on the project [*9*]. Most governments are concerned to secure value for money from investment expenditure. Hence, CBA was adopted as a technique for assessing 'value *for money' in precisely such circumstances.*

The real situation which comes closest to the analysis occurs when a government agency invests in transport infrastructure for which it does not charge directly [*10*]. This investment may reduce journey times and possibly the operating cost as well. The economic effects of noise, dirt, fumes, accidents and other disruption may also be considered. The following table 8.4, lists three main components of measure of benefit.

Table 8.4: Three main measures of benefit

8.3.1 External economic considerations

There are a number of economic considerations in relation to cost and benefit which require attention. The direct or indirect impact from their existence or reduction can be measured and include in the CBA. The most commonly considered are:-

i) *Noise*

Noise is evaluated through an analysis of individual choices [*10*]. There are a number of approaches to the evaluation of noise. For instance, how much would it cost to install sound barrier to buildings to prevent excessive noise etc.

ii) *Air pollution*

This subject relates to health effects, corrosion, smell, dirt, irritation etc. There are several sources of information regarding physical contribution of motor vehicles to air pollution which can be useful for the analysis.

iii) *Vibration*

This item has a direct physical effect which in turn result in financial costs. Example of these are repairs to structure, cleaning costs etc.

iv) *Value of life saved due to reduction of accidents*

The benefits from the reduction in the number and fatality of accident constitute an important element in the economic appraisal of any transport scheme (especially a road network). It is necessary to provide accident savings with an appropriate monetary valuation.

v) *Value of time saved due to reduction in congestion*

A changes in time taken by traffic to pass along road networks are the major items of a calculated benefits resulting from a road development. It is necessary to put money value on time savings to compare these to construction costs and vehicle operating costs savings.

8.4 Klang Valley Water Highway development: Project evaluation

8.4.1 Project analysis background

Major public transport infrastructure development projects in Malaysia are typically undertaken by the government or a semi-government body [*11*]. They are based generally on economic justification rather than financial profitability. The economic benefits of inland waterway transport (IWT) does not necessarily benefit the IWT authority alone but also other sectors of the national economy. IWT and terminal charges are kept at low level to enable other sectors to generate financial profits. The utilisation of waterways are therefore expected to generate both economic and financial benefits [*12*],[*13*].

According to ESCAP [*12*], the financial analysis is most often geared to analysis of IWT pricing strategies, budgeting of initial government investment and operating subsidies. Therefore the financial analysis of the project evaluation indicates the impact of the project on the financial well being of the authority.

The Malaysian Ministry of Finance would like to be convinced that the authority will be able to meet operating expenses, interest and repayment schedules and possibly the minimum internal rate of return (IRR) before considering acceptance. The acceptable return of the investment however, is highly judgmental and depend on the nature of the project and the approach of the government or private body making the investment. For instance, a strategic investment in the development of the inland waterways may be financially acceptable if it can pay the continuing operation, maintenance, loan interest and repayments with no financial return to the government.

The economic analysis of an investment is invariably based on the comparison of what is expected 'with investment' (WI) versus 'without investment' (WOI). Therefore, it is absolutely necessary to develop the scenarios for the 'with' and 'without' options under the expected future conditions (e.g. increasing cargo volumes) [*12*]. Several steps will be considered in identifying the relevant benefits. The most common benefits are:

i. Reduced transport costs due to shift of cargo from more expensive land transport to less expensive inland water transport.

ii. Reduced unit transport cost by using larger transport.

iii. Reduced accident costs by the reduction of vehicles on road.

iv. Reduced congestion costs by the reduction of vehicles on road.

v. Reduced capital investment per unit of cargo carried.

IWT project may affect other economic activities and achieve the external benefits. Where those benefits would not be feasible without IWT investment, the net value added of the increased outputs or improved living conditions may be considered as economic benefits. These benefits commonly include flood control, irrigation benefits, environmental etc.

The incremental economic costs include all of the incremental physical inputs (labour, material, etc.) but exclude such non-physical items such as financing costs (interest, debt payments, etc.) and non-cash items as depreciation. Import duties and taxation which are usually included in the financial analysis are excluded from the economic costs as they are not the cost to the economy but merely a transfer within the national economy [*12*].

It is preferable to carry out the financial analysis first (especially the FIRR) without inflation so the pure operational productivity of the investment can be better understood. Adding inflation will almost always increase the FIRR of the project. Some judgement is needed to compare the FIRR with and without inflation against the appropriate prevailing interest rates.

Developing countries often engage foreign loans to finance projects [*12*]. If local currency devalues substantially, there is difficulty in servicing the interest and repayments. As IWT revenues and most operation and maintenance costs are in local currency, the devaluation impact will be not be included in this analysis.

8.4.2 Inland waterway project financial and economic appraisal

The new inland waterway transport system will be in competition with other modes of transport. To be competitive, this new system is expected to provide benefits to all users in financial and economic terms. It will be to the interest of investors that financial gains are of prime consideration. The government authority would be interested in social and economic gains through a reduction of vehicles on road, i.e. less congestion and fatality cost, cheaper transport cost via inland water transport as well as enhancing environmental values.

In this study, the analysis for financial feasibility of the proposed project are examined through the net present value (NPV) of the investment over 25 years of the expected average project's life. According to the UK Department of Transport's Cost Benefit Analysis (COBA) [*13*], NPV is an appropriate technique for determining the feasibility of a transport system development project. In addition, a 10% interest rate has always been applied as the favourable test discount rate (TDR), although various rates can also be used for sensitivity analysis exercise.

The proposed individual system namely navigation channel, vessel operation and inland terminal merges together as a fully integrated inland waterway transport system. However, the financial analysis recognises the importance of each sub system to be assessed individually before the entire system is assessed as a complete system. In this way, the feasibility and the social and economic benefits of each sub system can be determined individually and then collectively.

The following sections examine the feasibility of the project through financial and economic analysis.

i. *Inland waterway track development analysis*

In this analysis, capital, operating, and maintenance costs of the waterway track for 25 years are assessed against the track revenue through toll charges imposed on a vessel's dwt plying the channel for 25 years. It has been estimated in chapter 7 of the case study that the capital investment would be RM 133 million at the start of the project. Annual operating cost for the waterway track is assumed to be 1.9% of capital cost whereas the maintenance cost is 1% of capital cost based on MSCC model [*14*].

Waterway track revenues through the imposition of toll charges of RM 4 per vessel dwt based on BWB model (chapter 4) generates RM 6.62 million per the first year [*14*] in 1995 prices. These revenues will increase in preceding years based on the number of vessel in the fleet thus increase the number of trips where tolls are applicable. The resultant net profit after 25 years is RM 55.25 million as shown in appendix 15. The net profit for waterway track would actually be much higher because the waterway track physical life cycle is expected to reach 50-75 years and still generate profit without further or even small investment. Similarly, if the channel development cost can be minimised, the net profit would also be higher.

ii. *Inland waterway vessel investment analysis*

In this analysis, the capital investment and annual operating cost for the vessel with an assumed life cycle of 25 years is assessed against the vessel's revenues through freight earnings over the same period of time. The vessel capital cost estimated using the model is as in chapter 4 of this study is RM 6.5 million each for both the dry bulk and container vessels of approximate identical size. Similarly, the total vessel's annual operating cost also estimated by the model is RM 1.22 million. On top of these the vessel would also be subject to navigation tolls and port charges.

Freight rates for both types of commodity are estimated at RM 14 per tonne and RM 130 per TEU for dry bulk cargo and containers respectively comparative to current freights charged by road transport in Klang Valley [*15*]. Toll charges for vessels equate with the toll revenues received by the waterway authority as indicated in the earlier analysis in section (i) above. The composition of port charges are as in table 8.5. Assuming the terminal only handles import cargo, the analysis has resulted in the financial account as shown in appendices 16 and 17 for dry bulk and container vessel respectively. The following sections are typical guidelines of charges for dry bulk and container vessel based on a study by ESCAP [*16*] in Ringgit Malaysia (RM) in 1995 prices.

Table 8.5: Composition of port charges for both type of vessels

The capital cost of constructing the terminal infrastructure and associated terminal equipment, is dependent on the projected cargo throughput for 25 years of project life. Terminal equipment requirement are assessed at five yearly intervals. This is done to ensure the equipment are provided according to the number of unit required, thus eliminating an overprovision and equipment redundancy.

The analysis for both the dry bulk and container terminals are carried out individually to examine the level of profitability to each system. However, these terminals will merge together as one system under the new integrated inland waterways transport system. Port expenditures, including annual operating and maintenance costs for both the infrastructure and equipment (dry bulk and container), are analysed against the revenues. The capital, operating and maintenance costs of the terminals are estimated using some of the guidelines as shown in table 8.6.

Table 8.6: Capital, operating and maintenance costs of terminals

Port revenues are obtained through two main sources. Firstly, the revenue from vessels making calls at terminal. This is chargeable against the vessel owner or charterer. Secondly, the revenues from the cargo handling operation assuming the equipment owned by the terminal authority. A revenue can also be obtained through warehousing and storage operation but not considered due to the complexities of charging practices characterised by far too many considerations.

In the following exercises, the port or terminal revenue obtained from a vessel can be referred to the previous section 8.5 (ii). In addition, the port or terminal revenue from cargo handling operation charged on shippers are given in the following paragraph [*16*]. The result of the analysis is shown in appendices 18 and 19 for bulk and containers respectively. The rate for cargo handling charges for both types of commodities are shown in table 8.7.

Table 8.7: Charges for bulk and containers handling operation at terminals

The transferring of 10% of total annual cargo flow from road to the proposed waterway as suggested in the scope of this study, has resulted in a reduction on heavy goods vehicles (HGVs) on the road. The productivity of one HGV equivalent to 1 x 24 tonnes/trip x 2 trips/day x 300 operating days/year carrying 14,400 tonnes of goods per transport per year. For containers, the productivity of one container transport of 1 x 2 TEUs/trip x 2 trips/day x 300 operating days/year generating 1,200 TEUs per vehicle per year. The productivity rate can determine the number of HGV reduction per year.

For an initial 10% of total annual bulk cargo of 6.274 million tonnes moved onto the waterway, this equates to a reduction in the road transport fleet of 32 vehicles. In the container transport analysis, a reduction of road vehicles is envisaged. These saving in vehicle stock against an all road system gradually increase over the life of the project.

The marginal congestion costs per vehicle-kilometre for Klang Valley is based on a study by a consultant [*17*] gives the value of RM 7.80/hour during peak hours and RM 1.15/hour during off-peak hours converted to 1995 prices. Assuming the peak hour of 2 hours in the morning (6.00 a.m. to 8.00 a.m.) and 2 hours in the evening (4.00 p.m. to 8.00 p.m.) would total up to 6 hours per day or 16.6% for peak and 83.4% for off peak hour of one day [*18*]. Thus the net congestion cost per vehicle-kilometre would be (0.166 x RM 7.8) + (0.834 x RM 1.15) giving a mean value of RM 2.25/hour. One vehicle can perform 2 trips/day x 140 kilometres/trip x 300 operating days/year i.e. 84,000 vehicle-kilometres.

The annual congestion cost reduction can be calculated from the vehicle stock reduction, the average annual vehicle kilometres and the weighted peak/off peak marginal congestion cost as tabulated in appendix 20.

v. *Fatality cost benefit analysis*

Based on a study by Malaysia's Department of Transport (DOT) the fatality rate is 7.3 deaths per 10,000 vehicles [*19*]. Assuming each heavy goods vehicle (HGV) travels an average of 40,000 kilometres per year minimum [*20*], the fatality rate for one HGV transporting the commodity to and from Klang Port and inland terminal (a distance of 70 kilometres) for 2 trips/day x 140 kilometres/trip x 300 operating days/year is 0.0015 death per vehicle as shown in the calculation as follows;

$$\text{Fatality Rate (FR)} = \frac{HGVi \times 7.3}{HGVii \times 10{,}000} \quad \text{where}$$

HGV*i* = 1 x 2 trips/day x 140 km/trip x 300 days/year = 84,000 Vehicle-km/year

HGV*ii* = 1 x 40,000 km/year = 40,000 Vehicle-km/year (assumed)

The UK Department of Transport's Cost Benefit Analysis model (COBA) uses a cost per fatality of GBP 744,000 based on 1992 prices [*13*]. With the application of the inflation rate and price indices, the cost equates to RM 1.75 million in 1995 prices as shown in appendix 20.

8.5 Discussion and summary

The analysis for the financial and economic analysis has been carried out with cautions. For example, maintenance and operating costs [*16*], and road fatality rates have been obtained from specific sources [*13*]. No extensive data is available for the Malaysian market. Although the application of data and estimates are valid for the available data, it is recommended that adjustment may be necessary for future application in terms of economics and locality of the development.

The financial and economic analysis has showed that the proposed development would give a NPV of RM 244.30 million for 25 years of project life as shown in table 8.8. The details of the overall result of these analyses is shown in appendix 21. A much bigger benefit can actually be realised if several other economic benefits can be evaluated and quantified such as the impact of noise, vibration reduction etc.

Similarly, the freight rate can be adjusted accordingly to a competitive level in comparison to road transport ensuring the revenues to the waterway transport system can be increased. Furthermore, most marine infrastructures, such as waterway channels and terminal infrastructures, have a longer life cycle than assumed in this project, thus more benefit can be gained.

Table 8.8: The Inland waterway system's financial and economic analysis

Items	Capital	Operating	M'nance	Tolls	Port costs	Freight revenue	Terminal revenue (vessel)	Terminal revenue (cargo)	Net Costs
Channel	-133.00	-63.30	-41.5	+293.00	NA	NA	NA	NA	+ 55.25
Bulk Vessel	Inclusive	-164.70	inclusive	-127.65	-101.15	+447.50	NA	NA	+ 54.00
Container vessel	Inclusive	-213.50	inclusive	-165.40	-81.80	+518.75	NA	NA	+ 58.10
Bulk terminal	-88.50	-166.63	-121.38	NA	NA	NA	+101.15	+465.00	+183.8
Container terminal	-75.40	-113.67	-62.76	NA	NA	NA	+81.75	+370.50	+193.00
Congestion									+689.9
Fatality									+ 9.8
NPV									+244.3

Notes: Detail result of analyses can be referred to appendices 15 to 21

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CHAPTER 9

Discussion

CHAPTER NINE

DISCUSSION

9.1 Introduction

The development of the three models in this study aimed to provide a simple yet comprehensive exercise in estimating the costs relating to a development of a new integrated inland waterway transport system, namely inland waterway channel track, inland waterway vessel and inland cargo terminal, combining together to provide cargo transportation by water. The optimum costs of the system, including the initial development costs as well as the cost of operating and maintaining the system has been investigated and assessed to examine the feasibility of the selected system. The combined model has been applied to a proposed inland waterway development in Malaysia to assess the scheme's commercial and economic viability.

Although the inland waterway system could be utilised for a number of activities, this study has specifically considered the development in relation to the provision of transportation capacity for selected goods, namely bulk and containers. After an extensive literature review, the work consisted of the acquisition of data from reliable sources around the UK and from Europe through publications as well as personal communications.

The data was gathered and analysed within the aims and scope of the study. The results are presented both in terms of graphical representation and numerical equations which form the body of each of the models developed. The models are validated and consolidated before any real attempt for their future application can be made possible. The following sections discuss the phases of the model development and is followed by an overview of the study. All costs in the analysis of this study have been adjusted to the base year of 1995.

9.2 Inland waterway track model

The inland waterway track model has been generated from first principles. The data was collected mainly from specialist estimates manual mainly for civil engineering works based on the GBP, 1995 prices. In addition, data from various reliable sources such as British Waterways Board, Manchester Ship Canal Company, shipping and freight transport consultant and others was included. This additional data was mainly in the form of historical development costs of the waterway systems which were then converted to a unit development cost similar to the civil engineering cost manual of particular elements of construction.

The inland waterway channel track model considers only the significant infrastructure support system, such as lock structure, embankment, bridges, bank protection etc., based on UK and continental waterways experience. A number of insignificant ones, such as aqueduct, weir, dam and navigation aids has not been considered due to these structures being not regularly available on most waterways.

The size of the channel track in this study has been based on the successful vessel size model in Europe and in relation to the present channel dimensions of the proposed inland waterway with regards to the minimum dredging and cutting works to minimise the development costs. A specific rule and guidelines has been adopted in determining the inter-relationship between vessel and channel dimensions as described in chapter 3.

It has been expected from the commencement of the study that data collection would be difficult on the basis that data for inland waterway system has not been regularly and properly compiled by relevant authorities. Statistical data on historical development costs of specific components of inland waterway track infrastructures, such as mentioned in the above paragraph, is very limited. However, estimates has been obtained through a number of personal communications have been very useful for the data collection and analysis.

Where data was not available, estimates were made using the Spon's Civil Engineering and Highway Works Price Manual [*1*]. This manual was able to provide specialist estimates for a number of civil engineering works to be undertaken in relation to the inland waterway channel track such as dredging, excavation, channel bank and bed stabilisation and protection schemes, embankment, bridges, roads etc. This data combined with the earlier data collection is used to generate a number of equations each representing a component of the channel's infrastructure to form the required model.

The analysis of the majority of data produces linear relationships within acceptable levels of correlation. This indicates that the increase in independent variables will proportionately increase the value of dependent variables. Where most of the dependent variables are represented by costs that the model is to estimate, it shows that there is no economy of scale to particular constructions. This is important in determining the right level of construction for the channel track infrastructures development for the acceptable level of financial commitment to the project.

9.3 Inland waterway vessel model

For the inland waterway vessel model, the development has considered a specific size and dimensions of a vessel to be employed and the number of vessels required to provide sufficient capacities for the movement of specific types of the projected cargo. In relation to this, the model was developed to be capable of estimating the required initial capital costs of providing the vessels as well as the annual fixed and variable costs of operating the vessels.

The size of vessel in this study was selected based on the successful model of European Class IV waterway of 1,350 dwt with a dimension of 80 metre length, 9.5 metre depth and 2.25 depth which is used extensively in a number of countries in Europe. In relation to this, the size has been selected in relation to the existing Klang River channel cross-section of an original width of 35 - 70 metres and depth of 2 - 3 metres as described in chapter 3. The original size and dimension of the channel is comparable to the proposed vessel size which has resulted in a relatively small channel dredging costs of GBP 383,595 (less than 1% of total channel development costs) for the proposed Klang Valley Water Highway (KVWH) thus adopted.

Similarly, the study has considered bulk cargo and containers only as these movement has proven based on the successful model on the Rhine in Europe. Furthermore, bulk cargo is naturally suitable for inland waterways and has been the dominant type of cargo moving on the inland waterways. Likewise, containers too, are becoming increasingly acceptable as proven on the Rhine.

In Malaysia, bulk and containers have been two dominant types of cargo moving on the road which is almost parallel to the proposed Klang Valley Water Highway (KVWH). Therefore, the development was intended to capture an assumed 10% of the cargo share from the road into the KVWH to examine the feasibility of this development proposal. In addition, a self-propelled vessel type was assumed to be mostly suitable on the KVWH due to numerous bends which would need massive realignments if push-tows system are to be introduced.

The literature provided a great deal of data which could be used to estimate the vessel's capital and operating cost. Nevertheless, due to great variations of the parameters being considered in the studies such as the range of vessel sizes, operating condition of short and deep sea operation, vessel service speed, utilisation of sea ports with different port charging practices etc. these do not always reflect inland waterway operating cost structures thus not considered.

Data for inland waterway vessel operation in the UK particularly was sought but without significant success. A study by TRRL [2] for instance, provided some historical data on inland vessel cost analysis but was inadequate as well as being too old for data analysis. Data from periodical publications provide vessel new building prices only for mostly ocean going vessels which is clearly not suitable to the inland waterways applications. However, data for various sizes of inland waterway self-propelled vessel's operating costs was supplied by the Port of Rotterdam Authority [3] for the analysis. The data was adjusted to UK currency in Great Britain Pound (GBP) based in 1995 prices by the application of the cost price index (CPI). The data analysis has resulted in vessel's capital and operating cost equations to form the vessel costs model. However, limited amount of data from several other sources were available for useful comparison and can be applied where necessary and appropriate.

The annual operating costs of the vessel such as depreciation, crew, insurance, and others has resulted in linear relationship indicating that the costs appreciate or depreciate linearly as a function of ship size. However, a relationship between vessel sizes and the capital costs has resulted in non-linear (curve) relationship indicating that there is an element of economy of scale for the use of bigger vessel. This relationship provides a general guideline in determining an appropriate vessel size in relation to costs in the model application.

9.4 Inland terminal model

In relation to the type of cargoes to be handled at the terminals, the proposed development has been dedicated to the development of bulk and container terminals. An inland cargo terminal can be developed independently, or within a complete port system where sometimes certain equipment can be commonly utilised. However, this study considered a simplified terminal system aimed at minimising the capital and operating costs but remain adequate for the anticipated cargo handling operation to take place without any major difficulties.

Data collection for the terminal model development has been mostly undertaken in the UK. Whilst it was not possible to obtain comprehensive development requirement and cost data from port or terminal operators, individuals such as Garratt [3], Cordiner [4] and Kent [5] have supplied a reasonable detail of data. A study from ESCAP [6] provides general planning guidelines for both bulk and container development which has been adopted as main reference for this part of the study. All the available data, combined and analysed, has produced the bulk and container terminal planning requirement and development cost model. In addition, Johor Port Authority in Malaysia was visited to gather useful information of a typical requirement for terminal development for comparison and can be used in model application when necessary.

In reality, different terminal operators adopt different development policies and planning strategies. It is a fundamental requirement for an investment to result in optimum benefit to the terminal users as well as operators. The ability of terminal operators to provide efficient services coupled with attractive charges is of prime consideration. Nevertheless, even if charges are higher due to high terminal investment costs, these can normally be off set with the higher vessel turnaround time. However, the study has examined and implemented the 'least option investment policy' i.e. to provide the minimum but adequate level of equipment required for the cargo handling operation. Furthermore, there are not too many vessels employed in the whole fleet thus minimising delays at terminals.

During the design stage of the inland terminals, which is located alongside the waterway channel, the specific terminal requirement has been discussed in reasonable depth. Among the points made, the terminal will only serve inland self-propelled bulk and container vessel of 1,350 dwt and 126 TEU's respectively. Combined with the projected cargo throughput and the vessel's size, the size of terminals and in particular the equipment and other facility requirement were estimated.

Terminal development was divided into two basic categories i.e. firstly the terminal infrastructures including berthing facility (quay), transit shed, warehouse and administration building. Although these infrastructures are not primarily related to cargo flow, it is however possible to relate the requirement of this facility as a function of cargo throughput. Secondly the estimation of cargo handling equipment and cost which is dependent on cargo throughput. Both terminal requirement has resulted in linear relationship as a function of cargo throughput.

In the study, the models were primarily developed based on the developed countries experiences as mentioned earlier on. Although the aim of the study is to apply the model to Malaysia, the overall aim is to ensure the model will be applicable to other inland terminal development in any part of the world. In the Malaysian development however, it is clear that a number of adjustment will be inevitable. For instance, most inland terminals in the developing countries adopt an inclined type of berth which is not included in the model.

Nevertheless, it is reasonable to assume that the berth cost estimated by the model is acceptable considering the scale of the development.

9.5 Validation and consolidation of the models

Before any real attempt to use the model for estimating purposes can be realised, the model parameters need to be checked to confirm its validity. In the study, the validation of the model has been carried out against a number of past and current development. The three models available namely inland waterway channel track, inland vessel and inland terminal, are validated independently. This is to ensure the model parameters considered in the study are valid and reliable.

In the case of inland waterway track channel model, two validations has been undertaken. Firstly, against river navigation i.e. the improvement of Sheffield and South Yorkshire Navigation (SSYN) in the UK in 1983 when the project completed [7]. Secondly against *canal* navigation i.e. the new development of St Aidan Waterway completed in 1995 also in the UK. Both validations have indicated that the model parameters and the equations derived in the study are valid to an acceptable level of accuracy.

Similarly, the vessel and terminal models have also been validated individually. The inland vessel model was examined against the vessel cost data from a model from the UK. For simplification of estimating purposes, the costs considered were only the capital and operating cost. The operating costs comprised of costs such as crew, insurance, repair and maintenance, stores, provisions and fuel cost needed to perform the movement of the vessel to carry cargo from one port to another.

The validity of the inland terminal model has been checked against the RO/RO terminal expansion scheme at ABP Immingham [5]. There is insufficient information available for the LO/LO terminal development for the validation to be done. However, both types of container terminal require similar infrastructure and equipment, with the particular exception of the link span (ramp) for the RO/RO operation. Thus the validation provides a reasonable comparison and indications to the validity of the model parameters.

Unfortunately, validation the model for the development for the bulk terminal has not been successfully achieved due to complete lack of information. However, it is assumed that the validation for the container terminal would be sufficient and the validation shows that the model parameters considered in the study are reasonably acceptable and appropriate resulting in small errors when estimated cost is compared to the actual development costs.

In reality, the three models developed can be utilised independently to accomplish a specific objective. In this study however, the three models have been consolidated to produce one general model dedicated to the application of an integrated inland waterway transport system combining the three elements together.

Such a transportation system needs to be assessed holistically in order to state its economic benefits. This mean that the system should be able to identify the possibility of diversion of cargo movement from the existing rail and in particular road onto the inland waterway system. This will only take place when the transportation cost per tonne is low in financial and/or cost benefit terms.

This may be achieved through a proper planning strategy involving a thorough consideration to each and every aspect of the development. This approach is called 'the cause and effect' approach whereby the decision of one parameter will affect the other. The best combination of the cause and effect should be investigated, analysed and selected to provide an optimum choice of development.

9.6 Application of models

The model has been applied to a Malaysian case study in order to estimate the costs of initial development as well as the ongoing operating and maintenance costs. A quick and reliable estimate is required in the event of such scale of development. The model will not be the ultimate basis for decision making on the project, but rather provide the opportunity for initial identification and assessment pending a more detailed feasibility study.

The model has been applied to a Malaysian inland waterway development case study in relation to the projected cargo throughput to be available for new waterway over the expected life of the project before new assessment can be further considered. Starting with the cargo throughput, the pre-determined vessel size, the size of required channel is estimated and finally the inland cargo terminal is planned. All the costs estimated by the model were converted to Ringgit Malaysia (RM) based on 1995 prices before financial and economic assessment was carried out.

Financially, the stream of costs relating to capital, operating, maintenance etc. are evaluated against the revenues obtained through operating the system. They are in the form of toll charges for the channel track operator, freight charges for vessel operators and terminal and cargo dues for terminal operators. Where most of the charges levied and revenues paid are between or within the same system, the real indicator of profit and income is from the users of this transport system. This is achieved through charges imposed to the shippers and cargo owner though cargo handling operation at terminals.

On the other hand, the ability of this waterway to capture the cargo from road will mean the road being less congested with a consequent reduction in injuries and fatalities. This is seen in economic terms as a benefit to the community as well as the country who would be less burdened with congestion and casualty costs on road networks. In real terms, particularly for a government promoted project such as a transport system development, this is assessed in monetary terms to be added to the financial benefit of the project. In the end, the whole stream of financial and economic costs and benefits are assessed and tabulated.

Similarly, in the proposed development of a Malaysian inland waterways, there is an indication that the project will generate positive NPV for the project life of 25 years at 10 percent test discount rate (TDR). Although this may not necessarily be the actual outcome of the project, a number of other possibilities can be examined through the sensitivity analysis where a number of parameters can be changed to check the cause and effect situation. For instance, the size can be upgraded to reduce the number of vessels to be employed but this results in a bigger channel size and higher capital and operating costs. It is difficult to judge at this stage which of the alternatives provide optimum benefits but through sensitivity analysis, this can be achieved. However, limited by the scope of the study, this has not been considered.

9.7 Financial and economic appraisal

The costs for the proposed KVWH, estimated using the models for the three sub-systems studied, have been further analysed to determined the feasibility of the project. In financial terms, the KVWH is assessed against the NPV of the project in 25 years at 1995 prices discounted at a Test Discount Rate (TDR) of 10%. In this analysis, the costs of developing, operating and maintaining the system are examined against the revenues from outside as well as within the system. For sensitivity analysis, a variety of TDRs can be tested to determined the optimum return of the project. The project yields a positive NPV indicating the feasibility of the project financially.

Apart from a financial return, the project provides other benefit in the form of environmental benefits. Amongst the aims of the KVWH development in particular is the relief of congestion and other related problems in the Klang Valley. As the result of the inland waterway development, a number of vehicles can be eliminated from the roads resulting in a reduction in congestion as well as accidents. Although there may be a number of other environmental related benefits, this study has been limited to these two examples. From the analysis, the predicted reduction in congestion and fatality on the road will result in benefits which are convertible in financial value and which may be added to the direct financial benefits. The viability of the scheme may be further enhanced should the model be developed to incorporate a wider range of cost benefits.

9.8 Overview

The study has developed the inland waterway transport system model to enable planners to estimate the costs required for an inland waterway project. In general most data is derived from UK experience of infrastructure provision and equipment operation. Although the model is UK oriented, its construction from basic principles allow it to be applied elsewhere, subject to the use of appropriate cost indices.

The model has shown the ability to be a useful estimating tool as shown in the Malaysian case study. However, the model is far from being complete for a widespread application all around the world. It is adequate in indicating the inland waterway parameters required for such a development, but requires additional local data to support its role as an initial investment appraisal tool.

This is true in the case of Malaysian proposed inland waterway development where a quantity of local data has been included to achieve a more realistic and meaningful result. Similarly, if the model is to be applied elsewhere, the same practice will have to be employed appropriately. However, a basic cost estimation for an inland waterway transport system has been derived, validated and applied in accordance to the underlying aims and scope of this study.

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CHAPTER 10

Conclusion

CHAPTER TEN

CONCLUSION

10.1 Conclusion

This research work has been carried out in accordance to the aims and objectives of the study stated at an earlier stage of the work. The work has been designed within a limited scope of study which are necessary in order to provide a reasonable detail and meaningful academic outcomes.

In general, the work can be considered reasonably successful in relation to the overall aims namely the development and application of the cost estimation model for inland waterway development. The work has consisted of se include the literature review, data collection and analysis for model construction, model validation against a number of case studies and finally model application. Data has come from a number of reliable sources i.e. individuals, organisations and publications and been supplemented by synthetic data where no other option existed. A simple data analysing technique has been consistently applied to produce the equations which make up the model.

In principle, the study has been successful in reaching the overall objective of the study as summarised in the general conclusions as follows;

i. *Model development*

The model has been generated from a series of widespread data collection as well as systematic analysis. It has proven possible to generate such a complicated inland transport system model combining three sub models for common application in estimating costs relating to the cost of developing the inland waterway transport system.

ii. *Model application*

Although the model application has only considered specific scopes and aims of the study, it has however been able to demonstrate its ability to estimate costs for the development of an inland waterway transport system. The application of the model in the estimating the costs relating the development of inland waterways particularly in Malaysia has proven reliable and acceptable. This is a very useful and significant indication to the relevant transport planning authorities in providing them the likely initial costs for a particular project before further action and decisions are taken.

In addition, model application has also been useful in providing indication of the environmental benefit in financial terms resulting from the development of the inland waterway system. However, where necessary, adjustment and additional input to the model should be considered to reflect local conditions.

iii. *Feasibility of the proposed Klang Valley Water Highway (KVWH)*

From the commencement of the analysis to the proposed development of the KVWH, the model has been intended to examine the feasibility of the project for a selected specific task. With regards to the 10% cargo share for the proposed inland water transport system in relation to the projected imported cargo throughput per annum for 25 years and based on a predetermined size of vessel of 1,350 dwt, the analysis results in the project generating the positive NPV, indicating the project is feasible.

Finally, it has also proven that inland waterway system is capable of contributing to the enhancement of environment with the a reduction of road congestion and accidents, resulting in a saving in social costs. These costs converted to money values, provide additional benefit to the development creating a realistic opportunity for it to become an alternative and favourable mode of transport in future especially for the transportation of commercial commodities in Malaysia in particular.

10.2 Recommendations for future work

There are numerous opportunities for further research in relation to the improvement of the model developed in this study. This is to ensure that the model can be further refined for widespread application in regards to the level of the development as well as the countries where the application is intended. The recommendations are as follows;

i. *Model parameters refinement*

(a) To refine the model parameters with more thorough data covering a comprehensive review of the most recent canal and river development. For instance, this includes the construction of aqueducts, viaducts, bridges of different types, etc. for the channel track model construction which has not been limited in this study.

(b) To refine the model parameters for the inland self-propelled vessel with the inclusion of wide range of data collection, particularly in the validation phase. The consideration of the push-tow system, and a variety of other cargo types, will add a further strength to the model.

(c) To refine model parameters with the inclusion of analysis on intermodal connections as well as a variety of other terminal types.

ii. A specific study or research in the area of optimisation of the proposed inland waterway transport system in terms of determining the optimal and economic size of vessel, channel and terminal in relation to projected cargo throughput. A sensitivity analysis can clearly be a useful tool for this task.

iii. In ensuring the model will be even more useful and quicker in its estimating tasks, an expert system through computer programming can be developed to incorporate the model developed in this study. This will make the task more quicker, reliable and higher degree of accuracy.

iv. Finally, it is recommended that the study to cover both the developed countries as well as developing ones in order to derive a development index for the three models for a quick and reliable method of converting costs between developed and developing countries to permit a worldwide application of the model.

APPENDICES

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Appendix 15: Inland waterway channel annual cost (RM million)

Year	Capital	Operating	Maintenance	Toll revenues	Net account
0	133.00				-133.00
1		2.53	1.66	6.62	2.43
2		2.53	1.66	6.62	2.43
3		2.53	1.66	6.62	2.43
4		2.53	1.66	6.62	2.43
5		2.53	1.66	6.62	2.43
6		2.53	1.66	9.45	5.26
7		2.53	1.66	9.45	5.26
8		2.53	1.66	9.45	5.26
9		2.53	1.66	9.45	5.26
10		2.53	1.66	9.45	5.26
11		2.53	1.66	11.34	7.15
12		2.53	1.66	11.34	7.15
13		2.53	1.66	11.34	7.15
14		2.53	1.66	11.34	7.15
15		2.53	1.66	11.34	7.15
16		2.53	1.66	14.18	9.99
17		2.53	1.66	14.18	9.99
18		2.53	1.66	14.18	9.99
19		2.53	1.66	14.18	9.99
20		2.53	1.66	14.18	9.99
21		2.53	1.66	17.01	12.82
22		2.53	1.66	17.01	12.82
23		2.53	1.66	17.01	12.82
24		2.53	1.66	17.01	12.82
25		2.53	1.66	17.01	12.82
Total	133.0	63.3	41.5	293.0	55.25

Notes:Annual operating cost = 1.9% of total capital cost [Chap 8, ref 17]
Annual maintenance cost = 1.0%-1.5% of capital cost [Chap 8, ref 19]
Toll charges = RM 4.0 per vessel's dwt/trip [BWB]

Appendix 16: Self-propelled bulk vessel annual costs (RM million)

Year	Operating	Port charges	Toll payment	Freight income	Net earning
0					
1	3.66	2.25	2.84	9.50	0.75
2	3.66	2.25	2.84	10.20	1.45
3	3.66	2.25	2.84	10.90	2.15
4	3.66	2.25	2.84	11.60	2.85
5	3.66	2.25	2.84	12.30	3.55
6	4.88	3.00	3.78	13.00	1.34
7	4.88	3.00	3.78	13.70	2.04
8	4.88	3.00	3.78	14.40	2.74
9	4.88	3.00	3.78	15.10	3.44
10	4.88	3.00	3.78	15.80	4.14
11	6.10	3.74	4.73	16.50	1.93
12	6.10	3.74	4.73	17.20	2.63
13	6.10	3.74	4.73	17.90	3.33
14	6.10	3.74	4.73	18.60	4.03
15	6.10	3.74	4.73	19.30	4.73
16	8.54	5.24	6.62	20.00	-0.40
17	8.54	5.24	6.62	20.70	0.30
18	8.54	5.24	6.62	21.40	1.00
19	8.54	5.24	6.62	22.10	1.70
20	8.54	5.24	6.62	22.80	2.40
21	9.76	6.00	7.56	23.50	0.18
22	9.76	6.00	7.56	24.20	0.88
23	9.76	6.00	7.56	24.90	1.58
24	9.76	6.00	7.56	25.60	2.28
25	9.76	6.00	7.56	26.30	2.98
Total	164.7	101.15	127.65	447.50	54.00

Notes: Bulk freight rate is estimated at RM 14/tonne [Chap 8, ref 18]
Toll charges is estimated at RM 4.0 per dwt/trip [BWB]

Appendix 17: Self-propelled container vessel annual costs (RM million)

Year	Operating	Port charges	Toll charges	Freight income	Net earning
0					
1	4.88	1.86	3.78	11.15	0.63
2	4.88	1.86	3.78	11.95	1.43
3	4.88	1.86	3.78	12.75	2.23
4	4.88	1.86	3.78	13.55	3.03
5	4.88	1.86	3.78	14.35	3.83
6	7.32	2.80	5.67	15.15	-0.64
7	7.32	2.80	5.67	15.95	0.16
8	7.32	2.80	5.67	16.75	0.96
9	7.32	2.80	5.67	17.55	1.76
10	7.32	2.80	5.67	18.35	2.56
11	8.54	3.26	6.62	19.15	0.73
12	8.54	3.26	6.62	19.95	1.53
13	8.54	3.26	6.62	20.75	2.33
14	8.54	3.26	6.62	21.55	3.13
15	8.54	3.26	6.62	22.35	3.93
16	9.76	3.73	7.56	23.15	2.10
17	9.76	3.73	7.56	23.95	2.90
18	9.76	3.73	7.56	24.75	3.70
19	9.76	3.73	7.56	25.55	4.50
20	9.76	3.73	7.56	26.35	5.30
21	12.2	4.70	9.45	27.15	0.80
22	12.2	4.70	9.45	27.95	1.60
23	12.2	4.70	9.45	28.75	2.40
24	12.2	4.70	9.45	29.55	3.20
25	12.2	4.70	9.45	30.35	4.00
Total	213.5	81.8	165.4	518.75	58.10

Notes: Freight rates is estimated at RM130/TEU [Chap 8, ref 18]
Toll charges is estimated at RM 4.00 per dwt/trip [BWB]

Appendix 18: Inland bulk terminal annual costs (RM million)

Year	Capital	Operating	Maintenance	Rev. vesse	Rev. cargo	Net account
0	88.50					-88.5
1		2.74	1.41	2.25	9.84	7.9
2		2.78	1.41	2.25	10.57	8.6
3		2.82	1.41	2.25	11.30	9.3
4		2.86	1.41	2.25	12.03	10.0
5	2.9	3.19	1.70	2.25	12.76	7.2
6		3.52	1.99	3.00	13.49	11.0
7		3.85	2.28	3.00	14.22	11.1
8		4.18	2.57	3.00	14.95	11.2
9		4.51	2.86	3.00	15.68	11.3
10		4.84	3.15	3.00	16.41	11.4
11		5.17	3.44	3.74	17.14	12.3
12		5.50	3.73	3.74	17.87	12.4
13		5.83	4.02	3.74	18.60	12.5
14		6.16	4.31	3.74	19.33	12.6
15	2.9	6.78	4.89	3.74	20.06	9.2
16		7.40	5.47	5.24	20.79	13.2
17		8.02	6.05	5.24	21.52	12.7
18		8.64	6.63	5.24	22.25	12.2
19		9.26	7.21	5.24	22.98	11.8
20		9.88	7.79	5.24	23.71	11.3
21		10.50	8.37	6.00	24.44	11.6
22		11.12	8.95	6.00	25.17	11.1
23		11.74	9.53	6.00	25.90	10.6
24		12.36	10.11	6.00	26.63	10.2
25		12.98	10.69	6.00	27.36	9.7
Total	94.3	166.63	121.38	101.15	465	183.8

Port revenues (vessel) = charges for vessels using port facility

Port revenues (cargo) = charges for cargo handling operation in port

Appendix 19: Inland container terminal annual costs (RM million)

Year	Capital	Operating	Maintenance	Rev. vesse	Rev. cargo	Net account
0	75.4					-75.4
1		3.45	1.42	1.86	7.98	5.0
2		3.51	1.42	1.86	8.55	5.5
3		3.57	1.42	1.86	9.12	6.0
4		3.63	1.42	1.86	9.69	6.5
5		3.69	1.42	1.86	10.26	7.0
6		3.75	1.42	2.80	10.83	8.5
7		3.81	1.42	2.80	11.40	9.0
8		3.87	1.42	2.80	11.97	9.5
9		3.93	1.42	2.80	12.54	10.0
10	3.72	4.05	2.58	2.80	13.11	5.6
11		4.17	2.58	3.26	13.68	10.2
12		4.29	2.58	3.26	14.25	10.6
13		4.41	2.58	3.26	14.82	11.1
14		4.53	2.58	3.26	15.39	11.5
15		4.65	2.58	3.26	15.96	12.0
16		4.77	2.58	3.73	16.53	12.9
17		4.89	2.58	3.73	17.10	13.4
18		5.01	2.58	3.73	17.67	13.8
19		5.13	2.58	3.73	18.24	14.3
20	3.72	5.31	4.03	3.73	18.81	9.5
21		5.49	4.03	4.70	19.38	14.6
22		5.67	4.03	4.70	19.95	15.0
23		5.85	4.03	4.70	20.52	15.3
24		6.03	4.03	4.70	21.09	15.7
25		6.21	4.03	4.70	21.66	16.1
Total		113.67	62.76	81.75	370.5	193.0

Port revenue (vessel) = charges for vessels using port facility
Port revenue (cargo) = charges for cargo handling operation in port

Appendix 20: Congestion and fatality benefits per annum (RM million)

Year	Veh. reduction	Congest cost	Lives saved	Lives cost	Total saving
0					
1	80	15.1	0.12	0.21	15.3
2	86	16.2	0.13	0.23	16.4
3	91	17.2	0.14	0.24	17.4
4	97	18.2	0.15	0.26	18.5
5	102	19.3	0.16	0.27	19.6
6	108	20.3	0.16	0.29	20.6
7	113	21.4	0.17	0.30	21.7
8	119	22.4	0.18	0.32	22.7
9	124	23.4	0.19	0.33	23.8
10	130	24.5	0.20	0.35	24.8
11	135	25.5	0.21	0.36	25.9
12	141	26.6	0.21	0.38	26.9
13	146	27.6	0.22	0.39	28.0
14	152	28.6	0.23	0.41	29.0
15	157	29.7	0.24	0.42	30.1
16	163	30.7	0.25	0.44	31.1
17	168	31.8	0.26	0.45	32.2
18	174	32.8	0.27	0.46	33.3
19	179	33.8	0.27	0.48	34.3
20	185	34.9	0.28	0.49	35.4
21	190	35.9	0.29	0.51	36.4
22	196	36.9	0.30	0.52	37.5
23	201	38.0	0.31	0.54	38.5
24	207	39.0	0.32	0.55	39.6
25	212	40.1	0.32	0.57	40.6
Total		689.9	5.6	9.8	699.6

Notes: Congestion and life saved costs are calculated for both type of vessels

Appendix 21: The inland waterway transport system costs and benefits account

Year	Track	Bulk vessel	Cont vessel	Bulk terminal	Econ.benefit	Total	Disc.(10%)	NPV
0	-133.00			-88.50		-222.50	1.000	-222.5
1	2.43	0.75	0.63	7.90	15.30	28.01	0.909	25.5
2	2.43	1.45	1.43	8.60	16.40	32.31	0.826	26.7
3	2.43	2.15	2.23	9.30	17.40	36.51	0.751	27.4
4	2.43	2.85	3.03	10.00	18.50	40.81	0.683	27.9
5	2.43	3.55	3.83	7.20	19.60	41.61	0.621	25.8
6	5.26	1.34	-0.64	11.00	20.60	43.56	0.564	24.6
7	5.26	2.04	0.16	11.10	21.70	47.26	0.513	24.2
8	5.26	2.74	0.96	11.20	22.70	50.86	0.467	23.8
9	5.26	3.44	1.76	11.30	23.80	54.56	0.424	23.1
10	5.26	4.14	2.56	11.40	24.80	58.16	0.386	22.4
11	7.15	1.93	0.73	12.30	25.90	59.01	0.350	20.7
12	7.15	2.63	1.53	12.40	26.90	62.61	0.319	20.0
13	7.15	3.33	2.33	12.50	28.00	66.31	0.290	19.2
14	7.15	4.03	3.13	12.60	29.00	69.91	0.263	18.4
15	7.15	4.73	3.93	9.20	30.10	70.11	0.239	16.8
16	9.99	-0.40	2.10	13.20	31.10	71.99	0.218	15.7
17	9.99	0.30	2.90	12.70	32.20	75.09	0.198	14.9
18	9.99	1.00	3.70	12.20	33.30	78.19	0.180	14.1
19	9.99	1.70	4.50	11.80	34.30	81.29	0.164	13.3
20	9.99	2.40	5.30	11.30	35.40	84.39	0.149	12.6
21	12.82	0.18	0.80	11.60	36.40	82.80	0.135	11.2
22	12.82	0.88	1.60	11.10	37.50	85.90	0.123	10.6
23	12.82	1.58	2.40	10.60	38.50	88.90	0.112	10.0
24	12.82	2.28	3.20	10.20	39.60	92.10	0.102	9.4
25	12.82	2.98	4.00	9.70	40.60	95.10	0.092	8.7
Total	55.25	54.00	58.10	183.90	699.60	1374.85		244.3

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