PORT COSTS AND PRICING

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ABSTRACT

Title of Thesis: PORT COSTS AND PRICING

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This thesis is an economic analysis of the pricing practices of seaports, the problems encountered by the ports when devising their tariffs and the alternative solutions which could be adopted - with particular reference to the Port of Liverpool.

The conditions necessary for the first best world of economic theory may not be met in the port case. As a consequence, it may be necessary to introduce further constraints into the welfare maximisation problem. The thesis carefully considers the pricing and investment problems facing the port under the unifying heading of jointness; discusses the recommendations of various official bodies and adopts a "commercial concern" maxim; and subjects the allocative properties of alternative pricing systems to detailed examination.

In spite of the violation of the assumptions of the basic model, marginal cost remains intact as the relevant basis for pricing, investment and traffic acceptance decisions. In an attempt to measure these costs a detailed examination of the concept of escapable cost and the allocation of joint costs to the relevant traffic is undertaken. This examination expands a methodology suggested for the railway case and extends the analysis to include the temporal dimension. This theoretical treatment of escapable costs is then applied to the port case, where the problems that may be encountered in its implementation are considered.

A detailed examination of the charging schedules is undertaken, where the properties of the charges are considered.

The charging base and tariff structures are analysed with: an empirical investigation of the relationships between alternative bases; an examination of measures of consumers' willingness to pay; and consideration of vertical and horizontal equity.

An overall approach to pricing and investment is outlined and some methodologies which may be employed by the port when computing its prices are developed.

ACKNOWLEDGEMENTS

I am indebted to J.A. Holt, the Research Supervisor, for his guidance and support in the preparation of this thesis.

I would also wish to thank the Chairman and staff of the Mersey Docks and Harbour Company for their time and the assistance which they have given to me.

It remains however to state that all errors, omissions and interpretations (particularly of the Ports' pricing practices) are the sole responsibility of the author.

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CHAPTER 1

INTRODUCTION

The pricing structure at a port will reflect the political, economic and social environment within which the port is operating. Pricing and investment decisions made by the port will therefore represent an amalgam of factors such as the requirements of financial backers; the expected reactions of other ports and port users; past experience and future expectations; social attitudes towards the ownership of capital and the benefits conferred on the hinterland by the port; the aspirations and attitudes of management and the quality and quantity of information available. Given this environment, charging schedules have evolved which either implicitly or explicitly have attempted to accommodate these factors. This process invariably results in criticism, as either the port cannot accommodate all of the factors or it concentrates on some factors to the exclusion of others.

In this thesis, the economic and financial aspects will be considered with particular emphasis on pricing and costs. In order to incorporate the port's wider environment into the analysis, it will be necessary to either assume some of the factors as given or to indicate how they may be accommodated.

One of the main assumptions of the thesis is that the port's demand forecast has been undertaken. This implies that the port has estimated the level of demand and that the Marketing Department can ascertain the user's willingness to pay.

A second area where guidelines are considered necessary is that of the port's financial and economic obligations. This arises because of the interrelationships and possible conflicts between financial objectives, investment criteria and pricing structure.

This Chapter will consider firstly the main types of tariffs and charging bases, secondly the criticisms and defences of the current structures and thirdly the financial, pricing and investment objectives that will be adopted. Finally, it will outline the structure of the thesis.

1.1 Port Tariffs and the Charging Base

The prices charged by the port generally fall into one of the three categories - charges on vessels, charges on goods, and charges for specific services rendered, UNCTAD [1] , Heggie [2].

The charges on vessels are variously called harbour, dock, quay, berth, port entry or tonnage dues, a distinction usually being made between the provision of water access to the port (conservancy) and the provision of the berth and docks (berth charges). The duties of the port under the heading of conservancy, as defined by Rochdale [3] ,

> "vary from port to port but they may include maintenance of approach channels, dredging, surveying and charting the tideway, removing or dispersing wrecks and obstructions, preventing pollution, salvage, regulating traffic, providing and maintaining moorings, lighting and buoying, supervision of the foreshore and licensing lightermen and watermen".

The revenue from conservancy is required to cover the cost of performing these duties. The charging base is the gross registered ton (g.r.t.), net registered ton (n.r.t.) or the number of tonnes loaded or discharged from the vessel. Where the registered tonnage is the basis, the charge can be either proportional (that is, the rate per ton is the same regardless of vessel size) or progresssive (that is, the rate per ton increases with vessel size).

The area of the port incorporated within berth charges is usually from where the port's conservancy duties end, up to and including the quaywall. Thus, the revenue from this charge is expected to provide for the depreciation, interest and maintenance of locks, docks, dockwater area, dockwall and quaywall. The charging base is a combination of either the tonnage of the vessel (g.r.t. or n.r.t.) or vessel length and the time spent at the berth.

The charges on goods similarly occur under various titles including port, dock, wharfage, quay or goods rates. The revenue providing, in principle, for the depreciation, interest and maintenance of the port infrastructure including the quays, transit sheds, roads, perimeter fences and lighting. The charging base is usually weight, volume or the unit adopted on the ship's manifest. The degree of complexity (as measured by the number of different rates or the number of listed commodities) varies considerably, for example, the Port of Bristol's 1966 schedule contained approximately 1,500 listed commodities.

The specific services provided by the port include pilotage, towage, linesmen, cargo handling, watchmen, the supply of fresh water and bunkers, warehousing and ship repair facilities. These services are provided by the port itself or private companies and are usually charged for separately. The charging base varies according to the service. A measure of vessel tonnage (g.r.t. or n.r.t.) is usually used for pilotage with vessel draft being included in some cases. Towage charges are levied either on the characteristics of the ship or the tugs used. If the ship basis is used then it is usally g.r.t. or n.r.t. and if the tug basis is used then it is per operation or per hour. The per operation basis is also used for linesmen as are the vessel's g.r.t. or n.r.t. The charge for cargo handling is generally based on weight or volume with a per unit charge being used in some cases (for example, livestock). The cargo handling tariffs appear in two forms, firstly where a separate rate is quoted for each commodity and secondly where cargoes with similar characteristics (for example, cartons, bags, etc.) are grouped together and a separate rate quoted for each group. Storage and warehousing charges are usually based on weight, volume or area occupied. In the case of "transit storage" there is usually a free period allowed for both import and export cargoes.

1.2 Criticisms of Existing Tariff Structures

The port tariff structures outlined above have at times been subject to strong criticisms from a range of sources. These criticisms can be summarised in the following extracts:

(i) "Publically owned ports rarely price port services on a commercial basis. They do not keep comprehensive cost accounts, and they make little attempt to relate specific revenues to costs in an organised way. By and large, their tariff structures were established before the turn of the century and have simply been extended and revised to cover their added responsibilities and their increased costs." Heggie [4]

(ii) "Few ports at present have a wholly rational port pricing system. One reason is that the concept of the autonomous port is a relatively recent one. In the past, many ports were administered by bodies such as customs or municipal authorities or directly as a governmental department, and charges were therefore established and amended to satisfy not only the port requirements, but also those of other parties involved. As a result, most port pricing systems are very complicated; in consequence of technical progress in the operation and use of ports, such old fashioned pricing systems have become inadequate." UNCTAD [5]

(iii) "...The commonest form of charging for ships is a fixed scale per gross or net registered ton covering a stated (and quite often lengthy) stay in port. The dues on cargo usually take the form of charges per ton weight, but are sometimes quoted per standard barrel, case, bale, etc., and occasionally ad valorem.... This system of charging bears no necessary relationship to either the average or the marginal costs (short or long period)."
Goss [6].

The conclusions which can be drawn from these quotations are firstly that the price of individual services are not based on cost, whether these be total, average, marginal, short-run or long-run. This criticism is made particularly of the charges on vessels and goods, Goss [7], for example, extending the criticism by observing that in the 39 ports he visited, no ports operated a peak/off-peak tariff and there seemed to be no differentiation in charges between berths or other services of differing qualities. Secondly, that one of the main reasons for the present structure is historical, that is, it was developed before the turn of the century and technical change has subsequently made it obsolete. Svendsen [8] reiterates this by stating that "the tariff policy is largely governed by custom, and not by economic principles." He also suggests that the method of pricing used is "based on formal political decisions of how the users would react". Walters [9] similarly suggests that "the long history of government regulation has not produced a rational system of charges either according to the marginal cost of providing the service or to any discernable principle of social justice....they relate more closely to what-the-traffic-will-bear principle". The third conclusion is that most ports do not keep comprehensive cost accounts and thus, in the absence of this information, it is not possible for the port to relate prices to costs.

In answer to these criticisms, the port may recognise that some charges are illogical, inequitable or inefficient. However they would argue firstly that the system has evolved from the market place and it works (in the sense that it is accepted and given favourable trading conditions meets an accounting requirement that total cost equals total revenue). Secondly, the advantages to be gained from an alternative which in theory may be financially and economically sound will generally be small and the disadvantages large. Thirdly, that given the competitive environment and the attitudes of users, any unilateral change in established pricing structures would lead to loss of traffic. Finally, that in practice it may not be possible for the port to operate some of the alternative theoretical systems, De Monie [10] for example suggesting that:

> "'Theorists' forget all too easily that in practice port authorities are not able to manipulate the tariff system of port dues in the short term as a function of the traffic in the port and of the available operating resources."

The three basic issues raised by the defences are the definition and information concerning costs; misunderstaning of pricing recommendations and their relationship to costs; and the coordination of ports' pricing and investment policies.

A suggestion that "dues must be related to cost" is usually interpreted by the port as meaning that prices must rise and traffic consequentially lost. On the other hand, the suggestion that "prices be set equal to marginal cost" is interpreted as meaning a fall in price which would lead to retaliation from other ports. Neither of these interpretations with respect to the price changes are implied by the suggestions. In both cases some prices may rise, whilst some may fall. If costs are defined as escapable or avoidable costs and traffic is lost because it is not willing to pay, then, its loss will result in a net saving to the port. De Monie [10] suggests however that the port does not have sufficient data at its disposal in order to calculate the "real cost" price. The port may therefore not have the relevant cost information on which to base prices and thus, the "advantages" and "disadvantages" cannot be ascertained.

The reaction of other ports and the implied oligopolistic interdependence of ports could however present a different problem for the port. If the port industry does exhibit decreasing costs (an hypothesis which is "extraordinarily difficult" to ascertain, Walters [9]) then there would be a tendency towards monopolisation of the industry. Given such a "market failure" then there may be a case for some coordination of ports. This control could range from nationalisation to the issuance of a set of guidelines which incorporate the financial, investment and pricing obligations of the port. The approach adopted in this thesis is the "guideline approach", as such recommendations would also be required in the case of nationalisation. The guidelines will be outlined later in this chapter.

The argument that the market solution is correct is suspect, particularly given the indivisibilities and resulting jointness involved in the port's operations. Similarly, given that a large proportion of the port's traffic is accounted for by a small number of users, the criteria of "acceptability of a tariff structure by the users" is also suspect.

This is not to deny that devising a tarrif structure is a complex problem. In the following chapters, both costs and prices will be considered including the development of a methodology for ascertaining relevant costs. If this information can be obtained then at least the port would be better informed in making traffic accept/reject and invest/disinvest decisions and additionally the information can form the basis for a rational pricing structure.

1.3 First Best Pricing and Investment

In a "first best" world, economic theory suggests a two-fold rule for optimising the allocation of resources within an economy. The pricing rule being to set price equal to short-run marginal cost and the investment rule being to invest in projects whose benefits (at the level of output determined by the pricing rule) exceed their costs [11]. The main characteristics of this first best world are perfect competition in all markets (no person or firm individually having the power to affect prices); each firm experiencing constant returns to scale before they become large enough to influence the market; divisibility of inputs and outputs (marginal adjustment can be made in both inputs and outputs); independence of utility and production functions (utility functions are solely dependent upon the goods which the person consumes and production functions are solely dependent upon the firm's inputs, no joint products being produced); and the consumption of the commodity by one person automatically excluding any other person from consuming the same unit.

Given these characteristics and assumptions, the firm will attain long-run equilibrium by adjusting capacity so that it is producing at the minimum point of its long-run average cost curve. At this point, price equals marginal and average costs in the short- and long-run.

Thus, setting price equal to short-run marginal cost (at this point) is consistent with an accounting objective that total revenue equals total cost.

In the cases where the port industry exhibits increasing returns to scale, there exists indivisibilities in factor inputs or there exists excess capacity, Short-Run Marginal Costs (SRMC) may be less than average costs. Walters [12] , for example, suggests that the SRMC of the passage of vessel in an uncongested dredged channel is virtually zero. If these conditions exist at a port then SRMC pricing will lead to an accounting deficit. This observation raises the particular question of how this deficit should be financed and more generally the question of the port's pricing objectives.

1.4 The Port's Pricing Objectives

Bennathan and Walters [13] outlined the two main doctrines associated with port pricing by labelling them the European view and the Anglo-Saxon view. "The European doctrine views the port as part of the social infrastructure of a region" and thus due to the external benefits which it confers on this region there is no requirement that the port breaks even in an accounting sense. On the other hand, the Anglo-Saxon view is that "the port, like the tub, should stand on its own bottom". Webster [14] , expressing the views of the National Ports Council (NPC) suggested that the primary objective is that "prices must yield the revenue from users required to attain the financial objectives". Subsidiary objectives included:

> "First, any sensible pricing policy must aim to promote the efficient and full use by shippers, shipowners and others of port facilities provided by the port. Secondly, it should not discriminate unreasonably between users, and thirdly, the prices should yield such a return on new investments as to encourage port authorities to develop and to improve."

The logic lying behind the primary objective is related to the allocation of the community's resources to the area where the most benefit can be obtained. Ceteris paribus, if the consumers are not willing to pay the cost of providing the port's facilities then the resources would have been better employed elsewhere. The logic behind each of the respective subsidiary objectives is firstly, that some flexibility in short-run pricing is desirable in order to obtain the maximum utilisation of existing resources. Secondly, it would appear from Webster's discussion that no "unreasonable discrimination" implies that as far as practically possible, prices should be related to costs. In particular, the objective could be rephrased as, "to avoid cross subsidisation with regard to escapable costs between port users". This objective would then require the port to ascertain the escapable costs of the traffic so that it could determine the extent to which there was "unreasonable discrimination". The third objective recognises that the pricing structures should act as signals not only in the short-run (first objective) but also in the long-run. In other words, they should assist the port in deciding upon the level of investment that should be undertaken.

In the nationalised sector the stated financial objective of the British Transport Docks Board is:

> "to employ their financial resources in a way that will ensure the long-term financial viability of each of the ports and of the Board as a whole and to establish and meet return on investment goals for each of the ports. In so doing to have regard to the financial obligations of the Transport Acts, 1962 and 1968, and to the Financial and Economic Objectives of the Nationalised Industries (Cmnd. 1337 and 3437)" [15]

and

> "In fixing charges at the ports, the Board endeavour to cover both direct and indirect costs of providing, maintaining and operating the facilities and services." [16]

Thus, in this sector of the port industry the NPC's primary objective has been stated.

1.5 Official Recommendations

In the United Kingdom, official recommendations relating to pricing, investment and financial objectives have initiated from the Rochdale Report (1962) and the NPC (1975). In addition, the three white papers discussing the Nationalised Industries (1961, 1967 and 1978) would appear to be applicable to the port industry. One of the reasons for this observation is that with respect to the financial objectives, the Rochdale Committee drew explicitly upon the 1961 White Paper and the Committee's recommendations on charges are similar to those in the 1967 White Paper.

1.5.1 The Financial and Economic Obligations of the Nationalised Industries (1961) [17]

This first White Paper considers the objectives of the Nationalised Industries under three main headings: Revenue Account (Financial Objectives), Capital Account (Investment and Borrowing) and Prices and Costs (Pricing).

Under the Revenue Account heading, it is required that surpluses are at least to cover deficits over a five year period.

When calculating costs, the following items should be included:

1. Interest.
2. Depreciation on an historic cost basis.
3. A provision for the excess of replacement cost over historic cost on new investments.

4. A provision to meet premature obsolescence or other unforeseen contingencies.

Under the Capital Account heading, the government exercises powers over the Industries' investment and borrowing proposals by; reviewing their plans for the next five years annually; fixing upper limits on the level of investment to be undertaken in the following two years and by requiring approval of proposed borrowing.

The third heading of Prices and Costs is concerned with impressing on the Industries their responsibility to the community; recognising some of the problems they have in setting prices; and noting that financial performance can be improved not only by increasing prices but also by increasing productivity and reducing costs.

1.5.2 Rochdale Report (1962) [18]

The Committee's first premise was that they could "see no reason why the major ports should not be treated as commercial undertakings" (para 155), thus rejecting "the concept of 'public service'". They then expanded the port's objectives under similar headings to those considered above. The principles of the White Paper's financial objectives were noted and the specific recommendations were "that ports should aim at providing, out of revenue, for (a) working expenses; (b) interest on loans; (c) depreciation of assets on a replacement cost basis; (d) taxation." (para 167). In addition, a provision to meet premature obsolescence, other unforeseen contingencies and minor improvements was recommended, however major new developments were to be financed from the capital market.

Under the heading of Investment and Borrowing, the Committee considered the existing controls and their defects. The system in existence was essentially one of a fixed limit to borrowing powers and the Committee recommended (para 221) the establishment of an Authority to approve schemes of capital development above a minimum figure.

Probably the most important point arising from the Committee's discussion of charges is that the general aim when setting their level is to ensure that the financial objectives are achieved. Thus implying that pricing considerations are of lower priority than financial considerations. Three further points were also considered relating to charges for specific services. Firstly, that a sound costing system should be used and that charges were to be related to the cost of providing the service; secondly, that prices should provide where necessary an incentive or deterrent "to ensure that the port is properly used as a transit facility"; and thirdly it was recognised that it may be necessary to bear losses on certain activities that the port undertakes - where this is the case "the reasons should be clearly understood and the costs measured".

1.5.3 Nationalised Industries: A Review of Economic and Financial Objectives (1967) [19]

This White Paper notes that a conflict can arise between a financial objective in terms of an overall percentage return on assets, the test discount rate used for new investment and a pricing system which is related to costs at the margin. However it also recognises the practical necessity of objectives and obligations. In the face of this conflict, the Paper adopts a flexible approach, whereby general principles are laid down and any conflict arising can be discussed with the Government.

In setting Financial Objectives (or Targets) the Government was to take into account "return on new investment, a soundly based pricing policy, social obligations not covered by a subsidy, efficient operation and national prices and incomes policy". Targets which have been agreed for the various industries at the time of publishing the Paper were in terms of income as a percentage of average net assets, income being either gross - before interest and depreciation - or net - before interest but after depreciation at historic cost. The only industry which took into account the replacement cost of assets was the National Coal Board which had the target "To break-even after interest and depreciation including £10 million a year to cover the difference between depreciation at historic and replacement cost".

The Paper's discussion of Investment can be conveniently divided into two parts - firstly a statement of the reason for control and secondly the vehicle of control. The reason for control "is that the most efficient distribution of goods and services in the economy as a whole can be secured only if investments are made where the return to the economy is greatest" and the vehicle is the use of Discounted Cash Flow (DCF) techniques using the Government's Test Discount Rate (TDR), which was 8 per cent in real terms at the time of publishing the Paper. The Government's flexible approach is again demonstrated when the conditions under which a proposed project, which does not meet the 8 per cent DCF rate of return may be accepted, or which does meet the requirement but may be rejected, are discussed. In the former case, the Paper is mainly concerned with those situations where there are social costs and benefits which are not normally included in a commercial investment appraisal but which are relevant when considering society as a whole. In the latter case it is recognised that the TDR is a long-term device for ensuring that the public and private sectors' calls on resources do not diverge markedly, however in the short-run the government may have to take into account competing claims for scarce resources and reject projects which pass the test.

The first statement in the Paper with respect to prices draws attention to the link between sound investment appraisal and pricing policies. In keeping with the general policy of treating the industries as commercial concerns, it then adopts the criteria that not only should prices be set such that revenue covers accounting costs, but also that prices should be related to costs at the margin. Whilst these are the broad principles, the specific aim of pricing policies (para 18) "should be that the consumer should pay the true cost of providing the goods and services he consumes, in every case where these can be sensibly identified". The section on prices then goes on to discuss three reasons why prices may differ from costs and suggests pricing systems which would be applicable in these cases. The first reason, is where the cost of providing the goods and services to specific consumers is difficult to identify and therefore difficult to allocate to these consumers. This situation can arise where there is jointness in production or consumption and the Paper cites the use of two-part or differential pricing systems as attempts to minimise distortions in the allocation of resources. The second reason is where there are (para 18) "wider economic or social considerations" and the third reason is where excess capacity or excess demand can be minimised by charging prices different from costs. These two phenomena can be both short- and long-run in nature.

In the short-run, it may be that there are peaks in demand - in this case, setting prices so as to encourage the utilisation of facilities during the off-peak period (such that the price does not fall below the variable cost incurred) and discouraging utilisation during the peak is suggested. In the long-run, it may be that there is unused capacity - in this case, pricing down to escapable cost (if this increases demand) is suggested.

Thus, one could interpret the discussion on pricing as being consumers should pay the true cost but at the same time the relevant (short- or long-run) marginal cost should be borne in mind when setting the charge.

1.5.4 The Nationalised Industries (1978) [20]

This White Paper attempts to resolve the conflict between marginal cost pricing, a test discount rate, and financial targets. The principle behind this attempt is shown in fig 1.1.

The test discount rate of the 1967 White Paper is replaced by the Required Rate of Return (RRR). This is currently set at 5% and represents the opportunity cost of capital (broadly reflecting the pre-tax real rate of return in the private sector). The Industries are expected to achieve this on all new investments, including those which are non-revenue earning (for example, investment in head offices, necessary replacements etc.).

An interpretation of the recommendations is that from the project proposal, the cost of providing the extra tranche of output is estimated. This cost estimate, the RRR and the expected demand are then input into an investment appraisal model which in turn outputs

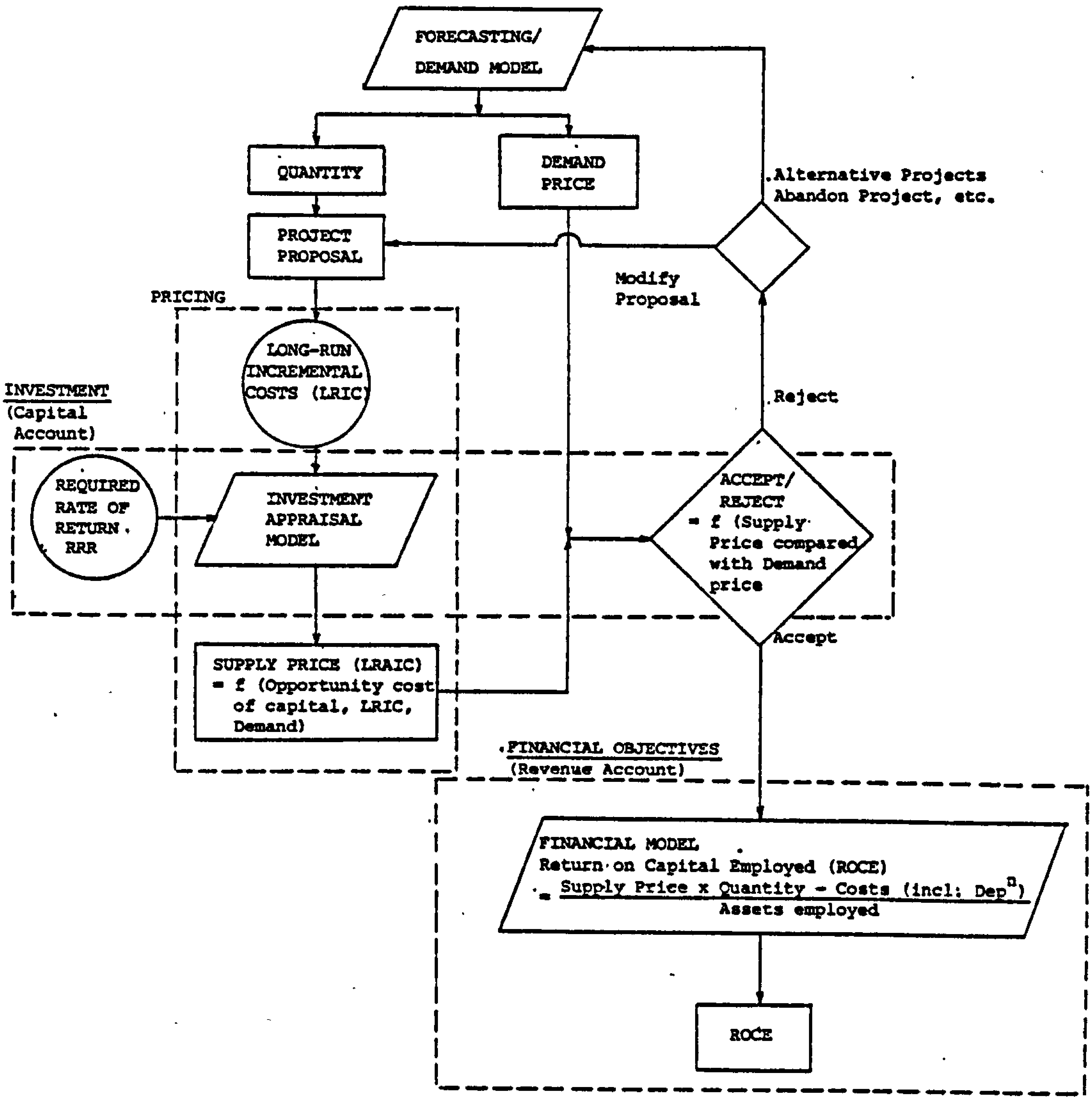

Fig. 1.1 Schematic presentation of the recommendations in the 1978 White Paper "The Nationalised Industries"

the supply price. The supply price representing that price which is required in order to meet the RRR.

The supply price is then compared with the prices obtained from the demand forecasts. Given that the supply price, and price and quantity obtained from the demand forecast are compatible then the project can be accepted. Paragraph 9 (of the Appendix [20]) suggests that:

> "In the case of industries where the outputs of old and new assets are indistinguishable, total revenue would be derived directly from the price needed to earn the RRR on new investment; where the price which can be charged for the output of old assets is different from that which would be charged for that of new assets, it will be necessary to take account of this in deriving the total revenue figure."

This implies that in cases where the outputs are indistinguishable, price is set such that total revenue would be sufficient to replace those assets for which demand exists (that is, price provides a signal to the producer indicating which assets should be replaced).

The data obtained up to this point are then converted into a financial target in terms of a Return on Capital Employed (ROCE). The total revenue is calculated according to the above quotation from para 9. "Costs, including depreciation, would then be deducted and the resultant net profit would be expressed as a return either on assets or some other appropriate base" (para 9).

Thus, by carrying out the calculations sequentially the three objectives are interrelated.

In practice, however, the government reserves the right to take into account "social, sectoral and wider economic considerations" when setting financial objectives.

The adoption of the RRR in preference to the TDR is the result of two main factors. Firstly, only a small percentage of investments had been appraised using the TDR of the 1967 White Paper and secondly, it represents an attempt to relate the return on investment in the public sector to that in the private sector. In other words it is attempting to recognise the opportunities foregone when one invests in the public sector.

The pricing policy which emerges from the series of calculations is that price is related to Long-Run Average Incremental Cost (LRAIC). Whilst this approach does not yield the Long-Run Marginal Cost (LRMC) (except in the constant returns to scale case) it does represent a closer approximation to LRMC than Long-Run Average Cost (LRAC) and thus is a workable interpretation of the 1967 White Paper's recommendation that prices should cover LRMC. In the section on pricing, the 1978 White Paper does reiterate the importance of the structure of prices, particularly that peak/off-peak rates should be related to the relative costs of supply and also that arbitrary cross-subsidisation between different groups of consumers should be avoided.

The financial target as calculated above will be set for three to five years, and will normally be expressed as a percentage return (before interest) on average net assets. However, in some industries, particularly those which are labour intensive, a more relevant measure would be a percentage return on turnover. The White Paper also recommends that as soon as possible, financial targets should be placed on an inflation adjusted basis.

1.5.5 Financial Objectives for the Ports Industry (1975) [20]

Whilst this memorandum is mainly concerned with financial objectives it is recognised that in order to achieve these objectives they must be based on sound pricing and investment decisions. The minimum condition laid down for prices is that they should never fall below the escapable cost of providing the service or facility and for investment the real return in DCF terms should not be below 10 per cent. The link between the port's objectives and those of the Nationalised Industries is also mentioned in this memorandum when it states that:

> "The application to ports of the same test discount rate as applies to investment proposals in the public sector generally is seen as one of many tools for ensuring the best allocation of new resources."

The two financial objectives that the document is concerned with are Return on Capital Employed and a Cash Flow Target. The general conclusion reached is that differing accounting practices and the problem of changing asset prices and technology over time produce a financial objective on a ROCE basis which is unsatisfactory. However if one uses cash flow concepts, where the cash flow has to be sufficient to cover specified items (for example, interest, taxation, dividends, redemption of capital debt. etc.) then most of the problems of the ROCE are bypassed.

1.6 Aims and Outline of the Thesis

The recurring theme of the Offical Recommendations is that ports should be treated as commercial undertakings. Rochdale adopts this view as a "yardstick" for measuring the financial performance of the port. The White Papers similarly suggest that where possible consumers should pay the "true cost" of the goods and services they consume. Whilst the concept of "true cost" has not been defined, the "commercial concern" maxim will be broadly adopted in the thesis. The more specific objectives of a pricing structure will also closely follow the views and recommendations of the two previous sections, namely:

(i) To promote the efficient and full use by shippers, shipowners and other users of the port's facilities.

(ii) To avoid cross-subsidisation between port users with respect to escapable costs.

(iii) To encourage the port to develop and improve facilities which are justified by demand.

The overall aims of the thesis are fourfold and include:

(i) To identify and expand upon the problems facing the port when attempting to develop a pricing system or to invest in new assets.

(ii) To investigate the merits of various pricing systems.

(iii) To consider a methodology for measuring escapable costs and attributing joint costs to the relevant traffic .

(iv) To outline the principles which could be employed by a port authority when considering the pricing policy.

In pursuit of these aims, the next chapter will consider the problems faced by the port when making its pricing and investment decisions. Having outlined the problems, the discussion will attempt to demonstrate that they are not insoluble. Chapter 3 will consider the merits of various pricing systems. The aim of the chapter not being to present a comprehensive list of pricing alternatives, but to consider some basic systems from which variations may be developed. Chapter 4 provides a discussion of the traffic characteristics, an input which will be used in later chapters. The thesis then contains a block of chapters concerned with the measurement of escapable costs. Chapter 5 outlines the principles involved in measuring these costs, whilst Chapters 6, 7 and 8 discuss the application of these principles to conservancy, the docks and cargo handling respectively. Chapter 9 expands thediscussion of section 1.1 (above) in the context of the Mersey Docks and Harbour Company. Chapter 10 considers the charging base which is currently used and Chapter 11 contains the summary and conclusions of the thesis.

Notes

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CHAPTER 2

THE PORT'S PRICING AND INVESTMENT PROBLEM

2.1 Introduction

The conditions necessary for the first best world (outlined in Chapter 1) are violated in the port case and thus the direct application of a marginal cost rule may not lead to an optimal allocation of resources. The problem facing the port is therefore one of optimisation in a second best world.

Apart from the oligopolistic interdependences, the features of the port industry which lead to this breakdown include:

(i) Jointness in consumption.

(ii) Technical jointness in production.

(iii) The discrete nature of factor inputs.

(iv) Temporal jointness in production, including the special case of fluctuations in demand over time.

(v) The specific and durable nature of the port's assets.

(vi) Technological change and the resulting excess capacity.

(vii) Externalities.

This chapter will discuss these features and outline their solutions.

2.2 Indivisibilities and Jointness

The recurring theme in these features is indivisibility and jointness [1]. These two words are used frequently in the context of public enterprise economics, however, their meaning is not always clear. Dictionary definitions include such phrases as, in the case of indivisible, "not separable into parts" and in the case of joint "shared by two or more persons". A large number of the port's problems arise from indivisibilities (interpreted in the broad sense of inability to separate) which leads to joint costs (interpreted as being shared by two or more persons or outputs). Thus, the problems arise because costs in particular cannot be separated (that is, are indivisible) which implies that they are shared (that is, joint).

Jointness can arise in both consumption and production, table 2.1, indicating the main areas in which it can occur. On the consumption (demand) side, the consumption of one good in some sense implies consumption of another good. These two goods can be either complements or substitutes. For example, given that a vessel enters port to transfer cargo, then the demand for this transfer implies a demand for cranes, a quay, deepwater alongside the berth, and approach channels. In other words, there is a joint (complementary) demand for these facilities. An example of a substitute is where increased demand for container berths implies a reduced demand for general cargo berths. Joint consumption can also occur in the case of externalities, where either the consumption of a good by one consumer confers benefits or imposes costs on other consumers. For example, the consumption of congested port facilities by one consumer imposes a delay cost on other consumers.

On the production (supply side), the production of one good in some sense implies production of a second or more goods. The "sense" can either mean production of different goods or the production of the same good (jointly) for other consumers. The four main cases where this can arise are where discrete factor inputs, "joint" production, externalities and public goods exist, with "joint" production incorpor-

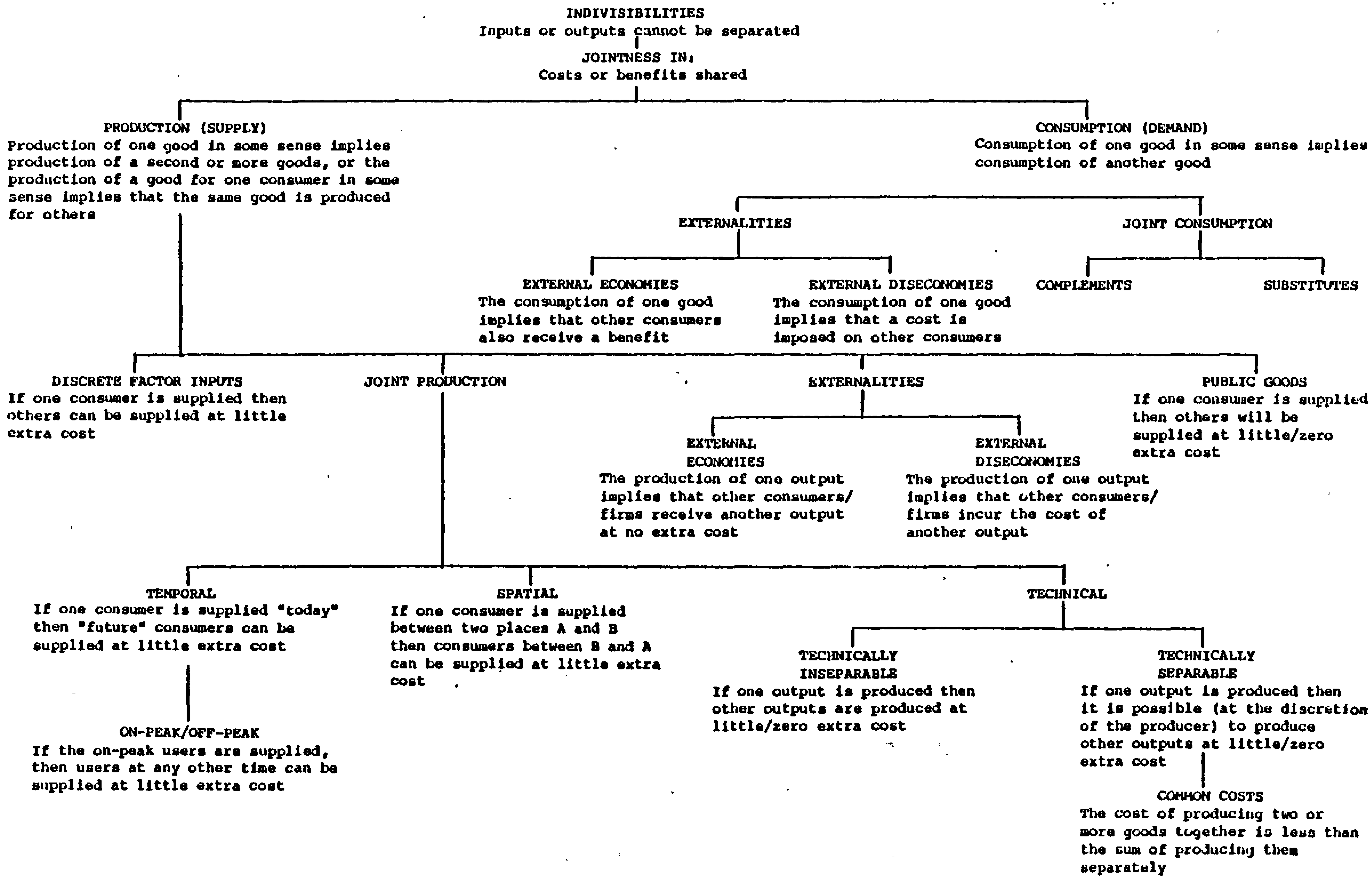


Table 2.1 Indivisibilities and Jointness in Production and Consumption

ating technical, temporal and spatial jointness. Assuming that the port's facilities are uncongested then the general comment attaching to each of the cases in table 2.1 is that supplying one output or consumer implies that another output or consumer can be supplied at little or zero extra cost. Thus, for example, supplying a (discrete) dredged channel for one ship implies that other ships can use it for no extra cost. If the channel has a life of a number of years then it will also be joint in a temporal sense. Spatial jointness occurs in the transport context with the "return load problem", that is, providing a transport service for traffic from place A to place B implies that capacity is available to transport goods or passengers from B to A. Technical jointness can occur where the output is technically inseparable or technically separable (Wiles [2]). Technically inseparable products are those where "the production of one object leads inevitably to the production of the other, whether in a fixed or a variable proportion". The classic example of this type of product is wool and mutton. It is difficult to envisage any cases where the port's output is joint inseparable, however, the case will be discussed below for completeness of argument. Technically separable production occurs where "the production of the second object in any proportion at all may be at the discretion of the producer." An example in the railway context is the running of both passenger trains and goods trains. Wiles further suggests that technically inseparable goods can be complementary or neutral and technically separable can, in addition, be competitive. For example "if the track is better maintained in order to increase goods traffic, passenger traffic is also facilitated; but the actual running of more goods trains obstructs passenger traffic". In the first case, the goods are complementary, whilst in the second they are competitive. Joy [3] draws a distinction between joint and common costs.

> "Common costs are incurred in the production of two or more products, where it is cheaper to produce them together than separately, but where the level of common cost would decline if production of one of the products ceased... Joint costs are those incurred for the production of two or more products, the level of which will not change with the abandonment of any of the separable outputs."

Thus it would appear that Joy's joint costs correspond to Wiles' neutral separable and Joy's common costs correspond to the complementary separable. Another feature of Joy's common costs is, to the extent that the level of costs change when one of the products cease, some element is directly attributable to one or more of the traffics. Given that this element can be attributed it is no longer of interest when considering jointness. There will however be a cost incurred as long as one output is produced, this being a "de facto (non-attributable common) joint cost" (Joy [4]). Baumol [5] suggests that since the proportions of traffic can be varied at the discretion of management it is possible, in principle, "to trace them to individual services". But (Mumby [6]) "though [common costs are] not truly joint, and therefore not entirely arbitrary in incidence, [they] involve sensitivity in allocation". As it will be difficult to isolate pure joint and Joy's "de facto" joint costs, "joint cost" will be used to incorporate both types.

The discrete nature of many of the port's factor inputs implies that, over the range of output represented by capacity, if one consumer is supplied then others can be supplied at little extra cost (assuming that the whole capacity is not supplied for the first consumer). This characteristic of the port's inputs leads to decreasing costs over most of the range of the asset's output.

Externalities, at their extreme, are a special case of technical jointness. External economies arise where the production of one output generates a beneficial effect on other producers or consumers whilst with external diseconomies a harmful effect is generated. Thus, external economies are similar.to complementary inseparable products and external diseconomies to competitive inseparable products. An example of an external economy in the port context is where the capital dredging of an approach channel for deep draftedvessels so alters the water flow in the approaches that maintenance dredging of another channel is no longer required.

"The essential feature of a pure public good is that its enjoyment by one person in no way detracts from its availability to others" [7]. Thus, again, if one consumer is supplied then the rest will be supplied (simultaneously) at zero extra cost. For the good to be a pure public good, two additional features are necessary. In production the producer does not have the power to exclude the consumption of the output and in consumption the consumer may be forced to consume the good or he may have freedom of choice. Thus, for example, a lighthouse located at the port entrance may be used (or not used) by vessels passing the port, the port authority having no powers to exclude these vessels from using the light. Given that the port can levy charges for vessels entering the port, the facilities (apart from the lighthouse) are not public goods; however, where facilities are uncongested the feature of enjoyment by one consumer not detracting from its availability to others is present.

2.3 Jointness in Consumption

In the analysis of a first best world, it is assumed, inter alia, that it is meaningful to discuss a consumer's Marginal Rate of Substitution (MRS) between two goods, say, X and Y. Under these conditions, the MRS (slope of the indifference curve) can be used to generate relative prices for X and Y for any level of consumption of X and Y.

If however, X and Y are perfect complements then one cannot sensibly discuss rates of substitution between them. Continuing the example of the previous section, if approach channels (X) were perfectly complementary to quays (Y), then it is meaningless to analyse the shipowners rate of substitution of more quays for less approach channel or vice versa. Given that quays and approach channels are divisible, all that exists is a consumption vector where X and Y are consumed in fixed proportions. Thus relative prices are indeterminant in that they can range from zero to infinite.

Whilst one cannot discuss MRS_{XY}, one can however consider the MRS of a numeraire, Z for port services (that is, X and Y jointly). This then suggests that a price can be found for X and Y jointly, but no individual prices for X and Y can be ascertained. Thus, the solution would appear to be to charge a single price for these port services (X and Y) which are consumed jointly.

This however is not the only solution. If the production side is examined then common Marginal Rates of Transformation of channels (X) for quays (Y) exist for all firms producing both, as do common marginal rates of transformation of channels for Z and quays for Z for all firms producing each pair. Since it is meaningful to trade off more quays against less channels and vice versa, relative prices can be obtained from the slopes of the production possibility curves.

If the quays and channels are measured in units so that one unit of port services provide one unit of channel and one unit of quay, then the optimality condition can be written in terms of the numeraire as:

$$MRS_{X \text{ and } Y,Z} = MRT_{X,Z} + MRT_{Y,Z}$$

Alternatively, the amount of Z that consumers are willing to give up in order to obtain an extra unit of port services is equal to the amount of Z society has to give up for an extra unit of channel plus the amount of Z that society has to give up for an extra unit of quay.

Thus, in the case where there are two products in consumption (Z and port services) and three in production (Z, channels and quays) prices can be obtained from the production side.

If the assumption of perfect complementarity is removed, then in principle the whole problem disappears, for, as soon as the smallest trade-off in consumption can be made an indifference curve of finite slope in the relevant range emerges and thus (assuming no corner solutions) price ratios can be ascertained.

2.4 Technical Jointness in Production

On the production side, the first best solution has similarly assumed that it is meaningful to discuss producers' Marginal Rates of Transformation (MRT) of two goods X into Y. Under these conditions the MRT (slope of the production possibility curve) can be used to generate ratios of marginal costs of X and Y for various combinations of X and Y produced.

It may however be the case that two outputs are produced jointly in fixed proportions (technically inseparable). In this case, marginal rates of transformation cannot be sensibly discussed as all that exists is a production vector where X and Y are produced together. Thus, relative prices are indeterminant as they range from zero to infinity.

One can however consider the MRT of the numeraire Z for X and Y jointly and therefore price these products jointly. Given however that X and Y are measured in units such that one unit of the joint product is one unit of X and one unit of Y, prices can be determined separately. As long as common marginal rates of substitution of X for Y exist for all consumers consuming both, as well as common marginal rates of substitution of X for Z and Y for Z for all consumers consuming both, relative prices can be determined from the community indifference curves.

Thus, stated in terms of the numeraire:

$$MRT_{X \text{ and } Y, Z} = MRS_{X,Z} + MRS_{Y,Z}$$

In other words, the amount of Z that society has to give up in order to obtain an extra unit of X and Y is equal to the amount of Z that consumers are willing to give up for an extra unit of X plus the amount of Z consumers are willing to give up for an extra unit of Y.

Thus, in the case where there are three products in consumption (X, Y and Z) and two in production (Z, and X and Y jointly) prices can be obtained from the consumption side.

If the assumption of perfect jointness in production is removed, then again the problem disappears, for once trade-offs can be made between

X and Y a transformation curve of finite slope in the relevant range emerges and (assuming no corner solutions) cost ratios can be ascertained from the production side.

2.5 Discrete Factor Inputs

In a large number of cases, it will be necessary for the port to supply services in increments, that is, it cannot make the marginal adjustments which were a characteristic of the first best world. This implies that the port incurs expenditures either before any output is produced or before increments of output are produced. Consider, for example, a numeraire Z and a canal leading to a port which provides an output, X, of canal transits for homogeneous ships. Assume further, that there are no other inputs (pilots, lockkeepers, maintenance etc), that the canal can be constructed instantaneously and that the life of the canal is one production period. The port is then faced with the twofold problem of whether the canal should be constructed and if it is, what price should be charged.

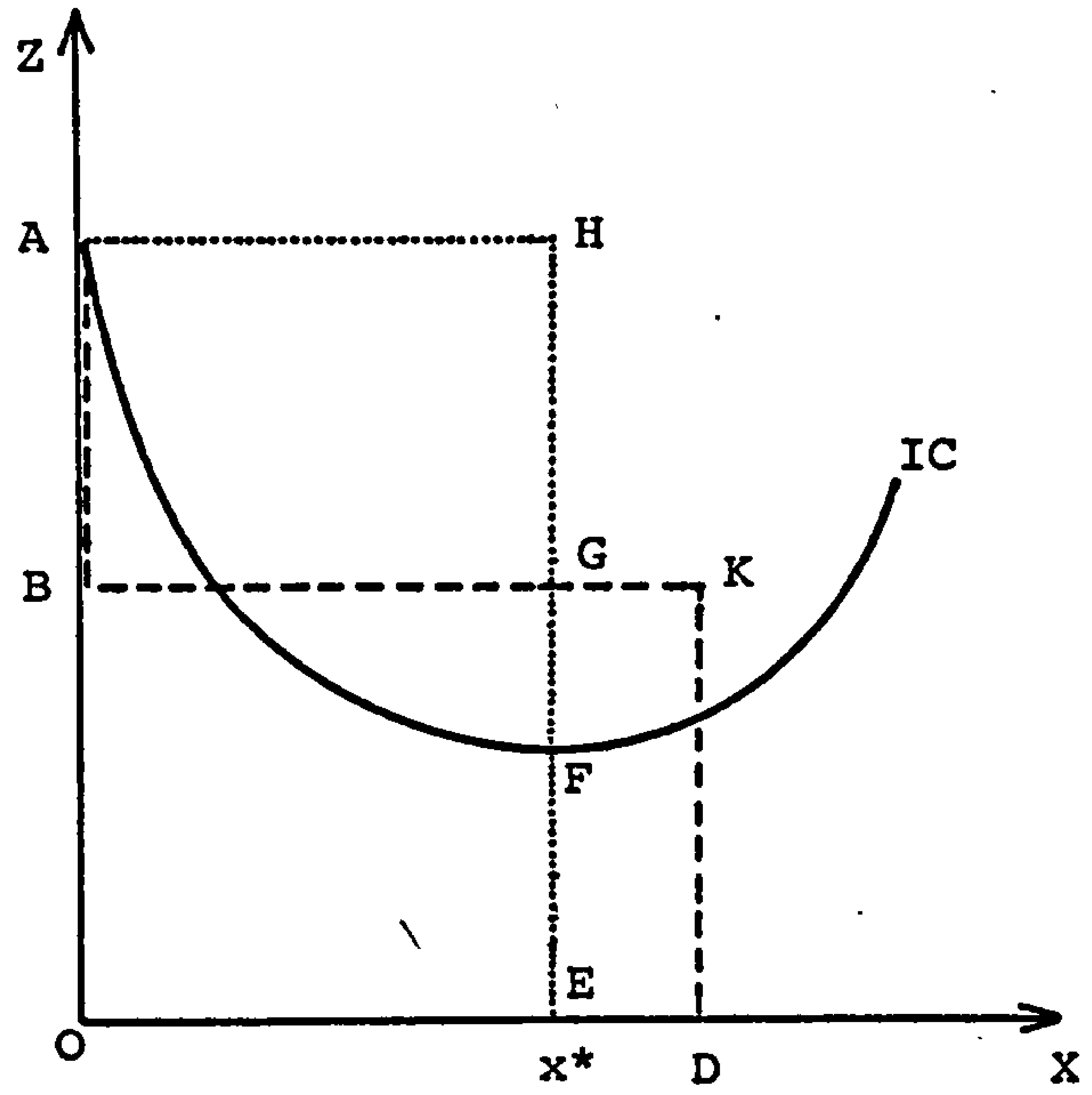


fig.2.1 Indifference and transformation curves for the canal example.

In fig 2.1, AB represents the amount of Z that society must give up in order to obtain OD units of X. The MRT up to the capacity of the canal (point K) is zero and at K it becomes infinite. On the consumption side, the community has a preference map where, along any indifference curve they can make marginal trade-offs between more X and less Z and vice versa. In order to resolve the twofold problem, the relevant indifference curve is IC . This curve represents all the points where the community is indifferent between OA units of Z and no X, and the various combinations of X and Z. Thus, along IC, consumers are being faced with an "all or nothing" choice with respect to the canal. The optimality conditions require that the port produces that output where $MRS_{X,Z} = MRT_{X,Z}$, that is, the amount of Z that society is willing to give up in order to obtain an extra canal transit is equal to the amount that society has to give up in order to obtain the extra transit. This condition can be restated as set price equal to short-run marginal cost, which in this case implies that, since $MRT_{X,Z}$ is zero at the optimum level of output OE, price should also be zero. Whether the investment should be undertaken depends upon whether the benefits exceed the costs. In fig 2.1, the maximum amount that consumers are willing to pay for OE units of X (compared with OA of Z and no X) is HF units of Z foregone. On the production side, the total cost of OE units of X is HG units of Z foregone. Since the consumer's willingness to pay is greater than the cost, the investment should be undertaken. In terms of the MRS and MRT, the total benefit can be written as:

$$\int_{0}^{x^*} MRS_{X,Z}(x) \, . dx$$

and total costs can be written as:

$$\int_{0}^{x^*} MRT_{X,Z}(x|c) \, dx + C$$

(where $MRT_{X,Z}(x|c)$ is the marginal rate of transformation of X for Z given the initial capital expenditure C (equal to AB)).

Thus the investment criteria is, invest if benefits are greater than or equal to costs, that is:

$$\int_{0}^{x^*} MRS_{X,Z}(x)\,dx \geqslant \int_{0}^{x^*} MRT_{X,Z}(x|c)\,dx + C$$

In this particular case $MRT_{X,Z}$ is zero for all X between 0 and x*, so that:

$$\int_{0}^{x^*} MRS_{X,Z}(x)\,dx \geqslant C$$

Thus the problem of accounting deficits outlined in the previous chapter arise in this example. This need not always be the case and will depend upon the consumer's MRS at the capacity level of output. On the production side at this capacity level, relative prices range from zero to infinite at the point K. If on the consumption side the MRS at this level of output is still negative then a positive price will emerge which may be sufficient to meet the accounting requirement. Thus whilst prices are indeterminant on the production side, they could be obtained from consumption. The general problem of meeting an accounting requirement given the discrete nature of factor inputs and excess capacity remains. Any alternative policy should have the objective of attempting to extract some of the consumer surplus from the $\int MRS_{X,Z}(i)$ term in the investment criteria whilst requiring that at the optimal output level $MRS_{X,Z} = MRT_{X,Z}$ in the pricing rule.

The problem of discrete inputs need not only be exhibited with a single investment. It could arise where indivisible assets are duplicated. For example, the port could be considering how many fork lift trucks to purchase. In this case the output, X, could be measured in fork-lift hours and assuming three identical trucks with zero operating costs there would be three production points K_1, K_2 and K_3 (fig 2.2).

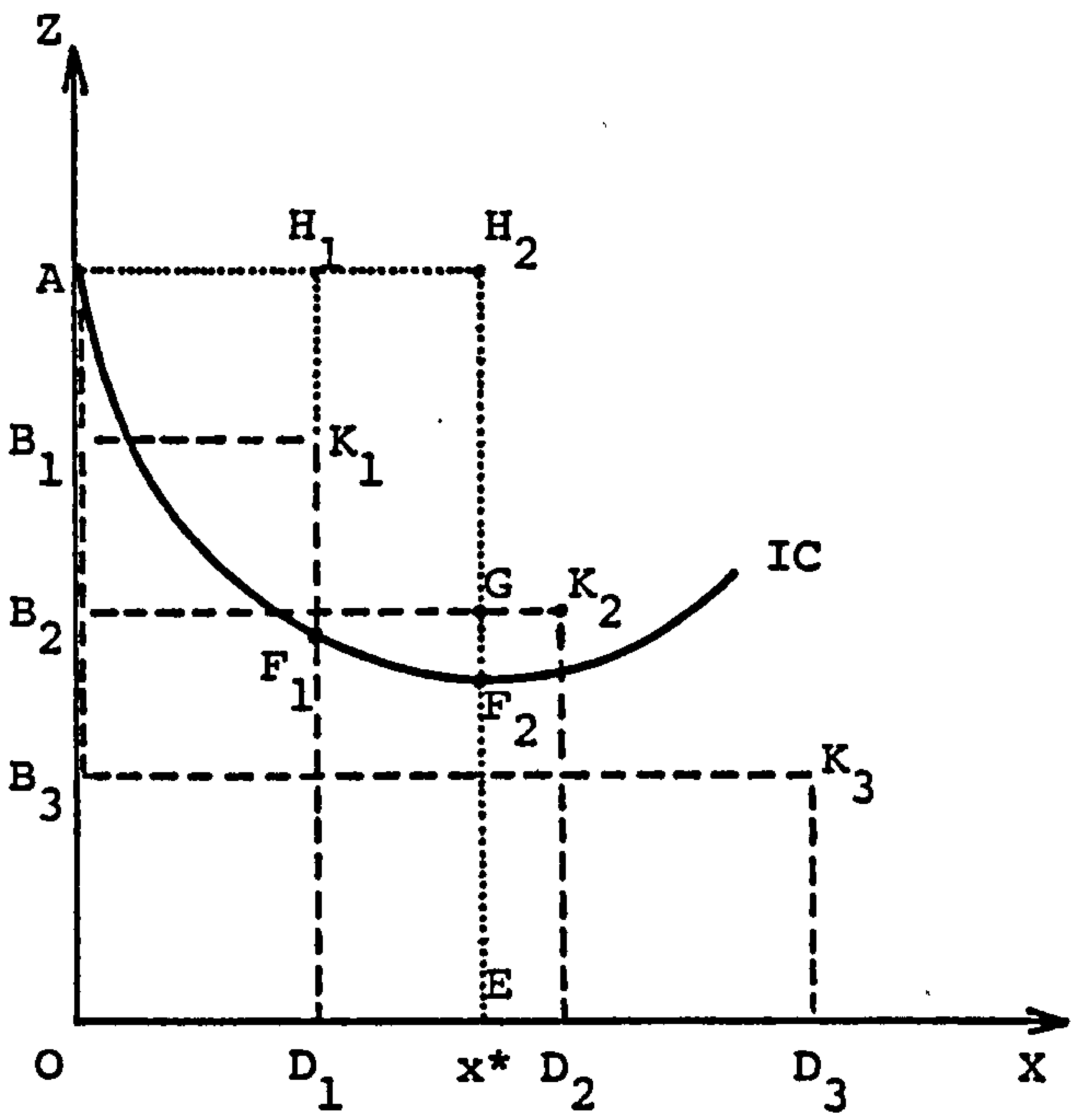


fig 2.2 Discrete output of fork-lift trucks

Applying the above analysis, one fork-lift costs H_1K_1 and consumers are willing to pay H_1F_1, therefore invest in at least one. Two fork-lifts cost H_2G and consumers are willing to pay H_2F_2, therefore invest in two. Consumers are not willing to pay for three, therefore do not invest in three. In a similar manner to the canal example, the optimum price for two fork-lifts is zero and there will be excess capacity of ED_2.

The problem of joint production can also arise in the context of discrete factor inputs. In this case the pricing and investment criteria require further modification. In the two output case, the pricing rule becomes, set price such that:

$$MRS_{X,Z} + MRS_{Y,Z} = MRT_{X \text{ and } Y,Z}$$

and the investment criteria becomes,

$$\int_{0}^{x^*} MRS_{X,Z}(x)\,dx + \int_{0}^{y^*} MRS_{Y,Z}(y)\,dy$$

$$= \int_{0}^{\max(x^*,y^*)} MRT_{XandY,Z}(x \text{ and } y)\,d(x \text{ and } y) + C$$

Alternatively, the amount of Z that consumers would be willing to give up for X (rather than go without it) plus the amount of Z that consumers would be willing to give up for Y (rather than go without it) is equal to the amount of Z that society has to give up in order to supply X and Y.

Thus, when considering discrete factor inputs, whether they are used to produce a single or joint product, the pricing and investment rules are clear. The question, however, of pricing to meet an accounting requirement remains and will be considered in the next chapter.

2.6 Temporal Jointness in Production

The technical cases of joint production and discrete inputs can be extended to intertemporal production. In the intertemporal case the port is considering an asset which takes zero to finite time to acquire or construct and which confers benefits on society for one production period (sometimes, for convenience, being taken as the calendar year) or more. Thus, society must sacrifice some consumption "today" (referring to the whole construction period) in order to obtain the benefit of more consumption "tomorrow" (referring to the whole life of the asset).

In the simpler case where construction is instantaneous, inputs are continuous and the asset has a life of two production periods then given perfect jointness over time the optimality condition becomes:

$$MRT_{X_t \text{and} X_{t+1}, Z} = MRS_{X_t, Z} + MRS_{X_{t+1}, Z}$$

In other words, the amount of Z that society has to give up in order to obtain an extra unit of X_t and X_{t+1} is equal to the amount of Z that consumers are willing to give up for an extra unit of X_t plus the amount of Z consumers are willing to give up for an extra unit of X_{t+1}.

Thus, again given three goods in consumption and only two in production prices can be obtained from the consumption side.

If the assumption of perfect jointness is removed then again the problem disappears. This occurs particularly in the case of an asset where its life is to a large extent determined by the intensity with which it is used. Thus it may be possible to force the machine in the first production period at the expense of reducing its potential output in the second production period. Once these trade-offs can be made, an intertemporal transformation curve of finite slope emerges and (assuming no corner solutions) prices can be ascertained.

If the continuous input assumption is removed then the analysis is similar to the technical production case. The pricing rule remains the same as with continuous inputs, namely:

$$MRT_{X_t \text{and} X_{t+1}} = MRS_{X_t, Z} + MRS_{X_{t+1}, Z}$$

and the investment criteria becomes:

$$\int_0^{x_t^*} MRS_{X_t,Z}(x_t)\,dx_t + \int_0^{x_{t+1}^*} MRS_{X_{t+1},Z}(x_{t+1})\,dx_{t+1}$$

$$= \int_0^{\max(x_t^*,x_{t+1}^*)} MRT_{X_t and X_{t+1}}(x_t \text{ and } x_{t+1})\,d(x_t \text{ and } x_{t+1}) + C$$

which can be stated as, the amount of Z that consumers would be willing to give up for X_t (rather than go without it) plus the amount of Z that consumers would be willing to give up for X_{t+1} (rather than go without it) is equal to the amount of Z that society has to give up in order to supply X_t and X_{t+1}.

Finally, the removal of the instantaneous construction assumption implies that the numeraire Z becomes a composite of Z's during the construction period. Thus if construction takes two years then in the above equation substitute Z_{t-1} and Z_t for Z (assuming that these costs are incurred at the end of the year to which they apply) and C_{t-1} and C_t (suitably discounted) for C_o.

Whilst the marginal rates of substitution incorporate the consumer's time preference, it will be necessary in practice to compound or discount the costs and benefits associated with the asset. Rewriting the above equation in these terms and, for convenience, taking the date at which the construction is completed as year zero then:

$$\frac{B_1}{(1 + r)} + \frac{B_2}{(1 + r)^2} = \frac{C_{C1}}{(1 + r)} + \frac{C_{C2}}{(1 + r)^2} + C_{-1}(1 + r) + C_o$$

where B_i = total benefit in year i.

C_{Ci} = total variable cost at the optimum output.

C_i = total capital expenditure in year i.

In general terms, the investment criterion is invest if, over the life of the asset the consumers are willing to pay, and the pricing rule is set price equal to short-run marginal cost.

Thus, the temporal extension of the canal example requires that the consumers, over the life of the canal are willing to pay the present value of the construction costs for the port to invest. The pricing rule suggests, under the assumptions of the example, that zero price is charged.

2.7 Fluctuations in Demand over Time

The main fluctuations in demand over time are hourly, seasonal, cyclical and secular. The solution to this problem being included within temporal jointness. Thus, the problems of the daily peak, fluctuations during the year due to the seasonal nature of the trade in various commodities, cyclical fluctuations due to the business or trade cycle and secular decline or growth of trades due to structural or technological change can all (if foreseen) be incorporated into the general solution of investing in the asset if consumers over the life of the asset are willing to pay and setting price equal to short-run marginal cost.

2.8 The Nature of the Port's Assets and Excess Capacity

In general, the relevant (opportunity or escapable) costs to the port are those associated with the decision that the port is taking. In the ex-ante case, the investment costs are relevant, since if it is decided not to accept the associated traffic then the cost could be escaped. In the ex-post case the relevant cost is still the opportunity cost measured in terms of the opportunities foregone by not employing the asset in its next best alternative. This next best alternative could be the use by other traffics or use outside the port. If the port is pricing according to the rules suggested above and excess capacity still exists then by definition other traffics are not willing to pay and the "internal yardstick" cannot be used to measure opportunity costs. Due to the specific nature and fixed location of the port's assets, the alternative uses externally may also be very limited and thus the opportunity cost may be correspondingly low. This arises because given the location and nature of the assets, second hand markets are virtually non-existent. Thus society as a whole has little opportunity to use assets such as dredged channels, locks, docks and quays to perform functions other than those for which they were specifically designed. Even in the cases where assets are mobile (for example, cranes and buoys) the virtual non-existence of markets for these assets implies a low external valuation.

Another characteristic of at least one of the port's assets (namely the channel where capital dredging has been undertaken) is that it is permanent and will not need replacing. The use of such an asset "gives rise to no social cost (Lewis [8]) and thus their opportunity costs (even in the long-run) are zero.

Assets which fall into the same class as permanent assets, in the sense that their long-run opportunity costs approach zero are assets that will not need replacing because of a contraction in demand. This contraction has presented a serious problem (in an accounting sense) for established ports in recent years and has arisen from the rapid technological change in shipping. As Lewis [8] states however, this is "an accounting but not a social cost", a point which has been realised by port authorities when having to "write these assets off" as a commercial loss.

2.9 Externalities

Given that externalities at their extreme are a special case of technical jointness the general pricing rule that:

$$MRT_{XandY,Z} = MRS_{X,Z} + MRS_{Y,Z}$$

is applicable (where X is the good or service produced and Y is the externality). However, it is possible for $MRS_{Y,Z}$ to be either positive or negative. If there are no institutional arrangements whereby Y is taken into account, the level of output will be set such that:

$$MRT_{XandY,Z} = MRS_{X,Z}$$

Thus, when Y is a good (that is $MRS_{Y,Z} > 0$) too little will be produced and if Y is a bad ($MRS_{Y,Z} < 0$) too much will be produced.

Therefore, for an optimal allocation of resources, it is required that the amount of Z that society must give up in order to obtain an extra unit of X and Y is equal to the amount of Z that all those affected are willing to give up for an extra unit of X and Y.

Thus, in the example of the capital dredging of one channel affecting the maintenance dredging in another channel, if the maintenance dredging is reduced then the willingness of the traffic using this channel to pay should be incorporated in the investment decision. Similarly if the maintenance dredging is increased then the willingness to pay of the traffic using the channel where the capital dredging is proposed should be taken into account. If this is not done, then respectively not enough and too much capital dredging will be undertaken.

In the case of congestion Bennathan and Walters derive the formulae that [9],

$$\begin{bmatrix} \text{Marginal} \\ \text{cost} \\ \text{(per} \\ \text{vessel} \\ \text{load)} \end{bmatrix} = \begin{bmatrix} \text{Port} \\ \text{cost} \end{bmatrix} + \begin{bmatrix} \text{Own} \\ \text{delay} \\ \text{cost} \end{bmatrix} + \begin{bmatrix} \text{Additional} \\ \text{delay costs} \\ \text{caused to} \\ \text{all other} \\ \text{vessels} \end{bmatrix}$$

An individual consumer perceives the cost of entering the port ($MRT_{X,Z}$) as being the port cost (charges that he has to pay) plus the cost to himself of any delay. However, his entry to the port implies that the bad (negative good) of delays to all other vessels is jointly produced.

It is also suggested by some port authorities that they experience some non-commercial constraints. They argue that these arise because they have a statutory duty "to take such steps as they consider necessary for the conservancy, maintenance, operation and improvement of the approaches to the port, docks, discharging and loading facilities, warehousing and consignment of goods " [10] and that these statutory duties are ranked prior to their financial duties. If this is the case, then one interpretation is that the statutory authorities have recognised that there are external costs and benefits associated with the port.

2.10 Summary and Conclusions

The discussion of the port's pricing and investment problem would indicate that indivisibilities and jointness are one of the major causes. Indivisibilities and jointness can occur in both consumption and production. In consumption, they arise because the user is demanding the set of port services and not just one element of this set. In production, they arise due to a number of causes including the discrete nature of factor inputs; technical, temporal and spatial production; externalities and public goods. Sections 2.3 to 2.9 considered these problems and indicated that they do not imply that prices are indeterminant. In consumption, prices can be ascertained from the production side (that is, costs), the constraint being the consumers' willingness to pay. Similarly in production, prices can be ascertained by concentrating on the consumption side (that is, willingness to pay), the constraint being total social costs.

In the cases where decreasing costs can arise (for example, where factor inputs are discrete) a two part rule is required. The optimal level of output is ascertained by equating the consumers' willingness to pay for an extra unit with the cost of that unit and price is set accordingly. The investment criterion requires that the consumers' total willingness to pay is greater than or equal to the total cost. Under these circumstances, the pricing rule may lead to an accounting deficit and given a commercial concern directive the investment rule gives no indication of how the total cost may be recovered from consumers. The next chapter will investigate various pricing systems whereby the port may attempt to allocate resources optimally and at the same time meet an accounting requirement.

Notes

[1] Winch, D.M., "Analytical Welfare Economics", Penguin, 1971. See also, Millward, R. "Public Expenditure Economics", McGraw-Hill, London, 1971.

[2] Wiles, P.J.D., "Price, Cost and Output", Blackwell, Oxford, 1961, Ch 7.

[3] Joy, S., "Pricing and Investment in Railway Freight Services", Journal of Transport Economics and Policy, Vol V, No 3, Sept 1971.

[4] Joy, [2] p 240.

[5] Baumol, W.J. et al, "Costs and Rail Charges", in Munby, D. (ed) "Transport", Penguin, 1968.

[6] Munby, D. (ed), "Transport" Penguin, 1968 p 13.

[7] Winch, [1] p 119.

[8] Lewis, W.A., "Fixed Costs" in Munby 6..

[9] Bennathan, E. and Walters, A.A., "Port Pricing and Investment Policy", O.U.P., 1979, pp 70,71.

Let, c_p = port costs per shipload

c = delay costs per shipload

X = throughput (shiploads)

$q(X)$ = queue length (number of shiploads)

$D(X)$ = delays per ship

$K(X)$ = total cost

then

$$K(X) = c_p X + c\, q(X)$$

but $$D(X) = \frac{q(X)}{X}$$

or $$q(X) = X\, D(X)$$

so that,

$$K(X) = c_p X + c\, X D(X)$$

Thus the marginal cost (per shipload) is,

$$\frac{d\,K(X)}{d\,X} = c_p + c\left[X \frac{d\,D(X)}{dX} + D(X)\right]$$

$$= c_p + c\,D(X) + c\,X \frac{d\,D(X)}{d\,X}$$

where c_p = port costs of extra ship

$cD(X)$ = own delay costs

$\frac{dD(X)}{dX}$ = delay per ship induced by increasing the throughput by an extra ship

$c\,X\frac{dD(X)}{dX}$ = additional delay costs caused to all other vessels by the entry of an extra ship

CHAPTER 3

PRICING SYSTEMS

3.1 Introduction

The discussion of alternative pricing systems requires the specification of firstly, the objective of the system and secondly,the criteria which will be used to determine whether one system is "better" or "worse" than any other system.

The objectives outlined in Chapter 1 could be incorporated within a more general objective of maximising community welfare subject to; total revenue equalling total cost; efficient utilization in the short-run; individual traffics paying at least the costs that could be escaped if they were not accepted, and encouragement to invest in "worthwhile" projects. This objective would require that the community indifference curve could, in principle, be ascertained,which in turn requires that a value judgement is made concerning the equity of the distribution of goods before the curves can be generated. Further, if a change in the current pricing system is being considered then this may also mean that the distribution of income changes, with some consumers "gaining" and others "losing". Given that we have no weighting system whereby changes in individual consumer's welfare can be compared it will not be possible to state whether a change in the pricing system would lead to an improvement or deterioration in community welfare.

In the following discussion, it will be assumed that the issue of the distribution of income is properly the concern of government and not seaports. Thus, the current distribution of income can be taken by the port authority as exogenously given. Similarly, in considering changes in a pricing system, the main concern of the port authority will be the allocation of resources and not the associated distributional issues. These assumptions are in keeping with current government policy in the U.K. For example, the 1978 White Paper [1] states that:

> "The Government intends that the nationalised industries will not be forced into deficits by restraints on their prices. When help has to be given to poorer members of the community it will be given primarily through the social security and taxation system and not by subsidising nationalised industry prices."

The approach adopted in the following analysis will be to consider a single consumer (or "n" homogeneous consumers). The criterion adopted for determining whether a pricing system is "better" or "worse" than another will be that "the system under consideration is better than an alternative if its application increases the consumer's welfare" (that is, places the consumer on a higher indifference curve) subject to the above objectives.

The advantage of this approach is that it is directly applicable to cases where there are single users (for example, a single user berth) or where homogeneous (or nearly homogeneous) traffics can be identified.

The disadvantage of the approach is that whilst it can be used to develop a tariff which discriminates intra-consumer (quantity discrimination) it does not lend itself to the analysis of inter-consumer (price) discrimination. In these cases the criteria for considering the relative merits of the proposed pricing system will have to be more qualitative in nature and will be related to the port's objectives.

It will also be convenient in assessing the desirability of alternative pricing systems to choose one system from which the others can be compared. The system chosen will be average cost pricing. Thus any alternative will be considered to be better than average cost pricing if it places the consumer on a higher indifference curve.

The framework for analysing the problem when considering heterogeneous consumers will be the standard partial equilibrium analysis [2]. The analysis in the case of the single or "n" homogeneous consumers will be conducted in both partial equilibrium and commodity space; the analysis in commodity space requiring a preliminary explanation.

The transformation or production possibility curve (PPC) is interpreted as a total cost curve (fig 3.1(b)) and the consumer's price-consumption curve or single price offer curve (SPOC) as a total revenue curve (assuming that the port can only charge a single price (fig 3.1(a)). The vertical axis is labelled money (the numeraire or all other goods) and the horizontal axis, X, the good or service with which the analysis is concerned.

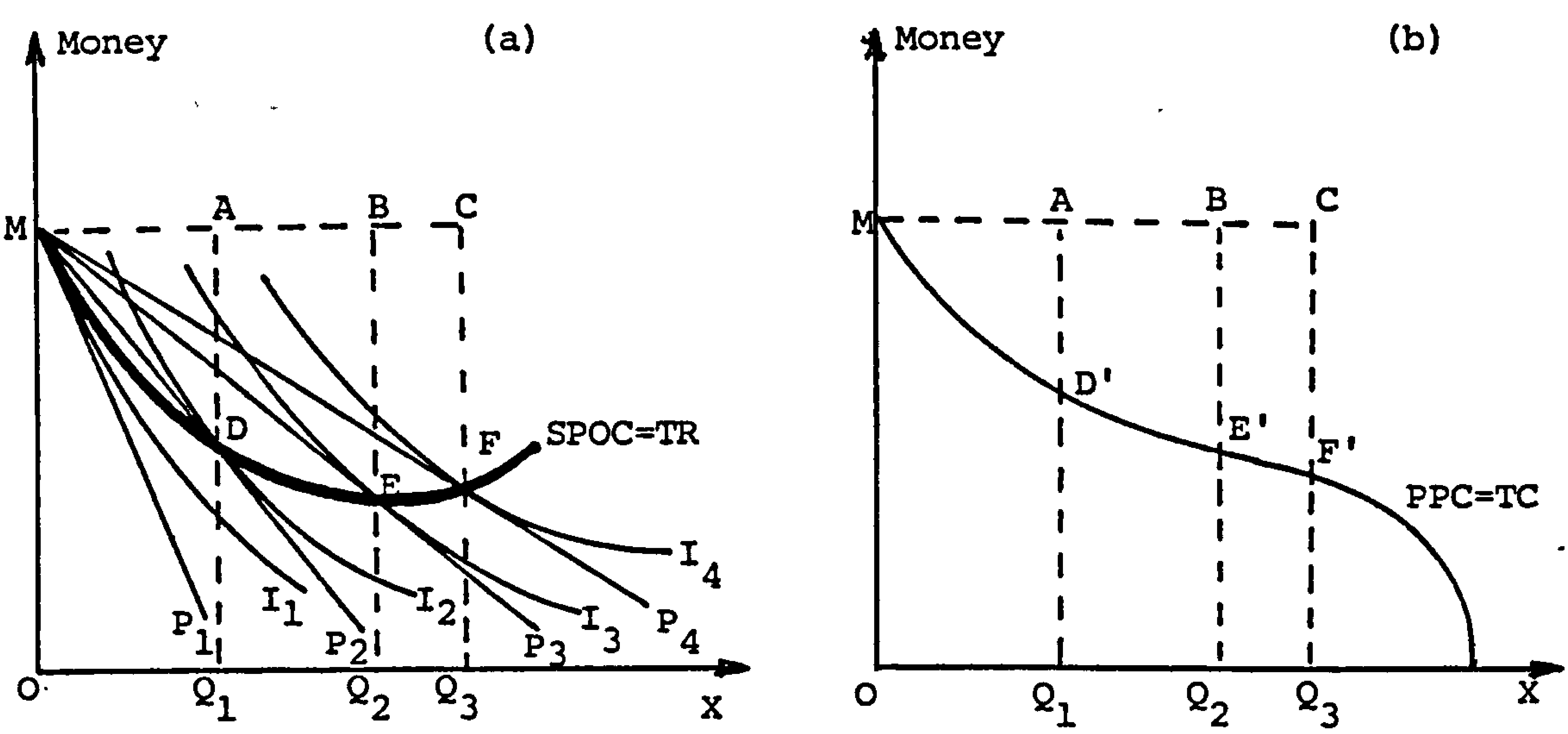


fig. 3.1 The SPOC and PPC curves

Thus, in fig 3.1(a) (where the quantities in (a) correspond to the quantities in (b)) given a single price of P_2 for X, consumers will maximise their utility by consuming OQ_1 units of X, for which they are willing to pay AD units of money. Similarly, BE and CF represent the total amount that they are willing to pay for outputs OQ_2 and OQ_3 given the single prices P_2 and P_3 respectively. Thus to the consumer this represents a total expenditure curve and to the producer, it is a total revenue curve, both being measured downwards from M. In fig. 3.1(b), if OQ_1 is produced then society will have to give up AD' units of money. Similarly, if OQ_2 and OQ_3 units of X are produced then society will have to give up BE' and CF' units of money respectively. Thus, the PPC is also the total cost curve, measured downwards from M.

Three cases, relating to the consumer's willingness to pay for any particular level of output can be distinguished. Given that consumers are free to purchase any quantity at a single price, fig 3.2 shows the offer curves that demonstrate these cases. With $SPOC_2$, there is only

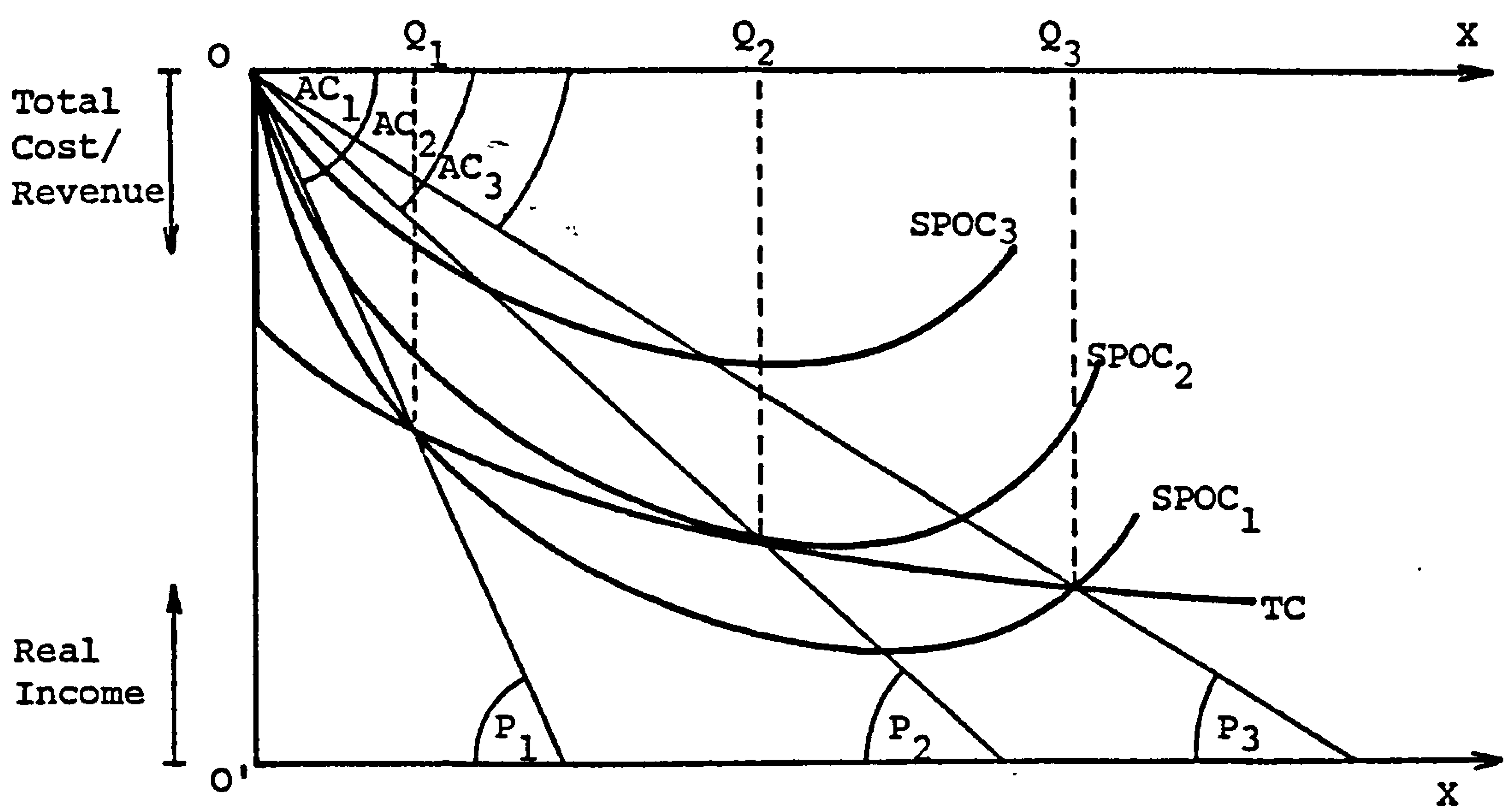


fig 3.2 Single Price Offer Curves and Willingness to Pay

one price (equal to average cost, AC_2) where total cost (TC) equals total revenue (TR), whilst with $SPOC_1$, there is a range of prices between P_1 and P_2 (corresponding to AC_1 and AC_2 respectively) for which an accounting requirement (including an excess profit) is met. However, in the case of $SPOC_3$, there is no single price where TC = TR. The two cases of particular interest are associated with $SPOC_2$ and $SPOC_3$ as most of the conclusions from the analysis of $SPOC_2$ apply to $SPOC_1$.

Thus, the discussion will consider firstly, the case where there exists only one single price where total revenue equals total cost and secondly, the case where there is no single price such that this accounting requirement can be achieved.

3.2 Homogeneous Consumers

Case I - A Single Price such that Total Revenue = Total Cost

3.2.1 Marginal and Average Cost Pricing

A comparison of marginal and average cost pricing under conditions of decreasing costs is shown in fig 3.3. In fig.3.3(a), the SPOC and TC curves are derived as in section 3.1. The single price, p*, at which total cost equals total revenue is found from the average cost at output level Q_1, where the SPOC is tangential to the TC curve (point A). This corresponds to point A' in fig 3.3(b). At this level of output, the marginal cost (slope of the TC curve) is MC_{Q1}. Assuming that the consumers' real income is unaffected by any deficit incurred by the port, the consumer's equilibrium with a price equal to MC_{Q1} is at E (E' in (b)). Thus, by setting price equal to marginal cost the consumers' welfare increases from I_1 to I_2 and excess capacity to the extent of Q_1Q_2 is utilised. Consumers' welfare can be further

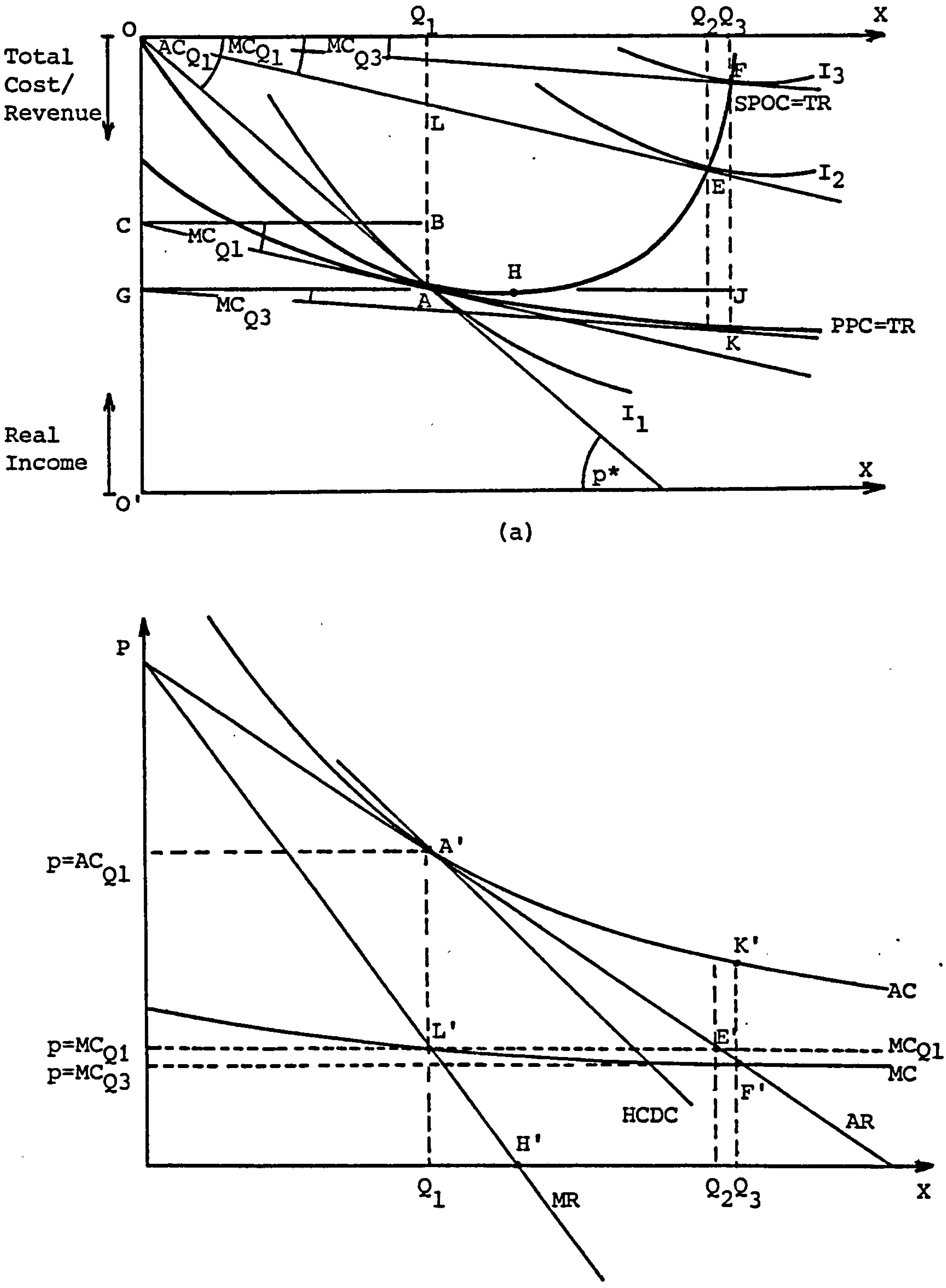


fig 3.3 Marginal and Average Cost Pricing

increased by charging the marginal cost at output Q_2. After further iterations final equilibrium is reached at F (F' in (b)) where MC_{Q3} equals the consumers' MRS and the level of welfare increases to I_3. At an output level Q_1, marginal cost pricing would recover a total revenue equal to AB or Q_1L ($Q_1L' \times Q_1$ in (b)) which would lead to a deficit of Q_1B, LA or OC ($A'L' \times Q_1$ in (b)). Similarly, at the final equilibrium output level Q_3, marginal cost pricing would yield a revenue of Q_3F or KJ ($Q_3F' \times Q_3$ in (b)) and the deficit would be Q_3J, FK or OG ($F'K' \times Q_3$ in (b)).

Thus, whilst welfare is maximised with marginal cost pricing, under the assumptions of this model the requirement that TR = TC is not met. Fig 3.3 indicates however that there is a considerable surplus accruing to consumers [3] and the following pricing systems will attempt to outline methods by which this surplus could be extracted.

3.2.2 Two-part Tariffs

The usual meaning of a two-part tariff is that it consists of one charge which is made irrespective of the quantity consumed and a second charge which is levied per unit of the good or service consumed.

One example of a two-part tariff is where the consumer pays a lump-sum regardless of the quantity of the service consumed, entitling him to pay the marginal cost for the usage of the facilities which he consumes. Fig 3.4 illustrates this example and compares it with average cost pricing. Average cost pricing meets an accounting requirement at output level Q_1, the corresponding point on the TC curve being A. The alternative two-part tariff at this level of output is to charge a lump sum of OY_2 (which effectively reduces the consumers' real income to $O'Y_2$) then the marginal cost at Q_1 for each unit of X consumed. With this system, the consumers' equilibrium is on indifference curve I_3 at point C compared with average cost pricing

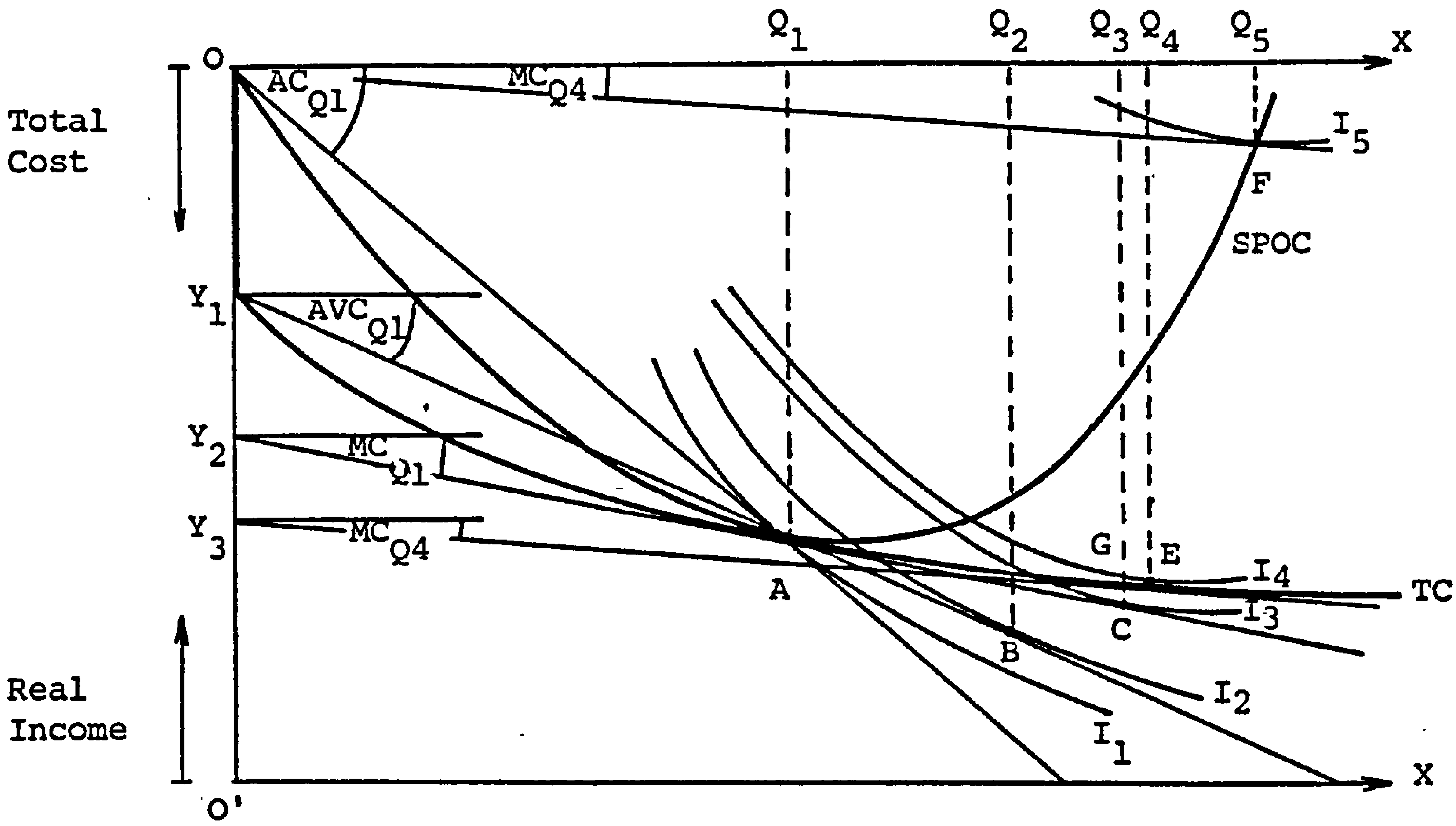


fig 3.4 Two-part Tariffs

where equilibrium is at point A on I_1. Thus this two-part tariff is "better than" average cost pricing as it leads to an increase in welfare from I_1 to I_3, utilizes some excess capacity (to the extent of Q_1Q_3) and implies that total revenue (Q_3C) exceeds total cost (Q_3G). Given that the producer only requires that total revenue equals total cost , the final equilibrium will be at E (on I_4) where marginal benefit is equal to marginal cost (that is, I_4 is tangential to TC or MRS = MRT). For this final equilibrium, a lump sum of OY_3 is charged followed by marginal cost (at output level Q_4) for each unit of X consumed.

A second example of a two-part tariff is based on the accountant's concept of overhead and prime costs. In this case, the consumer is charged a lump-sum equal to the overhead costs (costs which in the short-run do not vary with the level of output) - OY_1, in fig 3.4 - then average variable costs (AVC, or average prime costs) for each unit consumed. Whilst this system is superior to average cost pricing, it is inferior to lump-sum plus marginal cost pricing. Having paid the lump-sum OY_1 and faced with AVC, consumers will maximise their welfare at B where they consume OQ_2 units of X. Thus this system leads to an increase in welfare from I_1 to I_2, utilizes some excess capacity (Q_1Q_2) and also implies that total revenue exceeds total cost. Subject to the constraint that total revenue equals total cost, the final equilibrium will lie between Q_2 and Q_4, at which point MRS $>$ MRT (as is the case with average cost pricing).

The level of output produced under the lump-sum plus marginal cost compared with that under marginal cost only, will depend upon the income effect. In fig 3.4, the income effect is shown to be positive. and thus marginal cost only would lead to a greater output.

3.2.3 Block and Multi-part Tariffs

A further extension of the two-part tariff is to practice intra-consumer discrimination by the introduction of a block or multi-part tariff. This type of tariff discriminates amongst consumers according to the quantity which they consume. In its simplest form, it consists of a price per unit for the first block of output, then a follow-on rate for all subsequent units consumed. In its more complex form, there will be several blocks with price per unit declining as the consumer moves between blocks.

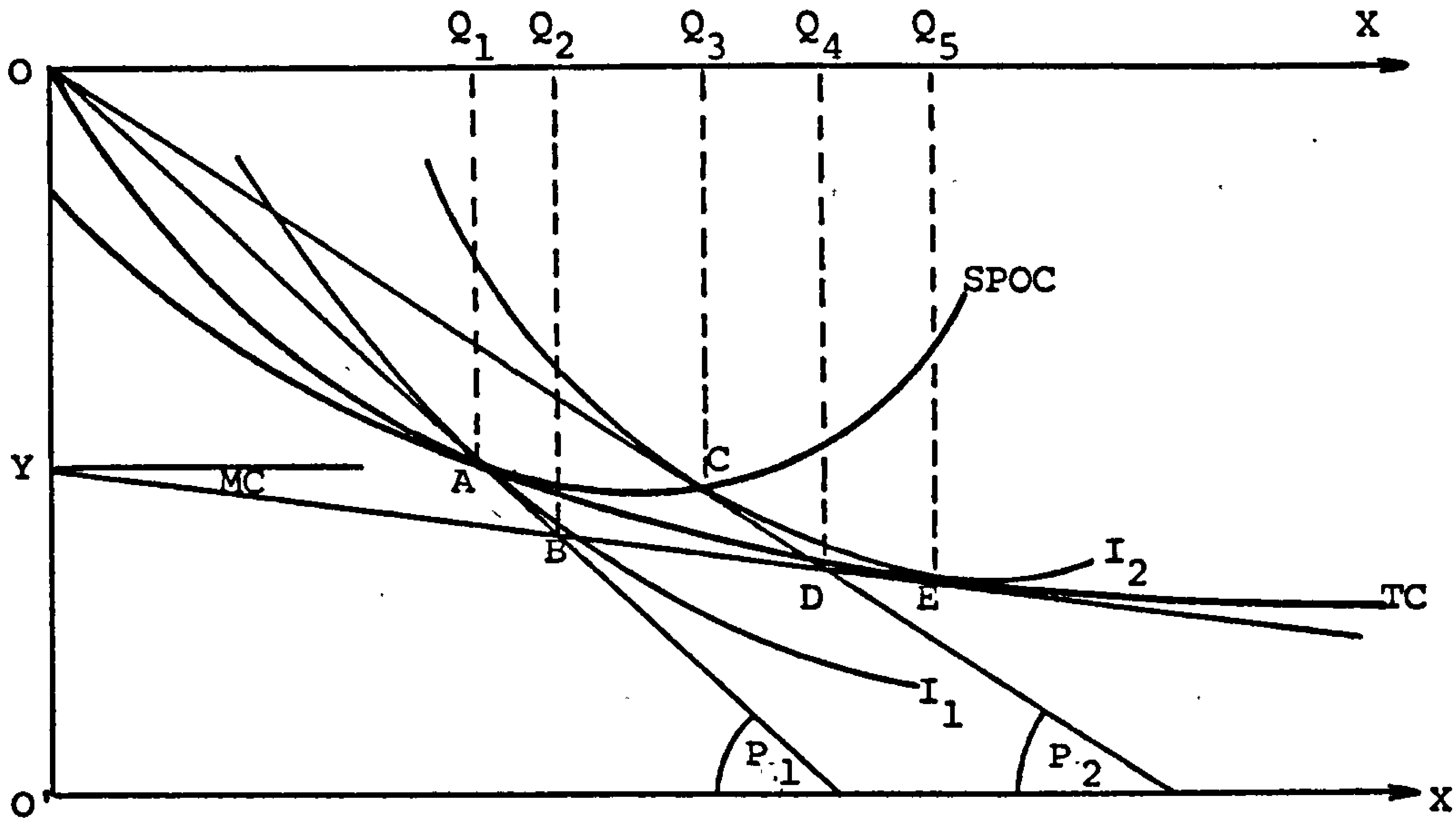


fig 3.5 Limits for a Two Block Tariff given that Total Revenue = Total Cost

There are numerous ways in which such a system can be applied; thus, at present, only the limits of a two-block tariff will be considered.

The lump-sum plus marginal cost two-part tariff represents one extreme of a two-block tariff. In this case, the first block is the first unit, for which the consumer pays the lump-sum. The second block consists of a price per unit equal to marginal cost. Point E in fig 3.5 shows the final equilibrium for this two-part tariff, the corresponding lump-sum being OY and the marginal cost is that at output Q_5.

The other extreme of a two-block tariff is to charge the price equal to p_2 for the first OQ_4 units consumed, then marginal cost (at an output of Q_5) thereafter. Price p_2 is ascertained (in principle) by drawing a price line from O, tangential to the indifference curve I_2 on which E lies. Since the consumer is indifferent between consuming at C or E it is not clear whether he will choose output Q_3 or Q_5. If, however, a price slightly greater than p_2 is charged for a block which is slightly less than Q_4, followed by marginal cost (at an output of Q_5) the consumer will be able to increase his welfare to I_2 by moving to E.

In between these two extremes, numerous two-block tariffs can be devised whereby a price, p, which lies in the range,

$$p_2 < p \leqslant \text{lump-sum}$$

can be charged for the first block with a follow-on price equal to marginal cost. The size of the first block corresponding to that level of output where the price line from O intersects the marginal cost line (YE). For example the port could charge price p_1 (equal to the only price at which TR = TC) for a block equal to OQ_2 units of X, followed by a price equal to marginal cost at output Q_5.

This system can be extended to a multi-part tariff where there are several blocks for which different prices (declining with output) are charged such that price equals marginal cost in the last block. For example,

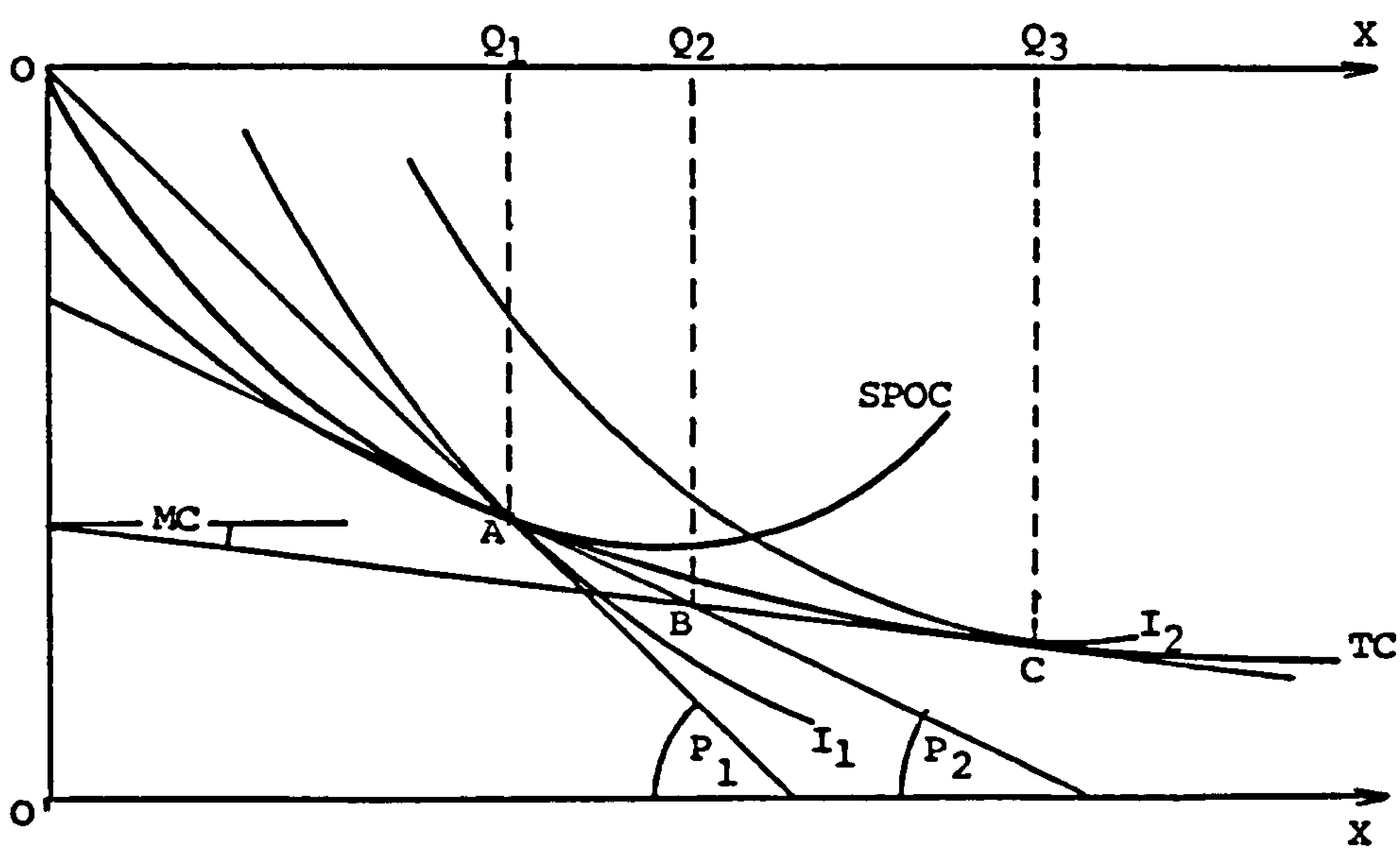


fig 3.6 Multi-part Tariff

fig 3.6 shows a three part tariff where price p_1 is charged for the first OQ_1 units, price p_2 for all units consumed between Q_1 and Q_2 then price equal to marginal cost for all units in excess of Q_2. The consumers' final equilibrium will be at C as movement from A to B to C leads the consumer to successively higher welfare levels. Thus, the multi-part tariff is "better than" average cost pricing as again it leads to an increase in welfare from I_1 to I_2, utilises some excess capacity and meets the accounting requirement that TR = TC.

There are numerous variations on this basic principle. Bennathan and Walters [4], for example, suggest three such systems: Lease-a-Quay (LAQ); Annual fee to enter (AFTE) and Shippers' license to use the port (LUP). At one extreme, with the LAQ system, the port leases a berth or quay to the user at a fixed rental regardless of the traffic volume. Thus, the marginal cost to the user is zero. The system may at the other extreme incorporate a volume related charge. Under the AFTE system the shipowner pays an annual fee, which entitles him to use the port's facilities for a low nominal fee which could approach zero if there is excess capacity. The LUP is similar to AFTE but applicable to shippers who regularly use the port.

Several other versions of the multi-part tariff which may or may not meet the requirement that marginal cost is paid for the last unit consumed are shown in fig 3.7. In fig 3.7(a) a rate α is charged for the first x_1 units consumed, a lower rate (which may be expressed as a percentage reduction on α) for the next $x_2 - x_1$ units and an even lower rate for units in excess of x_2. Whilst such a system may be "worse than" the multi-part tariff in fig 3.6 (marginal cost is not charged for the last unit consumed) it can be designed so that it is

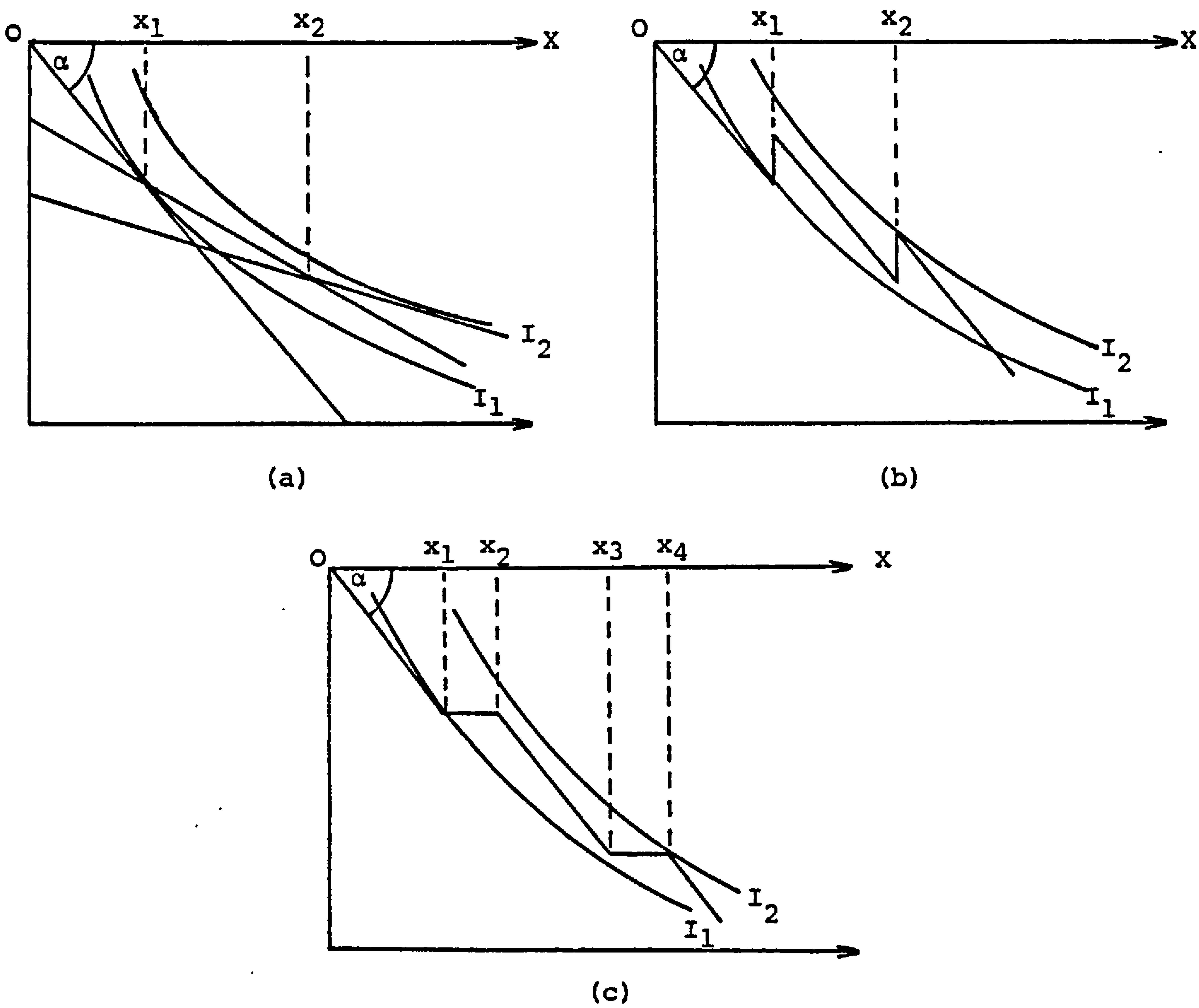


fig 3.7 Versions of the Multi-part Tariff

"better than" average cost pricing. For example, if α in fig 3.7(a) was average cost then consumers' welfare can be increased from I_1 to I_2 and some excess capacity can be utilized by changing to this tariff. In fig 3.7(b), a rate α is charged for all units consumed, with rebates being given once the user has consumed x_1 and x_2 units. If α is average cost, then this system can also improve the consumers' welfare from I_1 to I_2. A further variation on this system is to have the rate declining as the consumer moves between blocks. In fig 3.7(c) a rate α is charged for units in the blocks Ox_1, x_2x_3 and greater than x_4 with "free entries" to the extent of x_1x_2 and x_3x_4 after x_1 and x_3 entries have been made respectively. This tariff can be designed to improve consumers' welfare from I_1 to I_2 and the rate can decrease as the consumer moves between blocks.

Thus, multi-part tariffs can be designed so that they are "better than" average cost pricing but "worse than" the multi-part tariff where marginal cost is being paid for the last unit consumed.

3.3 Homogeneous Consumers

Case II- No Single Price such that Total Revenue = Total Cost

In the case which has been considered above, the accounting requirement that total revenue equals total cost has been achieved by extracting part of the compensating variation. It was further indicated when comparing average cost with a lump-sum plus marginal cost that an additional compensating variation could be extracted from the consumers

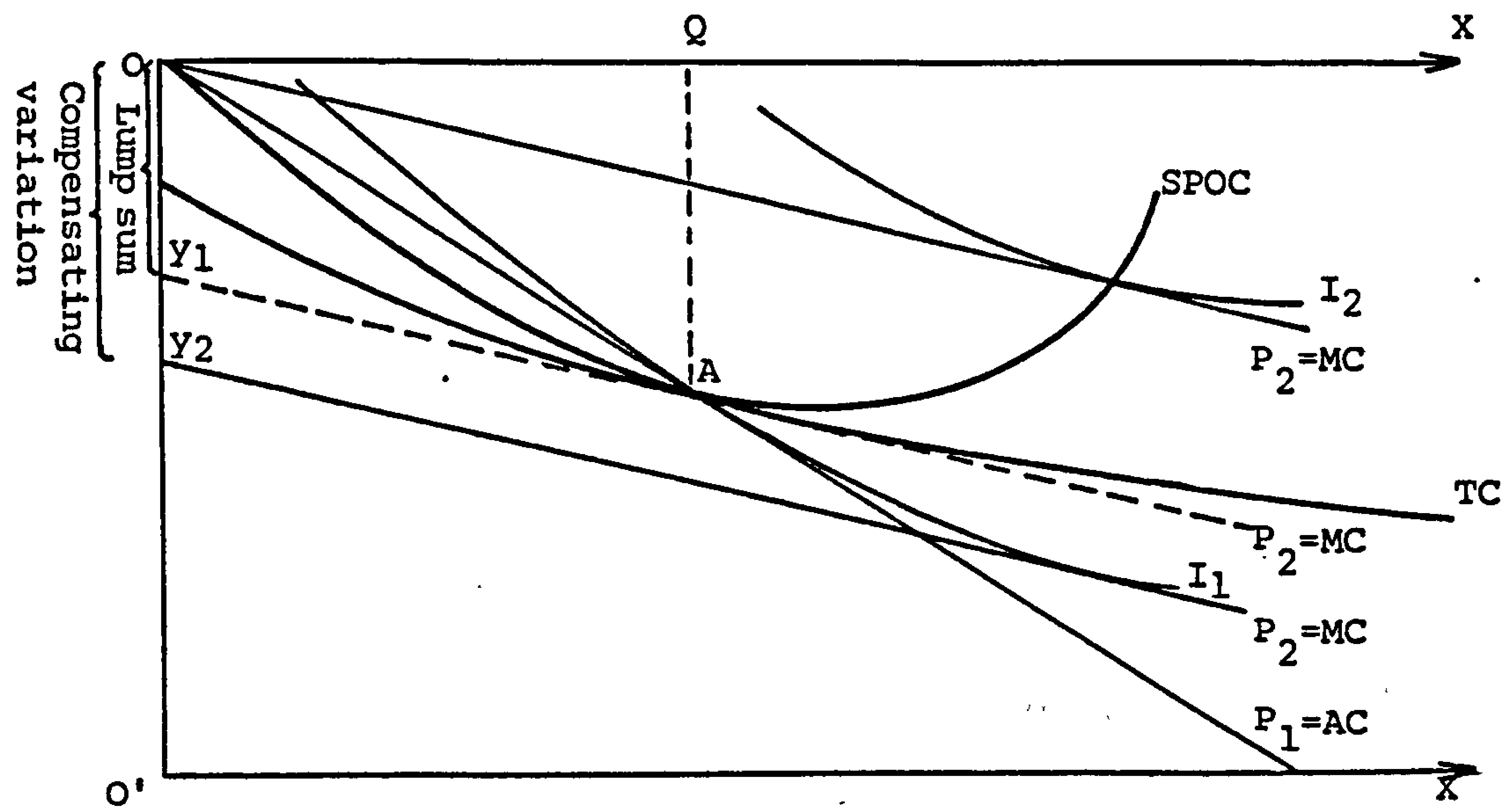


fig 3.8 Extracting compensating variation

(where "compensating variation" is defined as "the amount of compensation paid or received, that will leave the consumer in his initial welfare position following the change in price if he is free to buy any quantity of the commodity at the new price." [5]). Thus, in fig 3.8 the compensating variation, following a price change from P_1 = AC to P_2 = MC, is equal to OY_2, whilst the lump-sum is the lesser amount equal to OY_1.

Thus, the port authority could have charged a lump-sum equal to the compensating variation then marginal cost at A. This would have left the consumer on the same indifference curve as with average cost pricing, some excess capacity will have been utilized and an excess profit will have been made.

The observation that this compensating variation exceeds the lump-sum (from case I) can be employed in an attempt to meet the accounting requirement in the case where there is no single price at which this can be achieved.

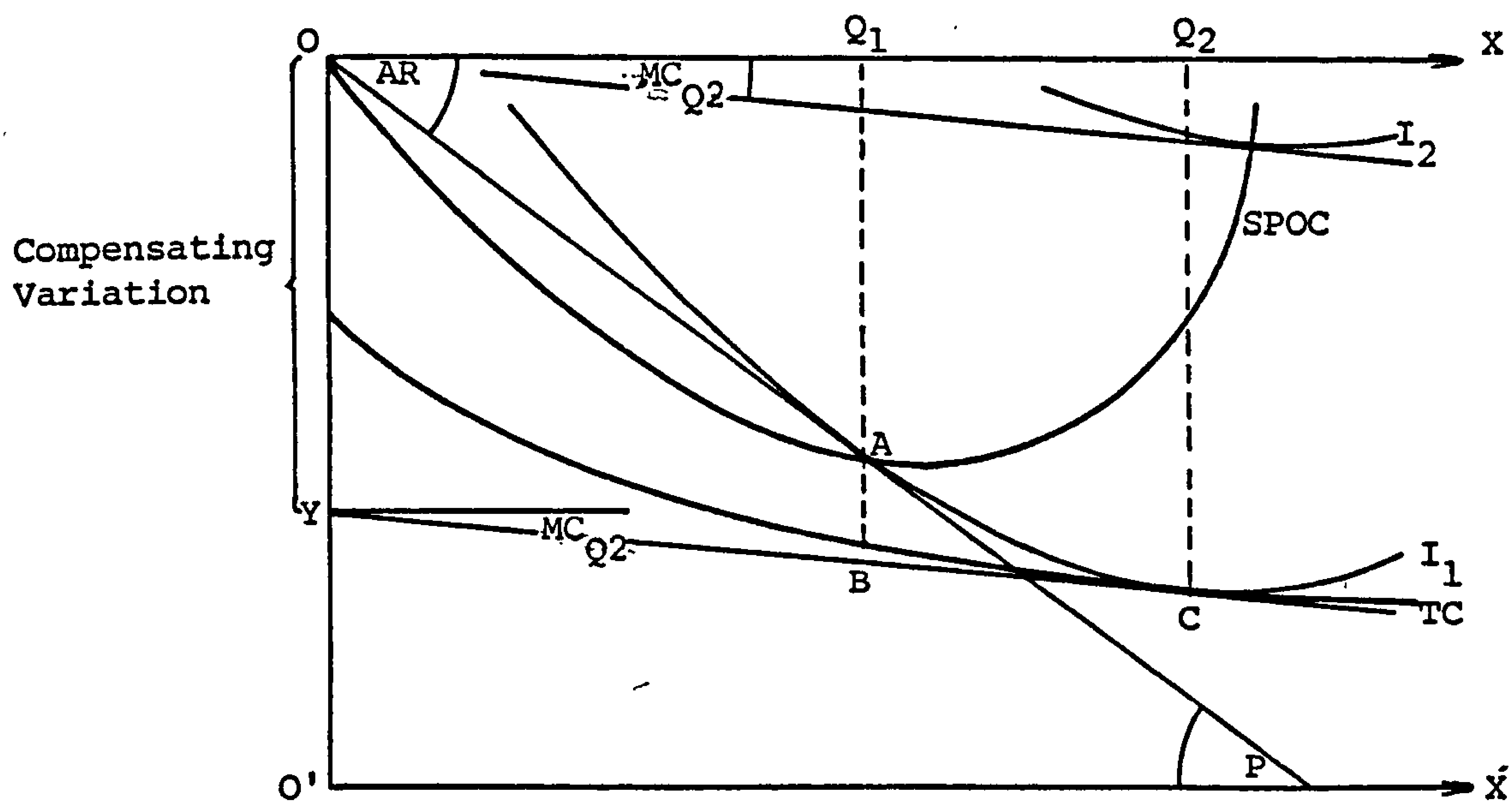


fig 3.9 No Single Price such that TR = TC

In fig 3.9, a price which minimises the producers' total loss, AB, has been chosen as the reference pricing system. Indifference curve I_1 (passing through A) is also (fortuitously) tangential to the total cost curve at C. Thus, in this example, it would be possible for the port to meet an accounting requirement by extracting all of the compensating variation, OY, in the form of a lump-sum payment, then to charge the marginal cost at Q_2 for each unit consumed. Indifference curve I_1 could have fallen below TC, in which case, the port could have extracted a revenue greater than the total cost. Alternatively it may lie above TC, in which case the port would still not meet the accounting requirement, however total revenue would have been greater than it would have been with a single price.

In general the maximum possible amount that the port can extract from the user is found from the indifference curve passing through O. The slope of this curve yielding Gabor's "exploitation possibility (EP) curve" [6] or the Hicksian compensated demand curve [3].

In fig 3.10(a) the relevant indifference curve is I_o. The consumer is faced with an "all or nothing" choice of varying quantities of X or no X. The vertical distance downwards from the OX axis to I_o then represents the absolute maximum amount that consumers are willing to pay. For example, at output level Q* consumers are willing to pay Q*B for X rather than go without it. Thus, in fig 3.10, the port could charge a lump-sum equal to OY then marginal cost or use a block tariff with P_o as the minimum price for a block OQ_1 followed by marginal cost.

Thus, even in the case where there is no single price such that total revenue equals total cost it may be possible by using a two- or multi-

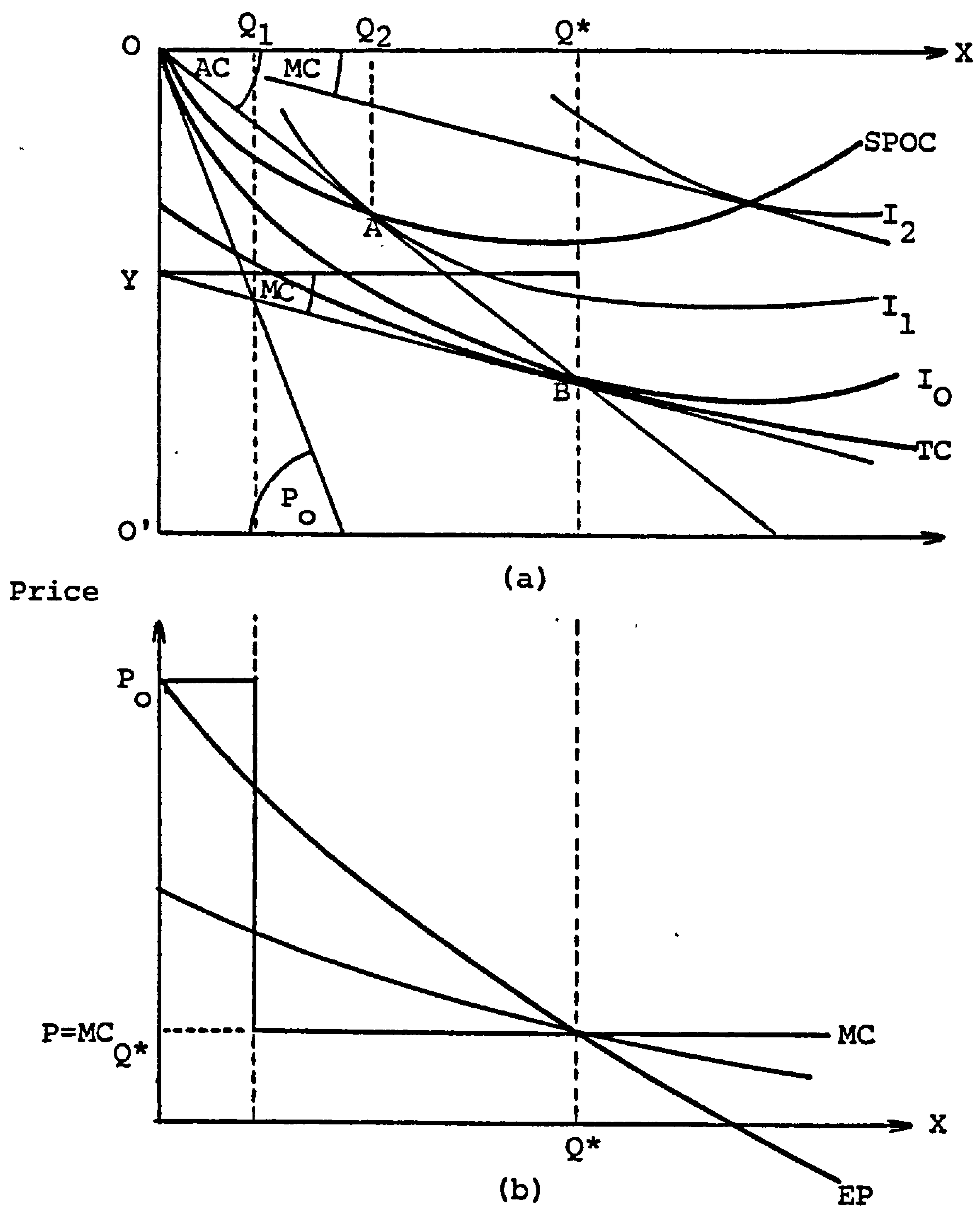


fig 3.10 Exploitation Possibility Curve

part tariff to meet this accounting requirement. Such systems can be designed to be efficient (in the sense that the marginal condition that MRT = MRS is not violated) as long as the consumer pays marginal cost for the last unit consumed. In other words, the consumers' surplus is extracted without violating the marginal conditions.

3.4 Heterogeneous Consumers

3.4.1 Perfect Price Discrimination

The block tariffs which have been discussed above are examples of quantity discrimination. In its limiting case, where the blocks consist of single units this becomes perfect price discrimination which is pareto optimal for a single or "n" homogeneous consumers. In the case where there are a large number of heterogeneous consumers perfect price discrimination is similarly pareto optimal. This can be demonstrated by considering two consumers who constitute total demand (fig 3.11). The total demand curve is simply the horizontal summation

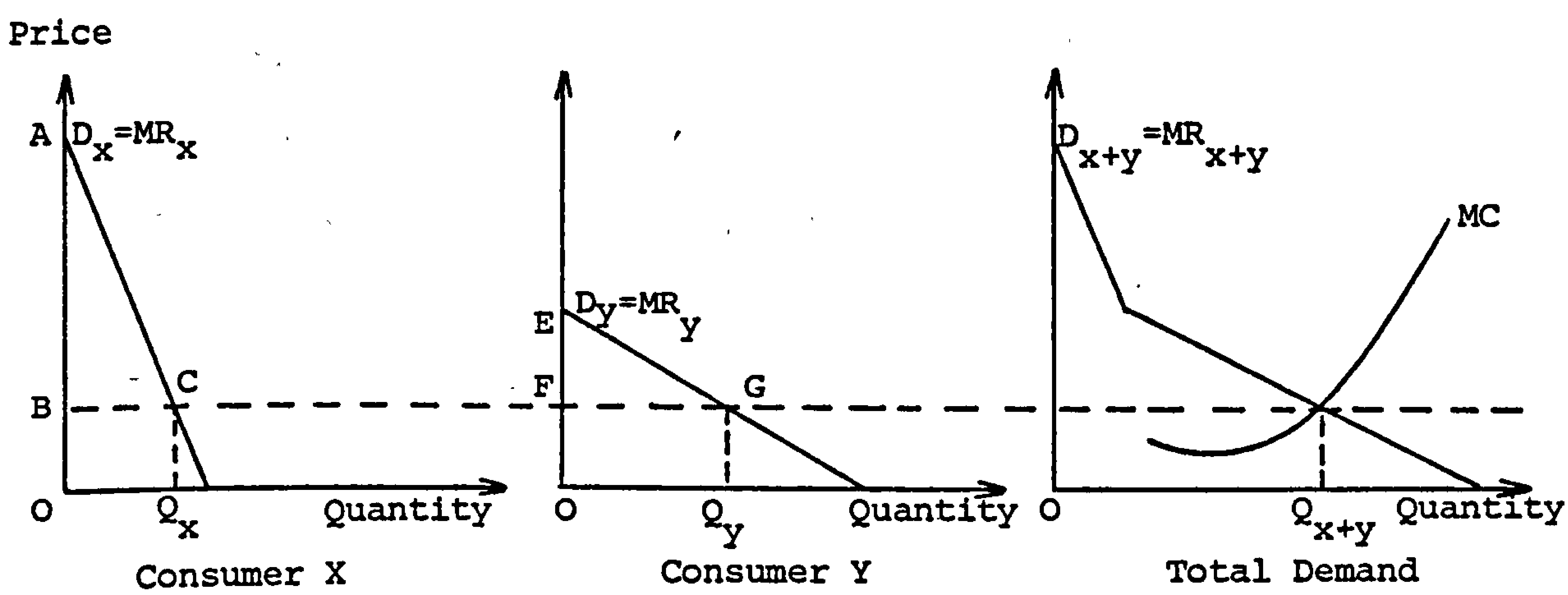


fig 3.11 Perfect Price Discrimination

of the individual demand curves and given perfect price discrimination and no income effects, the demand curves are also the marginal revenue curves. Setting price equal to marginal cost, equal to aggregate marginal revenue (Total Demand Diagram), then for the last unit both X and Y pay marginal cost. The difference however is that X pays OA for the first unit then a price declining to OB (equal to marginal cost) for the Q_x^{th} unit whilst Y pays OE for the first unit then a price declining to OF (also equal to marginal cost) for the Q_y^{th} unit.

In order to apply such a system when there are a large number of heterogeneous consumers involves the problem of ascertaining how much every consumer is willing to pay for each unit that they consume. It is highly improbable that this task could be satisfactorily attempted and thus the port must resort to various proxies for willingness to pay or simplification by grouping consumers into market segments with similar price elasticities of demand. The result is a system of imperfect price discrimination which by its very nature is pareto sub-optimal.

3.4.2 Imperfect Price Discrimination

Price discrimination is usually interpreted as being the act of selling the same commodity, produced under single control, at different prices to different buyers. Three conditions are required for it to take place. Firstly the goods bought on the cheaper market cannot be resold in the dearer market, secondly consumers cannot transfer themselves between markets and thirdly the price elasticities are different in each market. The principle involved can be demonstrated by considering consumer X and consumer Y in the previous example. In

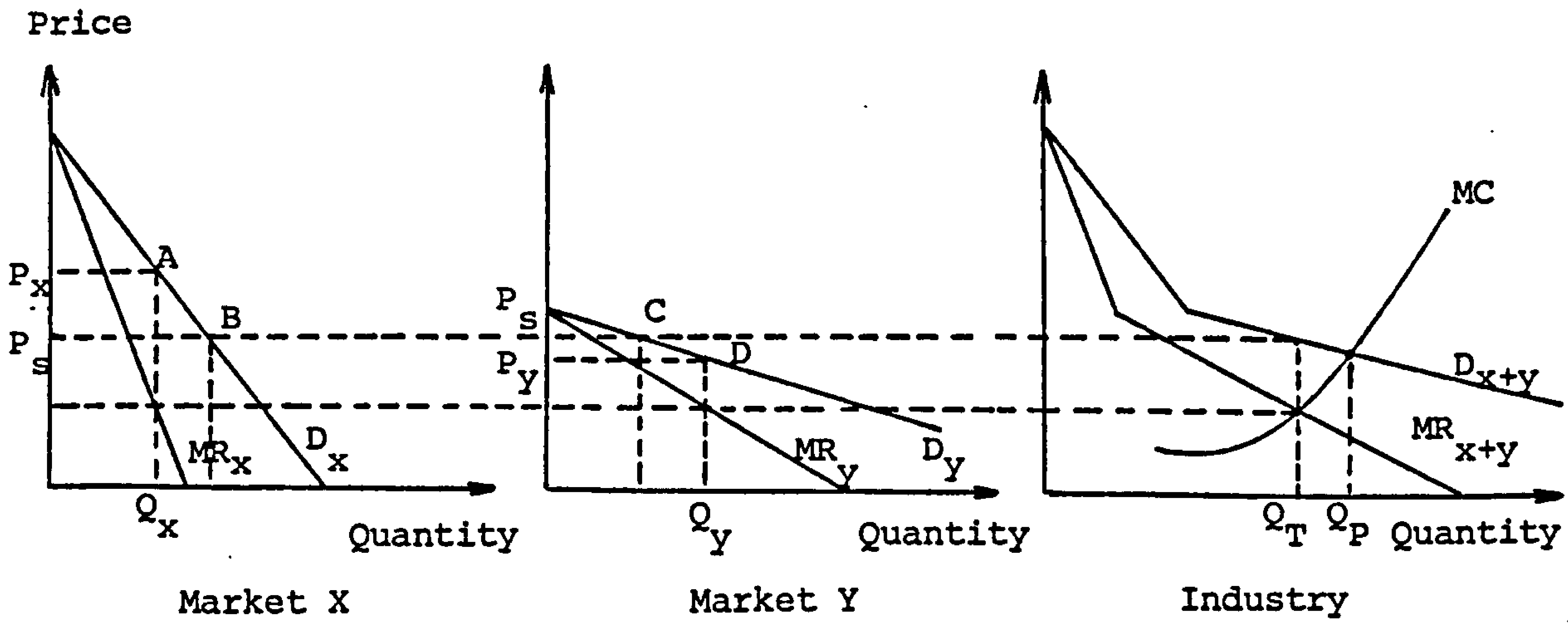


fig 3.12 Imperfect Price Discrimination

this case, price discrimination is not practical inside the sub-market so that the marginal revenue and demand curves do not coincide. The firm will then maximise its profits by producing that total level of output where marginal cost equals aggregate marginal revenue (Q_T), selling Q_x in market X and Q_y in market Y (both determined by the point where respective marginal revenues equal aggregate marginal cost) and charging separate <u>single prices</u> in each market (determined by the elasticities in each market at their respective output levels). As described, this system would lead to the same output as would be produced by the simple monopolist who would charge the same price, equal to P_s, in both markets. However, by redistributing his output from market X to market Y the simple monopolist can increase his total revenue. Since total revenue is equal to the area under the marginal revenue curve up to the output which is being produced the increase in total revenue leads to the marginal revenue curve shifting upwards. Similarly, since total revenue is also equal to average revenue times the output being produced,the demand curve will also shift upwards.

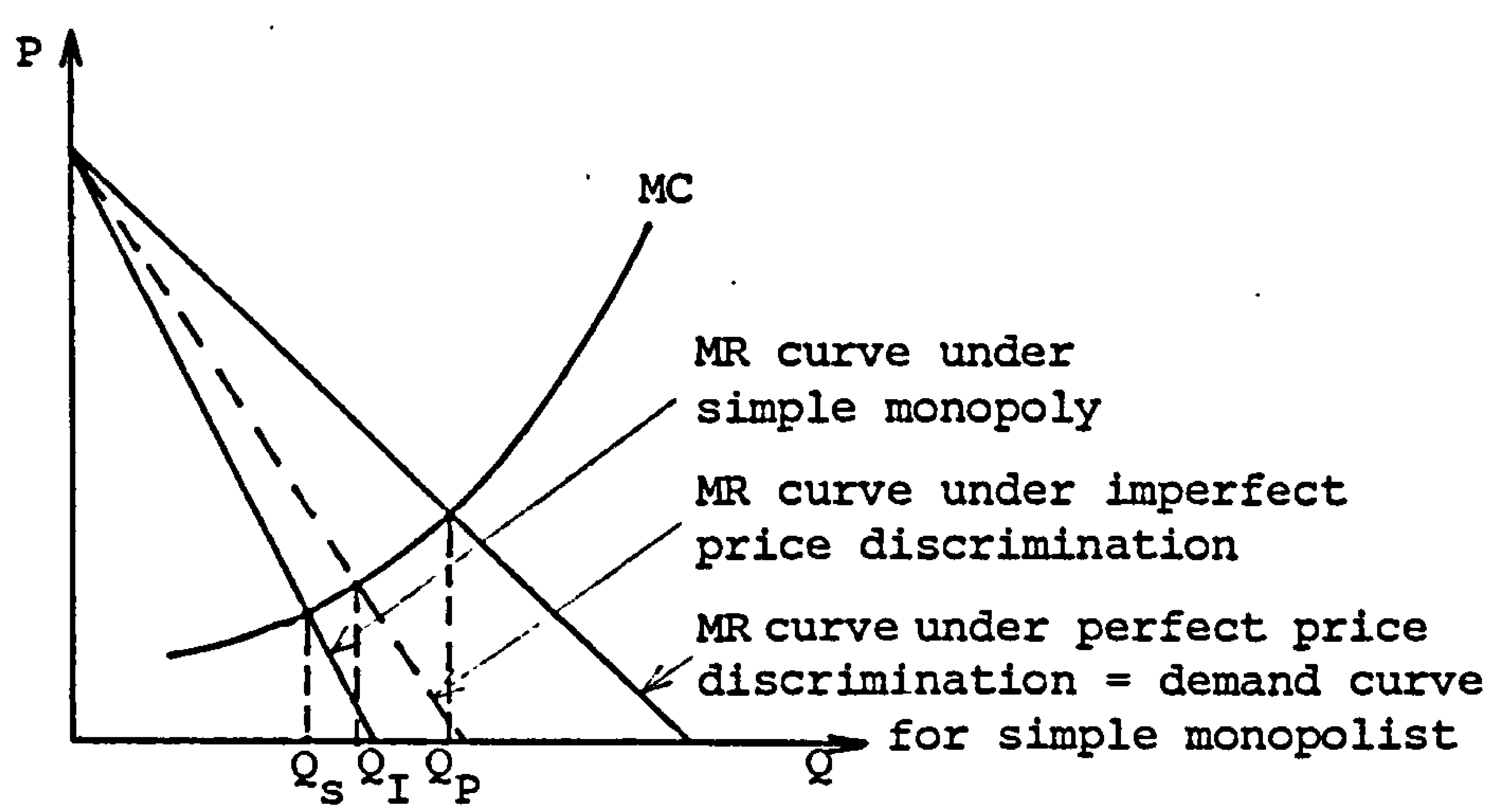


fig 3.13 Price Discrimination

Setting marginal cost equal to marginal revenue, the firm practising imperfect price discrimination will produce more than the simple monopolist. However, it is sub-optimal compared with perfect price discrimination as firstly output is less and secondly those consumers in each sub-market willing to pay marginal cost will not be supplied.

3.4.3 Full-Cost Pricing

There are several versions of full-cost pricing, however the basic principle applied is that:

$$P = AVC + AFC + \text{Profit margin}$$

where: P = price

AVC = average variable cost

AFC = average fixed cost.

Proponents of the model submit three main points in its favour. Firstly, it is argued that demand cannot be estimated with the certainty required by marginalists. Secondly, it is observed that prices are "sticky" in the trade cycle, reflecting the firm's goal of long-run profit maximisation (as distinct from the fluctuating prices which would be the result of the application of the short-run profit maximising objective of the marginalists). Thirdly, empirical evidence suggests that the firm's AVC curve is constant over the relevant output range (and thus coincides with the SRMC curve).

Following Koutsoyiannis [7] it can be demonstrated that full-cost pricing is consistent with marginalism and implicitly involves the estimation of <u>long-run</u> price elasticities [8].

For profit maximisation

$$MC = MR \qquad (1)$$

Given a downward sloping demand curve

$$MR = P\left[1 - \frac{1}{\eta}\right] \qquad (2)$$

given also that

$$MC = AVC \qquad (3)$$

then, substituting (2) and (3) into (1) and rearranging

$$P = AVC\left[\frac{\eta}{\eta - 1}\right] \qquad (4)$$

where: η = <u>long-run</u> price elasticity of demand ($|\eta| > 1$)

Now, the full cost principle is usually applied in the form

$$P = AVC\ (1 + \alpha) \qquad (5)$$

where: α = mark-up to cover fixed costs and profit ($\alpha > 0$)

Thus, from (4) and (5)

$$(1 + \alpha) = \left[\frac{\eta}{\eta - 1}\right] \qquad (6)$$

or

$$\eta = \left[\frac{1 + \alpha}{\alpha}\right] \qquad (7)$$

In other words, if a constant mark-up is used for all consumers, the pricing system is implicitly assuming that the long-run price elasticities of demand are the same for all consumers.

This method of pricing contains a fixed cost element in the price for a marginal unit and is thus inferior to a system based on marginal cost for the last unit consumed.

Whether the system is "better than" average cost pricing is difficult to establish. For example, the cargo handling schedule at Liverpool uses full cost pricing whereby there is a constant mark-up on the AVC's of handling the separate commodities or groups of commodities. Whether this system is "better than" average cost pricing depends upon firstly, the extent to which average fixed costs are related to average variable costs and secondly, the implied elasticity assumptions of the two systems. Fig.3.14 shows a hypothetical mapping of AVC onto the commodity (for example, if commodity B has an average variable cost of AVC_B - and therefore price of $AVC_B(1 + \alpha)$ - then it maps the corresponding points on the vertical axis to B on the horizontal axis).

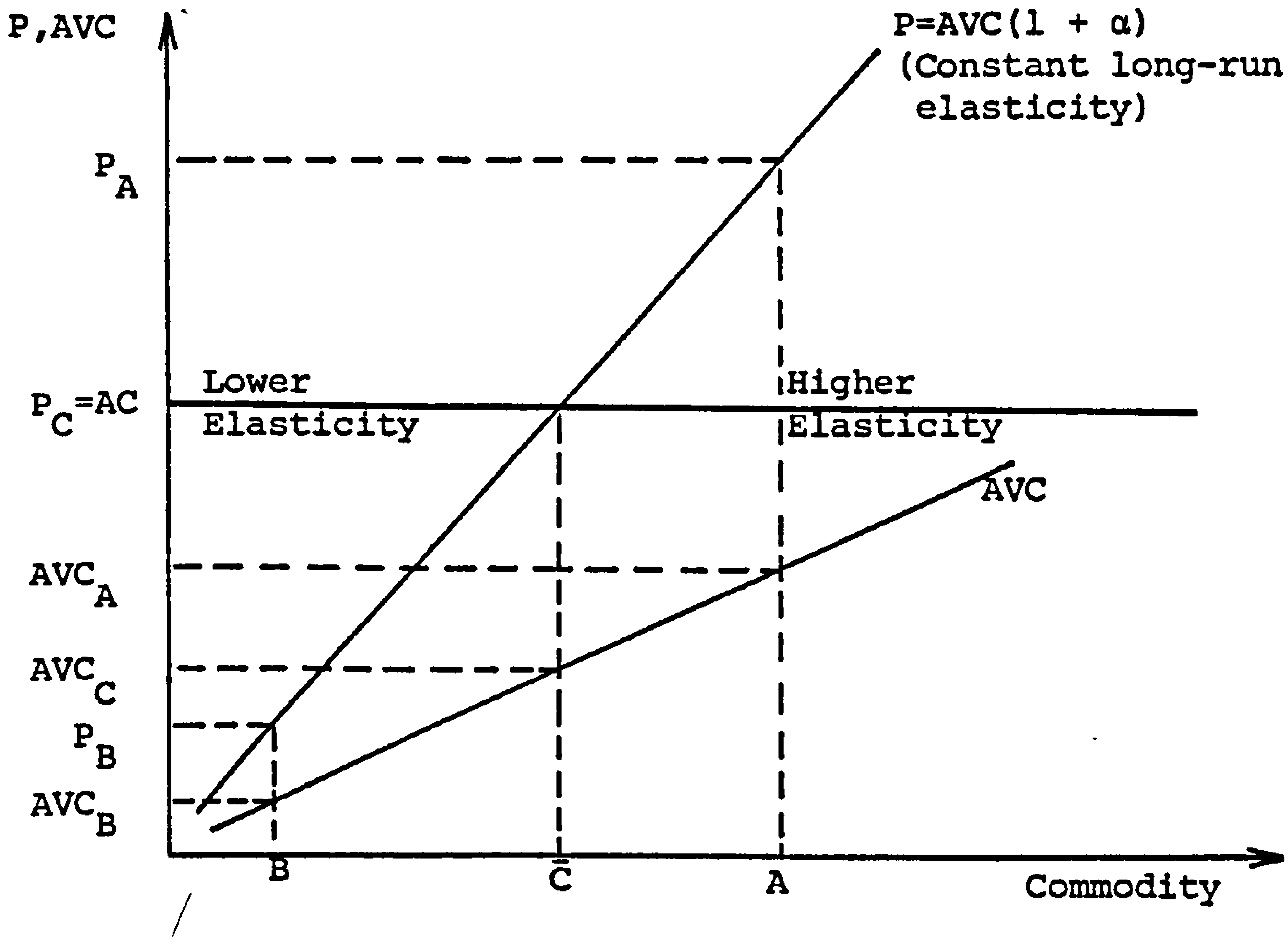


fig 3.14 Average Variable Costs and Commodities

$\bar{C}$ represents that (imaginary) commodity which all prices would map to if average cost pricing was used by the port.

If it could be demonstrated that average fixed costs are directly proportional to average variable costs (in a causal sense) then full cost pricing may be "better than" average cost pricing in the sense that the commodities which impose the higher long-run costs are required to pay these costs. Thus, in fig 3.14, B pays a rate lower than $\bar{C}$ and A pays a higher rate. On the other hand, if the line $P = AVC(1 + \alpha)$ is a constant long-run elasticity curve, then average cost pricing assumes that commodities with a less than average AVC have a greater ability to pay (lower elasticity) than commodities with a greater than average AVC (which conversely have a lesser ability to pay or higher elasticity). Thus, if the fixed costs were joint (where the traffic is required to pay jointly) and AVC was directly related to elasticity then average cost pricing would be less distortionary than full-cost pricing.

3.6 Summary and Conclusions

The objective of this Chapter has been to investigate alternative pricing systems which attempt to recover total cost without distorting the marginal conditions.

The spectrum of traffic demanding port services, according to frequency of service and trade volume, ranges from the regular users (for example, shipping lines, liner conferences, port based industrial users and other charterers) to the one-off user. It has been demonstrated that, in principle, the frequent user can be resolved with some form of block tariff. This type of pricing system can, in the circumstances discussed above, meet the objective by extracting consumers' surplus and simultaneously charging marginal cost for the last unit consumed. The surplus being extracted with either a lump-sum payment or by charging a rate per unit consumed for one or more blocks (with the rate decreasing to marginal cost as the consumer moves between blocks).

In the one-off user case, it is much more difficult to devise a pricing system which meets these objectives. For this case, the three basic systems, average cost, full-cost and price discrimination have been discussed. Whilst it may be possible to design these systems to meet the accounting requirement, they invariably imply that the marginal conditions are not met. Ruggles [9] however suggests that:

> "Demand curves are not smooth and continuous and single valued; they contain many discontinuities, and there are many products for which demand is almost perfectly inelastic within the relvant range. Taking advantage of such discontinuities and inelasticities, the construction of workable systems of price discrimination which will not violate the marginal conditions is quite feasible."

In the port case, the one-off user may have these demand characteristics in the short-run. This could, for example, arise if the port had a spatial monopoly. In the longer-run, however, demand may become more elastic and the marginal conditions may not be met.

One alternative is to adopt short-run marginal cost pricing for these users, so that when excess capacity exists they are charged a low rate and when congestion exists a higher rate. Depending upon the extent of excess capacity, such a system may meet an accounting requirement, however, in the case of Liverpool this is unlikely. If the system was adopted in conjunction with a block tariff for the frequent users, then with excess capacity, these users may prefer to claim that they are one-off users every time they enter the port. Thus, any system which is designed must maintain "equity" between the frequent and one-off users. This could include a system which covers at least the long-run escapable costs of accepting these traffics and which makes some contribution towards the port's joint and fixed costs.

If it can be demonstrated that the one-off user only represents a small proportion of the port's traffic, then, assuming equal weighting of gains and losses, the aggregate distortionary effects of average cost, full cost and price discrimination may be small in relation to the total traffic.

In practice, the implementation of a block tariff may be more difficult than the above analysis suggests. This arises firstly because each frequent user may be shipping different volumes through the port and secondly because many of the costs which the port is attempting to recover may be joint to several traffics. Under these circumstances an "inappropriate" choice of lump-sum or block rates and structure may be considered "inequitable" by port users (Port authorities in Great Britain usually being "prohibited by statute from discriminating between users in like circumstances as far as their principal charges are concerned"-- Rochdale [10]). One interpretation of "inequitable" could be that more surplus is extracted (in relative terms) from some users than others. For example, fig 3.15 shows two consumers with identical preference maps whereby all of consumer I's surplus is removed with LS_I but only part of consumer II's surplus is removed with LS_{II}.

Thus, the block tariff must be seen to be "equitable" in this respect.

Given that the users may be shipping different volumes this may also require that different lump sums or blocks are devised for each user. The alternative is to have a system similar to the United Kingdom light dues where, for example, coastal vessels pay for their first 14 entries and are then exempt from paying for all subsequent entries during the year. Such a system may again appear "inequitable"

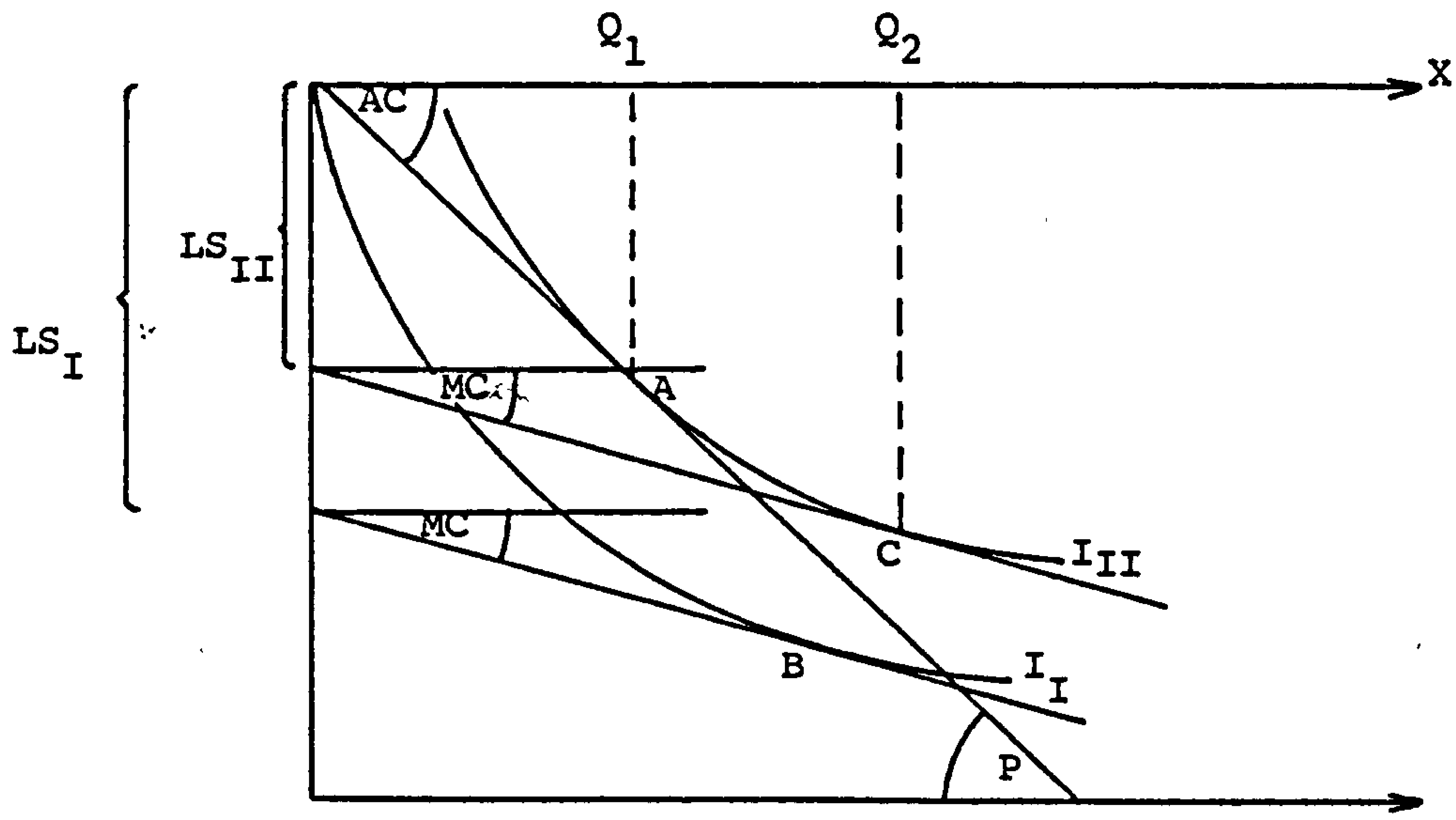


fig 3.15 Consumers with Identical Preference Maps and different Lump-sum Payments

between users if applied to the port case.

The above discussion has considered cost in general terms, however more specifically, it will be the escapable cost which is relevant to the pricing system adopted. Thus, it will be necessary to investigate these costs before considering further development of alternative pricing systems.

Notes

[1] HMSO, "The Nationalised Industries", Cmnd 7131, para 54.

[2] For example, Koutsoyiannis, A., "Modern Microeconomics" Macmillan, 1979.

[3] There are various measures of consumers' surplus including compensating variation, compensating surplus, equivalent variation, equivalent surplus and the Marshallian "extra expenditure" (Currie J.M. et al "The Concept of Economic Surplus and its use in Economic Analysis", Economic Journal, December 1971, pp 741-799.) The measure that will be used in the above analysis is compensating variation. This is defined as "the amount of compensation paid or received, that will leave the consumer in his initial welfare position [that is, on the same indifference curve] following the change in price if he is free to buy any quantity of the commodity at the new price". The main difference between this measure and the Marshallian measure of the area under the ordinary demand curve is that the Marshallian measure assumes constant marginal utility of money and thus constrains the consumer to buy the quantity associated with the new price.

In the figure below, OA represents the consumer's income. At a price greater than or equal to P_o no X is consumed. If price is lowered to P_1 the consumer's new equilibrium will include consuming OD units of X. By considering all such price changes and equilibria, the ordinary demand curve is generated. The Hicksian Compensated Demand Curve is derived by adjusting the consumer's income after each of these price changes so that the consumer remains on I_o. Thus the Hicksian curve shows the slope of I_o at each quantity of X. The amount AB represents the compensating variation (the amount the consumer would

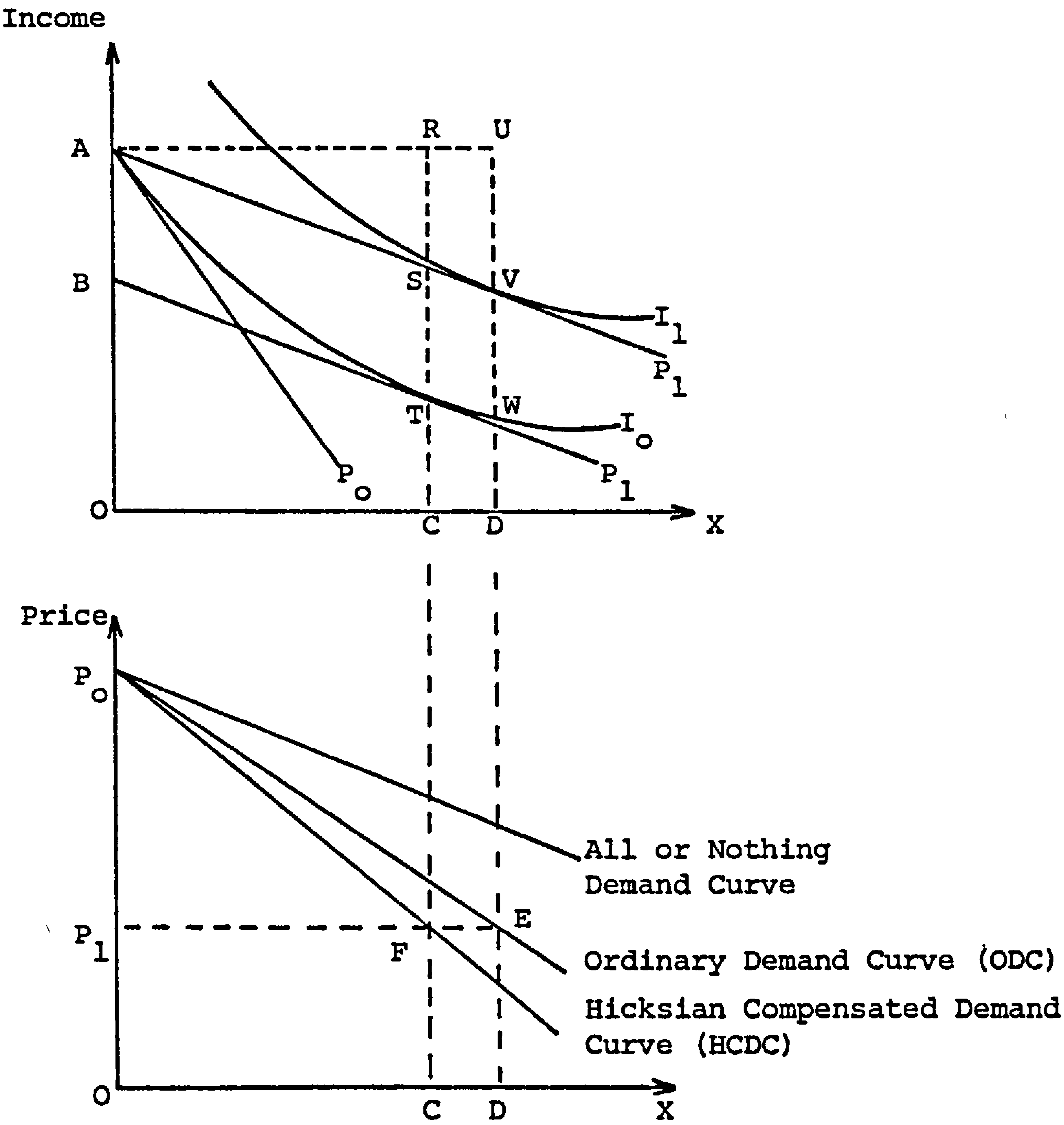


fig 3.16 Demand Curves

have to pay to stay on his initial indifference curve) and measures the welfare effect on the consumer of the price change. An alternative measure is the triangular area P_oP_1F. This arises because the compensated curve is the marginal curve to I_o. The amount the consumer would be willing to pay for OC of X rather than go without it is RT, and RT is equal to the area under the HCDC between O and C, that is OP_oFC. The consumer actually pays RS which is equal to OP_1FC. The difference of ST (= AB or compensating variation) is therefore equal to the area P_oP_1F (that is, $OP_oFC - OP_1FC$).

Thus, the welfare effect of the price change can be measured by AB or the area P_oP_1F under the HCDC.

If one is considering the welfare effect of a change in an existing pricing structure then, if compensation has already been

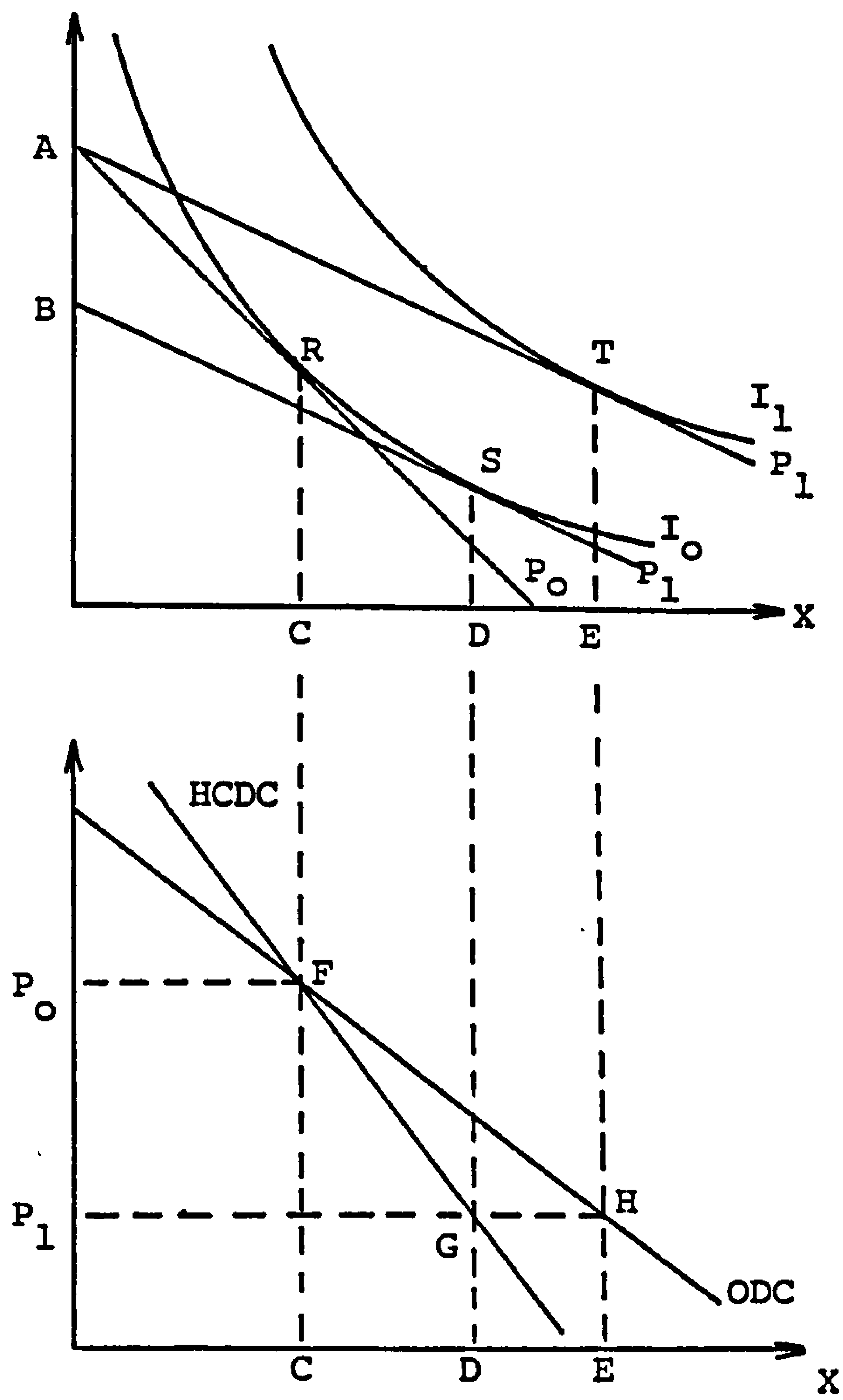


fig 3.17 Compensated Demand Curve

paid then a new HCDC is constructed starting from R and the welfare effect is measured by P_oFGP_1 or AB (in fig 3.17).

[4] Bennathan, E. and Walters, A.A., "Port Pricing and Investment Policy", O.U.P., 1979.

[5] Currie, J.M., [3].

[6] Gabor, A., "A Note on Block Tariffs", Review of Economic Studies, Vol 23, 1955, pp 32-41.

[7] Koutsoyiannis, [2] p 279.

[8] Layard, P.R.G. and Walters, A.A., "Microeconomic Theory", McGraw-Hill, 1978, p 262.
In the short-run, the price elasticity of demand for a factor of production (port services) can be quite low. However in the longer run, substitution can occur (for example, using other ports, making fewer port calls by using larger ships or reducing the number of ports in an itinerary) so that the elasticities will have larger absolute values.

[9] Ruggles, N., "Recent developments in the theory of marginal cost pricing", Review of Economic Studies, Vol 17, (1949-50).

[10] Rochdale, Viscount, "Committee of Inquiry into the Major Ports of Great Britain", Cmnd 1824, HMSO 1967, para 196.

CHAPTER 4

PORT COSTS AND TRAFFIC CHARACTERISTICS

4.1 Introduction

The broad conclusion of the criticisms of the current pricing practices of ports (Chapter 1) was that prices bear "no necessary relationship to either the average or the marginal costs (short or long period)" (Goss [1]). The Chapter also indicated that the relevant measure of cost is escapable cost. Before discussing the measurement of these escapable costs it is necessary to consider firstly the facilities provided by the port and the costs incurred in their provision and secondly the characteristics of the traffic and the costs which they impose on the port. Thus, this chapter will be divided into two parts, part I suggesting possible relationships between facilities and costs,and part II considering traffic characteristics,costs and demand. For the purposes of exposition, the port's services will be divided into the four areas: conservancy, docks and berth, cargo handling and the shore infrastructure and superstructure.

I FACILITIES AND COSTS

4.2 Conservancy

4.2.1 Entrance Channels

(a) Capital: The amount of capital dredging which the port will be required to undertake will be related to any geographical advantage which it may have, some measure of vessel size and a measure of the manoeuvrability of those vessels. The vessel dimension which will be of major importance will be draft. However the vessel's beam, length, manoeuvrability and whether the port will accept both incoming and outgoing vessels at the same time will affect both the width and curvature of the channel.

(b) Maintenance:- The amount of maintenance dredging required will depend upon the "natural depth" of the channel, the rate of siltation, the effects of capital dredging and training walls constructed by the port and any additional siltation created by larger and faster vessels. These factors form part of the very complex relationships which exist in tidal waterways. For example, Price and Kendrick [2] when investigating siltation in the Mersey Estuary stated in 1963 that;

> "It seems likely that the persistence of poor conditions on Bromborough Bar since 1953 might well be due to the excessively high dredging rate.....The M.S.C.C. were advised to consider the possibility of discontinuing, or at least severely limiting, the dredging on Bromborough Bar for an experimental period in order to see whether better conditions return naturally."

In order to ascertain whether dredging costs are related to draft it would be necessary to know a "natural depth" of the channel, the present depth, the rate of siltation and the relationship between the resource cost of dredging and the depth at which this dredging is undertaken. If the rate of siltation is constant and dredging costs are not related to depth, then in the long-run, the cost of "holding" the channel at any depth is joint to all traffic requiring more water than the natural depth. If, on the other hand, the rate of siltation is constant or increasing and cost increases with depth, or the rate of siltation increases with depth and cost increases, then in the long-run maintenance costs will be related to vessel draft.

4.2.2 Training Walls

(a) Capital: Whether training walls are required or not will depend upon the stability of the river bed and the scouring effect which they maintain. To the extent that they maintain the stability of the channel, the costs incurred can be said to be joint to all vessels. If on the other hand, they improve the channel's scouring effect one will have to consider the trade-offs between the cost of the training wall and changes in the level of maintenance dredging required.

(b) Maintenance: Expenditure on the maintenance of a training wall will in all probability be capital in nature and thus subject to a similar treatment. For example when considering the trade-off between maintenance dredging and a training wall, its maintenance over time would also be required to be taken into account.

4.2.3 Surveying and Charting

This will also depend upon the stability of the river bed, that is, if it is stable, then it will not be required to be surveyed very often. The utilization of the river will also be an important factor. If vessels are not using part of the river then surveys need not be as frequent as if it is being used. Similarly if only one particular traffic is using a section of the river, then the cost of surveying with that traffic less the normal surveying without any traffic can be directly allocated to that traffic.

4.2.4 Navigation Aids

The hypothesis submitted in the case of navigational aids is that the benefit gained from them is subject to diminishing returns as the standard supplied increases. Furthermore, the level at which diminishing returns "set-in" varies with traffic type and density.

The benefits of navigational aids will accrue in the first round to both the vessel and the port. Thus it is in the interests of both parties that certain minimum standards are attained.

In general, it is suggested that the standard of navigational aids required by the vessel will depend upon: firstly, the nature of the approach channel - the "more dangerous" the channel, the higher the standard required; secondly, the expected visibility at the port - if, for example, the port is affected by fog, then a higher standard will be required; thirdly, the rate of flow of the tide - the faster the rate, the more difficult it will be to correct a navigational error, and therefore the higher the standard required; fourthly, the size of the channel and the existence of navigable water outside the channel - if the channel is not very wide, and there is a lack of navigable water outside it, then a higher standard will be required; fifthly, the traffic density - the higher the traffic density, the higher the standard required; sixthly, the value of the vessel and cargo - the greater the value of the vessel and/or cargo the higher the absolute cost of loss, thus the standard required will be higher. One may further suggest that a low standard of aids would mean that the vessel will enter port at a slower speed and thus impose a cost of delay which will be higher for the more valuable vessels and cargoes.

On the other hand, the standard required by the port will depend upon: firstly, the consequences of an accident resulting from an insufficient provision of navigational aids, for example, the port being closed by a vessel obstructing the channel, or the pollution risk from a collision or vessel running aground; secondly, the increased berth productivity as a result of a vessel being able to enter the port at all states of the tide and time of day; thirdly the increased attractiveness of the port to shipowners.

In order to ascertain the costs imposed on the port by each traffic, it would be necessary to ascertain the minimum requirements of each traffic. Subjectively, one may state that the standard required by small coasters is lower than that required by VLCCs. In addition, the interaction between vessels would have to be taken into account as traffic density increases.

4.2.5 Contingencies

This service relates to the provision by the port of various facilities for the purposes of salvage; raising, removal or destruction of wrecks; and obstructions and pollution control. The level at which these facilities are required to be provided depends upon: firstly, the potential for the vessel to affect the port as a commercial concern (for example, a vessel sinking in mid-channel effectively closing the port) and secondly, the potential of the vessel to pollute the port.

A priori, one may state that: firstly the equipment necessary to control an oil spill from a coaster would be less than that required for a VLCC; secondly, the salvage equipment for a coaster would be less than that required for a foreign-going general cargo vessel; and thirdly, the facilities required to remove a wrecked coaster would be less than that for a foreign-going general cargo vessel. Thus it would appear to be vessel type and size which are the main determining factors in this case.

4.3 Docks and Berth

4.3.1 Locks

(a) Capital: This is also related to the geographical advantage which the port may have, for example, a port without a large tidal range may not require an enclosed dock system. The lock itself will have the dimensions of length, breadth and sill depth, and the material within which it is constructed. Its method of construction will impart various strengths to it. Thus, the cost of the lock will depend upon the vessel characteristics of draft (depth of sill), beam (width of lock), length (length of lock) and displacement (the strength of the lock walls) as well as any tidal restrictions in the port. Furthermore, the size of the lock will be affected by the number of vessels wishing to gain access to the enclosed dock system.

(b) Maintenance: A general comment which applies to the maintenance of all assets is that it can be required for four main reasons. These include maintenance required due to the passage of time (temporal), use of the asset (usage), accidents (stochastic) and legal requirements (statutory). Temporal and statutory maintenance may be required regardless of whether the asset is used. In addition to being related to traffic volume, usage and stochastic maintenance may be related to vessel size. It could, for example, be hypothesized that it is the vessels with greater displacement that cause more "wear and tear" on a given lock.

4.3.2 Enclosed Dock Wall

Apart from any geographical advantage (or disadvantage) that the port may have,the capital cost of the dock wall will depend upon the capacity and configuration of the docks and quays. The internal figuration of the docks will in turn be affected by the traffic type and size. For example, vessel type may affect the berth layout, and vessel size will influence the manoeuvring area required.

4.3.3 Quay Wall

(a) Capital: The two characteristics of the wall which will need to be taken into account are length and strength. The length of vessel will determine its length, and the displacement of the vessel its strength.

(b) Maintenance: Again, it is argued that it will be the larger vessels with greater displacement which will tend to cause more "wear and tear" at a given berth.

4.3.4 Dock

Dredging and Surveying: Whether or not these services are required will depend upon whether there is siltation in the docks. If there is, then the considerations may be similar to those of maintenance dredging and surveying of the main channel.

4.4 Cargo Handling

4.4.1 Dock Labour

In the longer run, the cost of dock labour will, inter alia, depend upon the volume of traffic passing through the port, the commodity structure and the packaging of the cargo (including the ship). The extent to which different cargoes impose costs on the port being outlined below.

4.4.2 Cranes, Fork-lifts and Other Mobile Equipment

(a) Capital: The main characteristic of this type of equipment is its lifting capacity expressed in tonnes. Thus, it will be the "optimum size" of lift which will determine the capacity of the crane. For example, the optimum lift for pallets may be 1.5 tonnes (that is, two pallets at 750 kg each) whereas for copper it may be 5 tonnes. Thus one could ascertain the minimum level of facility (lifting capacity of the crane) for each commodity and allocate the costs accordingly. The level required would depend upon the stowage factor and method of presentation.

(b) Operating Costs: Costs such as fuel and electricity will depend directly upon the particular traffic.

Maintenance cost considerations will fall into the four categories discussed under lock maintenance.

4.5 Shore Infrastructure and Superstructure

4.5.1 Quay apron, open storage areas, vehicle holding yards and roads within the port

(a) Capital: In general, there will be trade-offs between various factors when considering the surfacing. These include the land area required, the quality of the surfacing and the cargo handled. For break bulk, it will be the commodities with a high load concentration which will impose higher costs. This in turn will depend upon the density of the cargo (loosely defined as the reciprocal of the stowage factor). With container traffic, the quality of the surfacing in the holding area will need to be higher as stacking height increases.

The costs incurred by the port in the provision of the road system will depend upon the properties of the sub-soil, the axle load of the port's vehicles and the vehicles receiving and delivering cargo, and the traffic volume. The port will tend to construct those surfaces for maximum load conditions. However, the relative "damaging effect" would appear to increase as the fourth power of the axle load [3]. Thus some incremental costs may be allocable to specific traffics.

(b) Maintenance: Having designed the surfaces for maximum load conditions, maintenance will tend to be related to time (including weather conditions) and "unforeseen" faults in the subsoil. However traffic volume and axle loading will influence the life of the road system.

4.5.2 Transit Sheds

These are sheds constructed next to the berth so that cargo can be held for a short period of time prior to loading or delivery. Their construction will thus depend upon volume of each commodity, maximum floor loading, stacking height, time in transit and method of stowage in the transit shed (e.g. pallets may require more floor space than cartons in that the pallets will require access avenues).

Maintenance costs will again fall under the four headings of temporal, usage, statutory and stochastic.

4.5.3 Perimeter Fence

This will be required for the general security of vessels and cargo and may be required by the Customs and Excise Authorities.

Thus the level of security provided by the fence will depend upon local social attitudes towards property, the value or hazardous nature of the commodities handled by the port and the standard required by the Authorities.

4.5.4 Quay Lighting

Lighting will be provided for three main purposes - general security, as required under the Factories Act, and for working cargo during the night. Thus this cost will depend upon the value or hazardous nature of the cargo, the time of day at which the cargo is worked, and the statutory requirements.

II TRAFFIC CHARACTERISTICS

4.6 Characteristics of Ships and Goods

The above discussion has suggested that different characteristics of ships and goods could impose identifiable costs on the port. Traffics will also have characteristics which will affect their willingness to pay for the port's services and facilities, in other words, demand characteristics. In most cases, there is no clear line which distinguishes these supply and demand characteristics, however broad distinctions will be attempted.

Considering the port as being a transhipment point, then the major division of traffic is the ship and the goods.

4.6.1 Characteristics of Ships

The main characteristics of ships may be listed as follows:

(i) Physical dimensions:

Length, Beam, Draft, Height, g.r.t., n.r.t., deadweight, displacement.

(ii) Performance characteristics:

Speed.

Engine power (ahead and astern).

(iii) Type of vessel:

Tanker.

Bulk and ore.

Container.

General cargo.

Other specialist vessels.

(iv) Cargo handling equipment:

Derricks,

Cranes.

(v) Loaded state:

Loaded.

Partly loaded.

Light.

In Ballast.

(vi) Voyage length:

Home Trade.

Middle Trade.

Foreign Going.

(vii) Berth of area of destination within the port.

(viii) Time for which the port's facilities are required (particularly when the port is congested).

(ix) Nature of visit:

To lay-up vessel

Bunkering.

Drydocking.

(x) Frequency of service.

(xi) Value of vessel.

(xii) Value of cargo.

(xiii) Commercial characteristics:

Shipowner with single user berth.

Chartered vessel of major importer/exporter.

Ship belonging to a liner conference.

It could be argued that the main cost (supply) determining characteristics of the vessel, particularly in the long-run, are the physical dimensions, performance characteristics, type of vessel, berth of destination, commercial characteristics and the time for which the port's facilities are required (particularly when congestion exists). In the long-run, it will be these characteristics which will determine the level of capacity provided by the port. On the other hand, the port's ability to discriminate amongst consumers will depend upon the price elasticity of demand of the services and facilities which it is providing. The higher the unit value of the cargo, the more easily a charge can be absorbed. Economies of ship size indicate that as size increases, the unit sea transport cost decreases. Thus there may be scope to discriminate on grounds of size and voyage length. The loaded state and nature of visit to the port are both cases where the vessel may have a lesser ability or willingness to pay. The prices of substitutes for a port's services will affect the port's long-run elasticities, as will the elasticity of supply of the commodity shipped in the country of origin. (If the supply in that country is inelastic, then any increase in price will have a minimal effect on quantity demanded).

It may however be the case that specification of a particular berth in the port automatically determines both the supply and demand characteristics of the vessel and cargo. For example, the berth description,- oil jetty that can only handle partly loaded VLCCs - broadly defines all of the characteristics listed above. In general, it is likely that most of these characteristics will be correlated. For example, for any particular vessel type, the physical dimensions will be correlated. Similarly, vessel size will be correlated with voyage length, value of vessel, time for which the port's facilities are required and frequency of service. Thus, whilst it is possible to identify various vessel characteristics, it is difficult to classify them as being solely supply or demand factors.

4.6.2 Characteristics of Goods

The main characteristics of goods may similarly be listed as follows:

(i) Physical Dimensions:

Length, Breadth, Depth, Volume, Weight (Stowage Factor).

(ii) Size of individual units handled:

Cartons, Cases.

Drums, Barrels.

Pallets.

Containers.

Barges.

(iii) Awkwardness of the unit (for example, steel constructional pieces).

(iv) Special properties:

Protection from the weather.

Fragile.

Secure and safe stowage.

Hazardous cargo.

Refrigerated cargo.

Stacking height.

"Dirty" cargoes.

(v) Time for which service is required.

(vi) Unit value.

(vii) Size of consignment.

(viii) Volume of trade flow in commodity.

(ix) Origin/destination of the cargo.

(x) Nature of transit through the port (for example, transhipped cargo).

In building a model of relative prices in Conference Trades, Deakin [4] included the supply-based factors of cargoes which were hazardous, valuable and required refrigerated or cool chamber stowage. The demand-based factors included unit value, size of consignment, magnitude of trade flows in the commodity and "certain qualities of the market or markets supplied in the areas of destination of the service".

In general, it is the first five items which determine the costs incurred (particularly in the longer-run) by the port in providing services and facilities for goods. Weight will affect the surfacing, the type of handling equipment required and the speed of transit through the port. Volume will affect the transit area/volume required and thus the size of the transit shed. The size of the unit (e.g. carton, pallet or container) will affect the method of handling. This in turn will affect the transit area/volume required, since, for example, pallets will require a larger operational area for the machines. However, it may be possible to stack them higher than cartons particularly if pallet racks are used. Cargoes requiring special treatment will ceteris paribus impose higher costs, for example shed storage will be required by cargoes requiring protection from the weather. Similarly, high value, bonded, hazardous and refrigerated cargoes will require special facilities which impose higher costs. The amount of time which the cargo will spend in the port before and after loading will impose an opportunity cost if the port is operating optimally or with congestion and thus will be an important consideration when these conditions exist.

On the demand side, it will be the last five items in the list which are of importance, because they will influence the consumer's ability or willingness to pay. In addition, seasonal fluctuations, charges at other ports, supply elasticities in the market of origin and the size of the consignment are all important demand considerations.

The distinction between the supply and demand characteristics for goods tend to be more clear cut than for ships. There will however be correlations between unit value and special properties of the goods in that, ceteris paribus, the goods with special properties will tend to have higher unit values. Similarly it could be argued that large consignments cost less to handle (supply factor) but that a larger shipper is more important to the port's revenue (demand factor).

4.7 Summary and Conclusions

This chapter has attempted to suggest possible relationships between facilities and costs. In most cases, they only have the status of hypotheses and would need to be investigated further by the port. However, they will be used in order to provide an input in later chapters.

One noticeable feature of the discussion is that the suggested relationships tend to be longer-run in nature. In other words, they were the relationships which the port should have taken into account when considering investment in the asset. The only exception to this feature is the fuel cost of operating some of the port's equipment. In considering traffic characteristics, some additional items could be included in the exceptions. For example, labour may receive payments for handling certain types of commodities or congestion may impose costs on other users. Thus, it would appear that a large proportion of the port's costs are long-run in nature.

Notes

[1] Goss, R.O., "Port Investment", in Munby (ed) "Transport", Penguin 1968.

[2] Price, W.A. and Kendrick, M.P. "Field and Model Investigations into the Reasons for Siltation in the Mersey Estuary", Proc. Instn. Civ. Engrs, vol 24, pp 473-518, April 1963.

[3] Croney, D. "The Design and Performance of Road Pavements", HMSO, 1977. This paper quotes the result of American AASHO Road Test completed in 1962. This test found the number of passages of varying axle loads required to cause the same damage as one passage of a standard axle of 8160 kg (equivalence factor = 1). Regression analysis of these results suggest that,

$$\ln(EF) = -35.81 + 3.97\ln(AL) \qquad (r^2 = 0.999)$$

where EF = equivalence factor (8160 kg = 1)

AL = axle load (kg)

For example, the passage of one vehicle of approximately double the standard axle load is equivalent to 15 passages of the standard axle.

[4] Deakin, B.M. "Shipping Conferences", CUP, 1973.

CHAPTER 5

MEASUREMENT OF ESCAPABLE COSTS - INTRODUCTION

5.1 Introduction

The discussion in previous chapters has indicated that the relevant cost for resource allocation purposes is the escapable cost. In this chapter, a general model for ascertaining these costs will be outlined. The next section investigates the extent to which escapable costs can be obtained from the port's published accounts. The remainder of the chapter will consider the basic methodology for measuring these costs including a discussion of the problems which may arise in the approach, with possible solutions being suggested.

5.2 The Accountant's Approach to the Measurement of Marginal Cost

The two main branches in the accounting profession are financial and cost accounting. The financial (traditional) accountant is concerned with the ex-post recording and presentation of money flows. In performing this function, the financial accountant adopts a number of procedural conventions [1]. These conventions include, inter alia, the ongoing concern and the cost convention. These are particularly important if one is attempting to ascertain the feasibility of extracting marginal costs from financial accounts. The ongoing concern convention imparts into the firm's accounts the assumption that it will continue to exist in the foreseeable future. The implication of this assumption is that the financial accountant does not need to concern himself with the problem of valuation of assets if the scale of the firm's operations were significantly changed. The cost convention adopted by the financial accountant is that the cost of an asset is its historic acquisition cost. Thus in using these conventions, the financial accounts represent an historical record where costs are measured by tradition.

The cost accountant, on the other hand, is concerned with the costs of goods, processes and operations of a firm for the purposes of pricing, budgeting and control of manufacturing methods and factor inputs. One of the tools of the cost accountant is marginal costing and the following discussion of this tool draws upon "A Report on Marginal Costing" published by the Institute of Cost and Works Accountants (I.C.W.A.) [2] .

The definition of marginal cost suggested by I.C.W.A. [2,p 8], is:

> "...the amount at any given volume of output by which aggregate costs are changed if the volume of output is increased or decreased by one unit.
> Note - In this context, a unit may be a single article, a batch of articles, an order, a stage of production capacity, a process or a department. It relates to the change in output in the particular circumstances under consideration."

This definition is not inconsistent with the economist's definition, however, differencesin principle arise when an attempt is made to measure these costs from the data available. This measurement process, viz, marginal costing is defined as [2, p 8]

> "The ascertainment, by differentiating between fixed costs and variable costs, of marginal costs, and of the effect on profit of changes in volume or type of output."

(fixed and variable costs being differentiated according to whether the costs, respectively, are unaffected or vary with changes in the level of output). Thus, it is not clear whether the fundamental distinction between marginal and variable cost is being made at this measurement stage. It becomes even less obvious when an attempt is made to present financial results in accordance with marginal costing [2, pp 49-53]. These accounts are presented in the form:

Total Sales Revenue

less

Marginal (or variable)

cost of goods sold

yields

Gross profit (or contribution)

less

Total fixed overheads

yields

Profit before taxation.

and an accompanying note to the accounts states that:

> "In arriving at the gross profit the marginal cost of sales must be ascertained. This includes a small number of well defined items, such as direct materials, direct labour and sales carriage, which tend to vary with the volume of business and at the same time can be readily identified with the different segments of the undertaking."

In the list of fixed overheads, items such as overtime premiums, consumable stores, electricity and fuel are included. Thus, items which under some circumstances may be fixed, for example direct labour, are considered as being marginal, whilst other items which may be marginal, for example overtime, are considered as being fixed. This observation is recognised in the report and the I.C.W.A. therefore suggests that [2, p 49],

> "For this reason the main use of marginal costing is for ad hoc cost investigations to provide information for particular decisions, in which case the variability of each heading of cost can be assessed in the particular circumstances of the decision to be taken."

From this brief discussion it would appear firstly that the firm's financial accounts are an historical record and that costs are measured by convention. Secondly, that the money flows within a firm are recorded primarily for the financial accountant and that it is these data with which the cost accountant has to work. Thirdly, and partly as a result of the previous point, the distinction between marginal and variable cost is not clear and the time horizon over which costs are considered to be marginal is limited to the shorter end of the spectrum.

Thus, whilst marginal costing represents an attempt to measure marginal costs, the financial accounts of the firm appear to be an inadequate data base for such calculations particularly if one wishes to ask the "what would happen if?" type of question necessary to ascertain marginal costs. Therefore, one is left in the position stated by I.W.C.A. where each case must be considered according to its own particular circumstances.

5.3 The Economist's Approach to the Measurement of Marginal Costs

5.3.1 Escapable Costs

Whilst the economist would agree with the definition of marginal (or incremental) cost submitted by I.C.W.A. he would prefer to use the concepts of opportunity cost and escapability. There are various ways in which the opportunity cost concept can be stated:

(i) The value of the benefit lost, in not employing the factor in its next best use.

(ii) The value to other producers of the resources which are used to produce [the good] [3, p 61].

(iii) The value of the alternative opportunity given up by choosing the action rather than the alternative.

Whilst these statements may convey slightly different facets of opportunity cost, they are simply different ways of defining the same concept.

Lewis [3, p 61] extends the concept to measurement and states that:

> "cost is measured by computing what expenses <u>would</u> be saved if production were curtailed and resources released for use elsewhere."

Additionally, Lewis draws a distinction between fixed costs and opportunity costs, stating that [3, p 61]:

> "The economist's costs are those which can be escaped; fixed costs are those which cannot: escapability is the essence of the distinction."

Thus, from a resource allocation point of view (i.e. the Economist's view) the relevant costs are opportunity costs and these costs are measured by considering the costs which could be escaped (or saved) by not producing a particular output.

Foster [4, pp 330-4] in an Appendix briefly described an "Outline of a Costing System for Railway Charging", whereby one may attempt to measure the cost saving (escapable costs) of discontinuing particular traffic flows and then attribute these costs to specific traffic . In other words he divided the problem into two parts, the first being to ascertain the escapable costs and the second to attribute these costs to specific traffic.

Considering the first part of the problem, the escapable costs can be ascertained by asking the question:

WHICH COSTS WOULD BE ESCAPED IF THE FOLLOWING TRAFFICS WERE NOT ACCEPTED?

An alternative formulation of this question is to ask the two part question,

1. WHAT ARE THE TOTAL COSTS WITH THE TRAFFIC?
2. WHAT ARE THE TOTAL COSTS WITHOUT THE TRAFFIC?

The difference between the answers to 1 and 2 yielding the escapable cost. In principle, this information could be obtained from the port's accountant by asking him to draw up the port's accounts under the hypothetical conditions where the respective traffics were not accepted. The fixed costs (those costs which cannot be escaped) will appear in both the with and without cases and thus will cancel out on subtraction.

For the purposes of exposition, consider a port with four traffics (I, II, III and IV). In this particular case, there are sixteen calculations to be performed (Table 5.1). For example, using the second formulation, the escapable cost of not accepting traffic I and IV (item 8, table 5.1) is equal to the total cost of the port less the total cost without these two traffics.

One point of interpretation arising out of Table 5.1 which requires clarification is EC_O. This escapable cost represents the cost which could be escaped by not rejecting any of the traffic . $TC_{-(O)}$ is similarly interpreted as the total cost of servicing all of the traffic under consideration by the most efficient means (i.e. in a least cost sense). Thus, EC_O is a measure of the port's technical efficiency, taking the value zero when the port is operating efficiently and a

Table 5.1

Calculation of Escapable Costs (EC)

1. $EC_{o} = TC - TC_{-(o)}$

2. $EC_{I} = TC - TC_{-(I)}$

3. $EC_{II} = TC - TC_{-(II)}$

4. $EC_{III} = TC - TC_{-(III)}$

5. $EC_{IV} = TC - TC_{-(IV)}$

6. $EC_{IandII} = TC - TC_{-(IandII)}$

7. $EC_{IandIII} = TC - TC_{-(IandIII)}$

8. $EC_{IandIV} = TC - TC_{-(IandIV)}$

9. $EC_{IIandIII} = TC - TC_{-(IIandIII)}$

10. $EC_{IIandIV} = TC - TC_{-(IIandIV)}$

11. $EC_{IIIandIV} = TC - TC_{-(IIIandIV)}$

12. $EC_{IandIIandIII} = TC - TC_{-(IandIIandIII)}$

13. $EC_{IandIIandIV} = TC - TC_{-(IandIIandIV)}$

14. $EC_{IandIIIandIV} = TC - TC_{-(IandIIIandIV)}$

15. $EC_{IIandIIIandIV} = TC - TC_{-(IIandIIIandIV)}$

16. $EC_{IandIIandIIIandIV} = TC - TC_{-(IandIIandIIIandIV)}$

where TC = Total Cost

EC = Escapable Cost

Negative sign on subscript (e.g. $TC_{-(I)}$) = Total cost without I positive value when it is not (although there may be valid reasons for EC_o being positive, for example, where demand is fluctuating over time).

Given these escapable costs, the second part of the problem is to attribute these costs to the traffic . Examination of Table 5.1 indicates that there is a considerable degree of double counting, for example, $EC_{IandIIandIII}$ includes not only those costs which are truly joint to the three traffics, but also the costs which are truly joint to I and II, I and III, and II and III, the costs which are specific to I, II and III and the costs incurred due to technical inefficiency. This double counting problem can be overcome simply by deducting the escapable costs which can be allocated to other traffics or combinations of traffics. The resulting cost could be called the Joint Escapable Cost (JEC), a more formal definition of the concept being,

> Those costs which can be escaped if two or more traffics are not accepted and which cannot be attributed to any proper subset of these traffics.

Whilst this definition embodies the normal meanings of jointness and escapability as understodd in economics, it is not quite adequate for our case, as it does not include the case of a single traffic where one is required to deduct the costs incurred due to technical inefficiency. Thus it is proposed that Directly Attributable Cost (DAC) is used, its formal definition being,

> Those escapable costs which can be attributed solely to the traffic under consideration and which cannot be attributed to any proper subset of them.

Table 5.2 lists the sixteen calculations necessary in order to determine the DAC's in the four traffic case. Thus, for example, the DAC for traffic I, II and III (item 12, table 5.1) is equal to the EC for these three traffics ($TC - TC_{-(IxIIxIII)}$) less the costs which have already

Table 5.2 Calculation of Directly Attributable Costs (DAC)

1. $DAC_{O} = TC - TC_{-(O)}$

2. $DAC_{I} = TC - TC_{-(I)} - DAC_{O}$

3. $DAC_{II} = TC - TC_{-(II)} - DAC_{O}$

4. $DAC_{III} = TC - TC_{-(III)} - DAC_{O}$

5. $DAC_{IV} = TC - TC_{-(IV)} - DAC_{O}$

6. $DAC_{IxII} = TC - TC_{-(IxII)} - DAC_{I} - DAC_{II} - DAC_{O}$

7. $DAC_{IxIII} = TC - TC_{-(IxIII)} - DAC_{I} - DAC_{III} - DAC_{O}$

8. $DAC_{IxIV} = TC - TC_{-(IxIV)} - DAC_{I} - DAC_{IV} - DAC_{O}$

9. $DAC_{IIxIII} = TC - TC_{-(IIxIII)} - DAC_{II} - DAC_{III} - DAC_{O}$

10. $DAC_{IIxIV} = TC - TC_{-(IIxIV)} - DAC_{II} - DAC_{IV} - DAC_{O}$

11. $DAC_{IIIxIV} = TC - TC_{-(IIIxIV)} - DAC_{III} - DAC_{IV} - DAC_{O}$

12. $DAC_{IxIIxIII} = TC - TC_{-(IxIIxIII)} - DAC_{IxII} - DAC_{IxIII} - DAC_{IIxIII} - DAC_{I} - DAC_{II} - DAC_{III} - DAC_{O}$

13. $DAC_{IxIIxIV} = TC - TC_{-(IxIIxIV)} - DAC_{IxII} - DAC_{IxIV} - DAC_{IIxIV} - DAC_{I} - DAC_{II} - DAC_{IV} - DAC_{O}$

14. $DAC_{IxIIIxIV} = TC - TC_{-(IxIIIxIV)} - DAC_{IxIII} - DAC_{IxIV} - DAC_{IIIxIV} - DAC_{I} - DAC_{III} - DAC_{IV} - DAC_{O}$

15. $DAC_{IIxIIIxIV} = TC - TC_{-(IIxIIIxIV)} - DAC_{IIxIII} - DAC_{IIxIV} - DAC_{IIIxIV} - DAC_{II} - DAC_{III} - DAC_{IV} - DAC_{O}$

16. $DAC_{IxIIxIIIxIV} = TC - TC_{-(IxIIxIIIxIV)}$ - [L.H.S. of items 1-15 above]

been attributed to the three pairs of traffics I and II, I and III, and II and III; the three single traffics I, II and III; and the not rejecting any traffic escapable cost.

Having determined costs in this manner, one can apply the logic that if costs can be escaped (either singly, or jointly) then they can be rationally attributed to the traffic concerned. Further, if the traffics were not willing to pay these attributable costs then there are grounds for not accepting them.

5.3.2 Simplification of the Calculation of Escapable Costs

The previous section outlined the basic principles to be applied in order to compute a measure of marginal cost. In developing these principles various implicit assumptions have been made and several complications of the method have been overlooked. In this section, an attempt will be made to enumerate the main assumptions and complications and to indicate how they may be incorporated into a more general analysis.

In the above example, only four traffics were considered and this required sixteen calculations of Directly Attributable Cost to be undertaken. In general, there are;

$$\sum_{r=0}^{n} {}^{n}C_{r} = 2^{n}$$

where n = number of traffics

$${}^{n}C_{r} = \frac{n!}{r!(n-r)!}$$

calculations required. Thus, the number of calculations necessary to identify the Directly Attributable Costs increase very rapidly as the number of traffic increase.

One way in which this problem could be approached, is to devise simpler and more efficient means for calculating these costs than those indicated in Table 5.2. A brief inspection of this table, suggests that apart from the number of calculations increasing as the number of traffics increase one could easily "lose track" of; which DAC's had been calculated, whether the list was complete and whether the necessary number of DAC's had been deducted from the EC's. Thus a systematic means of listing all of the possible combinations of traffics and the necessary deductions is required.

One means of listing the possible combinations in a systematic manner is as follows;

O I II IxII	Write down the "reject no traffic case", traffic I, traffic II and the combination of traffic IxII.
III IxIII IIxIII IxIIxIII	Write down traffic III. Combined III with all of the traffics above it (excluding O) by running down the list.
IV IxIV IIxIV IxIIxIV IIIxIV IxIIxIV IIxIIIxIV IxIIxIIIxIV	Write down the next traffic i.e. IV. Combine IV with all of the traffics above it (excluding O) by running down the list.

If there is a fifth traffic, then write it down and combine it with all of the traffics above it (excluding 0) on the list.

Listing the calculations in Table 5.2 in this order and rearranging the sixteen equations as a matrix equation further facilitates the total calculation. Table 5.3 shows the result of performing these operations, namely, shifting all of the DAC's to the left hand side of the equations in Table 5.2, rearranging in the order suggested above, defining the right hand sides as escapable costs (see table 5.1) and writing the whole system as a matrix equation. Since the calculation of DAC is the objective of the exercise, it remains to invert the matrix A to obtain the equation,

$$\underline{DAC} = A^{-1}.\underline{EC}$$

(see Table 5.4). Since the matrix A is lower triangular with a recurring pattern the inversion is relatively straightforward. Alternatively the equation,

$$A.\underline{DAC} = \underline{EC}$$

can be solved by forward substitution. A further method of obtaining the equation,

$$\underline{DAC} = A^{-1}.\underline{EC}$$

is to derive the A^{-1} matrix directly from Table 5.2 supplemented by the escapable costs from Table 5.1 by substituting the relevant escapable costs for the directly attributable costs in the right hand sides of the equations in Table 5.2.

Inspection of Table 5.4 indicates that the matrix can be partitioned into 4x4 matrices of the form,

Table 5.3 Rearrangement of Table 5.2 in Matrix Form A.<u>DAC</u> = <u>EC</u>

	O	I	II	IxII	III	IxIII	IIxIII	IxIIxIII	IV	IxIV	IIxIV	IxIIxIV	IIIxIV	IxIIxIV	IIxIIIxIV	IxIIxIIIxIV	DAC		EC
O	1																DAC_{O}		EC_{O}
I	1	1															DAC_{I}		EC_{I}
II	1		1														DAC_{II}		EC_{II}
IxII	1	1	1	1													DAC_{IxII}		EC_{IxII}
III	1				1												DAC_{III}		EC_{II}
IxIII	1	1			1	1											DAC_{IxIII}		EC_{IxIII}
IIxIII	1		1		1		1										DAC_{IIxIII}		EC_{IIxIII}
IxIIxIII	1	1	1	1	1	1	1	1									$DAC_{IxIIxIII}$	=	$EC_{IxIIxIII}$
IV	1								1								DAC_{IV}		EC_{IV}
IxIV	1	1							1	1							DAC_{IxIV}		EC_{IxIV}
IIxIV	1		1						1		1						DAC_{IIxIV}		EC_{IIxIV}
IxIIxIV	1	1	1	1					1	1	1	1					$DAC_{IxIIxIV}$		$EC_{IxIIxIV}$
IIIxIV	1				1				1				1				DAC_{IIIxIV}		EC_{IIIxIV}
IxIIxIV	1	1			1	1			1	1			1	1			$DAC_{IxIIxIV}$		$EC_{IxIIxIV}$
IIxIIIxIV	1		1		1		1		1		1		1		1		$DAC_{IIxIIIxIV}$		$EC_{IIxIIIxIV}$
IxIIxIIIxIV	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	$DAC_{IxIIxIIIxIV}$		$EC_{IxIIxIIIxIV}$

Table 5.4 Rearrangement of Table 5.2 in Matrix Form $A^{-1} \cdot \underline{EC} = \underline{DAC}$

	O	I	II	IxII	III	IxIII	IIxIII	IxIIxIII	IV	IxIV	IIxIV	IxIIxIV	IIIxIV	IxIIxIV	IIxIIIxIV	IxIIxIIIxIV	EC		DAC
O	1																EC_{O}		DAC_{O}
I	-1	1															EC_{I}		DAC_{I}
II	-1		1														EC_{II}		DAC_{II}
IxII	1	-1	-1	1													EC_{IxII}		DAC_{IxII}
III	-1				1												EC_{III}		DAC_{III}
IxIII	1	-1			-1	1											EC_{IxIII}		DAC_{IxIII}
IIxIII	1		-1		-1		1										EC_{IIxIII}		DAC_{IIxIII}
IxIIxIII	-1	1	1	-1	1	-1	-1	1									$EC_{IxIIxIII}$	=	$DAC_{IxIIxIII}$
IV	-1								1								EC_{IV}		DAC_{IV}
IxIV	1	-1							-1	1							EC_{IxIV}		DAC_{IxIV}
IIxIV	1		-1						-1		1						EC_{IIxIV}		DAC_{IIxIV}
IxIIxIV	-1	1	1	-1					1	-1	-1	1					$EC_{IxIIxIV}$		$DAC_{IxIIxIV}$
IIIxIV	1				-1				-1				1				EC_{IIIxIV}		DAC_{IIIxIV}
IxIIxIV	-1	1			1	-1			1	-1			-1	1			$EC_{IxIIxIV}$		$DAC_{IxIIxIV}$
IIxIIIxIV	-1		1		1		-1		1		-1		-1		1		$EC_{IIxIIIxIV}$		$DAC_{IIxIIIxIV}$
IxIIxIIIxIV	1	-1	-1	1	-1	1	1	-1	-1	1	1	-1	1	-1	-1	1	$EC_{IxIIxIIIxIV}$		$DAC_{IxIIxIIIxIV}$

$$\begin{bmatrix} P & 0 & 0 & 0 \\ -P & P & 0 & 0 \\ -P & 0 & P & 0 \\ P & -P & -P & P \end{bmatrix} \quad \text{where} \quad P = \begin{bmatrix} 1 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

Given this simple structure a matrix of any required size can be generated as follows. For the five traffic case, the matrix will be $2^5 x 2^5$. Partition this array into four 16x16 matrices. The top left, bottom left and bottom right matrix are duplicates of the 16x16 case and the top right is the 16x16 zero matrix. For the n traffic case, the matrix will be $2^n x 2^n$. Partition this array into four $2^{n-1} x 2^{n-1}$ matrices. The top left, bottom left and bottom right are duplicates of the $2^{n-1} x 2^{n-1}$ case and the top right is the $2^{n-1} x 2^{n-1}$ zero matrix.

Whilst this may appear to represent a considerable amount of work, it is a task which can be performed by a computer, leaving the port to ascertain the vector of escapable costs.

In the event, the calculation of directly attributable costs can be further reduced to a conceptually easier task of ascertaining total costs without specified traffics. Reference to Table 5.1 shows that, in vector form,

$$\underline{EC} = \underline{TC} - \underline{TC}^*$$

where $\underline{TC}^*$ = vector of total costs without the specified traffics.

Thus,

$$\begin{aligned} \underline{DAC} &= A^{-1}.(\underline{TC} - \underline{TC}^*) \\ &= A^{-1}.\underline{TC} - A^{-1}.\underline{TC}^* \quad . \end{aligned}$$

Now, since firstly, TC is the same for every traffic and secondly, the row sum of all but the first row in A^{-1} is zero, $A^{-1}.\underline{TC}$ is a vector with the scalar TC as its first element followed by zeros. Thus, for all but DAC_o the directly attributable costs are found from $-A^{-1}.\underline{TC}^*$.

Thus, in principle, the problem at hand breaks down into one of considering what the total costs of the port would be according to whether various traffics are not accepted.

5.3.3 Reduction in the Number of Calculations

In principle, there exists an optimum number of traffics to identify. This optimum represents a trade-off between the costs and benefits of undertaking the calculations. The benefits are not only the cost savings to society of reducing the misallocation of resources. It may, for example, assist the port in marketing a schedule if they can demonstrate that the schedule is cost based.

In practice it may be difficult to ascertain this optimum number as, in particular, it may be necessary to undertake all of the calculations in order to ascertain the benefits. However, by selective choice of traffics and subsets of traffics it may be possible to reduce the number of calculations to a level well below that suggested by the formula in 5.3.2. Foster [4], for example, considered, in principle, six traffics (coal and general merchandise on three routes). This would imply that the directly attributable costs of 64 traffics are required to be calculated. Reduction in this number of calculations was acheived by considering the three traffics separately (total of eight calculations) and then considering coal and general merchandise as subsets. Thus the number of calculations was reduced from 64 to 22 [5].

A further reduction to 10 calculations is possible if coal is carried on only one route (8 combinations of three traffics plus the two subsets of coal and merchandise on one of the routes). However, as this example demonstrates, the extent to which it is possible to reduce the number of calculations depends upon the circumstances of the case. Thus this exercise will be considered further when dealing with specific cases.

5.4 Escapable, Opportunity and Conventional Costs

The essence of the methodology developed in the previous section is that escapable cost can be measured by deducting total costs without the traffic from total costs with the traffic. This outline has not however examined the full implications of not accepting a particular traffic.

In some cases, this may simply mean that a factor input is not purchased by the port and thus its cost is saved. In other cases, the port may own the asset and thus instead of letting it lay idle, they could find alternative employment for it. Assuming that this alternative employment earns the port a net revenue, then the total cost without the original traffic is effectively reduced by the extent of this revenue.

Interpreted in this manner, the escapable costs correspond to the opportunity costs. If a temporal dimension is introduced then the definition of opportunity cost becomes,

> "the present value of the benefit lost (to society) of not employing the factors in their next best alternative use.

In some cases, opportunity cost agrees with cost as conventionally understood, however in a number of cases it differs markedly.

The cases where opportunity cost most closely agrees with cost as conventionally interpreted are firstly, where there are inputs which are used up simultaneously with the production process (e.g. fuel) and secondly at the point in time immediately before the inputs of goods and services are purchased and contracts signed (that is, the ex-ante case). The reason for this is that by purchasing the inputs or entering into a contractual agreement, the producer pays, or commits himself to paying say £x for the input. Now, there are a number of ways in which this £x can be interpreted. Under conditions of perfect competition, price represents society's evaluation of the good in its next best alternative. Thus, the £x represents the value to other producers of the inputs under consideration. Alternatively, it could be argued that in purchasing the input for £x, the port forgoes a claim of £x over any alternative uses towards which the £x could be put. Thus, in the ex-ante case, market or contracted price (i.e. the conventional measure of cost) corresponds to opportunity cost, provided that perfect competition exists.

The case where opportunity cost and cost as conventionally measured diverge is from the point in time immediately after the goods and services are purchased or the contract signed (i.e. the ex-post case). In the port context, this problem arises with most of the traditional factor inputs (capital, land and labour) and thus it would be necessary for the port to reassess the "cost" of these assets using the opportunity cost definition.

1. Capital

The discussion of the "Port's Pricing and Investment Problem" (Chapter 2) suggested that due to the specific and durable nature of the port's assets they may have little alternative use and thus their opportunity costs may approach zero. This observation is not however uniform to all the port's assets and it will be necessary for the port to investigate the various options available for the deployment of these assets. At the simplest level, the port can decide to retain or to sell/scrap the asset. Figure 5.1 outlines further the main courses of action available to the port under these two headings.

Given the temporal definition of opportunity cost, if the port is to retain the asset and employ it in its current use, then the value imputed to it will be the maximum of; the amount that other port users would be willing to pay for it in its next best use; the amount that other producers would be willing to pay if the asset was leased or rented to them; the value to the port of leaving the asset idle for a period of time then either using or selling it; the value to the port of selling/scrapping the asset and replacing it or purchasing another asset; the value to the port of selling the asset and investing in paper assets, and; the value to the port of any feasible combination of the options. Whilst this list is not exhaustive it gives an indication of the main options open to the port. The costs calculated in this manner can be escaped and therefore can be allocated to the traffics concerned.

In each of these cases, the port is effectively required to appraise pairs of mutually exclusive projects on the basis of their discounted costs (the revenues which could be earned in the alternative to the

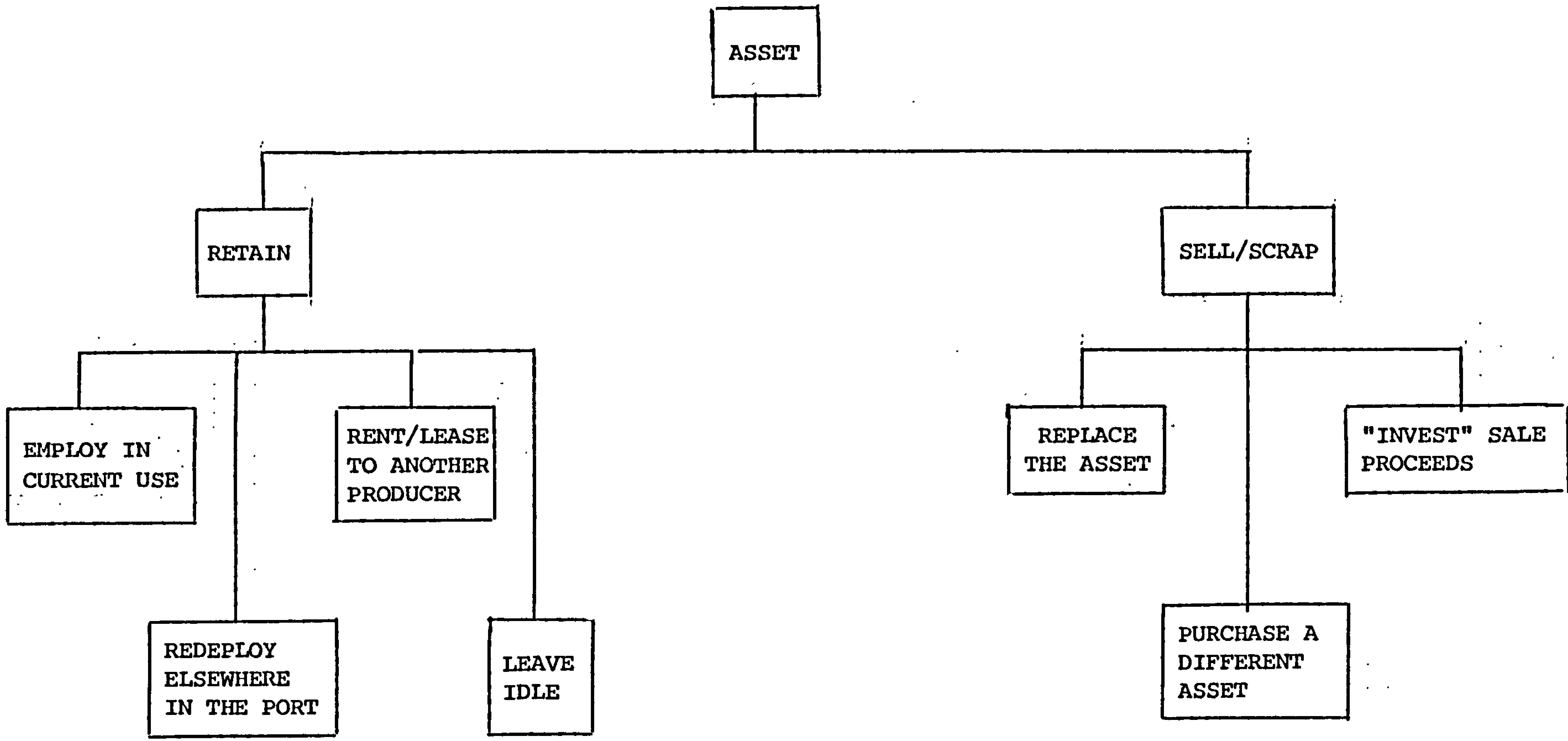


Fig 5.1 The Main Alternative Employment of a Port's Asset

proposed use being recorded as negative costs).

The incremental present value then represents the opportunity cost. In other words,

$$\begin{aligned}\text{Opportunity Cost} &= \text{Escapable Cost}\\ &= \text{Total Cost (with)} - \text{Total Cost (without)}\\ &= \text{Present value of Costs in Proposed Use (P)}\\ &\quad - \text{Present value of "Costs" in Alternative Use (A)}\\ &= \sum_i \frac{C_{P_i}}{(1+r)^i} - \sum_i \frac{(C_{A_i} - R_{A_i})}{(1+r)^i}\\ &= \text{Incremental Present Value.}\end{aligned}$$

Under the general heading of capital, there are a number of features which will need to be taken into account when considering opportunity cost. These features relate to the maintenance, economic depreciation and obsolescence of an asset and include:

(i) Maintenance due to the passage of time.

(ii) Maintenance due to use of the asset.

(iii) Stochastic maintenance (repairs).

(iv) Statutory maintenance.

(v) "Depreciation" due to time.

(vi) "Depreciation" due to use.

(vii) Obsolescence.

To be more specific, consider a particular asset, for example a crane and assume in the first instance that it is left idle for say a year.

Firstly, if it is left "in situ" some maintenance will be required due to the effects of wind, weather and climate. These effects will necessitate painting, oiling, greasing, etcetera of the crane. (Even if the crane "moth-balled", some preparation for this storage would be required.) Thus, there is a maintenance cost incurred due to the passage of time. Secondly, even with this maintenance, there will be a deterioration of the crane due to the passage of time. This deterioration will reduce the economic life and technical efficiency of the crane relative to when it was first left idle. This item is the economic depreciation due to time. Thirdly, in addition to this depreciation and regardless of the maintenance and storage conditions, the technical efficiency of the crane may be relatively lower at the end of the year due to technological change. This relative fall in technical efficiency is the obsolescence. Both economic depreciation and obsolescence will reduce the value of the asset to the firm and thus represent opportunity costs.

If the crane is used during the year, then the four additional opportunity costs are incurred. Firstly, there are the maintenance costs which are required to keep the crane in good working order and are incurred due to usage of the crane. Secondly, in spite of the maintenance carried out, the asset will deteriorate due to use. The fall in value of the asset due to this reduction in technical efficiency is the depreciation due to use. Thirdly, an "average" crane will breakdown for various unforeseen reasons, necessitating repairs to be effected (in excess of the maintenance due to use) and more cranes to be provided than may have been the case if these events did not occur. Thus, a cost is incurred by the port, the level of which can only be determined stochastically, given sufficient data, or subjectively when sufficient data do not exist. Fourthly, there may be statutory requirements that the crane is surveyed, tested and maintained to certain minimum legal standards.

Whilst these features of capital can be outlined in principle, in practice it may be difficult to identify them separately.

One measure of opportunity cost whose "neglect has been one of the commoner errors in economic discussion" (Lewis [6].) is the "user cost". Lewis suggests that "for any year (or unit of output)" there are three methods by which they can be calculated.

The first method is derived from the decision of whether to sell the asset today or operate it for the rest of its life. The criterion being, continue operating if:

$$\sum_{i=1}^{n} \frac{R_i - C_i}{(1 + r)^i} + \frac{P_n}{(1 + r)^n} \geqslant P_o$$

where R_i = gross revenue in year i.

C_i = running costs in year i.

P_i = proceeds of sale of asset in year i.

r = discount rate.

Re-arranging the inequality as follows,

$$\frac{R_1 - C_1}{(1 + r)} \geqslant P_o - \sum_{i=2}^{n} \frac{R_i - C_i}{(1 + r)^i} - \frac{P_n}{(1 + r)^n}$$

The right hand side gives the first measure of user cost. In words, the present value of the net revenue earned by employing the asset in its current use must at least equal the price for which the asset could be sold today less the present value of the net revenue (in its current use) over the remaining life of the asset, less the present value of the scrap value.

The second method compares sale today with operating for a year and then selling. The criterion for continuing operation is,

$$\frac{R_1 - C_1}{(1 + r)} \geqslant P_o - \frac{P_1}{(1 + r)}$$

the right hand side giving the second measure of user cost. In other words, the user cost is at least equal to the loss in present value through selling next year instead of now.

The third method compares the return from operating this year with the return which is excluded by operating this year. If the life of the asset is determined by obsolescence then clearly this user cost is zero. If however life is determined by use then it will be positive. For the purposes of exposition consider the specific alternatives of operate the the asset for n consecutive years from now compared with leave the asset idle this year then operate for n consecutive years. The criterion for operation this year is,

$$\sum_{i=1}^{n} \frac{R_i - C_i}{(1 + r)^i} - P_o + \frac{P_n}{(1 + r)^n} \geqslant \sum_{i=2}^{n+1} \frac{R_i - C_i}{(1 + r)^i} - P_o + \frac{P_{n+1}}{(1 + r)^{n+1}}$$

$$\frac{R_1 - C_1}{(1 + r)} \geqslant \frac{R_{n+1} - C_{n+1}}{(1 + r)^{n+1}} - \left[\frac{P_n}{(1 + r)^n} - \frac{P_{n+1}}{(1 + r)^{n+1}}\right]$$

the right hand side giving the third measure of user cost. In words, it states that the present value of the net revenue earnt by employing the asset this year must at least equal the present value of the net revenue foregone by operating this year less an adjustment for loss in present value of the scrap value by selling the asset in year (n+1) compared with year n.

It would appear that Lewis has only taken into account the "sell" and "leave idle" options in fig.5.1, however, the use elsewhere options are implicitly taken into account in the second method whereby it is assumed that the loss in present value through selling the asset next year instead of now reflects (at the margin) the value of the asset to other producers or if redeployed elsewhere in the port. This loss in present value also incorporates the concepts of obsolescence and economic depreciation due to use and time.

In approaching the problem in this manner, Lewis has implicitly assumed that a year is a relevant time horizon for the purposes of ascertaining opportunity costs. The relevant time horizon is that associated with the decision which the port is taking and may therefore be different from the year. The principles outlined can however be extended to take into account different time horizons.

It must also be taken into consideration that opportunity cost is concerned with what would be the next alternative and in the port case, it may not be feasible to be continually buying and selling assets.

2. Land

In the case of land, the two main alternatives available to the port are to sell the land or to rent/lease it to another user. Potential land users could include office block, housing or marina developers, industrial users,or simply a firm proposing to provide car-park facilities.

The opportunity cost of using the land area as a port is then the maximum of the alternative users willingness to pay for the land (either in terms of a sale price or rental).

3. Labour

Accounting practice tends to treat labour as a current resource cost. In the event, however, labour is employed on a contractual basis and immediate escape is extremely difficult. The contract with labour precludes the transfer of labour outside of the port and also defines their area of employment within port. Thus, the opportunity cost of labour could also be low. The two main next best alternatives are to redeploy the labour elsewhere (within the terms of their contract) or to leave them idle. The measure of opportunity cost obtained in the first case is the amount which other port users would be willing to pay and in the second case the difference between "standby pay" and the amount actually paid. (including any payments on this increment which employers are required to make, for example employers' National Health Service Contributions).

5.5 Opportunity Cost and Asset Valuation

The pricing rule of the 1978 Nationalised Industries White Paper [7], in the case where the output of new and old assets are indistinguishable, is that the price of the output from the old assets should be equal to the supply price of output from the new assets. The implicit recommendation of this rule is therefore that the price of all output should be related to the replacement cost of an increment of capacity.

This recommendation is implemented after a demand forecast and investment appraisal have been undertaken. Thus, it assumes either that the existing capacity is fully utilized and extra capacity is required or that existing capacity is deteriorating and there is a demand for replacement capacity. Therefore, in the case where demand for the asset exists and where asset replacement/investment will be undertaken the value of the existing asset is implicitly related to its replacement cost.

This replacement cost will be fully reflected in the opportunity cost measures discussed above in that alternative port users will be willing to pay this cost. In the case, however, where excess capacity exists (and consequently no replacement or investment undertaken), these opportunity cost measures may tend to be low (particularly where the assets are specific to the port). Consequently, a pricing system based on these costs will not yield sufficient revenue to replace even that part of capacity for which there was a demand. Lewis [8] suggests that:

> "This transfer of income to the consumer is a gift which he never expected, to which he has no particular right, and which he will receive only temporarily while excess capacity lasts."

It could be argued that given perfect competition there is nothing wrong with this in that the market is performing one of its functions of removing excess capacity. The port industry does not however satisfy the conditions necessary to be a perfectly competitive industry and "experience shows that the agony may be very long-drawn-out, and that it is not always the right firms that disappear." [9]

Even if, the next best employment of the asset suggests a low opportunity cost, this does not imply that the valuation of the asset by existing users is correspondingly low. The users may be willing to pay an amount in excess of the opportunity cost but not the full replacement cost. Thus in both cases,where the asset will and will not be replaced,some means of asset valuation is necessary.

The traditional accounting valuation used in the preparation of the Balance Sheet is historic cost or professional valuation (for example, the valuation of land by estate agents or ships by brokers). In addition to this method, Merrett and Sykes [10] cite three commonly used methods namely; the cost of replacing the asset with a similar asset; the value that could be realised if the asset were sold;and the net present value of the expected future earnings of the asset.

There are two further methods by which the full replacement cost can be incoporated into the computation of opportunity cost. The first method "simulates the capital investment decision which would need to be made when the assets under consideration require renewal" (Bromwich [11]). Thus, the port is treated as though it is a new capital investment, with those assets which will require to be replaced being valued at replacement cost and those assets which will not be replaced because of their durability having zero replacement cost imputed to them.

The second method is to adopt the general valuation formulae developed by Merrett and Sykes [12]. The concept of value used by Merrett and Sykes is:

> "the sum of money which would just compensate the firm for [the asset's] loss in stated conditions, given the action that will be taken by the firm to minimize this loss."

In order to obtain this valuation, the present value of the costs of continuing to operate the asset followed by its infinite stream of replacements ("project" A) is compared with loss of the asset now and replacement by the infinite stream ("project" B). For the firm to be no worse off after the hypothetical loss than it was before the loss, the present values of these two streams should be the same. Thus, by setting the present value of A equal to the present value of B the value of the existing asset can be found. Fig 5.2 shows the costs involved in these two alternative "projects".

Let: $K(m)$ = value of existing asset in year m (= z - k) of its life.

C = capital cost of replacement asset.

$D(k)$ = present value of operating costs of existing asset over its remaining economic life k.

$R(n)$ = present value of operating costs of replacement asset over its economic life n.

$S(i)$ = present value of scrap value of the asset over its economic life, i = k for existing asset and i = n for replacement asset.

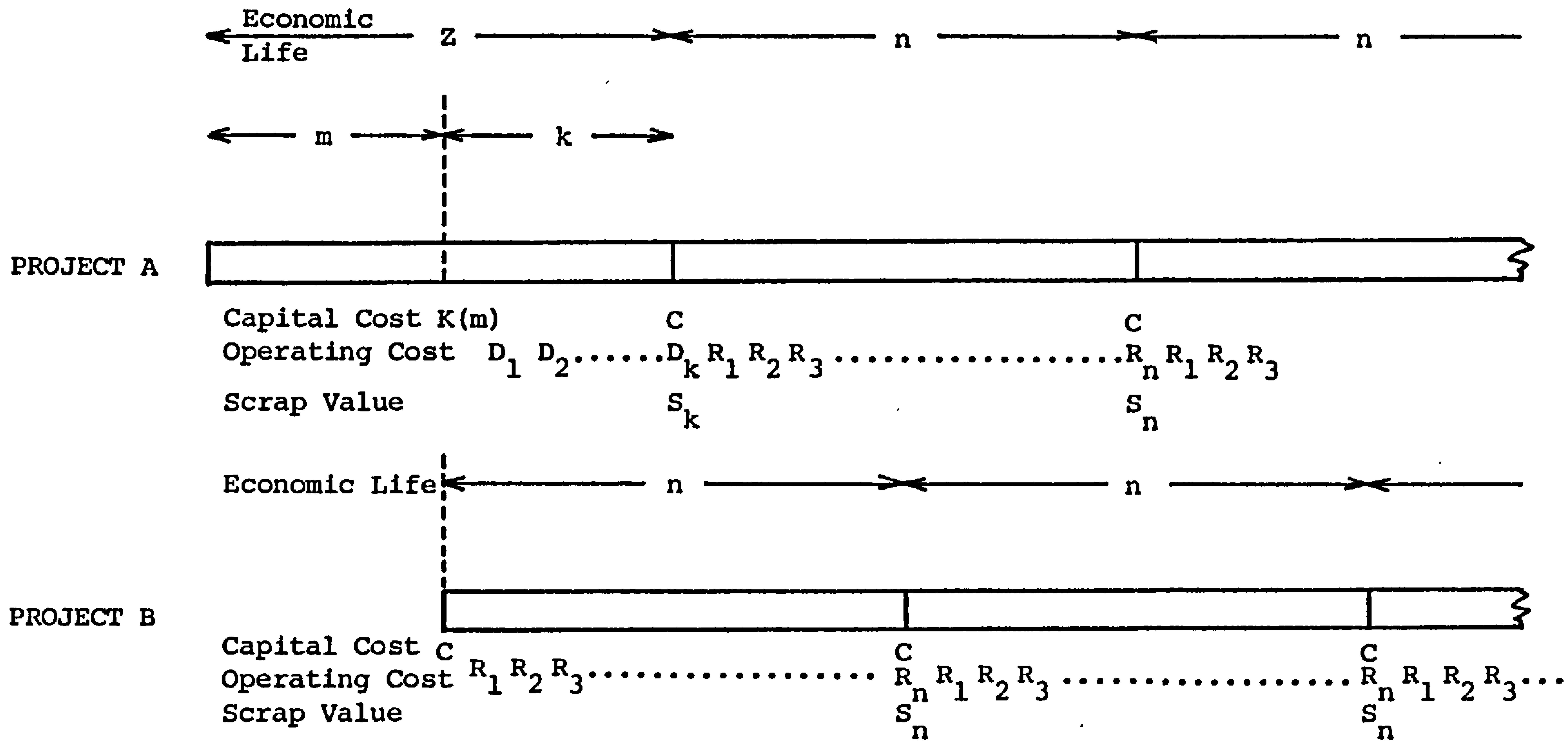
r = discount rate.

Then the present value of the infinite stream of replacements (project B) is equal to,

$$PV_B = \left[\frac{C + R(n) - S(n)}{1 - (1 + r)^{n}}\right]$$

Converting this into an annuity,

$$A = \left[\frac{C + R(n) - S(n)}{1 - (1 + r)^{-n}}\right] r$$



$$K(m) = [C + R(n) - S(n)]\left[\frac{1 - (1 + r)^{-k}}{1 - (1 + r)^{-n}}\right] - D(k) + S(k)$$

fig 5.2 Asset Valuation

and the present value of this annuity over k years is,

$$= \left[\frac{C + R(n) - S(n)}{1 - (1 + r)^{-n}}\right] r \left[\frac{1 - (1 + r)^{-k}}{r}\right]$$

$$= \left[C + R(n) - S(n)\right]\left[\frac{1 - (1 + r)^{-k}}{1 - (1 + r)^{-n}}\right]$$

Thus, the present value of project B can be considered to consist of this amount plus an annuity of A per annum from year (k + 1) to infinity.

The present value of project A can similarly be considered to consist of,

$$K(m) + D(k) - S(k)$$

plus the same annuity from year (k + 1) to infinity. Thus when the present values of A and B are set equal to each other the annuities cancel out and,

$$K(m) + D(k) - S(k) = \left[C + R(n) - S(n)\right]\left[\frac{1 - (1 + r)^{-k}}{1 - (1 + r)^{-n}}\right]$$

Thus, the value of the existing asset in year m of its life is,

$$K(m) = \left[C + R(n) - S(n)\right]\left[\frac{1 - (1 + r)^{-k}}{1 - (1 + r)^{-n}}\right] - D(k) + S(k)$$

This method assumes that the time pattern of revenue flows for both alternatives are the same and that the net present value of project B is non-negative (that is, consumers are willing to pay for the set of infinite replacements). If the time patterns of revenue flows are different then it will be necessary to incorporate them into the analysis. If X and Y are the present values of these revenue flows (to infinity) for A and B respectively, then the value of the existing asset will be changed to the extent of (X - Y). This could arise because it takes a number of years to replace the asset after loss. In this case (assuming that the revenue flows are the same after the lost asset is replaced) the value of the existing asset will be increased to the extent of the present value of the lost revenue.. Revenue could also change over time due to the deterioration (and obsolescence) of the existing asset. This could be incorporated into the analysis by adding a term,

$$X(k) - Y(n) \left[\frac{1 - (1 + r)^{-k}}{1 - (1 + r)^{-n}} \right]$$

to the above formula.

Where, X(k) = present value of revenue from the existing asset over its remaining economic life k.

Y(n) = present value of revenue from the replacement asset over its economic life n.

The reduction in revenue, in this and the more general case, could also be included in the analysis by imputing it as a cost resulting from the asset's reduced productivity.

Of the seven possible valuation methods, the historic cost is the least useful. This arises because of possible changes in the price level, technology and capacity utilization since the original investment was undertaken. The resale value has been discussed above, and represents a possible lower limit on opportunity cost. An upper limit is the cost of replacing the asset with another of similar age and state. In a perfect second-hand asset market, the replacement cost with a similar asset, the resale value and the general valuation formula (assuming replacement with a duplicate asset) should yield the same asset value. However, given the transactions costs and the imperfections in the second-hand market (due partly to the specific nature of the port's assets), the cost of replacing the asset with a similar asset will be greater than the resale value, with the formula possibly yielding a value in-between these two. Replacement with a similar new asset will clearly yield a value higher than these valuations, however, one is not comparing like with like as asset lives and operating cost patterns will be different. The present value of expected future earnings yields the "true" value to the port of the asset if these expectations are realised. In general, this value in relation to new cost, second-hand value and resale or scrap value provides signals to the port as to when to invest or sell an asset (Merrett and Sykes) - if the expected value of earnings is greater than the new or second hand value, then invest, and if it is likely to fall below resale value then disinvest. In the context of this thesis, the present value of expected future earnings would introduce some circularity of argument if used to value the asset. This arises because one is attempting to devise a "cost based" pricing system and such a method of valuation would require a knowledge of prices before costs could be ascertained.

Thus, given the imperfections in the second hand market, the possibility of replacement with an asset of different capacity and that the general formula implicitly incorporates replacement cost and the differing time pattern of operating costs, the formula method is preferred.

Thus, in the circumstances where the existing asset will be duplicated or replaced with an asset of different capacity the formula for K(m) could be used.

There remains however three cases where some difficulty may be encountered in using this method. These arise firstly where the asset is permanent (that is, it will not require replacement in the foreseeable future), secondly, where the asset is likely to be replaced but at the point in time when valuation is being attempted neither the nature, location nor cost of the replacement can be ascertained with any degree of certainty, and thirdly where the asset will not be replaced because replacement is not warranted by demand.

In these cases, it may be necessary for the port to adopt an iterative approach in order to value the assets. This would require, in the first instance, the computation of the limits of a range of costs. The lower end of this range representing the opportunity cost of the asset (which could be zero) and the upper limit reflecting the replacement cost of the asset. Given this range of "costs", the port authority will have to attempt to estimate the user's willingness to pay (present value of expected future earnings) so that prices may be obtained. Alternatively, given the range, the port would have a basis for negotiating prices with consumers.

In these three cases the estimation of the lower limit is, in principle, easier than the upper limit. Where the asset is permanent, its opportunity cost approaches zero, but, by definition, the asset does not require replacing. The 1978 White Paper to a certain extent bypasses this problem by employing the long-run average incremental cost of a proposed investment. Thus, it suggests a "yardstick" (the incremental investment) with which to work. Given the excess capacity at United Kingdom ports, such a "yardstick" may not be available. Thus the port may have to resort to artificial investments (that is, the port authority will have to investigate and cost feasible expansion and replacement projects) or to the use of data from "recent" investments.

The third case can arise either because users are not willing to pay for a discrete factor input which has a capacity in excess of that required or where demand is declining over time. In both of these circumstances, the valuation formula can be used to ascertain the upper limit of "costs".

5.6 Opportunity Costs, Asset Valuation and Time

The approach to measuring escapable cost outlined in section 5.3 did not specify the time horizon to which the costs referred. As Lewis [13] states however,

> "Escapable cost is not just short-run and long-run, intermediate and ultimate. It varies for as far ahead as you care to look...as each commitment falls due for renewal, say for x years, all those due to expire during those x years have to be considered, since if any of those will not pay and will be discontinued, this may not pay either. [Thus] ...this collection of costs itself varies from day to day, as current commitments alter."

Of this "collection of costs", it is necessary to ascertain the short-run escapable costs, as these are directly relevant to the pricing of marginal units of output. The intermediate- and long-run escapable costs are relevant to the traffic accept/reject and invest/disinvest decisions, and the pricing of output in the medium- and long-run.

A second problem which the analysis has not yet considered is the allocation of costs to traffics over time. The only requirement to date has been that the traffic over the infinite time horizon is willing to pay the long-run escapable costs. The accountant approaches this problem by using the device of depreciation. Thus, according to the rule adopted (straight line, reducing balance, sum-of-years-digits, etcetera) these costs are allocated to each year of the asset's life. In chapter 2 however, it was suggested that these costs are joint to the traffic over the asset's life and consequently it will be necessary to ascertain prices from the consumption or demand side. If the year is considered appropriate for pricing purposes, a measure of the value of the asset to users during any year is the loss in the present value of the consumer's willingness to pay during that year. Thus, having ascertained whether the traffic is willing to pay over the asset's life (which in principle also requires that the willingness to pay during each year of the asset's life is ascertained) the port can attribute costs to the traffic in each year. If demand is stable or the traffic's willingness to pay is constant over time, then equal allocation of costs to each time period using an annuity formula may be appropriate. If however demand conditions or willingness to pay are changing over time then it may be necessary to consider each year separately. This approach applies to the asset; any assets which the port may require in conjunction with the asset; and any operating costs. Thus, for example, in the provision of a cargo handling service the port may required a berth (life 30 years), a crane (life 10 years) and annual operating costs for both of these assets. Even if the traffic is not willing to pay for the replacement of the berth, it will be required to pay for; the replacement of the crane if it demands the facility after year 10; and the annual operating costs each year if it is to be accepted each year. In other words there are subsets of costs that can be rationally attributed to traffic in subintervals of time.

A third problem in the analysis is that it has assumed that it is possible for the port to forecast costs and revenues into the indefinite future. Clearly, it is unreasonable to require of the port authority that these forecasts are undertaken and thus a more manageable time horizon will have to be adopted. Prudent planning practice will however require that the port makes some attempt to ascertain the traffic from which they propose to recover their capital outlays.

A formal approach to the problem is to consider a "planning horizon" over which it is deemed feasible to estimate costs and demand. The time horizon normally used for such an exercise would appear to be five years, for example, the five year Corporate Plan, Planning horizons in some cases extend beyond this period, for example, the MDHC Ten Year Profitability Study. In other industries, the planning horizon may be 15 years, for example, in the Gas Industry in the United Kingdom, the "Area Board" model considers a 15 year period [14], and in the case of the planning of major capital investments (Portbury [15]) a time horizon in excess of 25 years was used.

In deciding upon the appropriate planning horizon it will be necessary for the port to consider the longevity of its assets, the nature of long-run forecasts and the relative magnitude of individual expenditures.

The estimates of asset life suggested by the N.P.C. (for depreciation purposes) are shown in table 5.5. These lives would suggest (if one accepts the depreciation life as a proxy for economic life) that if the port was to commence operation "today" with a new set of assets then the minimum planning horizon would be 10 to 20 years. The assets whose lives exceed this period presenting a problem that will be considered below.

The ability of the port to forecast future traffic will also influence the choice of time horizon. In general, their ability to forecast year on year fluctuations in traffics decreases with time. Thus, as the planning horizon expands forecasts will, by necessity, be expressed in terms of underlying trends and growth (or decay) rates. There will however be varying "degrees of confidence" with which particular traffic can be forecast and thus there are "degrees of confidence" with which these trends and growth rates can be expressed.

The third factor influencing the time horizon is the relative magnitude of the expenditure. If there is a proposed major investment likely to be undertaken within the relevant time horizon, then it may be desirable to consider this as a separate subset of the port's overall planning process.

Thus, whilst one can consider the factors which may be relevant to the planning horizon, the actual choice of time horizon will depend upon the circumstances of the case. It is however suggested that 10 years represents the minimum time and the recent (1980) Profitability Study of M.D.H.C. would suggest that it is technically feasible to adopt at least this time period as a planning horizon.

The adoption of a planning horizon of h years effectively truncates

Table 5.5 NPC Asset Lives

	Life
Land	-
Excavations and dredging	35
Grants	Various
Docks, quays and river walls	35
Roadways and surfacing	25
Railway lines	25
Landing stages and jetties	35
Warehouses	25
Sheds	25
Other buildings	25
Miscellaneous items	15
Oil installations	20
Lighthouses	35
Hydraulic mains	25
Hydraulic machinery	20
Bridges	25
Cranes other than electric or mobile	15
Mobile cranes and trucks	10
Electric cables	15
Electric cranes	15
Electric machinery	15
Floating plant	15
Scale beams and weights	10
Weighbridges	15
Locomotives	15
Public lighting	15
Canteen equipment	5
Air compressor	10
Heating installations	10
Hoists	15

Table 5.5 (continued)

	Life
Pipelines	20
Grain elevators	15
Boilers	10
Motor vehicles	5
Dust and fume extraction plant	10
Radio communications	10
Refuse handling plant	15
Scientific instruments	10
Office machines	10
Electronic computer	7
Hardening and tempering furnaces	20
Buoys and beacons	15
Salvage pumps	15
Accumulators	15
Lanterns and flashers	15
Radar equipment	10
Diesel oil engines	20
Salt water mains	25
Heating equipment foundry	20
Hose handling facilities	20
Diesel welding sets and oil lighting sets	15
Baling presses	15
High pressure steam cleaners	10
Decca Hi-fix installations	10
Dock gates	35
Caissons	35
Container cranes Seaforth (Inc. Marine Leg)	15
Grain - marine towers, silos	40
Machine tools	10
Timber handling m/c	10
Misc. cargo handling	10

the analysis at this point in time (fig.5.3). Thus assets will fall into one of the four categories:

(a) Assets purchased and used up during the planning horizon.

(b) Assets existing at the beginning of, and used up during the planning horizon.

(c) Assets purchased during, and still existing at the end of the planning horizon.

(d) Assets existing at the beginning and the end of the planning horizon.

Category (a) assets are relatively easy to deal with - if the traffic was not accepted then their cost could be escaped. Thus, their costs are attributable to the years during which the asset is used. Category (b) assets will however require valuation at the beginning of the horizon. For the purposes of valuation the valuation formula can be used. In effect, this formula equates the present value of the costs of the existing asset (including the unknown K(m)) over its life with the present value of an annuity over the same number of years. This annuity is found by converting the present value of the capital costs, operating costs and scrap value of the first replacement asset (project B) into an annuity. Category (c) assets will, in the absence of any other information, require some arbitrary apportionment of costs to both sides of year h. One method of achieving this is to find the present value of the capital cost and scrap value of the replacement asset, convert this into an annuity over the asset's life of n years, then attribute the present value of this annuity over (h - k) years (project A) to the planning horizon and the balance to the (n - h + k) years beyond the planning horizon. If however the port does have

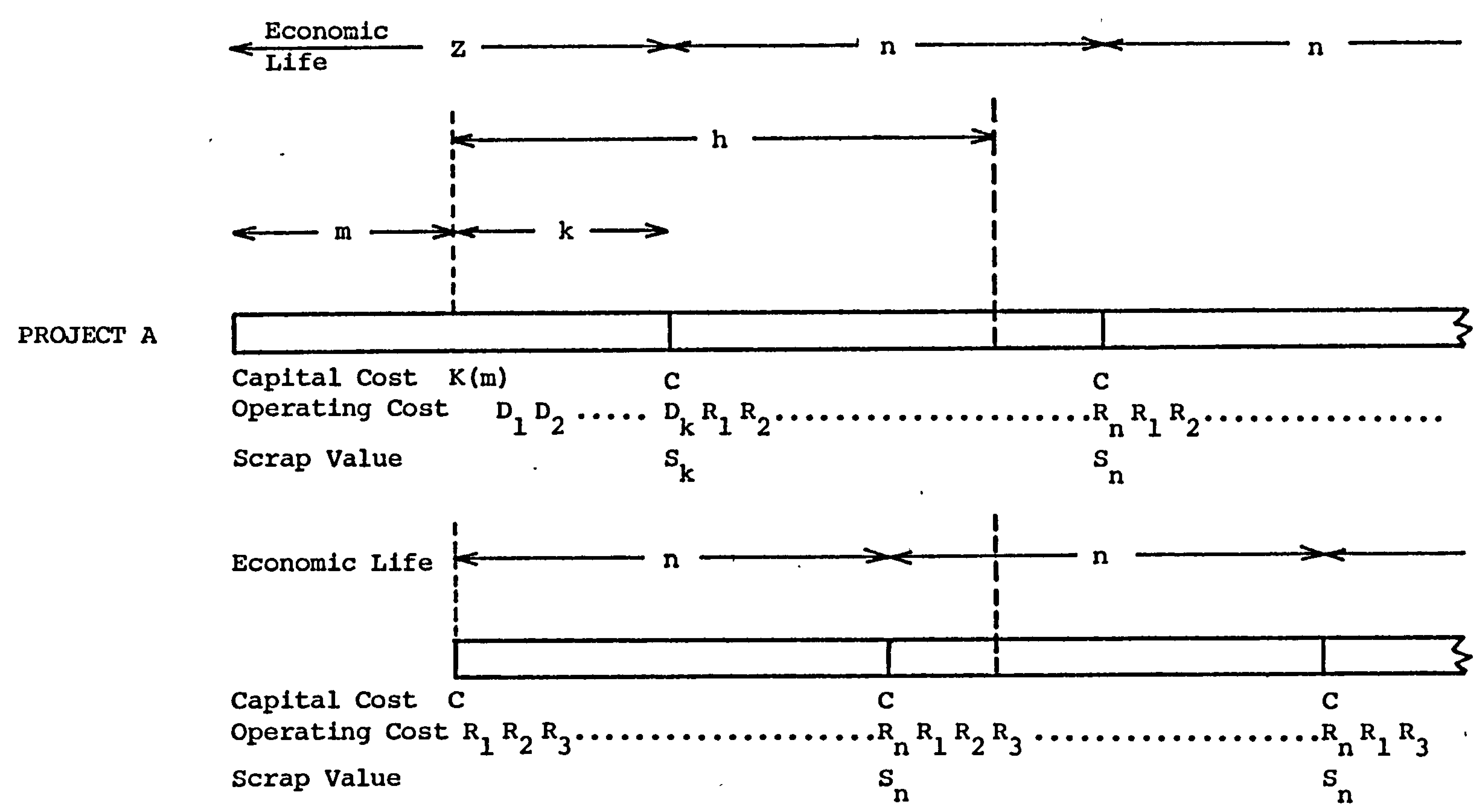


fig 5.3 Asset Valuation with a Planning Horizon

knowledge of the traffic's demand and willingness to pay then this can be used to attribute costs. Category (d) assets represent a combination of (b) and (c) and can therefore be treated accordingly. Alternatively, the asset can be valued at the beginning and end of the planning horizon, using the valuation formula. The loss in present value of these valuations being attributed to the planning horizon.

The suggested method for attributing costs where the asset exists at the end of the planning horizon can be criticised for being arbitrary, however, there are a number of reasons why this may not be particularly serious. Firstly, it is suggested as a last resort and only to be used where no other information is available. Secondly, in discounting the costs, the effects of errors tend to be reduced. The scale factor is equal to the discount factor. Thus for example, with a discount

Discount Rate	Years	Discount Factor
10	5	0.6209
10	10	0.3855
10	15	0.2394
10	20	0.1486
10	25	0.0923

factor of 10 per cent any error in costs at year 10 are reduced to one-third of the initial error and at year 15, to one quarter. Thirdly, as Turvey [16] states, "We do not have to decide this year what to do next year; we only have to decide what to do this year. Next year and subsequent years are relevant now only because what will be possible or desirable for us to do then will depend partly on what we have done this year...Thus, in order to make an actual decision now, we have, at the same time, to make hypothetical decisions about the future."

Thus, given that some of these costs are ex-ante they are hypothetical and can be considered in more detail when one arrives at the purchase date. It is however important to consider them now since if the commitments today will "not pay" then these commitments in the future may "not pay either" (Lewis [17]). Finally, the forecasts near the end of the planning horizon may only be expressed in terms of general trends and thus an annuity based method (tilted to reflect a trend if necessary) would appear appropriate.

5.7 Directly Attributable Costs and Time

In principle, the incorporation of a temporal dimension into Directly Attributable Costs leads to the same calculation as outlined in the first part of the chapter, that is,

$$\underline{DAC} = A^{-1}.\underline{EC}$$

In practice however, when time is introduced each asset (or service) enters the calculation with two extra properties, namely a date and an economic life. In general, if costs can be escaped in any time interval then they are attributable to the traffic in that interval. This implies that both the DAC and EC vectors will be matrices (or tables) with the rows representing traffic and the columns time.

The stages involved in ascertaining attributable costs include, estimating demand, identifying the facilities required to meet this demand, imputing the costs of these facilities then allocating the cost to traffics.

Consider for example, the provision of a conservancy service by a port. Assume that the port has two areas of destination and that the only facilities provided are buoys, which once on station require no maintenance or servicing for their lives (fig 5.4). There is one main channel buoy (M) which costs150; one buoy to area A (A1) which costs50; and one buoy to area N (B2) which costs80. The buoys have zero scrap value and their lives and replacement dates are shown in fig 5.5.

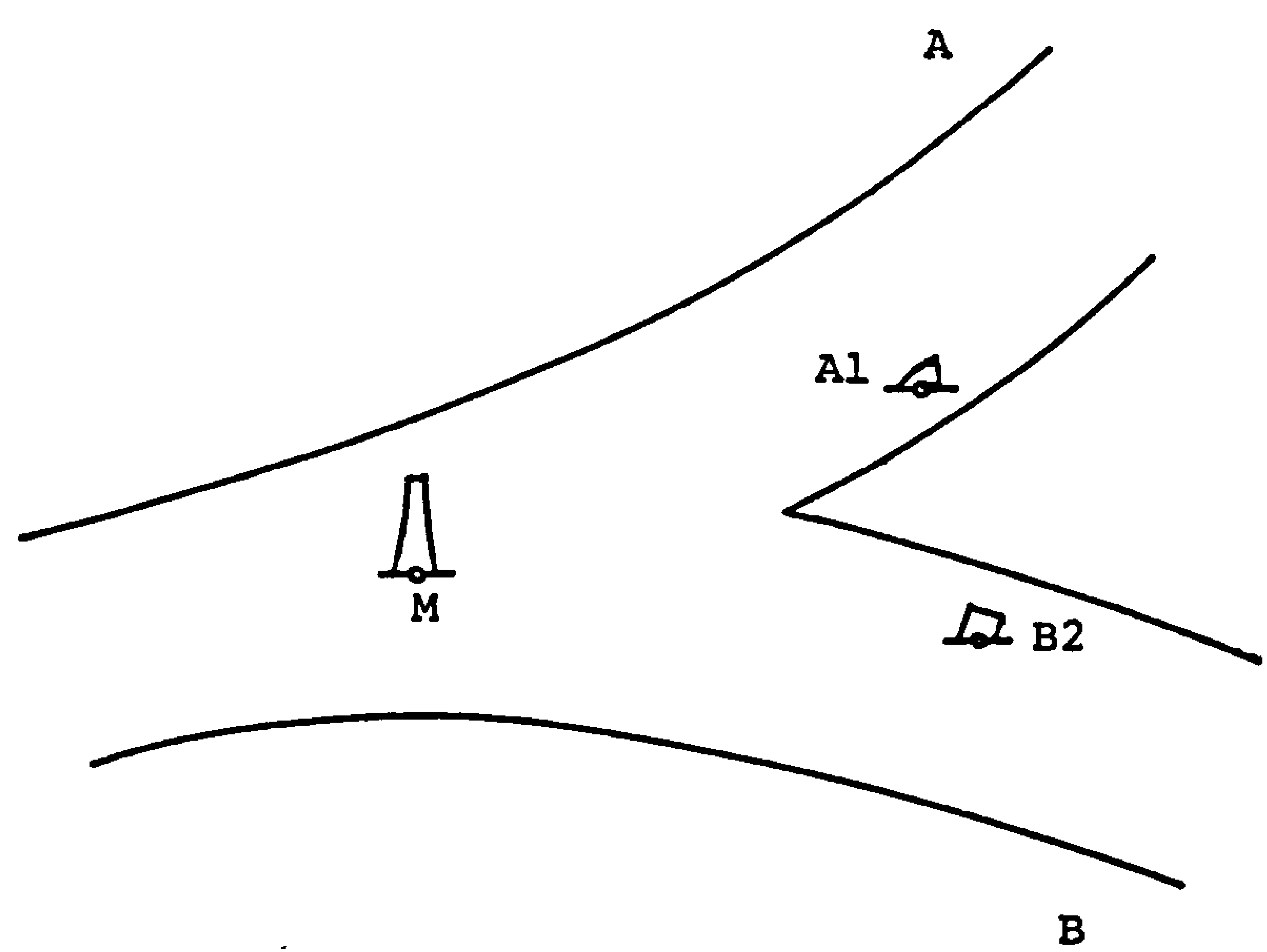


fig 5.4 Conservancy Example

The calculation of escapable cost proceeds as follows;

Let $$p_{m,n} = \frac{1 - (1 + r)^{-m}}{1 - (1 + r)^{-n}}$$

Area A:

Buoy A1

Existing Buoy	0 to $(50p_{2,5})_{0,2}$
1st replacement	$(50)_{2,5}$
2nd replacement	$(50p_{3,5})_{7,3}$

Area B:

Buoy B2

Existing Buoy	0 to $(80p_{3,7})_{0,3}$
Replacement	$(80)_{3,7}$

Area AxB:

Buoy A1 } As Area A and B
Buoy A2 }

Buoy M

Existing Buoy	0 to $(150p_{10,15})_{0,10}$

where, (i) lives are given in fig 5.5

(ii) subscripts outside bracketed items refer to the date and the period of time to which the costs are allocable (the date referring to the end of the year)

The matrices for the general two areas of destination and ten year time time horizon case (assuming discrete time) are written out in full in table 5.6, whilst table 5.7 contains the matrices of the maximum escapable costs for the example under consideration. The minimum escapable cost matrix is found by inserting zeros in the place of $(50p_{2,5})$ for buoy A1, $(80p_{3,7})$ for buoy A2 and

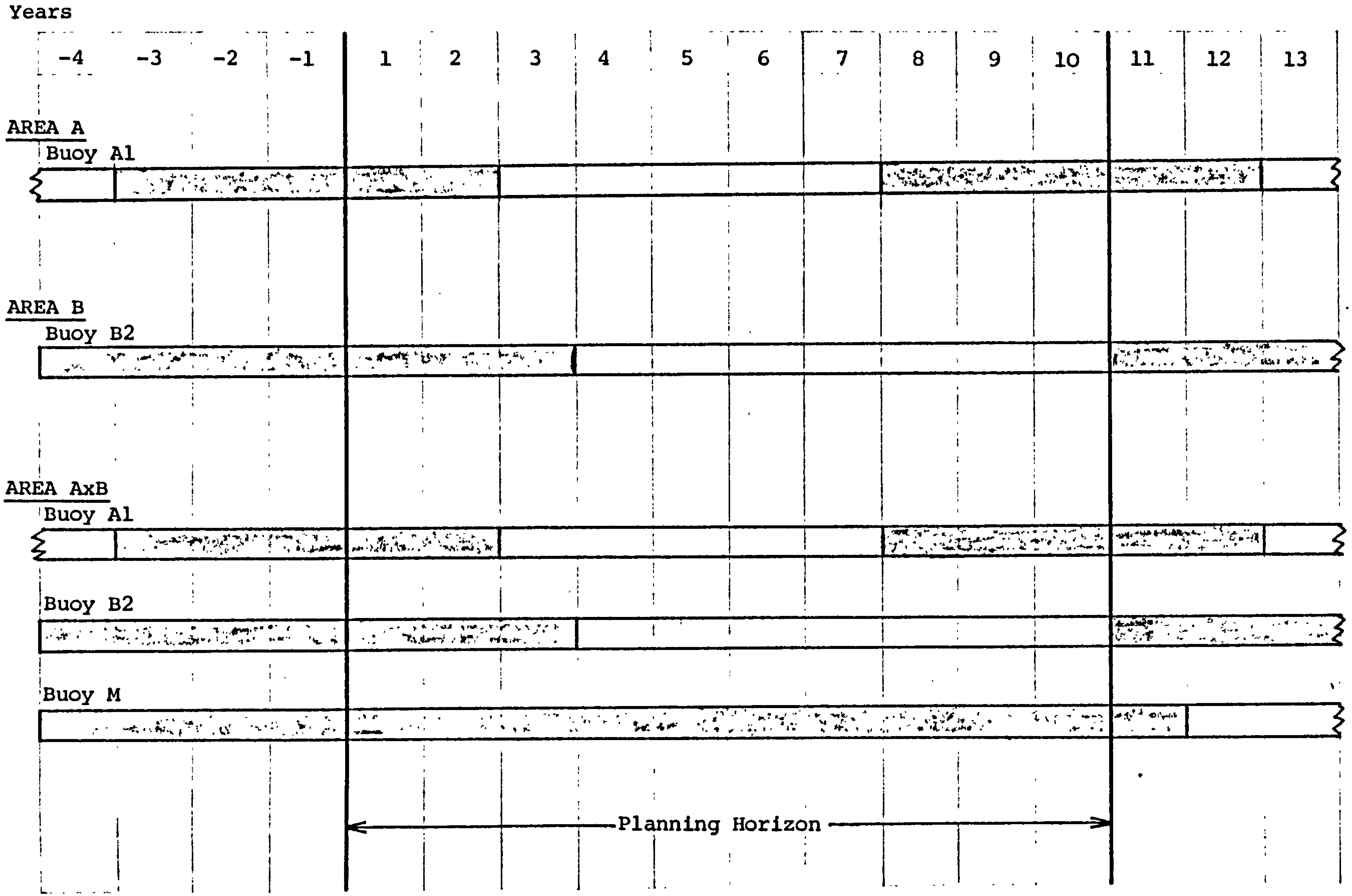


fig 5.5 Conservancy Example - Port with two Areas of Destination

Table 5.6 Directly Attributable and Escapable Cost Matrices for the two Traffic Case

$$\begin{bmatrix} DAC_{O,0} & DAC_{O,1} & DAC_{O,2} & DAC_{O,3} & DAC_{O,4} & DAC_{O,5} & DAC_{O,6} & DAC_{O,7} & DAC_{O,8} & DAC_{O,9} & DAC_{O,10} \\ DAC_{A,0} & DAC_{A,1} & DAC_{A,2} & DAC_{A,3} & DAC_{A,4} & DAC_{A,5} & DAC_{A,6} & DAC_{A,7} & DAC_{A,8} & DAC_{A,9} & DAC_{A,10} \\ DAC_{B,0} & DAC_{B,1} & DAC_{B,2} & DAC_{B,3} & DAC_{B,4} & DAC_{B,5} & DAC_{B,6} & DAC_{B,7} & DAC_{B,8} & DAC_{B,9} & DAC_{B,10} \\ DAC_{AxB,0} & DAC_{AxB,1} & DAC_{AxB,2} & DAC_{AxB,3} & DAC_{AxB,4} & DAC_{AxB,5} & DAC_{AxB,6} & DAC_{AxB,7} & DAC_{AxB,8} & DAC_{AxB,9} & DAC_{AxB,10} \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 1 & -1 & -1 & 1 \end{bmatrix} \begin{bmatrix} EC_{O,0} & EC_{O,1} & EC_{O,2} & EC_{O,3} & EC_{O,4} & EC_{O,5} & EC_{O,6} & EC_{O,7} & EC_{O,8} & EC_{O,9} & EC_{O,10} \\ EC_{A,0} & EC_{A,1} & EC_{A,2} & EC_{A,3} & EC_{A,4} & EC_{A,5} & EC_{A,6} & EC_{A,7} & EC_{A,8} & EC_{A,9} & EC_{A,10} \\ EC_{B,0} & EC_{B,1} & EC_{B,2} & EC_{B,3} & EC_{B,4} & EC_{B,5} & EC_{B,6} & EC_{B,7} & EC_{B,8} & EC_{A,9} & EC_{B,10} \\ EC_{AxB,0} & EC_{AxB,1} & EC_{AxB,2} & EC_{AxB,3} & EC_{AxB,4} & EC_{AxB,5} & EC_{AxB,6} & EC_{AxB,7} & EC_{AxB,8} & EC_{AxB,9} & EC_{AxB,10} \end{bmatrix}$$

where: subscript i,j = area,year.

Table 5.7 A Specific Example of the DAC and EC Matrices in the two Traffic Case

(continuing from Table 5.6)

$$
\begin{bmatrix} 1 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 1 & -1 & -1 & 1 \end{bmatrix}
\begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
(50p_{2,5})_{0,2} & 0 & (50)_{2,5} & 0 & 0 & 0 & 0 & (50p_{3,5})_{7,3} & 0 & 0 \\
(80p_{3,7})_{0,3} & 0 & 0 & (80)_{3,7} & 0 & 0 & 0 & 0 & 0 & 0 \\
\begin{array}{c}(50p_{2,5})_{0,2} \\ +(80p_{3,7})_{0,3} \\ +(150p_{10,15})_{0,10}\end{array} & 0 & (50)_{2,5} & (80)_{3,7} & 0 & 0 & 0 & (50p_{3,5})_{7,3} & 0 & 0
\end{bmatrix}
$$

$$
= \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
(50p_{2,5})_{0,2} & 0 & (50)_{2,5} & 0 & 0 & 0 & 0 & (50p_{3,5})_{7,3} & 0 & 0 \\
(80p_{3,7})_{0,3} & 0 & 0 & (80)_{3,7} & 0 & 0 & 0 & 0 & 0 & 0 \\
(150p_{10,15})_{0,10} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
$$

where $p_{m,n} = \left[\dfrac{1 - (1+r)^{-m}}{1 - (1+r)^{-n}}\right]$

subscripts i,j outside brackets = date,duration and $(150p_{10,15})_{0,10}$ for buoy M (assuming they have no alternative use).

Thus, for example (table 5.7) over the first two years the traffic to A should be willing to pay between zero and $50p_{2,5}$. However over years three to seven (inclusive) they will be required to pay 50 and over years eight to ten (inclusive) $50p_{3,5}$ (unless the port authority has other information concerning the traffic's willingness to pay in these last three years and the two years beyond the planning horizon).

In the case of the buoy M, the traffic would be required to pay between zero and $150p_{10,15}$ over the whole planning horizon [18]. If operating costs were also introduced into the analysis, then they would accrue to the years over which they could be escaped.

5.8 Summary and Conclusions

This chapter has outlined a methodology whereby the port authority can attempt to measure escapable costs. The escapable cost of a specific traffic can in principle be ascertained by asking "which costs would be saved if that traffic was not accepted?" In general, the port's existing financial accounts have not been designed to answer questions of this nature and thus in a similar manner to marginal costing, it may may be necessary to undertake separate investigations into these costs. Further investigation into the practicalities of measuring escapable cost suggest that for even a small number of traffics the calculation becomes complex and thus a systematic approach was outlined. The number of traffics still remained considerable, however, by judicious choice of traffics and subsets of traffics this could be reduced and it was further suggested that the extent to which these reductions could be achieved depended upon the specific case.

Section 5.4 outlined some of the conceptual differences between opportunity cost and cost as conventionally understood. In section 5.5, it was suggested that the opportunity cost of some of the port's assets may tend to be low; equally this does not imply that these assets are of no value to their users. By approaching pricing from the cost side one does however lose this "degree of freedom" and thus artificial investments which reflect the replacement cost of the asset are considered. Given the opportunity cost and escapable cost the port authority has a range of costs within which it can place the user according to his willingness to pay. Alternatively this range can be used when negotiating prices with users.

Section 5.6 introduced intertemporal jointness and noted that the only requirement in the case of the port's capital assets was that the traffic was willing to pay over the life of the asset. Thus costs would have to be allocated to each time interval according to the traffic's willingness to pay in each of these intervals. The analysis also recognised the unreasonable requirement that the port authority forecasts costs and revenues into the indefinite future. It was therefore suggested that a "planning horizon" approach is adopted whereby the port authority forecasts costs within the horizon and values assets at the beginning and end of the horizon. There is however, even when using this approach, an implicit assumption that a forecast beyond this horizon can be undertaken. It was however suggested that the analysis may not be particularly sensitive to this assumption.

Finally in section 5.7 the temporal dimension was introduced into the basic methodology for ascertaining directly attributable costs. The suggested approach was to change the escapable cost and directly attributable cost into matrices with time for columns and traffic for rows. These matrices can be alternatively considered to be (the conceptually easier to understand) tables of costs.

The analysis has indicated that a general model of escapable costs would be particularly complex, however if particular cases are considered then the problem may become manageable. In the following three chapters the three areas of conservancy, docks and cargo handling at the Port of Liverpool will be considered in an attempt to ascertain the extent to which the general model can be simplified.

Notes

[1] Glautier, M.W.E. and Underdown, B., "Accounting Theory and Practice", Pitman, London, 1976, pp 56-77.

[2] Institute of Cost and Works Accountants (I.C.W.A.), "A Report on Marginal Costing", London, 1961.

[3] Lewis, W.A., "Fixed Costs" in Mumby, D. (ed) "Transport", Penguin, 1968, pp 61-97.

[4] Foster, C.D., "The Transport Problem", Croom Helm, 1975, 2nd Revised Edition, p 330.

[5] The number of combinations of traffics (excluding the case where no traffic is rejected as this has no subsets) is equal to;

$$\sum_{r=1}^{3} {}^{3}C_{r} = (2^3 - 1)$$

The number of subsets of each of these traffics is similarly;

$$\sum_{s=1}^{2} {}^{2}C_{s} = (2^2 - 1)$$

Thus the total number of calculations are;

$$(2^3 - 1)(2^2 - 1) + 1$$

(the case, no traffic being rejected, being added back in at the end).

[6] Lewis, W.A., [3] pp 62-3.

[7] HMSO, "The Nationalised Industries", Cmnd 7131, London, 1978, Appendix, para 9.

[8] Lewis, W.A., [3] p 69.

[9] Lewis, W.A., [3] p 71.

[10] Merrett, A.J. and Sykes, A., "The Finance and Analysis of Capital Projects", Longman, 1963, 2nd Ed. p 423.

[11] Bromwich, M., "Port Costs - An Alternative Approach", International Journal of Transport Economics, Vol 5, No. 3, pp 227-240.

[12] Merrett, A.J. and Sykes, A., [10].

[13] Lewis, W.A., [3] p 63-4.

[14] National Board for Prices and Incomes, Report No. 102, "Gas Prices" (Second Report), HMSO, Cmnd 3924, London, 1969.

[15] "Portbury: Reasons for the Minister's Decision not to authorise the construction of a new dock at Portbury, Bristol", HMSO, London, 1966.

[16] Turvey, R., "Economic Analysis and Public Enterprises", Allen and Unwin, 1971, p 53.

[17] Lewis, W.A., [13].

[18] Given the nature of the data in this example, as long as the traffic is willing to pay the escapable cost, then it is not necessary in practice to consider all of these cases. The

requirement is that over the planning horizon, A pays $50p_{10,15}$, B pays $80p_{10,8}$ and AxB pays $150p_{10,15}$. The example however illustrates the general methodology.

CHAPTER 6

MEASURING ESCAPABLE COSTS - CONSERVANCY

6.1 Introduction

The exercise of ascertaining the attributable costs of the services and facilities provided under the heading of Conservancy will be approached in the steps outlined at the end of the last chapter. These steps are summarised in fig 6.1

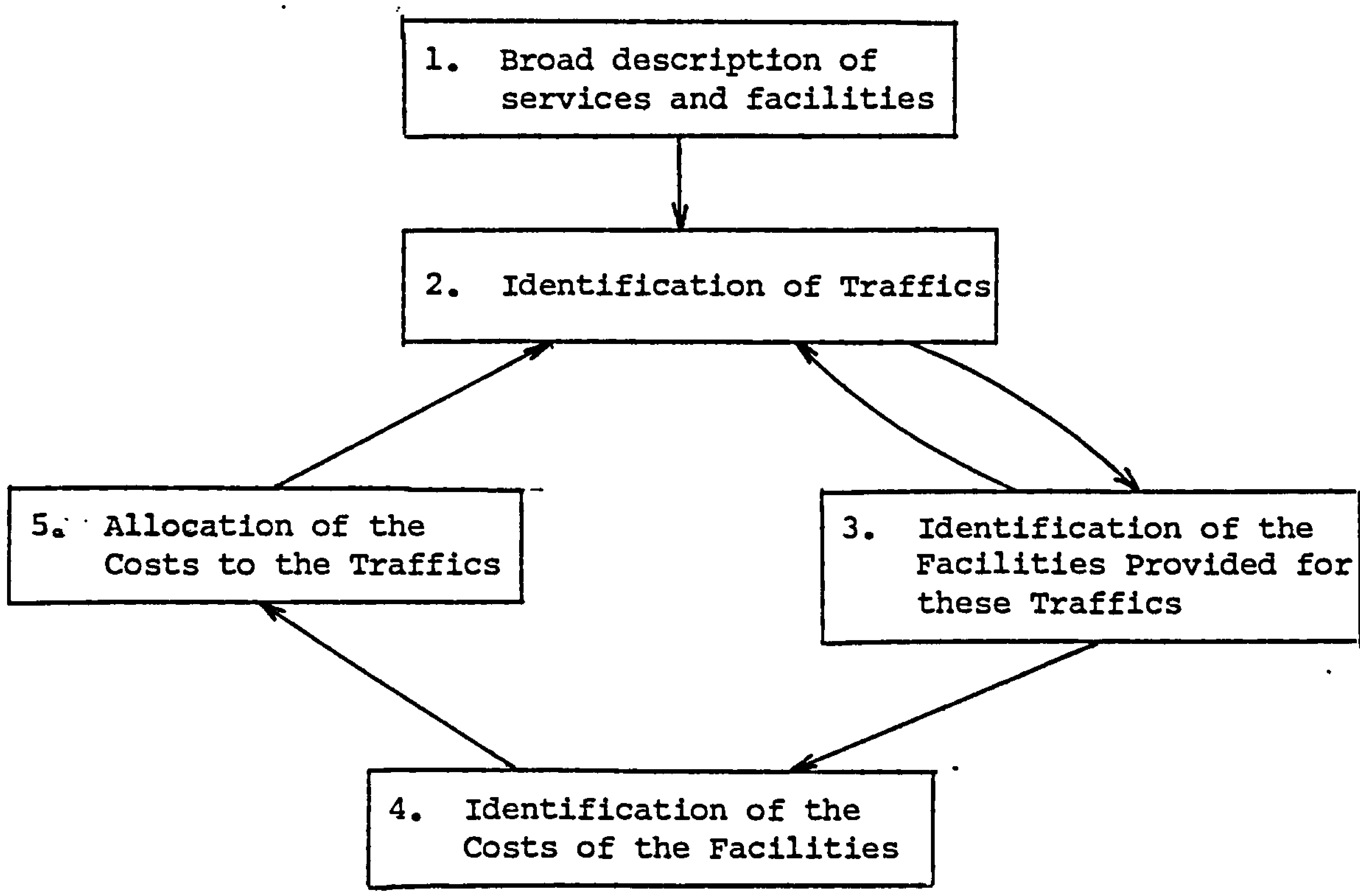


Fig 6.1 The Approach to Measuring Escapable Costs

6.2 The Services and Facilities

Under the general heading of Conservancy, the port provides four main services, namely:

1. Surveying.
2. Buoys and Lights.
3. Dredging.
4. Port Radar Station.

6.2.1 Surveying

The Hydrographic Department of the Port undertakes surveying inside the Liverpool and Birkenhead Dock complexes and also in the River Mersey. For the purposes of Conservancy, only the surveying in the river and at dock entrances will be considered. The main assets used in surveying the river include:

- 3 x 12.2 m wooden launches - used for surveying upstream of the port radar station. There are usually two launches operational at any one time, with the other being overhauled etc.
- 1 x 16.5 m catamaran - used for surveying in the main channel.
- Position fixing
  - Hi-Fix Chain - on shore.
  - Hi-Fix Receivers - on board.
  - Sextants and Station pointers.
- Sounding
  - Kelvin Hughes Echo Sounders.
  - Hand leads.
- Tide Measuring
  - 6x automatic tide gauges.

- Miscellaneous bottom samplers, water samplers, current meters, salinity/temperature meters and siltmeters.

and, the labour force comprises

- 5 hydrographic surveyors.
- a pool of 14 seamen for manning the launches.
- 4 cartographers and draughtsmen in the drawing office.

In order to systematically survey the river, it is divided into approximately 31 areas. The frequency of survey varies from area to area depending upon, its utilization, experience of previous siltation rates, and movements in banks and the navigation channel. Table 6.1 contains a list of the survey areas, the frequency of survey and the number of working days spent surveying each area.

6.2.2. Buoys and Lights

Entrance to the River Mersey is effected by proceeding along the Queen's Channel then the Crosby Channel, there being no alternative channels for commercial vessels. The Queen's Channel is buoyed with approximately 14 buoys and boat beacons. (lightfloats), whilst the Crosby Channel is buoyed with approximately 29 buoys and floats. The light floats are all located on the port hand of the channel (the reason for using floats being that the buoys heel over in the strong currents of the Mersey and become difficult to observe from a ship); some are named, but the majority are numbered (the named floats being larger than the numbered floats). All are "first class" buoys and floats. Up until 1981, the spacing of the buoys along the channel was based upon an assumed minimum visibility of one quarter of a mile which implies that they were spaced one half of a mile apart. However, with

Table 6.1 Survey Areas and Frequency of Survey

	Frequency	Days per Survey	Days per annum	Cumulative Total
River Mersey - Rock Lt. Ho to Warrington	5Y	150	-	-
River Mersey - Eastham & Garston to Rock.Lt. Ho.	2Y	20	-	-
Eastham Channel	6M	6	12	12
Eastham Bar	3M	3	12	24
Garston Channel	2M	6	36	60
Garston Bar	1M	1	12	72
Pluckington Bank	6M	2	4	76
Middle Deep/South Anchorage	1M	2*	24	100
Tanker Cleaning Jetty	6M	½	1	101
Tranmere Oil Stages	2W	1	26	127
Cammell Lairds Wall	6M & AR	3	6	133
Monk's Ferry to Woodside	1Y	1	1	134
Woodside Stage	1Y	½	½	134½
Alfred Entrance	2W	½	13	147½
Liverpool Stage (Monthly)	1M	½*	3+	150½
(2 monthly)	2M	1*	6+	156½
I.O.M. Stage	6M	2	4	160½
Waterloo Entrance (Exam)	2W	½	10†	170½
(Full)	2M	1	6†	176½
Langton South Bank	1Y	1*	1	177½
Langton Entrance	2W	1	26	203½
Gladstone South Bank	1Y	1*	1	204½

Table 6.1 (continued)

	Frequency	Days per Survey	Days per annum	Cumulative Total
Gladstone Entrance	2W	1	26	230½
Shoal of New Brighton				
(Monthly)	1M	½	4°	234½
(Quarterly)	3M	2	8°	242½
Crosby Channel (South)	1Y	1½	1½	244
(North)	2W	1½	39	283
(Margins)	1Y	2	2	285
Queen's Channel (East)	2W	1	26	311
(East Margins)	1Y	1½	1½	312½
(West)	1M	2	24	336½
(West Margins)	1Y	2½	2½	339
Queen's Channel & part of Taylor's Spit	2W	1½	39	378
(Margins)	1Y	2½	2½	380½

Notes:

Y = Year, M = Month, W = Week, AR = As Required

* Estimated

‡ 2M = 6 times per yr x 1 day = 6

1M = {12 times/yr - (6 times for 2M)} x ½ day = 3

† 2M = 6 times/yr x 1 day = 6

2W = {26 times/yr - (6 times for 2 M)} x ½ day = 10

° 3M = 4 times/yr x 2 days = 8

1M = {12 times/yr - (4 times for 3M)} x ½ day = 4 the modern navigation aids available, this has been thought no longer necessary so that the new spacing is 1.1 km except on the bends, where the old spacing will be retained.

In the River Mersey between the Port Radar Station and Bromborough there are seven first class buoys marking miscellaneous banks.

The channels to Eastham and Garston are both buoyed with can and conical buoys, there being approximately 7 and 9 buoys respectively with a lit dolphin at the end of each channel. The buoys in the Eastham Channel and numbers 1 and 2 in the Garston Channel are all first class buoys. The remaining buoys in the Garston Channel are smaller and constructed of GRP (glass reinforced plastic).

The moorings for the buoys depend upon the size of the buoy/float and its location. The larger floats are moored with two anchors or with a 4 ton cast iron sinker and a 30 cwt "backer" sinker (especially for the buoys/floats on the edge of banks). The ordinary buoys and floats are moored with sinkers of 30 or 50 cwt.

All of the buoys and floats are lit with gas, the gas bottles in most cases having a capacity to last for 15 monhts. This, in conjunction with a need to scrape and paint the hulls of the buoys and floats means that they are kept on station for approximately 12 months with some of the named floats, however, remaining on station for 2 years. This requires an annual programme for lifting and maintaining them. In order to lift and position the buoys, the port owns an 817 g.r.t. buoy tender and salvage vessel called "Vigilant". This vessel was purchased in 1978 and replaced a similar vessel which was built in 1953.

The shore facilities for repairing and maintaining the buoys consist of a branch dock (in an otherwise unused part of the port) and a large single level building for storing equipment, working undercover and overhauling and resetting flasher units. At this buoy store, the port employs a gas fitter, an assistant gas fitter and a labourer. As well as working on the lights in the buoy store, the gas fitters undertake minor repairs, resetting and relighting of buoys on station.

6.2.3 Dredging

Dredging is undertaken inside the docks, at the dock entrances and in the main approach channel. No dredging is currently being undertaken in the river (including the Garston and Eastham Channels). The port itself dredges the docks and dock entrances whilst the dredging in the main channel is contracted out to a private firm.

The contract dredging is performed by trailer suction dredgers on a campaign basis (that is, it is undertaken for a number of weeks at a time and not on a continual basis). The contract was negotiated in 1975 and runs for six years. The contract names seven dredgers with one being used as a basis for calculating the amount due to the contractor. Twelve weeks' work for the standard dredger is guaranteed with eight weeks' notice being required. The minimum length of a single campaign is four weeks (one week mobilisation and three weeks' dredging). In 1975, the least depth in the main channel was 7.5 m below chart datum, however, 7.0 m is currently maintained in this channel. The two main areas dredged by the contractors are Queen's East Channel and Crosby Shoal, with approximately 200,000 m^3 and 100,000 m^3 respectively being removed from these channels annually.

The port owns two grab hopper dredgers and employs them in the docks and at the dock entrances. During each of the years 1979 and 1980, these dredgers removed in excess of 1¾ million tonnes of silt, however, in considering conservancy, we will only be concerned with the dock entrances. There are four dock entrances, three at Liverpool where ½ million tonnes were removed and one at Birkenhead where 50,000 tonnes were removed. Thus, approximately 30 per cent of the silt is removed from the dock entrances.

6.2.4 Port Radar Station

The Port Radar Station is located on the seaward side of the Seaforth Docks. It is operational for 24 hours a day and provides radar coverage for a radius of 20 miles from the station. In addition to general traffic surveillance the station broadcasts traffic movements at set times and on request. In reduced visibility vessels may also request reports on their own position whilst navigating within the station's coverage.

6.3 Traffic Identification

Schiller [1] when considering cost allocation in the electricity industry suggested that:

> "For the purpose of cost allocation it is convenient to deal in the first place with groups or classes composed of consumers of similar characteristics, whereby "consumer" may be taken in a personal sense (e.g. purchaser of energy) or material sense (e.g. water heater). The group performance is determined essentially by the behaviour of the majority, and consequently reflects general trends and characteristics."

Whilst Schiller was investigating the peak-pricing problem, the principle of identification of groups or classes or traffic with similar characteristics is equally applicable to the problem at hand.

In the case of Conservancy at the Port of Liverpool one notes the geographical area covered by the port in the performance of its duties. For some of these areas, the port provides a service for particular groups of traffics. Thus it would appear that one similar characteristic could be the area of destination within the port.

The other possible characteristics were discussed in chapter 4 and included measures of vessel size, manoeuverability and type. In the case of Conservancy, the port itself has suggested that particular attention is paid to maintaining and surveying channels for the deep drafted vessels which proceed to Seaforth Container and Grain terminals and also for the large tankers proceeding to Tranmere. Thus a measure of size may also be an appropriate characteristic to classify the traffic. Vessel type, whilst being highly correlated with the traffic proceeding to particular areas of the port is not that important in the case of Liverpool. In particular, the Port does not adopt specific procedures for the arrival and departure of these vessels (for example, other traffic movements in the port are not significantly curtailed when specific vessel types are moving).

Thus, in the first instance, the "similar characteristics" by which the traffics are grouped will be area of destination, with vessel size being noted for the traffics proceeding to Gladstone and Tranmere. Fig.6.2 indicates the ten areas of destination within the port.

The decision to use area of destination and possibly a measure of vessel size as the characteristics relevant for cost identification still confronts one with a problem which is overly complex for

Fig 6.2 River Mersey

practical application. Given the 10 main areas of destination within the port there are;

$$\sum_{r=0}^{10} {}^{10}C_r \doteq 2^{10}$$

or 1024 different combinations of these traffics. If one further considers three different vessel sizes to each of these 10 areas then there are 2^{30} (over 1 billion) combinations. Thus, a considerable degree of simplication is required. Two ways by which this simplication may be attempted are to consider size as a subset of area of destination and then to introduce a "natural sequence", into the order in which the areas are considered, which does not require one to delve into all of the possible combinations of areas. Table 6.2 shows the extent to which the number of calculations may be reduced by using these two devices in the 10 destination, 3 size example. In the second case (Table 6.2) size is a subset of area. Thus, for the 1024 combinations of areas the escapable costs are ascertained. Then, within each of these combinations, (excluding the not rejecting any traffic case), theeescapable costs of the seven combinations of three sizes are computed. In the third case, the areas of destination would all lie (geographically) on a single line. Here, it is only necessary to consider the 10 areas (plus the reject no traffic case) and the nine combinations of areas in order (for example AxB; AxBxC; etc - areas being named from upstream starting at A),.then within each combination the seven size combinations. Whilst this has reduced the number of traffics to a more manageable 140 combinations, some costs may be computed as being joint to more traffics than they should have been. For example if B and D are the only areas to which deep drafted

Table 6.2 The Number of Combinations of Traffics

Traffics	Formulae	Number
1. 10 areas and 3 sizes.	$\sum_{r=0}^{30} {}^{30}C_r = 2^{30}$	1,073,741,824
2. 10 areas, 3 sizes as subsets of the areas.	$\left(\sum_{r=1}^{10} {}^{10}C_r\right)\left(\sum_{s=1}^{3} {}^{3}C_s\right) + 1$	
	$= \{(2^{10} - 1)(2^3 - 1) + 1\}$	7,162
3. 10 areas separately plus combinations in order, 3 sizes as subsets.	$((n + 1) + (n - 1))\left(\sum_{s=1}^{3} {}^{3}C_s\right)$ $= (2 \times 10)(2^3 - 1)$	140
4. 10 areas separately plus combinations in order, 3 sizes separately plus combinations in order as subsets.	$((n + 1) + (n - 1)(s + (s - 1))$ $= (2 \times 10)(2 \times 3 - 1)$	100

Notes:

(i) Case 2 - $\sum_{r=0}^{n} {}^{n}C_r$ includes the not rejecting any traffic case which has no subsets. Thus it is not included in either of the summations, but it is added back at the end of the calculation.

(ii) Case 3 - $(n + 1)$ = n separate areas plus not rejecting any traffic.
$(n - 1) = 1x2; 1x2x3; \ldots; 1x21\ldots xn$.

(iii) Case 4 - s occurs by itself as the not rejecting any traffic case is not relevant to subset s.

vessels proceed, then the joint costs of these two traffics will be allocated jointly to AxBxCxD. If this problem does not appear to be particularly prevalent then extra traffic combinations (B and D in this case) may be added to reduce its effect. Case 4 indicates how a further reduction of 40 combinations may be achieved by considering size in order, instead of all the combinations. However, similar comments to case 3 also apply to this case.

The reductions in cases 3 and 4 were made possible by taking a specific example. In general, simplification may be achieved by considering the circumstances of the case including the geographic configuration of the port and the facilities provided for these various traffic.

6.4 Traffic and Facilities

In order to identify the traffic by facility provided, it will be necessary to investigate the extent to which the level of the facilities provided would change if traffics were abandoned. This investigation will be undertaken by considering the four main services provided under the heading of Conservancy.

6.4.1 Port Radar Station

It is unlikely that the level of service provided by the station would be reduced if a particular traffic was not accepted. Thus, the costs associated with the station will tend to be joint to all of the traffic entering the port.

6.4.2 Buoys and Lights

In general, the quality and spacing of the buoys is determined by the weather and sea conditions and not by the traffic. Thus, neither the quality nor the spacing of the buoys would be changed if traffics were not accepted. The abandonment of particular traffics would however allow the port to reduce the number of buoys in certain areas. For example (see fig 6.2) if the traffic to Garston (A) was not accepted then the Garston Channel (I) would not have to be buoyed. Similarly, if traffics to B and C were not accepted then sections II and III would not have to be buoyed. Thus, in the case of the buoys, it is not necessary to consider every possible combination of area of destination. Starting at A and B one can proceed downstream through each of the numbered sections, allocating the cost of the buoys in each section to its corresponding area and areas upstream of it. For example, the cost of a buoy in area IV (Pluckington Bank Buoy) is joint to all of the traffic upstream and including Tranmere (D), whilst the costs of the buoys in the Queen's and Crosby Channels (X) are joint to all of the traffic using the port.

The two remaining facilities associated with the buoys are the "Vigilant" and the buoy store. Again, one asks whether by rejecting specific traffics the level of provision of these facilities could be reduced. In the case of the "Vigilant" this is unlikely, as a vessel of similar size and type would still be required to lift the buoys in the open waters of the main channel. In the case of the buoy store it has been hypothesized that no significant reduction in cost could be achieved by rejecting particular traffics. The port has approximately 65 buoys on station, 42 in the main channel, 7 in the River Mersey, 9 in the Garston Channel and 7 in the Eastham Channel. It is therefore conceivable that the hypothesis is incorrect and that the storage area at the buoy store could be reduced if the traffic to Garston and/or M.S.C. were rejected. If this were the case then this cost would be joint to these two areas. The remaining costs would then be joint to all of the traffics (the labour costs are joint due to their indivisibility, that is, even if the port serviced only the buoys in the main channel it would still require the gas fitter, his assistant and a labourer).

6.4.3 Dredging

Chapter 4 indicate that the port may provide the service of a channel where capital dredging has been undertaken and also the service of maintaining the channel. In the ex-ante case, the relationship between traffic and capital dredging will depend upon the reason for the dredging. If it is for channel deepening then the dredging is related to the deeper draft vessels. If however it is channel widening or investment to maintain the stability of the river bed then it may be related to all traffics jointly. In the ex-post case, capital dredging tends to be a permanent asset (not requiring replacement) and thus has zero opportunity cost.

The two areas where maintenance dredging is undertaken by the port presents two different problems when attempting to identify traffic with the facility. In the main channel, there may exist in principle a natural depth where no maintenance dredging was required. Consider, for example, a case where there are four possible depths (metres) at which the channel could be maintained (that is, dredging is a step function of depth). The cost of maintaining the channel for the first (top) metre(S_1) will be joint to all traffic requiring more water than the natural depth. If the cost of maintaining the channel at the second metre is $S_1 + \delta S_1$, then δS_1 is joint to all vessels requiring this depth and more. Table 6.3 indicates the joint costs for the four possible depths. The problem facing the port authority however, is one of forecasting the costs of maintenance dredging at these various

Table 6.3 Joint Maintenance Dredging Costs

Natural depth plus: (metres)	Maintenance dredging cost	Joint escapable cost	Attributable to vessels of max. draft equal to natural depth plus:			
			1	2	3	4
1	S_1	S_1	X	X	X	X
2	$S_2 = S_1 + \delta S_1$	δS_1		X	X	X
3	$S_3 = S_2 + \delta S_2$	δS_2			X	X
4	$S_4 = S_3 + \delta S_3$	δS_3				X

depths. No comprehensive study has been undertaken to ascertain these costs and it has been suggested that even if such a study was attempted, there would be a considerable degree of uncertainty attached to the results. Thus, whilst one may hypothesize that it is the deeper draft vessels which impose higher dredging costs on the port, there is no substantial information upon which to base the hypothesis.

The considerations in this case raise the question of whether these costs could be deemed to be joint (due to lack of information) to all the traffics. Whilst it is recognised ex-hypothesi that they may not be joint, it may be appropriate as a practical expedience to consider them so. For pricing/traffic acceptance purposes, the implication of this assumption is that the traffic in aggregate will be required to pay. If in turn, the shallow drafted vessels, say, are only willing to make a relatively small contribution to this cost, then this condition could still be met by the deeper draft vessels making a correspondingly larger contribution.

The dredging at the dock entrances presents a problem of jointness across Conservancy and the Docks themselves. If the port dredged solely inside the docks, then it is unlikely that the capacity of the grab hopper dredgers would be changed. This, combined with the observation that a little under 30 per cent of the silt is removed from the entrances suggests that the costs of the dredgers are joint to both the Conservancy and Dock Undertakings. Thus, these costs will be further discussed when considering the Docks.

6.4.5 Surveying

Surveying presents a similar problem to that of dredging in that this service is provided for both Conservancy and the Docks. In the case of surveying however, the factors used in the provision of the service are more easily associated with one or other of these undertakings and thus the problem is less severe.

The 16.5 m catamaran and the Hi-Fix navigation system are used for surveying the main channel. One could argue along similar lines to those of the dredging case and suggest that, in the main-channel, it is the deeper draft vessels which require the surveys. This is unlikely to be the case as the size of the catamaran and the navigation system are determined by the location of the channel and not the traffic. Thus the cost of these two assets are joint to all the traffics.

In the River, it may be possible to save some costs, however due to the indivisibility of the launches and labour these savings are unlikely to be significant. Column 4 of table 6.1 indicates the number of days per annum required to survey the various sections of the Port. Column 5 further shows the cumulative total commencing at Eastham. Now, a hydrographic surveyor spends approximately 200 days per year on the boat surveying and one launch is used for surveying purposes for approximately 150 days per year. Thus from table 6.1 nearly all of the port's traffic would need to be rejected before the cost of one hydrographic surveyor could be saved and all of the traffic excluding Liverpool and Birkenhead would beed to be abandoned in order to save the cost of a survey launch. Thus the labour costs and two launches are joint to all of the traffic with the third launch possibly being joint to the traffic upstream of Birkenhead (although a more rigorous analysis than that suggested above would be required to ascertain the traffics to which this cost is joint).

6.4.6 The Escapable Cost Matrix

In summary, the following facilities would appear to be joint to all of the traffics:

> Port Radar Station; Buoys in the main channel (42 out of a total of 65 bueys); "Vigilant"; most of the buoy store and all of the labour at the store; dredging in the main channel (due to lack of information); catamaran and Hi-Fix navigation system for surveying the main channel; 2 of the three launches for surveying the River and all of the hydrographic surveyors required for main channel and river surveys.

The remaining facilities may be joint to smaller groups of traffic or specific to particular traffics and include:

The buoys in the River, and Garston and Eastham Channels; that part of the buoy store not joint to all of the traffics (joint to Garston and Eastham); one survey launch for surveying the River (joint to all of the traffics excluding Liverpool and Birkenhead).

Thus, the above considerations would suggest firstly that most of these facilities are joint to all of the traffics using the port. Secondly, it has not been possible to associate any of the costs with vessel size and therefore it will only be possible to take area of destination as the traffic characteristic..

Another group of costs which have not been taken into account when considering the facilities are the current factor inputs. This includes items such as the fuel for the launches, catamaran and the "Vigilant" (fuel for the hopper dredgers will be considered under the Dock Undertaking), other consumable items (for example paint for the buoys) and gas for the buoys. Some of these items will tend to be specific to particular areas of destination within the port. For example, the fuel used in surveying the Garston Channel is directly attributable to the traffic proceeding to Garston. In other cases the costs are incurred whilst servicing joint facilities and thus are joint to groups of traffics. It is also conceivable that a further element of jointness occurs with these costs where for example the "Vigilant" lifts two buoys from different areas of the port on the same day, without returning to the buoy store after the first buoy was lifted. In general this problem is not particularly significant and will therefore not be dealt with. If however it was occurring to any significant extent the actual practice of the port would need to be taken into account.

Referring to the geographical configuration of the Port (fig 6.2) and the considerations of the facilities provided under the heading of conservancy it is appropriate to consider the 10 areas separately plus the combinations of areas in order, with a slight adjustment being made for the fork at Garston and Eastham Channels. Table 6.4 sets out the matrix for ascertaining the directly attributable cost in the timeless case, time being introduced by considering the DAC and EC vectors as matrices.

6.5 Identifying Escapable Costs

The identification of escapable cost requires that the port's planning horizon is defined. Having identified the traffics, facilities and this time horizon, the computation of the individual elements of the escapable or directly attributable cost matrices can proceed. This exercise requires that a table (or matrix) is constructed which shows the facilities (including their lives) required to service the expected demand over the planning horizon. In order to demonstrate the methodology, the principles for computing the escapable costs of the traffic proceeding to Garston will be outlined. The procedure for ascertaining these costs for other areas and combinations of areas will be similar to the Garston example. However, a number of issues which are different in nature arise when considering the escapable costs of not accepting the traffic to all areas. These issues will be considered after the Garston case.

Table 6.4 Escapable Cost Matrix for Conservancy

	O	A	B	C	D	E	F	G	H	J	K	AxB	BxC	A↔C	A↔D	A↔E	A↔F	A↔G	A↔H	A↔J	A↔K			
O	1																					DAC_O		EC_O
A	1	1																				DAC_A		EC_A
B	1		1																			DAC_B		EC_B
C	1			1																		DAC_C		EC_C
D	1				1																	DAC_D		EC_D
E	1					1																DAC_E		EC_E
F	1						1															DAC_F		EC_F
G	1							1														DAC_G		EC_G
H	1								1													DAC_H		EC_H
J	1									1												DAC_J		EC_J
K	1										1											DAC_K	=	EC_K
AxB	1	1	1									1										DAC_{AxB}		EC_{AxB}
BxC	1		1	1									1									DAC_{BxC}		EC_{BxC}
A↔C	1	1	1	1								1	1	1								$DAC_{A\leftrightarrow C}$		$EC_{A\leftrightarrow C}$
A↔D	1	1	1	1	1							1	1	1	1							$DAC_{A\leftrightarrow D}$		$EC_{A\leftrightarrow D}$
A↔E	1	1	1	1	1	1						1	1	1	1	1						$DAC_{A\leftrightarrow E}$		$EC_{A\leftrightarrow E}$
A↔F	1	1	1	1	1	1	1					1	1	1	1	1	1					$DAC_{A\leftrightarrow F}$		$EC_{A\leftrightarrow F}$
A↔G	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1				$DAC_{A\leftrightarrow G}$		$EC_{A\leftrightarrow G}$
A↔H	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1			$DAC_{A\leftrightarrow H}$		$EC_{A\leftrightarrow H}$
A↔J	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		$DAC_{A\leftrightarrow J}$		$EC_{A\leftrightarrow J}$
A↔K	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	$DAC_{A\leftrightarrow K}$		$EC_{A\leftrightarrow K}$

6.5.1 Area of Destination - Garston

1. Services and Facilities Provided

The conservancy services and facilities provided for this area include the nine buoys (including flasher units and gas bottles), the maintenance of the buoys, surveying of the bar and surveying of the channel. Table 6.5 lists these items along with the life of the asset and frequency of the maintenance or surveying for an assumed planning horizon of ten years. The port has suggested that all of the buoys have a remaining life of at least twenty years and thus it is unlikely that they will require replacement within any foreseeable planning horizon. Given that this channel is the only one with glass reinforced plastic buoys, any spare buoys of this type should also be included. The buoys are lifted annually for maintenance and to refill the gas bottles. The Bar is surveyed monthly, and the Channel every two months.

2. Factor Inputs

(i) Buoys

The main factor input under this heading is the buoy itself, the gas bottles and the flasher unit. The maintenance of the buoy will however require further factor inputs. At the annual maintenance, the usual procedure is for the "Vigilant" to go out to the buoy, lift and replace it with a buoy prepared for that station then return it to the buoy store. At the store, the buoy is repaired, scraped and painted, the gas bottles recharged and the flasher unit overhauled. Thus, the factor inputs attributable directly to this traffic include: the fuel and any other consumable stores used by the "Vigilant"; the paint for the buoy and any parts required for minor repairs; the gas; and any

Table 6.5(a) Services and Facilities Provided Specifically for Garston

BUOYS / YEARS	1	2	3	4	5	6	7	8	9	10	11	12
G1												
Maintenance												
G2												
Maintenance												
G3												
Maintenance												
G4												
Maintenance												
G5												
Maintenance												
G6												
Maintenance												

Table 6.5(b) Services and Facilities Provided Specifically for Garston

YEARS	1	2	3	4	5	6	7	8	9	10	11	12
BUOYS (cont'd)												
G7												
Maintenance												
G9												
Maintenance												
Spare Buoy												
Spare Buoy												
BUOY STORE												
Spare Flasher Units												
Spare Gas Bottles												
SURVEYS												
Garston Bar												
Garston Channel												

consumable stores or parts used in overhauling or repairing the flasher unit. The parts and consumable stores used in major repairs of the buoys or flasher units are also to be included as factor inputs, however, the period of time to which they are attributable will usually be greater than the annual maintenance.

In this case the spare GRP buoys are included as they are not interchangeable with other buoys. In the more general case where they are interchangeable, the port will have to investigate whether the holding of spare buoys could be reduced if the traffic under consideration was not accepted. If this was possible then the saving is attributable to that traffic.

(ii) Buoy Store

The buoy store itself is included where there are cost savings in reducing the capacity of the store if the traffic was not accepted. Similarly, it may be possible to reduce the labour force necessary to paint, scrape and repair the buoys. The spare flasher units and gas bottles being treated in a similar manner to the general case of spare buoys.

(iii) Surveying

The discussion above has indicated that the only factor input which is even slightly significant in the surveying of this area is the fuel cost and other consumables of the launch.

3. Valuation of Factor Inputs

The valuation process follows the procedure outlined in chapter 5.

(i) Buoys

If the buoys will be replaced at the end of their economic lives (that is, if consumers are willing to pay for the replacement of the buoys), then the escapable cost is the present value of the loss in value of the asset. Thus, for each buoy (including the spare buoys);

$$EC = V(0) - \frac{V(10)}{(1 + r)^{10}}$$

where: EC = escapable cost

V(i) = valuation of asset in year i of the time horizon

and this cost is attributable to the Garston traffic over the ten year planning horizon. If the buoys will not be replaced because the Garston traffic is not willing to pay, then the cost floor for pricing purposes is the loss in opportunity cost over the planning horizon. Thus,

$$EC = OC(0) - \frac{OC(10)}{(1 + r)^{10}}$$

where: EC = escapable cost

OC(i) = opportunity cost in year i.

The actual magnitude of the opportunity cost of the buoys is difficult to obtain as the only experience the port has of selling buoys is for scrap metal (a first class buoy containing approximately 10 tonnes of scrap iron). If the buoys were interchangeable then by not using them in the Garston Channel, there may be cost savings resulting from the port being able to postpone replacement of buoys in other channels.

The escapable costs of the maintenance of the buoys includes the fuel and other consumables required by the "Vigilant" to lift and reposition the buoy, and the paint, parts and minor repairs to the buoy. These are all current factor inputs and are therefore valued at their market price. These expenditures are however similar to the expenditure on a capital asset which has a life of one year because they are undertaken so that the buoy can be used for a year. Thus (assuming discrete time) they are attributable to the year in which the expenditure is incurred. In the case of major repairs, the life of the asset is usually prolonged for more than a year and thus the escapable costs of these repairs are attributable to a correspondingly longer period of time.

(ii) Buoy Store

If it is possible to reduce the capacity of the buoy store by not accepting the Garston traffic then there is an incremental cost which is attributable to this traffic. Assuming that the life of the store exceeds the planning horizon, then this can be computed by valuing the store at the beginning and end of the horizon using the replacement cost with and without the Garston traffic. Thus,

$$
\begin{aligned}
EC_G &= \left[V_L(0) - V_S(0)\right] - \left[\frac{(V_L(10) - V_S(10)}{(1+r)^{10}}\right] \\
&= \left[V_L(0) - \frac{V_S(10)}{(1+r)^{10}}\right] - \left[V_S(0) - \frac{V_S(10)}{(1+r)^{10}}\right] \\
&= EC_L - EC_S
\end{aligned}
$$

where: EC_G = escapable cost, Garston traffic.

EC_L = escapable cost, large capacity (that is, with Garston).

EC_S = escapable cost, small capacity (that is, without Garston).

$V_L(i)$ = valuation in year i, large capacity.

$V_S(i)$ = valuation in year i, small capacity.

and EC_G is attributable to the Garston traffic over the planning horizon.

If the labour necessary to paint, scrape and repair the buoys could be reduced by not accepting the traffic to Garston then this cost saving should also be incorporated into the analysis.

The spare flasher units and gas bottles are treated in a similar manner to the buoys.

(iii) Surveying

The current factor inputs used in surveying the Channel and Bar are valued at their market prices. They are attributable to the time horizon over which they are incurred, that is, monthly to the Bar and two monthly to the Channel.

6.5.2 Traffic to All Areas

In considering the escapable cost of accepting no traffic, dredging presents a number of different issues. A channel in which capital dredging has been undertaken represents an asset which is permanent in nature and thus by definition will not require replacement. In the ex-ante case, as long as the traffic is willing to pay then the investment may be undertaken. Ex-post the opportunity cost approaches zero and it is doubtful whether any attempt to value the asset from the cost side would yield meaningful results. Thus, whilst the asset may be of value to port users the port may not be able to obtain an upper limit to the asset's value from the cost side. In this case it would therefore appear that the port authority will have to value the asset at its opportunity cost then reassess this position when considering the traffic's willingness to pay.

The cost of contract dredging the main channel has three aspects: the contract cost of twelve weeks' work per annum of the standard dredger over the six year life of the contract; the incremental cost of any dredging in excess of the basic case; and the cost of reneging on the contract. The opportunity cost in the basic case is equal to the present value of contract payments for the standard dredger over the remaining life of the contract less the present value of a settlement which would allow the port to withdraw from the contract. This amount is attributable to the traffic over the remaining life of the contract. The incremental cost of any dredging in excess of the basic case is also escapable and therefore attributable. The period of time to which it is attributable is however not always well defined. If it is undertaken specifically for the traffic in a particular year then it is attributable to that traffic. If however it is undertaken so that dredging can be reduced for a number of years then this cost is correspondingly attributable to the traffic in these years. If the contract will be renewed, then the present value of the contract is attributable to the traffic over the life of the contract.

6.6. Allocation of Costs

The overall requirement for the port to continue supplying a particular facility is that the present value of the consumer's willingness to pay over the planning horizon is at least equal to the present value of the escapable cost over this time horizon. Thus from the escapable cost matrix (Table 6.4) the present value of the DAC's can be ascertained by inserting the EC's in the escapable cost vector. Alternatively it may be possible in this case to ascertain the DAC's without computing the intermediate EC's. For example, in the case of Garston, the escapable costs are also directly attributable as this is a single traffic. It has however been suggested that some costs are attributable to particular temporal subsets of the planning horizon and that the user's willingness to pay may fluctuate over time. Thus for the purposes of providing data for the pricing of conservancy services, the DAC's can be left as a matrix (table). The port authority will then be required to match this matrix with each traffic's willingness to pay over time.

6.7 Summary and Conclusions

This chapter has attempted to apply the methodology outlined in the previous chapter for measuring marginal costs in the conservancy case. The approach adopted in the chapter has been: to describe the services and facilities; to identify the traffic by similar characteristics then to identify the facilities provided for the traffic; and to identify and attribute the escapable costs.

Section 6.3 identified the similar characteristics of the traffic as being area of destination and size (any other characteristic being highly correlated with these two). The Port was consequently divided into ten areas of destination. Even this division led to a large number of possible combinations of traffic and thus methods by which this number could be reduced were discussed. A considerable reduction in the number of traffics was achieved by taking into account the particular case and by considering size as a subset of area of destination.

One important conclusion of the identification of the facilities provided for the traffic (section 6.4) was that the majority of the facilities provided were joint to all of the traffic. Whilst a more detailed study may reveal that some of these facilities are joint to less than all of the traffic, it is not believed that such a study would significantly alter this conclusion. One of the observations which led to this conclusion was related to an hypothesized relationship between vessel size and dredging in the main channel. It was suggested that (at the Port of Liverpool) even if an investigation was undertaken to test this hypothesis, the degree of uncertainty associated with its results would severely limit the validity of any conclusions drawn from it. It was therefore decided to reject vessel size as a possible cost characteristic for traffic identification and to consider these dredging costs to be joint to all of the traffic. (This however does not exclude the use of vessel size when considering the demand side and the benefits accruing to larger vessels).

Section 6.5 considered the identification of escapable costs and also prempted the discussion of the allocation of the costs (Section 6.6). For illustrative purposes, the principles for ascertaining the escapable costs of the traffic proceeding to Garston were outlined. This outline was followed by a discussion of a number of issues which may arise when undertaking the same exercise for all traffic. In particular it was suggested that attempting to value a channel (where capital dredging had been undertaken) on the cost side, would not yield meaningful results. The solution adopted for this problem was to value the asset at its opportunity cost and to incorporate the consumers' evaluation of the asset when considering their willingness to pay. Finally, section 6.6 suggested that the directly attributable costs are left in a matrix or tabular form so that the data can be matched with the traffic's willingness to pay.

Notes

[1] Schiller, P.,"Methods of Allocating Classes of Consumers or Load the Demand-Related Portion of the Standing Costs of Electricity Supply.", The British Electrical and Allied Industries Research Association, Technical Report K/T106, 1943.

CHAPTER 7

MEASURING ESCAPABLE COSTS - DOCKS

7.1 Introduction

The durability and spatially fixed nature of the port's assets are particularly noticeable in the Docks case. The implications of these characteristics are that opportunity costs may be low and replacement costs difficult to ascertain. This chapter will outline the problems that may arise under these conditions and will suggest some possible solutions. For the purposes of exposition and given that the port can trade-off the facilities provided for goods, the docks will be separated according to these facilities, that is, the dock entrance to the quay wall (inclusive) and the berth to the dock gate (inclusive).

7.2 Services and Facilities - Dock Entrance to the Quaywall

7.2.1 The Dock Systems

There has been in recent years a considerable contraction in the area over which the port handles cargo in the Liverpool North Dock System (fig 7.1). The M.D.H.C. Profitability Study - 1980 (hereinafter referred to as "the MDHC Study") suggests that there are four main reasons for this decline, namely;

(i) the deepening trade recession which is particularly hitting deep sea exports.

(ii) the change in U.K. trading patterns with growth in trade with the E.E.C. favouring East and South coast ports.

(iii) the constraints imposed by the National Dock Labour Board Scheme which inhibits the ability to balance manpower.

(iv) increases in fuel costs making diversions from Northern European routes extremely costly.

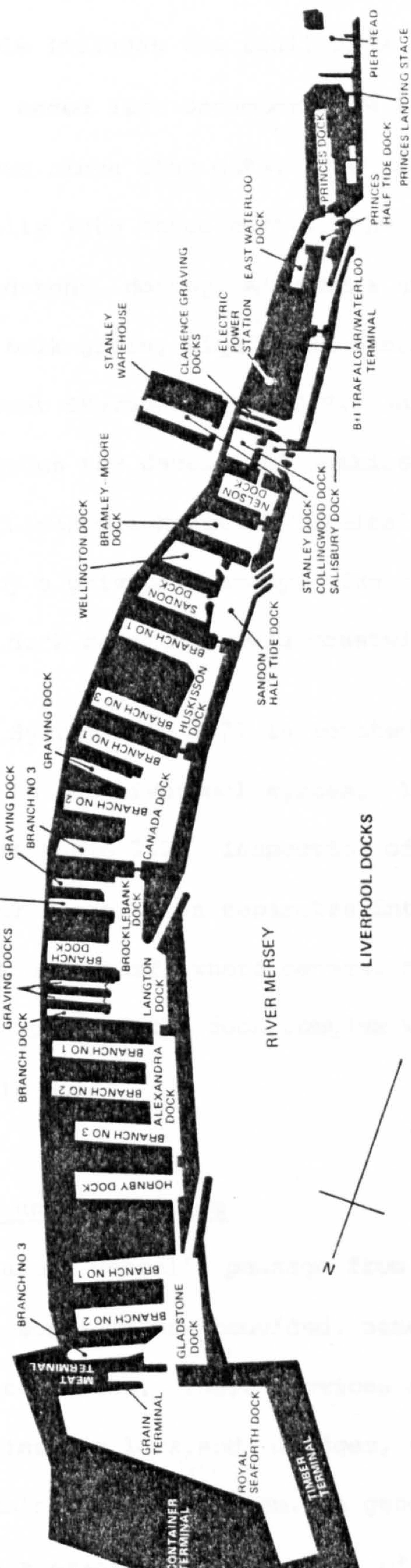


fig 7.1 Liverpool North Docks

The scale of operation is indicated by the figures contained in table 7.1. This table includes the facilities at, and the tonnages handled for the year ended 31st December 1979 less the berth's known to have been withdrawn since that date. The table suggests that the docks fall commercially into three parts. The first part consists of the Seaforth, Gladstone, Hornby, Alexandra and Langton Docks where containers, timber, bulk grain, liquid and general cargo are handled by M.D.H.C., West Coast Stevedoring (W.C.S.) and private operators. The second part includes the Canada and Huskisson Docks where general cargo is handled by Liverpool Maritime Terminals (L.M.T.) and bulk molasses and sugar by a private company. The third part is the Waterloo end of the dock complex, where coastwise traffic is handled.

The Birkenhead Dock System (fig 7.2) is located on the opposite side of the River Mersey to the Liverpool system. The scale of the operation is shown in table 7.2. Inspection of this table indicates that the cargo transfer operation separates into broadly two areas, namely Vittoria Dock and Wharf, where general cargo is handled by the M.D.H.C. and the rest of the dock complex where bulk commodities are handled by single users.

7.2.2 The Services and Facilities

In order to facilitate a vessel's passage from the river entrance to the berth, two main services are provided, namely, a lock and a known water depth within the docks. These services require that the port operates and maintains the lock, and dredges, surveys and maintains the water level within the dock system. A general description of the docks including the average annual quantity of silt removed in the years 1979-80, and the frequency and time taken to survey each dock

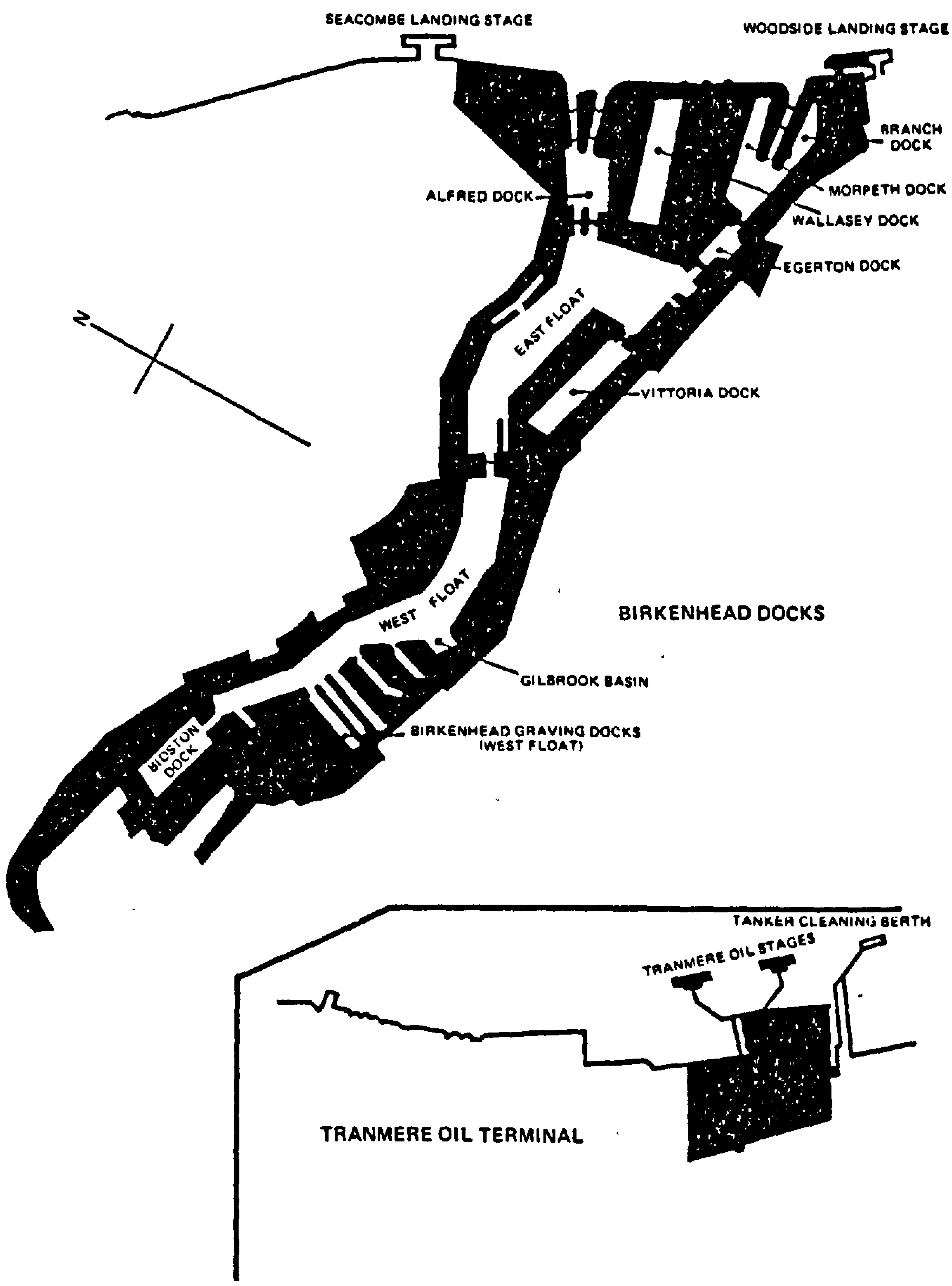


fig 7.2 Birkenhead Docks

is contained in tables 7.1 and 7.2.

The level of Mean High Water Springs at the Port is 9.3 m above chart datum, the corresponding figure for Mean High Water Neaps being 7.4 m. Thus, given the sill levels in tables 7.1 and 7.2 (which represent the extreme dimensions) the maximum drafts for vessels entering the port at Neaps and Springs are: Gladstone 13.0 to 14.9 m; Langton 12.7 to 14.6 m; Waterloo 12.2 to 14.1 m; North Alfred 9.4 to 11.3 m and South Alfred 10.6 to 12.5 m. The extreme width of the Langton Extrance is 39.6 m and the extreme lengths and widths of the other entrance locks are respectively: Gladstone 326.1 m x 39.6 m; Waterloo 137.1 m x 19.9 m; North Alfred 146.3 m x 30.3 m and South Alfred 182.8 m x 24.3 m. Within the Liverpool Dock System, access to the working areas between Seaforth and Huskisson Docks can be gained by all but the largest vessels through either the Gladstone or Langton Entrances. (The Gladstone-Hornby Lock and the Hornby Dock having a slight bend which prohibits passage of these larger vessels).

The water in the Liverpool and Birkenhead Docks is impounded at a level of approximately 9.7 m and 10.0 m above chart datum, respectively, and the sill depths are the depth below this impounded level. The widths of the various passages or entrances in the system are also shown in tables 7.1 and 7.2.

A high level of dredging is undertaken by the Port within the docks. The previous chapter indicated that two Grab Hopper Dredgers perform this function and that all of the costs of the dredgers including dredging at the entrances will be considered under the heading of the Docks. The two dredgers are employed continuously over the year apart from a six week period in July/August when one only is operational

Table 7.1 Liverpool North Docks - Description, Dredging and Surveying

Dock or Lock	Description				Dredging		Surveying		
	Pos^{n} & Width of passage or entrance (m)	Sill depth (m)	Water area (ha)	Linear Quayage (km)	Silt removed (t)	Silt "Depth" (m)	Frequency New (Old) (weeks)	Days per Survey	Days Surveying per annum
<u>River Entrance</u>									
Gladstone					166,874		2	1	
Langton					275,700		2	1	
Waterloo					48,175		{ 2 2 mths	½ 1	
<u>Docks</u>									
Royal Seaforth West	} S 39.62	15.3	34.8	2.713			5 (8)	2	20.8
Royal Seaforth East					} 409,971	0.88	5 (8)	1	10.4
Royal Seaforth Grain	W 44.19	-	0.9	0.448			10 (8)	½	2.6
Gladstone Dock	-	-	10.0	0.772	52,238	0.40	5 (4)	½	5.2
Gladstone Branch No. 3	W 36.58	13.8	1.4	0.535	3,825	0.21	5 (4)	¼	2.6
Gladstone Branch No. 2	-	-	4.8	0.864	6,575	0.11	5 (4)	¼	2.6
Gladstone Branch No. 1	-	-	5.3	0.954	7,764	0.11	5 (4)	¼	2.6
Gladstone Dock (326.14 m)	S 39.62	15.3	1.3	0.722	650	0.04	5 (4)	¼	2.6
Gladstone-Hornby Lock	27.20	12.2	0.6	0.427	-		5 (4)	¼	2.6
Hornby Dock	S 27.43	9.8	6.8	1.335	8,725	0.10	5 (4)	½	5.2
Hornby Lock	-	-	-	-	-				

Table 7.1 (continued)

Dock or Lock	Description				Dredging		Surveying		
	Pos$^{\underline{n}}$ & Width of passage or entrance (m)	Sill depth (m)	Water area (ha)	Linear Quayage (km)	Silt removed (t)	Silt "Depth" (m)	Frequency New (Old) (weeks)	Days per Survey	Days Surveying per annum
Alexandra Dock	S 27.36	12.2	7.2	0.977	25,450	0.27	5 (4)	½	5.2
Alexandra No. 3 Branch	-	-	3.1	0.774	4,575	0.11	5 (4)	¼	2.6
Alexandra No. 2 Branch	-	-	3.9	0.936	4,075	0.08	5 (4)	¼	2.6
Alexandra No. 1 Branch	-	-	3.7	0.899	1,050	0.02	5 (4)	¼	2.6
Langton Dock	-	-	7.5	0.880	88,640	0.91	5 (4)	½	5.2
Langton Branch	W 18.29	9.6	1.2	0.613	1,050	0.07	- (8)	¼	
Langton Lock	S 39.62	15.0	1.0	0.566	26,279	2.02	5 (4)	¼	2.6
Brocklebank Dock	S 39.62	12.2	5.2	0.648	38,540	0.57	5 (4)	½	5.2
Brocklebank Branch	-	-	3.8	0.745	29,429	0.60	5 (4)	½	5.2
Carriers Dock	-	-	1.2	0.591	3,200	0.21	10 (8)	¼	1.3
Canada Dock	S 27.43	10.3	10.8	1.110	159,851	1.14	5 (2)	½	5.2
Canada No. 3 Branch	-	-	3.0	0.733	26,350	0.68	5 (2)	¼	2.6
Canada No. 2 Branch	-	-	2.6	0.669	33,600	0.99	5 (2)	¼	2.6
Canada No. 1 Branch	-	-	3.0	0.753	57,355	1.47	5 (2)	¼	2.6
Huskisson Dock	S 27.36	12.2	5.3	0.681	5,387	0.08	5 (4)	½	5.2
Huskisson No. 3 Branch	-	-	3.3	0.905	7,875	0.18	5 (4)	¼	2.6
Huskisson No. 1 Branch	-	-	3.7	0.899	1,500	0.03	5 (4)	¼	2.6
Sandon Half-tide	-	-	5.7	1.013	NIL		10 (2)	½	2.6

Table 7.1 (continued)

Dock or Lock	Description				Dredging		Surveying		
	Pos$^{\underline{n}}$ & Width of passage or entrance (m)	Sill depth (m)	Water area (h)	Linear Quayage (km)	Silt removed (t)	Silt "Depth" (m)	Frequency New (Old) (weeks)	Days per Survey	Days Surveying per annum
Wellington Dock	W 21.36	8.0	3.2	0.750	NIL		10 (8)	½	2.6
Bramley-Moore	N 18.29	7.9	3.9	0.855	NIL		10 (4)	½	2.6
	S 18.29	7.9							
Nelson Dock	S 18.21	8.0	3.2	0.734	NIL		10 (4)	½	2.6
Salisbury	-	-	1.4	0.371	2,025	0.11	10 (4)	¼	1.3
Collingwood	W 18.21	8.0	2.0	0.505	NIL		10 (4)	¼	1.3
Stanley Dock	14.78	7.7	1.5	0.514	NIL		As req$^{\underline{d}}$	¼	
Stanley Lock	5.41	6.1	-	-	NIL		-	-	
Trafalgar Dock	N 18.29	8.6	3.5	1.243	8,800	0.19	5 (2)	½	5.2
	S 21.34	-							
West Waterloo Dock	S 18.29	8.5	2.7	0.849	33,975	0.97	5 (2)	¼	2.6
East Waterloo Dock	S 18.29	8.5	1.1	0.463	-		As req$^{\underline{d}}$	¼	
Waterloo Lock (137.16 m)	S 19.96	14.5	0.3	0.319	26,938	6.91	5 (2)	¼	2.6
Princes Half-tide	-	-	1.9	0.397	-		5 (4)	¼	2.6
Princes Dock	N 18.29	8.5	3.5	1.218	675	0.01	5 (4)	¼	2.6
Liverpool Total					1,076,367				141.7

Source: MDHC.

Table 7.2 Birkenhead Docks - Description, Dredging and Surveying

Dock or Lock	Description				Dredging		Surveying		
	Pos^n & Width of passage or entrance (m)	Sill depth (m)	Water area (ha)	Linear Quayage (km)	Silt removed (t)	Silt "Depth" (m)	Frequency New (Old) (weeks)	Days per Survey	Days Surveying per annum
Alfred Lock (146.31 m)	N 30.33	12.0	0.4	0.328	16,545	3.18	5 (2) (both Alfred Locks)	¼	2.6
Alfred Lock (182.88 m)	S 24.38	13.1	0.4	0.421	2,675	0.51			
Alfred Dock	-	-	3.5	0.467	43,500	0.96	5 (2)	¾	7.8
East Float Passage	N 30.48	9.2	-	0.221	-				
	S 24.3	11.0	-	0.196	-				
Morpeth Dock	W 21.26	8.0	1.5	0.535	-		As req^d	½	
Morpeth Branch	W 25.83	10.7	5.2	1.153	-		As req^d		
Egerton Dock	W 21.26	8.7	4.9	1.401	-		As req^d	¼	
British Rail Basin	-	-	1.6	0.644	-				
Corn Warehouses Dock	S 9.14	6.4	0.4	0.507	-				
East Float	-	-	23.8	2.926	98,590	0.32	5 (4)	2	20.8
Vittoria Dock	E 30.48	9.8	5.0	1.188	16,725	0.26	5 (4)	½	5.2
Duke Street Passage	30.10	9.4	-	-	-				
West Float	-	-	20.8	3.323	19,615	0.07	5 (4)	1½	15.6

Table 7.2 (Continued)

Dock or Lock	Description				Dredging		Surveying		
	Pos$^{\underline{n}}$ & Width of passage or entrance (m)	Sill depth (m)	Water area (ha)	Linear Quayage (km)	Silt Removed (t)	Silt "Depth" (m)	Frequency New (Old) (weeks)	Days per Survey	Days Surveying per annum
Basins nr. Canada Works	W	-	0.6	0.497	-				
	E	-	0.4	0.357	-				
West Float Passage	30.48	9.2	-	-	-				
Bidston Dock	-	-	4.3	0.793	NIL		5 (4)	½	5.2
Total Birkenhead					197,650				57.2

Source: M.D.H.C.

(the other being drydocked). Column 6 of tables 7.1 and 7.2 shows that the annual average tonnage of silt removed from both Liverpool and Birkenhead Docks was just over 1¼ million tonnes. The same column further indicates the tonnages removed from each dock. In an attempt to standardise these tonnages, given the different water areas of the separate docks, a "silt depth" has been calculated (column 7) which assumes an average silt density of 1.3 tonnes per cubic metre (where "silt depth" equals tonnage divided by the product of water area and density).

The surveying of the docks is performed in a ten week cycle. In this period of time, all of the docks are surveyed, with most areas being surveyed twice. Two 18 foot fibreglass boats are used (one located in Liverpool and the other in Birkenhead) with a crew of three including a hydrographic surveyor. During the cycle, the Liverpool Docks are surveyed for approximately a month, then the crew moves over to Birkenhead to survey these docks for two weeks. Tables 7.1 and 7,2 show the frequency with which each dock and entrance is surveyed along with the approximate time spent on each dock per survey and per annum (Note that the surveying at the dock entrances was considered under conservancy).

7.3 Services and Facilities - Berth to the Dock Gate

7.3.1 The Royal Seaforth Dock

The Royal Seaforth Dock was officially opened in July 1973 and cost approximately £50 m. The total land area reclaimed from the River Mersey for the site was 200 hectares, although some of this area would require further development to make it useable. Within the complex, there are a number of Terminals which handle specific cargoes, including containers, bulk grain, timber and forest products, vehicles and general. Table 7.3 indicates the berths used for these purposes and the tonnages handled during 1979.

The Container Terminal is located on the northern side of the Dock and has a continuous quay length of 1,000 metres. The quay is nominally divided into 4 berths. There are 5 gantry cranes (2 x 35 ton and 3 x 40 ton) on the quay and 30 straddle carriers used for moving containers within the Terminal. The stacking area is 24 hectares and can accommodate 13,000 x 20 ft containers. Container movements from arrival to loading, and discharge to departure from the port are computer controlled by the "Container Information Control System" (CONICS). This system can control up to 1,300 containers at any one time. Behind the stacking area there are two groupage sheds (152 m x 46 m each), providing facilities for the stuffing and unstuffing of containers. In addition to these facilities the terminal has two RO/RO ramps, a heavy lift quay strengthened to 1,000 tonnes and additional parking facilities for trailers and export cars.

The Timber Terminal is located on the western side of the Dock and has a continuous quay length of 427 metres. The quay is nominally divided into 3 berths. There are 4 x 10 ton cranes on the quay and an unspecified number of fork-lifts for moving the timber to the holding area and onto road transport. The stacking area adjacent to the quay has an area of 6 hectares and there is a back-up area of 7 hectares. Behind the stacking area, there is a transit shed (97 m x 53 m).

The Grain Terminal is located on the southern side of the Dock. The facilities provided for ships consist of a single berth in the main dock capable of discharging vessels up to 75,000 d.w.t. and a 183 m x 44 m transhipment dock for loading barges and small coasters. The discharging facility consists of two marine towers which are each fitted with a marine leg rated at 1,000 tons per hour, two pneumatic pipes (for cleaning-up and, whilst not encouraged by the Port, discharging vessels less than 8,500 d.w.t.) rated at 250 tons per hour each and lifting gear for a clean-up vehicle. From the marine towers, the grain is fed by various transfer systems, conveyor belts and weighing machines to the workhouse (located on the top of the grain silos). The grain can then be routed to either the lorry loading house or to the silos. In the lorry loading house, there are 36 x 200 ton bins which can load up to 6 lorries simultaneously. The total silo capacity is 100,000 tons, consisting of 81 x 1,000 ton bins with the interspaces taking up the balance of the storage. From the silo, the grain can be distributed either directly to the adjacent mill sites or to the transhipment dock. Vessels are loaded in this Dock via six spouts fed from 12 transhipment bins, each of 300 tons capacity.

The Meat Terminal is located next to the Grain Terminal and consists of a single berth. This berth is operated by West Coast Stevedoring (W.C.S.). The facilities available include an undercover discharging operation with five mobile conveyors which transport the meat from the ship's hold to the shed. In the shed, the meat can be palletised and placed in cold storage and loaded onto road transport (there being sufficient capacity to load 52 vans simultaneously).

7.3.2 The Liverpool Dock System

The Liverpool Dock System,has a number of specialist bulk handling facilities. Table 7.3 includes the molasses and vegetable oil berths in Gladstone; the sugar berth in Alexandra; the molasses berths in Canada and the sugar berth in Huskisson. For smaller vessels, the bulk facilities include the bulk ores and scrap berths in Bramley Moore; the bulk wines and spirits in South Nelson and the bulk oils in Collingwood and Salisbury Docks.

The general cargo berths at Liverpool Docks are also listed in table 7.3. This table includes the cranes located on each quay. "Ports of The World, 1980" [1] lists the total crane capacity of the Port (including Birkenhead) as; three heavy lift floating cranes of capacity up to 200 tons; "180 quay cranes; one 50-ton electric crane; 240 mobile cranes including one at 40 tons, one at 35 tons, one at 30 tons; 360 fork-lift trucks". In the case of the quay cranes the total available on working berths is considerably less than the 180, table 7.3 listing 71 cranes of 6 tons or less at these berths. (Although in a number of cases information concerning the number of cranes at the berth was "not available"). Most of the general cargo berths have transit shed facilities.

The Docks are surrounded by a perimeter fence which encloses the customs area and provides security for the vessels and goods. There are a number of gates in the fence whereby access may be obtained from the public road (Regent Road) to the Docks. Generally, an entrance gate is associated with traffic proceeding to a particular dock. Within the Docks, there is a system of roads allowing vehicular access to each berth. In the case of the berths on the western side

Table 7.3 Liverpool North Docks - Traffic and Facilities

Berth or Berth Group	No. of Berths	Tonnage Handled	Commodity	Utilization %	Cranes etc.	Stevedoring company	Single or Various users/trades
S1 Seaforth	1	1,641,600	Bulk Grain	72	2 x Marine Legs	M.D.H.C.	Grain trade
S2 Seaforth	1	88,000	General & Combi.	63	1 x 40 T	W.C.S.	Various users
S3/4/5/6 Seaforth	4	1,312,088	Containers and Vehicles	49	5 x Gantry Cranes	M.D.H.C.	Container RO/RO & Groupage
S7 Seaforth	1	67,712	General & Combi.	47	3 x 2 T	W.C.S.	Single user
S8/9/10 Seaforth	3	212,764	Timber and Forest Products	20	4 x 10 T	M.D.H.C.	Timber trade
S2 Gladstone	2	64,895	General	25	3 x 5 T	M.D.H.C.	Primarily single user
N1 Gladstone	2	62,452	General	31	3 x 5 T	M.D.H.C.	(Primarily single user)
S1 Gladstone	2	87,152	General	26	6 x 5 T, 3 x 3T	M.D.H.C.	Contracted to single user
N2 Gladstone	2	89,936	General and Molasses	26	NONE	W.C.S.	Part Molasses trade
N3 Gladstone	1	72,922	General and bulk vegetable oil	42	NONE	W.C.S.	Single user
W Gladstone	1	40,733	Timber	18	NONE	M.D.H.C.	Timber trade
NW Hornby	1	33,685	General and Tomato	23	5 x 6 T, 1 x 32 T	M.D.H.C.	Part single user
NE Hornby	-	-	Coastwise, I.o.M.	-	-	Ireman	Single trade RO/RO

Table 7.3 (Continued)

Berth or Berth Group	No. of Berths	Tonnage Handled	Commodity	Utilization %	Cranes etc.	Stevedoring Company	Single or Various users/trades
W Alexandra	1	87,119	Coastwise Ireland	-	-	-	Single trade RO/RO
N1 Alexandra	2	16,723	-	10	-	M.D.H.C.	Various
N2 Alexandra	2	66,070	General and cold store	22	NONE	W.C.S.	W. Single trade E. Cold store
N3 Alexandra	2	81,036	General	26	8 x 2 T	M.D.H.C.	Various users
S1 Alexandra	2	19,729	General	12	-	M.D.H.C. & others	Various users
S2 Alexandra	2	17,035	Timber & vehicles	8	NONE	M.D.H.C.	Port timber trade
SE2 Alexandra	1	123,310	Sugar	54	2 Grab cranes	Sugar company	Single user
W Langton	2	102,319	General	30	2 x 5 T, 4 x 3 T	M.D.H.C.	Single user/trade
S Brocklebank (Branch Dock)	1	12,240	General	3	-	M.D.H.C.	Various users
N3 Canada	1/2	89,751	General & Combi.	19	NONE	L.M.T.	Used as one berth for combi vessels
S1 Canada	2	198,659	Molasses	11	-	Molasses company	Molasses trade
S3 Huskisson	2	168,269	General	39	8 x 3 T, 2 x 5 T	L.M.T.	} Single trade
N1 Huskisson	2	125,392	General	35	8 x 3 T, 2 x 5 T	L.M.T.	}

Table 7.3 (Continued)

Berth or Berth Group	No. of Berths	Tonnage Handled	Commodity	Utilization %	Cranes etc.	Stevedoring company	Single or various users/trades
N3 Huskisson	2	259,498	Sugar	32	8 Grab cranes	Sugar company	Single user
Bramley Moor	2	70,375	Bulk ores/Scrap	24	2 x 5 T	Private company	Single user
South Nelson	1	2,807	Bulk wines & spirits	1	-	M.D.H.C.	Single trade
Collingwood/ Salisbury Docks	2	28,620	Bulk oil	5	NONE	Private company	Single user
E Trafalgar	-	-	Coastwise - Ireland	-	-	-	RO/RO ferry terminal
E Waterloo	1	7,531	Grain	6	NONE	Private company	Single user

Note: $\text{Utilization} = \frac{\text{Ship Days Worked}}{\text{Number of Berths x 365}} \times 100$

Source: M.D.H.C.

of the docks a number of opening bridges are required to gain access. These bridges are located over the passages between Hornby and Alexandra, Alexandra and Langton, Brocklebank and Canada and Canada and Huskisson Docks.

In addition to the roads, there is the surfacing of the stacking areas at Seaforth and the quays in general. Some sections of the Port's berths have also been specially strengthened to accommodate heavy lifts including Seaforth (S6), East Gladstone 1 and 2, Alexandra Knuckle 1/2 and 2/3, East Canada 1, 2 and 3, North Canada 3 and Canada Return Berths.

The maintenance of the facilities in the Port is undertaken by the Chief Engineer's Department. The main items of maintenance including roads, quays, river walls, sheds, hydraulic machinery, electrical machinery, cranes, canteens, pontoons, caissons, bridges, dock gates, boundary walls and fences.

The total labour employed by the M.D.H.C. in January 1980 was 6,523. This comprised 992 salaried staff, 2,271 weekly paid staff and 3,260 Registered Dock Workers. The Chief Engineer's Department and the Plant and Equipment Section of the Cargo Operations Division currently account for 42 per cent of all the salaried and weekly staff employed.

7.3.3 The Birkenhead Docks

Table 7.4 lists the main facilities and their usage at the Birkenhead Docks during 1979. From the table, it can be seen that the general cargo operations in the Docks are confined to the Vittoria Docks and Wharf systems. There are 12 x 6 ton cranes on the Wharf, and it is

Table 7.4 Birkenhead Docks - Traffic and Facilities

Berth or Berth Group	No. of Berths	Tonnage Handled	Commodity	Utilization %	Cranes etc.	Stevedoring company	Single or various users/trades
S Vittoria	3	145,876	General	19	-	M.D.H.C.	2 Berths single user 1 Berth various
Vittoria Whf	4	185,061	General	30	12 x 6 T	M.D.H.C.	1 & 2 Single trade 3 & 4 Single trade
S Bidston	1	14,761	RO/RO Cars	10	-	M.D.H.C.	Single user
N Alfred	1	30,787	Bulk liquids	11	-	Private company	Single user
Tower Warehouses	2	225,736	Bulk grain	28	2 Grain elevators	Private company	Single user
Buchanan's Mill	1	20,293	Bulk grain	8	2 Grain elevators	Private company	Single user
Esparto Quay	1	2,156	Heavy lifts	3	NONE	-	Various users
E Lewis Quay	1	105,250	Bulk liquids	26	NONE	Private companies	Two users
Cheshire Quay	1	10,139	Bulk liquids	5	-	Private company	Single user
Rea's Cavendish/ Duke St. Wharves	2	568,973	Bulk ores and coal	39	2 x 10 T, 4 x 7½T	Private company	Single user

Table 7.4 (continued)

Berth or Berth Group	No. of Berths	Tonnage Handled	Commodity	Utilization %	Cranes etc.	Stevedoring company	Single or various users/trades
Ocean Mills	2	38,053	Bulk grain	6	2 Grain elevators	Private companies	Two users
Ilchester Wharf	1	30,248	Mineral Oil	8	NONE	Private company	Single user
North Bidston	2	1,180,106	Bulk ore and coal	32	3 Gantry cranes	Private company	Single user

Note: $\text{Utilization} = \frac{\text{Ship Days Worked}}{\text{Number of berths x 365}} \times 100$

Source: M.D.H.C.

believed that there are at least 7 cranes on West Vittoria quay. Both areas have extensive transit shed facilities.

The balance of the dock facilities are mainly for handling bulk commodities and are leased by single users or operators. Heavy lift facilities are available at Esparto Quay and West Vittoria.

The remainder of the facilities have been either included with, or are similar to those available at Liverpool. The figures for total crane and fork-lift capacity incorporated Birkenhead and the maintenance functions of the Chief Engineer's Department extends to this Dock system.

7.4 <u>The Port's Technical Efficiency</u>

The methodology developed in Chapter 5 suggested that the first escapable cost to be identified is that of not rejecting any traffic. The magnitude of this cost giving an indication of the port's technical efficiency, that is, the extent to which the current output is being produced at its least cost. If it is likely that this cost will be significant then it is also probable that changes in operating procedures and plant utilization are advisable. This in turn may affect any relationship which may exist between costs, facilities and output and consequently the identification of traffic by the facilities provided. In the case of the Port of Liverpool, one of the objectives of the M.D.H.C. Study was:

> "To determine the physical requirements of the Port that will minimise capital investment and operating costs whilst still maintaining the port's competitive position and sustaining the Dock related busineses which provide valuable revenues."

Thus, such an investigation represents an exercise similar in spirit to that of asking the escapable cost of not rejecting any traffic.

The recommendations of the Study include significant changes in current operating procedures and berth usage. Thus a brief outline of the main recommendations will be considered before discussing the relationship between traffics, facilities and characteristics.

The main recommendation of the Study is, with the exception of the L.M.T. and bulktraffics, a further concentration of the principle cargo handling activities into the Royal Seaforth, Gladstone and Vittoria Docks. The L.M.T. operations in Canada and Huskisson Docks are to be continued pending the port being able to offer alternative faciliites in one of the above docks. By postponining any decision regarding this L.M.T. traffic, the Port also maintains a degree of flexibility.as the capacity would be available if there was an upturn in trade. This contraction would also include withdrawal of all operations from the west side berths in Liverpool, as and when this becomes practical. The main reason for this withdrawal being that the access bridges to these berths are relatively expensive to man and maintain. This action would allow the port to leave most of the bridges permanently open or on emergency standby only. The exception would be the Alexandra/Langton Bridge which would be operational 24 hours to provide access to the berths and the Gladstone and Langton River Entrances. The coastal traffic is to be continued at the Waterlook end of the North Docks as long as it "provides a positive contribution" or until it can be relocated at River Berths. With respect to maintenance and repairs of the port's assets the Study suggests that "charges to other Departments, although regarded as internal paper transactions, should be competitive with external prices".

7.5 Traffic, Facilities and Costs

The services and facilities provided under the heading of the Docks will be separated into the two parts outlined in the introduction, that is, dock entrance to the quaywall and the berth to the dock gate.

7.5.1 Dock Entrance to the Quaywall

1. Capital Assets

In the ex-ante case (for example, the decision to build the Seaforth Docks), it is in principle possible for the port to experiment with costs by hypothesizing different dock designs and investment or replacement dates. One procedure is for the port authority, given the expected demand, to design an optimal dock (which, due to the longevity of the asset, will require a forecast longer than the normal time horizon). The port could then investigate the cost savings of not accepting particular traffic. Consider for example the cost saving of not accepting the container traffic. It is likely to have been the case that the Seaforth complex would not have been built in 1973 if this traffic was not accepted. However, this does not imply that all of the cost of the complex is attributable to that traffic. Assuming that all of the other expected traffic was accepted then it would have been necessary in the short-run for the port to undertake alternative investments to accommodate the traffic (for example the grain traffic). In the long run it would also become necessary for the port to replace the existing assets and facilities. The computation of total cost without the container traffic will therefore include both the immediate investments and the present values of the replacement investments. Thus the escapable cost of the container traffic could be substantially less than the cost of the Seaforth Docks. In a similar manner the port could investigated the cost saving in not accepting the grain, timber or general cargo traffic. In each of these cases, the characteristics discussed in chapter 4 are correlated with these traffic types. For example, it will tend to be the larger container and grain vessels which may impose size related costs on the port.

In the ex-post case there is the range of costs which the port may attempt to compute. At the lower end of this range, there will tend to be little opportunity of finding an alternative use for the docks, quaywalls and locks. Thus using this measure, the opportunity cost would approach zero. It will however be necessary for the Port to undertake a number of major capital projects during the 1980's in order to be able to accept traffic in each of the three areas. These projects include (Tables 7.5 and 7.6): the damming of the Sandon Entrance and the replacement of the engines at Canada; the modernisation at the Langton Entrance and the new middle gates at the Gladstone Entrance; the various projects at the Birkenhead Locks; and the gate repairs at the Waterloo end (although these repairs will only prolong the life of the gates until 1990). Given that the port has undertaken a study which indicates the optimum location for performing its cargo transfer operations, these investments are necessary so that traffic in general can be accepted. In other words, the port has some flexibility in performing these operations.

This applies particularly to general cargo traffic where in principle it would be possible for some traffic handled at Liverpool to be

Table 7.5 Major Capital Project - Liverpool

Year(s)	Project	Cost ('000)	Comments
Liverpool			
1981/82	Dam Sandon River Entrance	370	To secure safety of the Liverpool Dock Systems.
1981/82	Replacement of Diesel Engine at Canada Impounding Station	200	Existing Engine's life expired
Gladstone End			
1980/81	Modernisation of Caisson Drive at Langton Entrance	100	-
1985	New Middle Gates at Gladstone Entrance	1,100	To ensure continued availability of lock when inner or outer gates damaged or under repair after end of life of existing middle gates
Waterloo End			
1983/86	Repairs to machinery and gates Waterloo River Entrance	200	Minimum repair cost to keep Entrance open until 1990.
1990	Three new gates at Waterloo Entrance	3,000	-

Table 7.6 Major Capital Projects - Birkenhead

Year(s)	Project	Cost ('000)	Comments
Birkenhead			
1981	Repair Alfred 100' Passage Gates	100	Minimum repair cost for estimated life of 10 years
1981/2	Renew machinery at Wallasey Impounding Station	305	Boilers, Turbines and Auxiliaries life expired (substantial savings in manning and maintenance costs)
1981/82	Secure Alfred 80' Passage and Dam 80' Entrance	365	Substantial savings in capital and revenue expenditure
1981/83	Modernisation of Hydraulic System in Birkenhead	610	-
1982/83	Modify Sandon Gates (see Liverpool) and install at Alfred 100' Entrance	210	To release existing 100' outer gates for repair and eventual installation as 100' passage gates
1981/85	Repairs to "A", Duke Street and Poulton Bridges	360	Minimum repair costs solely to maintain bridges in operation

switched to Birkenhead and vice versa. The exception to this general observation is where a traffic requires a specific berth or a berth in a specific area of the port. To the extent that this would require the port to deviate from an optimum plan then the extra cost is allocable to the traffic causing the deviation. This could for example arise in the case of the coastal Ro-Ro/Passenger traffic which may prefer berths located as close as possible to the City of Liverpool.

The upper limit of the cost range may be particularly difficult for the Port Authority to estimate. It was argued in chapter 5 that this escapable cost is related to the replacement cost of those assets whose renewal is justified by demand. The concentration of the Port's principal deep sea cargo handling activities into Seaforth, Gladstone and Vittoria Docks, and the comments relating to the continuance of the L.M.T. operations in Canada and Huskisson Docks until alternative facilities can be offered would suggest that the capacity of Seaforth, Gladstone and Vittoria Docks is the relevant capacity when considering the replacement of assets for deep-sea traffic. In the case of the coastal traffic at the Waterloo end of the North Docks, the Port appears to be adopting the middle ground between opportunity cost (including major capital repair projects) and replacement or relocation costs of some of the facilities (that is, replacement of the lock gates in 1990 or relocation at the River Berths).

There are a number of methods by which the port could attempt to estimate the upper limit of cost for the valuation formula. Table 7.7 shows two extremes (1 and 4) and two intermediate methods (2 and 3). The historic cost (or valuation) of the Port's assets are shown in

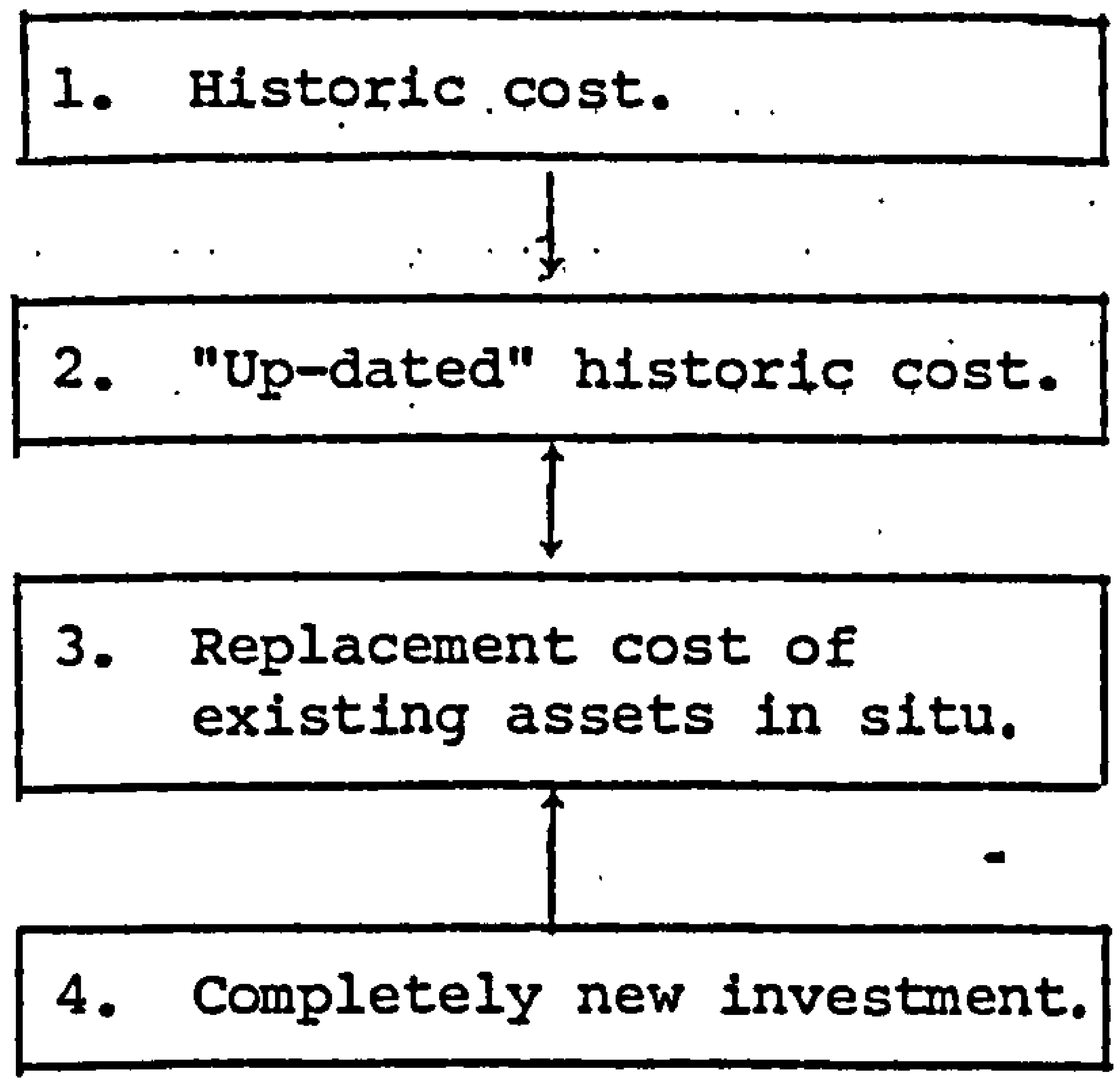


Table 7.7 Costs of Capacity Warranted by Demand

Table 7.8. From the Port's accounts it would appear the "valuation" mainly applies to "Freehold and leasehold land and buildings". The headings which apply to the Docks include "Dock and harbour structures including excavations" and part of "Plant and Machinery" (as the transfer of £1,624,000 from "Capital works in progress" to "Plant and Machinery" was "mainly in respect of the replacement gates at the Gladstone Entrance"). The historic cost of Dock and harbour structures at 31st December, 1979 would be inappropriate for valuation purposes because it will include assets which will not be replaced and it does not reflect the current replacement cost. It may however be possible to "update" these historic costs by using suitable inflation indices. At the opposite extreme historic cost, the port could hypothesise a completely new investment. This investment could for example involve the relocation of the Port's capacity to the seaward of the current Royal Seaforth Docks. It suggested that in the MDHC case such an approach would be purely speculative and thus it would also be inappropriate for valuation purposes. An alternative approach is to consider the cost of replacing, in its current location, the capacity

Table 7.8 MDHC Fixed Assets

	Freehold and leasehold land and buildings	Docks and Harbour Structures including excavations	Buildings on operational land within the dock estate	Roadways, bridges and permanent way	Floating craft	Plant and Machinery	Capital works in progress	Total
	£'000	£'000	£'000	£'000	£'000	£'000	£'000	£'000
COST OR VALUATION								
At 31st December 1978	18,633	76,807	34,414	9,158	5,494	33,187	2,260	179,853
Less amounts written off consequent on the Capital Reconstruction Scheme	-	9,046	4,288	1,509	248	3,389	-	18,480
	18,633	67,761	30,126	7,649	5,146	29,798	2,260	161,373
During the year								
Additions	24	868	65	352	48	1,498	1,951	4,806
Disposals	-	-	-	-	(100)	(392)	-	(492)
Transfer from Capital Works in progress	-	-	18	32	305	1,624	(1,979)	-
At 31st December 1979	18,657	68,629	30,209	8,033	5,399	32,528	2,232	165,607
DEPRECIATION								
At 31st December 1978	94	36,547	18,291	3,972	2,575	16,966	-	78,445
During the year								
Provisions	94	1,333	563	155	239	1,804	-	4,188
Disposals	-	-	-	-	(100)	(363)	-	(463)
At 31st December 1979	188	37,880	18,854	4,127	2,714	18,407	-	82,170
NET BOOK VALUE at 31st December 1979	18,469	30,749	11,355	3,906	2,685	14,121	2,232	83,517
NET BOOK VALUE at 31st December 1978	18,539	31,214	11,835	3,677	2,571	12,832	2,260	82,928
THE NET BOOK VALUE at 31st December 1979 allocated as follows:								
Dock Undertaking	18,469	28,038	11,144	3,906	437	13,753	2,225	77,972
Conservancy	-	2,591	152	-	1,772	284	7	4,806
Pilotage	-	120	59	-	476	84	-	739
	18,469	30,749	11,355	3,906	2,685	14,121	2,232	83,517

Source: MDHC, Annual report and accounts for the year ended 31st December 1979.

for which demand exists. This measure is similar to the "updated" historic cost and thus it may be possible for the Port to devise a valuation which is a compromise between the two methods (2 and 3 - Table 7.7). None of these methods are entirely satisfactory, however the compromise approach provides a figure which may be generally accepted for the accounting requirement that total cost equals total revenue.

Whilst this measure indicates the total replacement cost of the capital assets, there remains the problem of ascertaining the escapable costs of the various traffic using the port. This problem will be considered further after discussing the operating costs incurred between the lock and the quaywall.

2. Operating Costs

In order to accept traffic into a dock system, it will be necessary to maintain the locks. These costs will be incurred when traffic in general is serviced in the various areas of the port and will tend not to be specific to any particular traffic. For example, when considering the maintenance of water depth in a dock system the port could investigate the cost escapability in not dredging the access from the lock to specific berths or docks. Costs could then be attributed to specific traffic or groups of traffic in a similar manner to that outlined in the initial discussion of conservancy. Consideration of the reasons for dredging and the location of silt by "silt depth" indicates that this logic may not be applicable. In order to maintain the impounded water levels in the Dock Systems, water is pumped from the River into Seaforth, Canada and Alfred Docks. This process, combined with the entrance of River water when vessels are locked in and out, leads to the siltation within the docks. Thus, in principle it is possible to distinguish two causes of siltation. Firstly, there is that which occurs in the port's attempt to maintain the impounded water level against natural drainage of water from the docks. This occurs regardless of the traffic volume. Secondly, there is that which occurs due to the effect of the inflow of river water when vessels are locked in and out. This amount of siltation is directly related to the traffic volume and inversely related to ship size. The inverse relationship arises because, for a given lock and height of tide, more river water will need to be pumped into the dock for a small ship than a large ship.

Inspection of the "silt depth" in Tables 7.1 and 7.2 also indicates that some docks require more silt to be removed per unit area than others. Not unexpectedly, these docks correspond to those where river water is pumped into the docks.

Considering the first cause of siltation, the cost of the resultant dredging would appear to be joint to all of the traffic using the port. This jointness arising in two ways. Firstly, the provision of an impounded water level for one traffic implies that all other traffic is provided with that level. Secondly there is an externality whereby the provision of the service for traffic not located near a pumping inlet (and consequently not requiring as much dredging at its berth) impose a cost in the provision of the service for traffic located near the inlet. Now, it is conceivable that the port could consider the cost savings of not accepting traffic at particular berths or docks and thereby reduce the level of dredging. In the short-run this may lead to some savings, however after a period of time the silt would spill over into other docks. In the longer-run it may be possible to dam the passages between docks. This may lead to a reduction in costs however a further study would be required to ascertain the possible savings. (The Port would argue that such a study would be to no avail as they have a statutory obligation to maintain access to the Leeds and Liverpool Canal. However, it would give an indication of one of the costs of meeting this obligation). If one further admits the indivisibility of dredgers then there is a considerable degree of jointness associated with these costs.

Some of the considerations applicable to dredging are also relevant to surveying within the docks. For example, the surveying is required because of the siltation of the docks and therefore there will be the associated jointness. Inspection of Tables 7.1 and 7.2 further indicates that there are approximately 200 days per annum spent surveying both the Liverpool and Birkenhead Docks. This corresponds to the number of days a hydrographic surveyor spends on the boat surveying and thus represents an indivisible cost. It should also be noted that the Port's Hydrographic Department undertakes surveying both under the headings of Conservancy and in the Docks. Thus, some of the costs will be joint to both of these undertakings.

3. Traffic Identification

Traffic could be identified according to the berth of destination within the port. Figure 7.3 shows an hierarchical structure which identifies traffic according to this characteristic. The above discussion would suggest however, that whilst some of the Port's costs may be related to specific areas (for example, the size related costs) this general approach would be inappropriate. This arises because of the mobility of a wide range of traffic between berths. A more

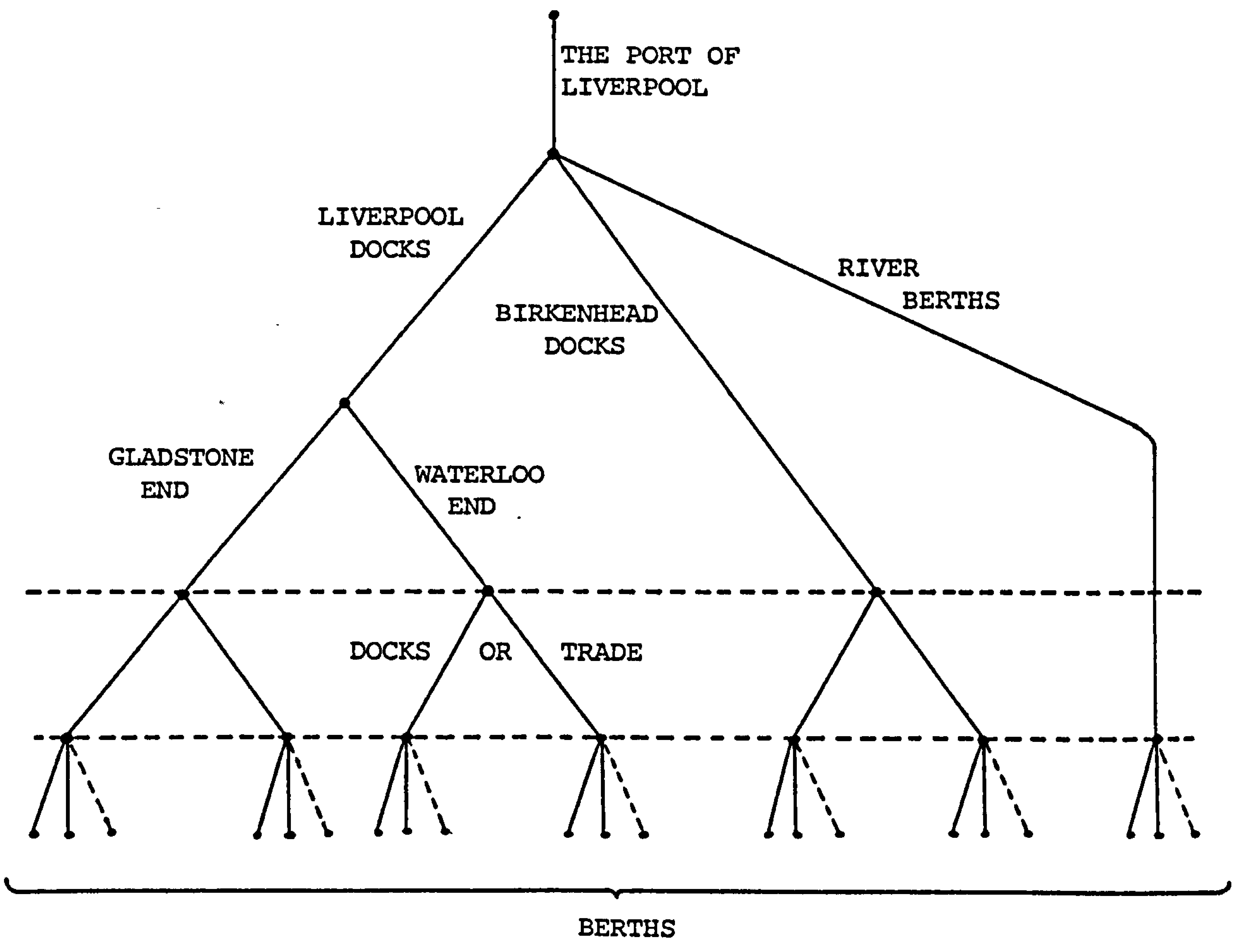


fig 7.3 Hierarchical Structure for Traffic Identification

appropriate approach would be to consider a classification according to vessel type with the trades in which the vessels are engaged as subsets of type (see fig 8.3 - chapter 8). Thus at the broadest level, the port would consider, for example, the cost saving in not accepting all general cargo vessels then the cost saving of not accepting particular trades. This classification is discussed further when considering cargo-handling (Chapter 8). The problem arising with this approach is that it could lead to a very large number of computations. Consider for example a general cargo trade currently using the facilities at Vittoria. In order to ascertain the escapable cost of not accepting this traffic it would be necessary for the port to simulate the demand patterns of the remaining traffic so that the optimum capacity without the Vittoria traffic can be ascertained. Having obtained this capacity it will be necessary for the port to ascertain its replacement cost for the valuation formula. This exercise would then have to be repeated for each traffic and combination of traffic. Given the exponential nature of the increase in combinations of traffic as the number of identified traffics increase it may not be feasible to undertake such an exercise.

An alternative approach is for the port to consider the long-run cost of a marginal berth. This estimate could be devised whilst ascertaining the compromise measure of replacement cost.. For example, the Port could estimate the cost of an extra River berth, or if the date were available, the cost of an extra (or the last) berth when the Seaforth complex was constructed. This cost can then be allocated to each berth for which demand exists, whether it is located in Seaforth, Gladstone, Huskisson, Waterloo or Vittoria. Given economies of scale in berth construction (due to indivisibilities) it is unlikely that the sum of this cost over the berths for which demand exists would be sufficient to replace the capacity required. Thus the difference between this sum and the total replacement cost will have to be considered as common to all the traffic.

7.5.2 The Berth to the Dock Gate

1. Traffic and Facilities

The port, having constructed the dock system, can "fit out" the berths for various different types of cargo transfer operations. The degree of flexibility available when considering which type of cargo to handle at a particular berth will however be constrained by the dock configuration and the land area adjoining the berth (these factors being taken into account when planning the port or the replacement/ expansion of capacity). Thus, whilst an initial port plan will include a proposed use of the berth this decision does not rigidly bind the port. Flexibility is also available when the port considers the level of service to provide at a berth. For example, transit sheds could be different sizes, the quay surface could take different loadings, or there may be cranes of different capacities (or no cranes at all). Apart from these considerations the port tends, given expected demand levels, to "fit out" particular berths or groups of berths for specific cargo transfer operations. Thus, to the extent that specific vessel types or specific users require berths that have been fitted out by taking their characteristics into accouut, there is a relationship between the traffic and facilities. Some of these facilities will be joint to all of the traffic using the berths whilst in a number of cases it may be possible to ascertain the escapable costs of specific traffic.

Such an approach is a facility related approach to ascertaining escapable costs; the method being to compute the escapable cost of each berth or group of berths whose renewal is warranted by demand. Whether the Port considers a single berth or group of berths will depend upon the cargo transfer operation and the associated back-up area and facilities. In the case of some single "commodity" berths, the back-up facilities tend to be located at the berth itself. For example, the grain handling and storage facility at the Grain Terminal is linked directly to the berth. However, at the Container Terminal any one berth tends to be more generally associated with the container stacking and control facilities as a whole. In the case of a general cargo quay, it is usual to provide a transit shed (and cranes) for the whole quay. Thus, there are savings to the user because the cost of supplying a single shed for two berths is less than the cost of supplying two separate sheds. If the savings are signficant, then the quay can be treated, in the first instance, as the main indivisible unit, then the berths as subsets. At some of these general cargo berths, the Port may provide facilities "in excess of the facilities normally provided for a general cargo berth"; to the extent that these facilities are supplied for specific users then they are attributable to those users.

In this approach the question being considered is which costs could be saved if the facility (berth or groups of berths) was no longer supplied? Whereas the question to which the Port requires an answer is which costs could be saved if a particular traffic or group of traffic was no longer accepted? However given that berths are fitted out for specific traffic types, these two questions are related. Consideration of the escapable costs of traffic would have required an investigation of all possible traffic and their combinations. Thus by examining the facilities an attempt is being made to simplify and reduce the number of computations required.

Summation of the escapable costs over these facilities will yield a cost which is less than the total escapable cost of the facilities provided between the berth and the dock gate. The difference will include maintenance, land and buildings, access to the berth, and perimeter fences. The maintenance, land and buildings associated with the berth can be incorporated within the above analysis. The access to the berth and perimeter fences could be considered as being more general in nature and thus joint to all traffic using the port. They could also be considered as being part of the wider services provided at the berth. Even in this second case, they are not necessarily attributable to specific traffic - they will tend to increase the cost of the marginal berth.

2. Escapable costs

In the short-run, the opportunity cost of land owned or leased by the Port is the most difficult item to obtain. The approach adopted in the MDHC's annual reports is to obtain an "open market value for existing" or "alternative use". However, it is noted in the accounts that;

> "The values of operational land could not be fully realised except in particular circumstances and over a long period of time." [1]

At the berth itself, the opportunity cost of the transit sheds can be ascertained by considering the alternative uses of warehousing, distribution or light industry. The Port has some experience in leasing these buildings at berths where cargo is no longer handled and thus can obtain values for their opportunity cost. Similarly, the Port's past experience in maintaining the buildings, quay surface, access roads and perimeter fences can be used to estimate the short-run maintenance costs.

In the long-run, the replacement costs of buildings, surfacing, roads, fences and gates are relatively easy to ascertain. Thus, in order to compute the upper limit of escapble costs, these replacement costs can be imputed into the valuation formula.

7.6 Summary and Conclusions

The adoption of the full methodology for measuring escapable costs, as outlined in chapter 5, would lead to a particularly complex set of calculations. In essence, they would involve firstly estimating and costing the capacity which would be replaced. Secondly, it would be necessary to withdraw each identified traffic and combination of traffic from this demand and re-estimate and cost the capacity required. Given the nature of this problem and the difficulties in estimating replacement costs some simplification is necessary in order to make the problem manageable.

The main difference between the facilities provided between the lock entrance and the quaywall, and the berth and the dock,gate is that berths tend to be fitted out for particular cargo transfer operations whilst the lock to quaywall (apart possibly from some size related costs) tend to be provided for traffic in general. Thus, a suggested approach for the berth to the dock gate is to consider a coarse set of traffic according to the facilities provided, but differentiating these according to vessel type. This would require the port to estimate the aggregate demands for relevant berth types including container, grain and general cargo; then to estimate and cost the capacity that would not be required if these facilities were not provided. The resulting estimate being the escapable costs of each of these traffics in aggregate. Where possible (for example with general cargo) the port can then attempt to estimate the escapable cost of a basic marginal berth. This cost is then attributable jointly to the traffic requiring a berth of the relevant type. If a specific traffic requires facilities in excess of those at a basic marginal berth then the cost of these facilities can be attributed to that traffic.

The difference between the sum of the marginal berth cost over all berths of a particular type and the escapable cost of this berth type in aggregate is common to all vessels of this type. Similarly the difference between the sum of the escapable costs of the aggregate berth types and the total escpable costs of the Docks are common to all traffic. Treating these costs as being common (as distinct from being joint) does to a certain extent leave the allocation of the common costs to the discretion of the Port Authority.

Notes

[1] Riethmuller, J. (ed), "Ports of the World 1980", Benn Publications Ltd, London, 1980.

[2] The Mersey Docks and Harbour Company, Annual report and accounts for the year ended 31st December 1979, p 16.

CHAPTER 8

MEASURING ESCAPABLE COSTS - CARGO HANDLING

8.1 Introduction

The approach adopted in this chapter will be to consider the constituent elements of the cargo handling revenue rates (price). These rates are heavily based on the direct labour costs and thus the development and construction of the labour schedules will be considered in some detail. The chapter will then consider the escapable costs in both the short- and long-run, and the problems that may arise when attempting to measure these costs.

8.2 Cargo Handling Operations

There are four distinct processes involved in the cargo handling operation (fig 8.1).

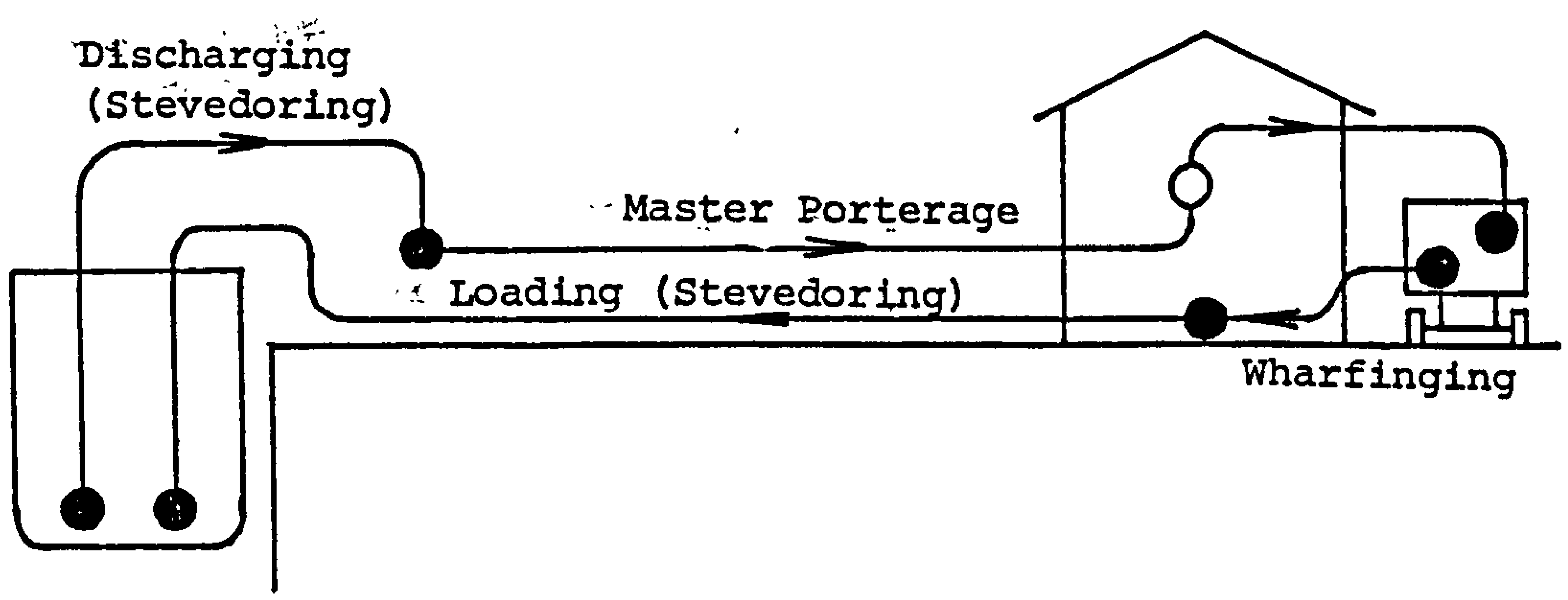


fig 8.1 Cargo Handling Operations

These processes are performed by Registered Dock Workers (RDW) with staff employed in a supervisory and clerical capacity.

The functions of each process include;

(i) Wharfinger:

(a) Receives cargo to be loaded.

(b) Measures and checks cargo against documents.

(c) Issues Wharfinger's receipts for cargo.

(d) Stows cargo in the shed or on the quay.

(e) Instructs hatch checkers as to the manner in which tallies are to be carried out.

(f) Compiles the ship's cargo plan, and provides the information for the shipowner's Bills of lading.

The labour employed consists of a receiving quay foreman (in charge of the whole process) and a receiver, a plant driver and two porters in multiples of 2, 3, 4 or 5 according to the volume of cargo being received. The office side on average consists of one plan man, one man attending vehicle drivers' notes, one tonnage man, one man returning shipping notes and perhaps one to two men assisting where required.

This operation is to the shipowner's account.

(ii) Loading (Stevedoring)

These men used to be called "Master Stevedores" and their function is to:

(a) Move the cargo from the shed to the ship's side.

(b) Load the cargo into the ship.

(c) Stow the cargo in the ship's hold.

For a ship using derricks rigged in "Union Purchase", there are twenty men employed directly; a ship's hatch foreman who supervises the loading (stevedoring) operation, four deckhands, eight holdsmen and one checker at the ship, and five quaymen and a mobile crane driver on the quay and in the shed. The operation is again to the shipowner's account.

(iii) Discharging (Stevedoring):

These men used to be called "Master Lumpers" and their function is to discharge the cargo to the point of landing it on the quay. With "Union Purchase" gear, there are approximately fourteen and a half men employed viz. a ship's hatch foreman, four deckhands, eight holdsmen, one landing man and half a checker (i.e. his earnings are split on a 50/50 basis between the ship and quay). The operation is to the shipowner's account.

(iv) Master Porterage:

The function of the Master Porter is to:

(a) Land the cargo on the quay.

(b) Select the cargo by mark (so that the cargo can be delivered direct to the consignee's vehicles or when the consignee arrives to collect the cargo it can be easily located).

(c) Stow the cargo in the transit shed.

(d) Deliver the cargo to the consignee.

These operations are supervised by a quay foreman, who has a hatch foreman (at the ship's side) and delivery foreman (delivering cargo to the consignee) assisting him. The direct labour employed consists on average of fourteen and a half men involved in the processes of landing, selecting and stowing; eight porters, two electric truck drivers, one mobile crane or fork-lift truck driver, one landing man and half a checker. All these men's earnings except for half of their bonus payments are to the consignee's account. Half of the bonus payments are allocated to the discharging stevedores (that is, the shipowner's account) and the other half to master porterage (that is, the consignee's account). The origin of this practice is that under the old payment scheme (see below) "quay awards" were debited to the ship, and these awards represented half the new bonus. For the process of delivery, the number of men involved varies according to the number of consignees requiring their cargo. However on average, five men are employed; two porters, one checker, one crane driver and the delivery foreman. The process is to the consignee's account.

The historical development of the Master Porter arose, from a unique service which the Port of Liverpool offers to consignees (although now it is only offered on a small scale). This service was that the port offered its facilities as a "market place" for the sale and trade of goods and commodities ex-ship or ex-quay. It was the Master Porters who performed this operation.

8.3 The Costs of Labour

On the 12th October 1974, a new scheme of bonuses was brought into effect. This scheme was an attempt by the port to group all the various scheduled and discretionary payments to labour into a single scheduled rate. The new schedule was successful in the discharging tafiff, however, there are still additional scheduled payments in the receiving, loading and delivery operations. The scheme is basically an averaging of previous payments, these payments recognising the disutility to the dockworker of handling certain types of cargo and therefore indirectly the costs to the port. In the following sections, three areas will be investigated. Firstly the old payments scheme, secondly the reasons for change and thirdly the new scheme and how it was developed.

8.3.1 The pre-October 1974 Labour Tariff

Under this scheme, labour engaged in loading and discharging received various different types of payment, some of which were according to a specific schedule and others which were determined by ship side negotiations. These payments included:

(i) Basic Rates of Pay

This is the basic rate of pay which the RDW receives regardless of the capacity in which he is employed (that is, from General Dock Worker to Hatchboss this is the basic rate). The rate is quoted per hour, half day and day and depends upon the shift in which the work is performed. The shifts worked at Liverpool are:

Monday to Friday:

Day - 0800 to 1200 and 1300 to 1700

Evening - 1700 to 2300

Night - 2300 to 0600

Saturday:

Day - 0800 to 1200

Night - 2300 to 0600

Sunday:

Day - 0800 to 1100 and 1300 to 1600

Night - 2300 to 0600

different basic rates being paid for each shift (the rates are the same for both periods in the day shifts).

(ii) Occupational Differentials

When a RDW is allocated to a ship, he is also employed to perform a particular job (for example, deckhand, stevedore, crane driver, checker, hatchboss etc.). An "occupational differential" is then paid in addition to his basic rate for performing this job. This payment also varies according to the shift (see above) and in the case of deckhands according to the season - summer or winter.

(iii) Commodity Differentials and Award Payments

From about 1964, there existed in the Port an award scheme under which payments to labour were made to cover:

(a) Impedance - this was mainly related to the cargo stow. Thus for example if cargo was stowed in such a manner that it was difficult to discharge (that is, reduced labour productivity) then an impedance claim would be made.

(b) Infestation - these claims were usually made where the vessel's hold had not been swept clear of a previous cargo (for example asbestos).

(c) Other - these were claims of a miscellaneous nature. Examples include trucking cotton bales over cobbles and stowages which were over dunnaged.

(d) Dirty cargoes - this applied to cargoes which were particularly dirty .

These claims were settled by ship-side negotiations.

In addition, there was a set schedule of commodity differentials which was a list comprising the commodities which were known to merit extra payment due to their dirty or obnoxious nature and other unique characteristics. Two lists were in existence, one for discharging and delivery and one for loading and wharfinging.

In mid-1968, the "dirty cargo awards" were incorporated into their respective "Discharging" and "Loading Bonus Schemes". The remainder of the scheme for impedance, infestation, other awards and the commodity differentials were retained until October 1974.

(iv) Bonus Payments

This modified scheme came into existence in mid-1968 and applied to discharging and loading. Bonus payments were laid down in a schedule and quoted on a per man per ton basis. They were broadly related to the inverse of the net productivity (that is, the higher the productivity, the lower the bonus and vice versa).

There were various rules to be applied when determining the bonus including the following:

(a) That the bonus was the same in overtime hours as it was in normal hours. It applied to cargo workers employed in the hold, on deck, on the quay, in craft, and to crane drivers and checkers engaged at a vessel. Ancillary staff such as porters, coopers and stitchers on delivery and receiving were not included in the scheme.

(b) In order to calculate the net productivity, the total tonnage of cargo handled during the period was divided by the net hours. If the men worked from normal hours into overtime the tonnage handled was averaged over the whole period.

(c) When determining the tonnage of cargo handled, the additional operation of weighing affected the bonus payments. If beam scales were used, 35 per cent was to be added to the bonus payments and if cargo was weighed by steel yard on raised platform scales, 15 per cent was added. Both of these methods are slower and therefore affect the gang's net productivity.

(d) An additional allowance was made (flat rate per man per tonne) for handling polypropylene wrapped bales and bags. The main reason for this was that this type of wrapping does not stow readily (that is the slippery nature of the bag causes stowages to slip during handling and stack-piling). A secondary reason is that bag hooks cannot be used.

Incorporated in the discharging bonus schedule, was a dirt list. As mentioned above, this was quoted separately for other cargo-handling operations.

(v) Booster Payments

This scheme was linked to the Bonus Payments and therefore only applied to discharging. It was in effect a productivity incentive payment. There are two ways in which such a scheme can be developed:

(a) Standard net productivities can be agreed for each commodity, the dock worker's basic pay then being linked to say 70 per cent of this standard. An incentive payment is then made as follows:

Percentage of standard performance	Incentive payment (per man per hour)
Up to 70	2p
71 to 80	2½p
81 to 90	3p
91 to 100	3½p
101 to 110	4p
111 to 120	4½p
121 and over	5p

This method has the disadvantage that it involves considerable clerical time to calculate the payment.

(b) The principle of a bonus scheme is that the total "bonus" payment for achieving standard productivity is the same for all commodities, that is;

$$\underset{(£/\text{man/tonne})}{\text{Bonus rate}} \times \text{TPNGH}^* = \underset{(£/\text{man/hr})}{\text{Basic Bonus}}$$

$$= \text{constant (K)}$$

The actual bonus paid then depends upon the extent to which actual productivity exceeds this standard. That is;

Actual Bonus (£/man/hr)

$$= R \times \text{TPNGH}$$

$$= R \times \sigma \times \text{TPNGH}^*$$

$$= \sigma(R \times \text{TPNGH}^*)$$

$$= \sigma K$$

where R = Bonus rate (£/man/tonne)

TPNGH = Actual productivity

TPNGH* = Standard productivity

σ = (TPNGH - TPNGH*)/TPNGH*

= Proportion of standard performance.

Thus, the actual bonus can be ascertained by knowing the proportion of standard performance.

The extra incentive payment (booster) can then be introduced by adding a percentage to the actual bonus, that is;

Actual Bonus + Booster

$$= \sigma K(1 + \rho)$$

where ρ = percentage addition.

The percentage addition used by the Port was an increasing step function, Table 8.1 showing an example where the basic bonus is 10 pence (that is, K = 10).

Table 8.1 Booster Payment Scheme

Actual Bonus Payment (per man per hour)	Percentage Addition	Bonus plus Booster Payment (per man per hour)	Productivity increase above standard
Up to 10p	-	10p	-
Over 10p to 15p	10	11p to 16½p	50% at 15p
Over 15p to 20p	20	18p to 24p	100% at 20p
Over 20p to 25p	30	26p to 32½p	150% at 25p
Over 25p	40	35p and over	Over 150%

The advantage of formulating the problem in this manner is that the scheme is applicable to all commodities. Thus, once the port has calculated the actual bonus the booster payment can be ascertained without reference to the commodity.

Example

Gang works 8 a.m. to 5 p.m. with two hours detention. The commodity discharged has a bonus rate of £0.0125 per man per tonne. During the period 125 t are discharged

$$\therefore \text{ Bonus payment per man per hour} = \frac{\text{Bonus rate x Tonnage}}{\text{Net hours}}$$

$$= \frac{0.0125 \times 125}{6}$$

$$= £0.26.$$

From the Port's actual tables, the booster for 26p was 100 per cent.

$\therefore$ Booster payment per man = 26p per hour

(vi) Overtime Payments

For any work performed outside normal hours (0800 to 1700 Monday to Friday excluding statutory holidays) RDW's receive overtime payments. These consist of a higher basic rate of pay and higher occupational differentials (for those RDW's who normally receive occupational differentials). Thus, for example, a hatch boss receives over double (2.2 times) his normal basic pay and half as much again as an occupational differential on the Saturday night shift.

Bonus, booster and commodity payments remain the same in overtime hours.

8.3.2. Reasons for Change

The changes which occurred in October 1974 were primarily in the loading and discharging schedules. The four main reasons which contributed towards the need for change were:

(i) Management's concern with the very high incidence of strikes and disputes.

(ii) Management's concern with the escalation of impedance awards.

(iii) Dissimilarities between rates in the existing system and the lack of uniformity in their application.

(iv) Requests from superintendents to be relieved of arbitration duties in regard to award payments.

An hypothesis to explain the large number of different payments which evolved and the anomalies in the system is that labour evolved their own "schedule" of what they considered "reasonable payment" for handling each commodity. If the scheduled rates of payment were inadequate then they demanded other payments to compensate for this inadequacy. Hypothetical examples of how this situation could arise include:

(i) If the standard productivity was well in excess of that actually being attained, so that the men could not conceivably reach a level of bonus where the booster became applicable, then this "loss" of booster could be compensated for by either relying on the guaranteed basic payment and not putting any "effort" into the work or by claiming impedance payments.

(ii) Where the specific circumstances of the ship or stow dictated that the standard productivity could not be achieved (although for a "normal" ship and stow it could be) then an impedance award would be claimed.

(iii) Where it was thought that the scheduled dirt allowances did not adequately remunerate the men then compensation would again be claimed in an award payment.

The escalation of impedance awards were most likely explained by an attempt by the men to maximise their income.

8.3.3 <u>The post-October 1974 Labour Tariff</u>

The principles developed in this tariff are those which are currently applied. This new scheme incorporates the outstanding award payments into the discharging bonus schedule or the loading bonus schedule, however the loading and delivery "dirt lists" were retained. A scheme based on productivity was also introduced for ancillary dockworkers (on Receiving and Delivery operations).

The <u>aims and objectives</u> as stated in one of the preliminary papers on the scheme were that it should:

(i) be a comprehensive scheme incorporating the old bonus and booster schedules, all award payments, and all dirt allowances.

(ii) encourage improved productivity in the port.

(iii) be simple, clear and easy to administer.

(iv) have explicit methods of dealing with "exceptional circumstances".

(v) be robust and proof against exploitation.

(vi) be acceptable to the payboard.

(vii) be consistent with the commercial aims of the port.

(viii) not jeopardise any future change in the scheme.

(ix) be fair and capable of being negotiated with RDW representa-ives

(x) be capable of being monitored.

The method used, was to conduct a stratified sample of vessels loaded and discharged between January and September 1973. All principal trades were sampled, with not less than five vessels per trade. The earnings of RDW's in this sample were analysed in terms of basic, piecework (bonus, booster and dirt allowances) and awards. Awards being later broken down into impedance, infestation and others.

In essence, the methodology was as follows:

(i) find the total hourly earnings of the dock worker (in excess of his basic pay and occupational differentials) for each commodity.

(ii) group these into seven different rates of "earnings per net man hour" (ENMH).

(iii) obtain a consensus of views on standard productivities - "tonnes per net gang hour" (TPNGH) - for each commodity.

(iv) calculate the new bonus from the formula:

$$\text{Bonus} = \frac{\text{ENMH}}{\text{TPNGH}}$$

thus arriving at a rate per man per tonne.

One of the major concerns of the port was that the new schedule should be fair to labour and capable of negotiation. In other words, it was absolutely essential to be able to demonstrate that no RDW would be worse off (receive less total earnings) under the new scheme than under the old scheme.

For the discharging schedule, the methodology actually used was as follows:

(i) The 51 different bonus rates ranged from 0.32p to 4.92p per man per ton. These were multiplied by the productivity to obtain the bonus earnings per man per hour, that is

Bonus x productivity = constant (bonus earnings per man per hour)

To these were added the booster payments. It was found that the average booster payment percentage addition was 60 per cent so instead of using the "stepped" booster a "linear" booster was found for each commodity, as shown in figure 8.2.

(ii) A weighted average of these payments (bonus and booster) was then calculated for all commodities. Similarly a weighted average of award payments was obtained yielding the following results (pence per man per hour):

Bonus and booster average	38p
Award payments average	34p
Total ENMH above wages and differentials	72p
Less weighted average of dirt allowances	3p
Non-dirt basic rate	69p

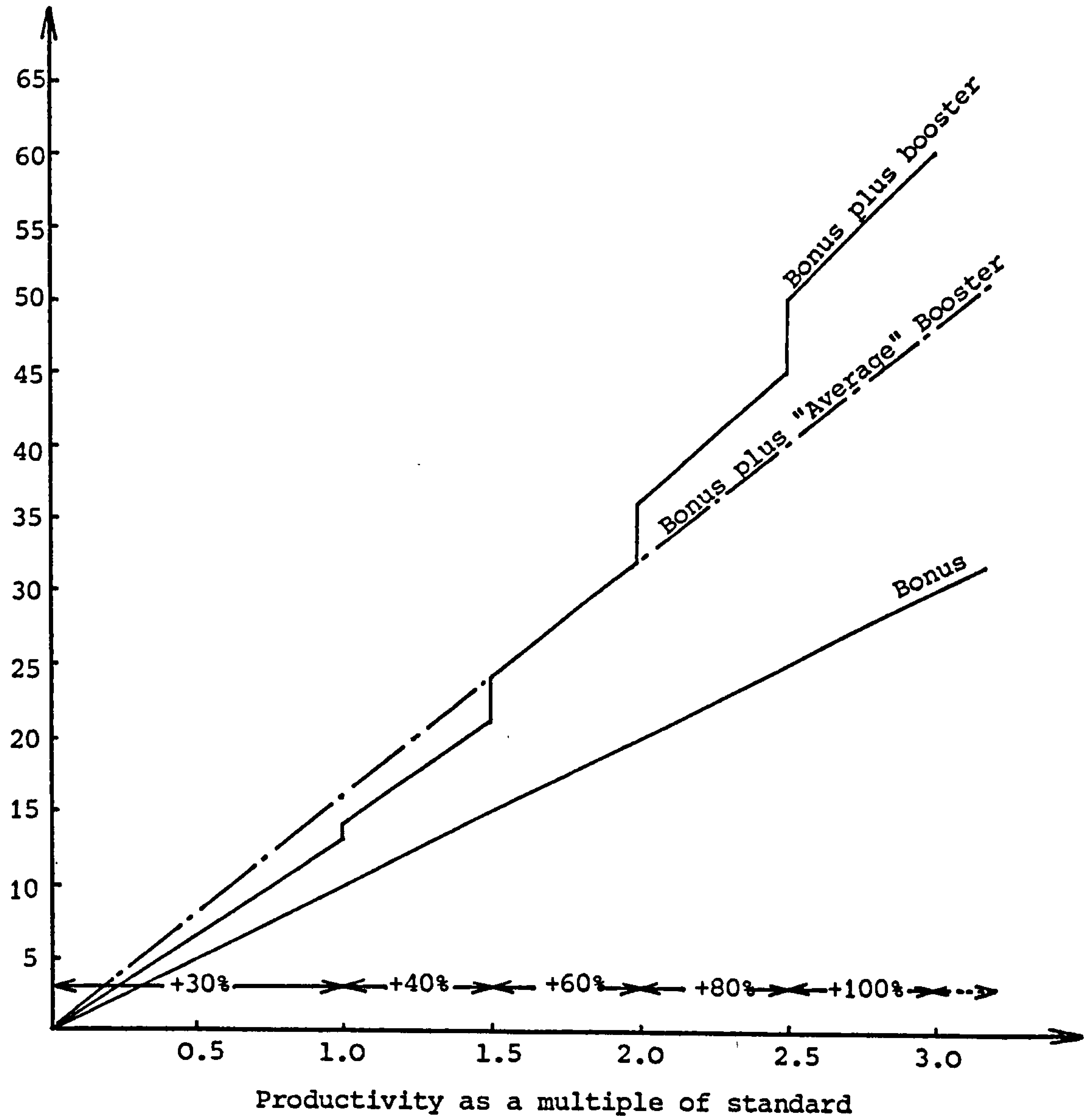


Fig.8.2 Stepped and Linear Booster

(iii) The actual ENMH were compared with this average and it was found that there were 31 actual rates which ranged between 20 per cent and 76 per cent above the average. It was decided to reduce these to six categories, viz. +25%, +35%, +45%, +55%, +65% and +75%.

(iv) Further calculations adjusted these to seven ENMH; one non-dirt at 69p, and six dirt rates at 73p, 80p, 88p, 94p, £1.02p and £1.09p.

(v) A consensus of views was obtained on the standard TPNGH and the new bonus rates calculated from the formulae:

$$\text{New Bonus Rate} = \frac{\text{ENMH}}{\text{Standard TPNGH}}$$

the rate being expressed in £ per man per tonne.

The tariff developed contains approximately 330 listed cargoes which are differentiated according to the commodity, packaging or weight of individual units.

The approach adopted, when considering the <u>loading schedule</u> was to group commodities into eleven categories. For the first nine categories the bonus rate increases. The last two categories are for full cargoes of metals and loose rubber tyres. Whilst there are a number of listed commodities in each category, the broad structure indicates that either the weight of an individual unit decreases or the stowage factor increases with the category number (Table 8.2).

One reason why it has been possible to devise a much smaller list than was the case with discharging is that the "Flat Payment Dirt Allowances" have been retained for loading. This lists approximately 130 commodities and the rate is paid per man per deadweight tonne.

Table 8.2 Labour Loading Schedule Categories

Category	Bags (kg/bag)	Drums (kg/drum)	Stowage Factor (m^3/tonne)
1	> 51	> 51	$\leqslant 1.133$
2	> 14 to 51	> 18 to 51	> 1.133 to 1.982
3	$\leqslant 14$	-	> 1.982 to 5.663
4	-	$\leqslant 18$	-
5	-	-	-
6	-	-	> 5.663 to 8.495
7	-	-	> 8.495 to 11.327
8	-	-	> 11.327 to 14.158
9	-	-	> 14.158

Labour which was not engaged in loading and discharging, that is, labour engaged on delivery, receiving and other ancillary operations prior to the 1974 changes received the basic rate of pay, occupational differentials and the dirt allowance (in accordance with a scheduled dirt list). However in October 1974, a Port Productivity Scheme was introduced in addition to these payments. The scheme is based upon the total tonnage handled in general cargo and groupage operations and upon the total gross hours worked. The tonnage to be included is contained in an appendix to the schedule. The payment is computed as follows:

The average weekly productivity is found from the formula:

$$\frac{\text{Total Weekly Tonnage}}{\text{Total of Ancillary Workers Gross Hours}}\ .$$

The resulting figure is called the Port Index and has the standard value of 1.24. If the actual exceeds the standard then the hourly payment of the ancillary worker is found from the following table:

Tons per man per gross hour (Port Index)	Payments per gross man hour (pence)
1.24	40.0
1.3	42.4
1.4	46.4
1.5	50.4
1.6	54.4
1.7	58.4
1.8	62.4
1.9	66.4
2.0	70.4
2.1	74.4
2.2	78.4

If the weekly performance falls below 1.24, then a payment of 37p per gross man hour is guaranteed.

The table is developed from the principle that, in addition to the 40 pence per hour for attaining the Port Index, ancillary workers will be paid at the rate of 40p per tonne (pro rate for each part of a tonne) by which performance in the week exceeds the index. In other words:

Payment per gross man hour	= 40 + 40 (Actual ∿ Standard)
	= 40 [1 + (Actual ∿ Standard)]

Example: Assume that the total weekly tonnage was 14,000 t and that total gross hours of ancillary workers was 10,000 hours.

$$\text{Actual Index} = \frac{\text{Total weekly tonnage}}{\text{Total gross hours}} = \frac{14,000}{10,000} = 1.4$$

$\therefore$ Payment per gross man hour = 40 [1 + (1.4 - 1.24)]

= 46.4p

8.4 Establishing the Revenue Rate (Price)

The basic method of establishing a revenue rate (price) is to mark-up on direct labour costs and to charge separately for any extras on a cost-plus basis. Thus the price charged has the following components:

(i) Wages of the RDW.

(ii) Occupational differentials.

(iii) Commodity differentials - including loading and discharging "Bonus Schemes" and the loading "Dirt List".

(iv) Other "Awards": the only "Awards" which remain in the Port are for:

(a) cargo which has been damaged by fire and salvage cargo.

(b) "abnormal abnormalities".

(v) Mark-up: The function of the mark-up is to recover the overhead costs associated with the provision of the cargo-handling process. These costs include:

Wage Related Costs:

1. Fall back pay.

2. Holiday pay.

3. Sick pay.

4. National Insurance.

5. National Dock Labour Board Levy.

6. Inter Employer Surcharge.

7. Transport of Registered Dock Workers.

8. Port Labour Transfer.

9. Amenities.

District/Terminal Office Costs:

10. Salaries.

11. National Insurance.

12. Telephones.

13. Transport.

14. Domestic fuel.

15. Sundries.

16. Wages.

Miscellaneous:

17. Insurance.

18. Security.

19. Electricity.

20. Claims.

21. Damages.

22. Cleaning berths.

23. Engineer's costs.

24. Miscellaneous costs.

25. Berth Allocation fees.

Quayside Plant

26. Mobile cranes (up to six tonnes capacity).

27. Fork lift trucks (up to six tonnes capacity).

The Quoted Revenue Rate is then found from the following accounting equation:

$$\text{Revenue Rate} = \left[\text{Wages} + \begin{matrix}\text{Occupational}\\ \text{Differentials}\end{matrix} + \begin{matrix}\text{Commodity}\\ \text{Differentials}\end{matrix} \right] (1 + \alpha)$$

These five components represent the basic price quoted in the Port's schedules of cargo handling, the separate charges for extras include the following:

(vi) Extra plant: Included in the mark-up, is an allowance for "minimum" or "normal" plant used between the berth and the shed, however plant in excess of this is charged for separately on an "at cost" basis. At the ship, extra plant includes such items as:

(a) Mobile cranes over 6 tonnes S.W.L.

(b) Floating cranes.

(c) Quayside cranes.

(d) Plant employed aboard ship in stowage (e.g. fork-life trucks).

whilst on the quay it includes:

(a) Mobile cranes or fork-lift trucks used in "long-runs" for loading operations.

(b) Mobile cranes used in "top stowing" cargo in the transit shed for discharging operations.

For the next three components (overtime, detentions and extra labour) the Port has a "Table of Premium Charges". This table is constructed on a cost-plus basis, with the mark-up being less than that for the revenue rate.

(vii) Overtime Payments: As outlined above, higher payments are made for work performed outside normal hours (that is, higher basic rates of pay and occupational differentials). For the purposes of establishing a price which will recover these costs and make a contribution to overheads, the port marks-up on the average direct costs of providing the service. Thus the accounting equation is:

$$\text{Premium charge for overtime} = (\text{Average gang cost})(1 + \alpha)$$

where the average gang cost is derived from the number of men scheduled for the commodity and the average overtime payments including occupational differentials.

(viii) Detentions: On the cost side, labour is guaranteed a minimum bonus earnings level on a daily basis if no delays or detentions occur. If delays occur due to causes other than weather (for example, a breakdown of the ship's gear) a lower minimum payment is guaranteed. If delays occur due to weather an even lower per hour payment is made for the duration of the interruption.

The accounting equation for detentions therefore becomes:

$$\text{Premium for detentions} = (\text{Average gang cost} + \text{average detention payment})(1 + \alpha)$$

(ix) Extra Labour: There are two schedules quoted for extra labour, that at "premium charges" and that at "rates". The "premium charges" are calculated in a similar manner to overtime and detentions, Extra labour at "rates" is calculated in a similar manner except that the mark-up is greater.

Premium charges are used in the majority of cases, however in special cases where it is felt that the user should make a higher contribution to overheads, extra labour at "rates" is charged. This may occur for example when extra labour is required to discharge and reload cargo which is overstowing Liverpool cargo.

(x) Rechargeables: This is a charge to recover the cost of plant and equipment which the ship uses and has been debited to cargo handling. Examples of these charges include canteen facilities, cargo watching services, Her Majesty's Customs charges and floating cranes.

(xi) Sundries: These are charged in a similar manner to extra plant, that is on an "at cost" basis. Sundries include items such as: shed lights, protective clothing, coopersmats etc.

In order to compute the revenue rates, the following elements are required:

(i) Number of men in gang.

(ii) The standard manning for the commodity and circumstances.

(iii) The hourly rate of pay per man - including differentials.

(iv) The standard net productivity per commodity.

(v) The bonus payment and flat rate dirt allowances (where appropriate) per man per tonne.

(vi) The extras, overtime, detentions and sundries incurred by the vessel.

(vii) The mark-up to apply in each case.

Table 8.3 shows a pro-forma calculation of the quoted and total revenue rates per tonne.

$\dfrac{\text{Standard manning x respective rates incl. differentials}}{\text{Standard net productivity}}$	= XX (£/t)
Bonus rate x standard manning	= XX (£/t)
Total direct costs	= XX (£/t)
Percentage addition for overheads	= XX (£/t)
Quoted revenue rate per tonne/unit	XXX (£/t)
Extra plant	XX (£/t)
Premium charges for - Overtime	XX (£/t)
- Detentions	XX (£/t)
- Extra Labour	XX (£/t)
Extra Labour at rates	XX (£/t)
Sundries and Rechargeables	XX (£/t)
Total Revenue per tonne/unit	XXX (£/t)

Table 8.3 Pro-forma for Computing the Revenue Rate

8.5 Traffic

A broad classification of traffic by similar characteristics could incorporate a coastal/deep-sea distinction; vessel type; either the trade/liner conference in which the vessel is engaged or the commodity carried; and (where appropriate) vessel size (for example, large tankers and other tankers). Fig.8.3 shows such a structure for the deep-sea traffic.

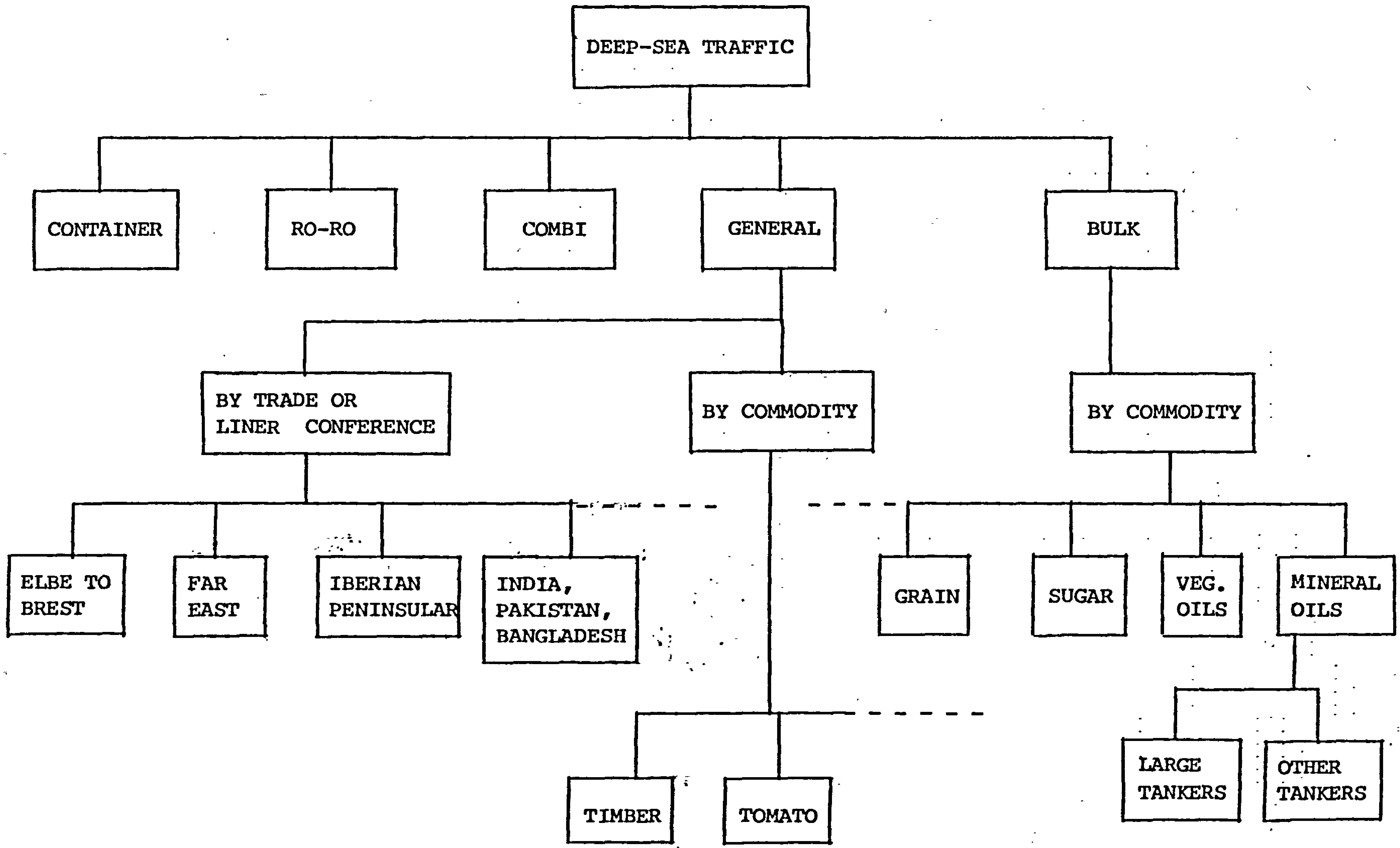


fig 8.3 A Classification of Deep-Sea Traffic for Cargo Handling

At the vessel type level, the port provides cargo handling services and facilities which are different in nature for each of these types. These facilities were outlined in chapter 7 when considering the Docks. Thus for example the cargo handling facilities provided at the grain terminal are different from the container cranes, straddle carriers, CONICS control system and groupage facilities at the container terminal. Similarly the facilities provided for handling bulk sugar are different from the quayside cranes and fork-lifts provided for general cargo operations. Therefore, some of the facilities provided are specific to vessel types. There are however a number of services and facilities (for example, labour) which are provided for more general use within the port. These factors have varying degrees of mobility around the port and thus are not generally associated with a specific traffic. There are also varying degrees of service mobility within vessel types, for example, there is in principle no reason why the trade using the berths at Huskisson could not be transferred to say Vittoria. Thus when considering general cargo vessels the relevant services and facilities will in some cases be those provided for the incremental traffic.

8.6 <u>Escapable Costs in the Short-Run</u>

In the short-run, there are a number of costs which could be escaped if a particular traffic was not accepted. These costs will therefore be directly relevant to the pricing of marginal units. As discussed above, the labour tariff consists of the basic wage, occupational differentials, bonus payments and in the case of some operations a dirt allowance. Once an RDW is allocated to a ship, he receives the occupational differential and is also guaranteed a minimum daily bonus payment (provided that any delays or detentions are beyond the men's control). The actual bonus payment will depend upon the gang's performance, and in the discharging case the dirt category into which the commodity falls. For loading, delivery and receiving the extra dirt allowances are paid. In the discharging schedule the bonus plus occupational differentials represent a not insignificant proportion of the total revenue rate. For example, in the rate for Mixed General Merchandise, Brest to Elbe and the Far East the percentage is approximately fifteen, this figure not being atypical. Within the overhead costs (included in the mark-up) there are also some costs which are relevant to the marginal unit. For example, given that the employer's national insurance contribution is a proportional tax, the employer will have to pay national insurance on the bonus plus occupational differential. The fuel or electricity costs of "normal" plant will similarly be relevant to the marginal unit as will any consumable items or cleaning of protective clothing.

In addition to the traffic's basic requirements further costs are incurred for extra plant and rechargeables, and if labour works outside the weekday shifts (0800 to 1200 and 1300 to 1700 hours) overtime costs are incurred. The fuel used for this plant and the extra overtime payments are all short-run escapable costs. With respect to rechargeables, the extent to which they are escapable costs in the short-run depends upon whether they are an internal paper transaction or an external transaction. In the case of Custom's charges they are short-run escapable, however in the case of internal transactions the non-fuel costs may not be short-run escapable.

Some of these costs are jointly attributable to the commodities handled during a shift and include the occupational differentials, basic bonus, overtime, sundry consumables and fuel for the normal plant. Other costs are attributable to specific commodities handled, for example, the bonus in excess of the basic bonus and in some cases the fuel and overtime required for extra plant.

The above comments apply to deep-sea general cargo handling, however, the principles are equally applicable to the container, Ro-Ro and bulk handling operations.

8.7 Escapable Costs in the Long-Run

In the long-run it will be possible for the port to introduce "voluntary severance schemes" and not to replace labour when natural wastage occurs. Similarly there is the option of not replacing cranes, fork-lifts and other plant. Thus, these costs are escapable in the long-run.

A decision not to accept a particular traffic in the long-run will also have repercussions which extend beyond the provision of fork-lifts, cranes and labour. For example, not accepting the traffic may imply: lower wage related costs (holiday and sick pay, levies and surcharges); lower supervisory, administrative and management costs (salaries, wages, national insurance, telephones and transport); lower levels of maintenance staff and stocks of repairs; less garaging facilities for fork-lifts; and a lower level of miscellaneous items (insurance, security and cleaning of bertha). Thus, these costs must also be considered as being escapable in the long-run.

The opportunity costs (lower limit) of these assets could be low. For example, the port authority will have little opportunity to employ

RDW's in capacities other than dock work. Similarly, it may be difficult for the port to use the quaycranes other than for discharging ships. It may however be possible to find employment for some of the mobile plant and equipment. For example the port may be able to lease or hire out fork-lift trucks and mobile cranes. If these opportunities are available on a short-term basis (for example, hiring out the cranes for a day) then these costs become short-run escapable costs and an opportunity cost equal to that charged by outside plant hire firms (given a competitive market) is relevant. If it is only possible to lease the equipment then the outside rate is again relevant however the decision is long-run in nature.

The escapable costs (upper limit) are in principle easier to ascertain than in the docks case. Given a crane or fork-lift with specific characteristics then the port could obtain from the manufacturers a replacement cost and therefore a required input for the valuation formula. If the asset would be replaced with one of different specifications then the replacement cost of this asset can equally well be included in the valuation formula. In the long-run the escapable cost of labour will be the basic time rate of pay.

8.8 The Escapable Cost Matrix

The A matrix for calculating the directly attributable costs applicable to the traffic identified in table 8.3 is shown in table 8.4. Three important features are omitted from this matrix when compared with the theoretical model of chapter 5. The first is that a number of trades have not been included. This is for the purposes of exposition only - they can be included in the full matrix. The second feature relates to the relative absence of joint traffics. For example the traffic

	O	Elbe-Brest	Far East	Iberia	India	Trade/Conf.	Timber	Tomato	Comm. (Gen)	General	Large Tankers	Other Tankers	Mineral Oils	Grain	Sugar	Veg. Oils	Bulk	Container	Ro-Ro	Combi	Deep Sea
O	1																				
Elbe-Brest	1	1																			
Far East	1		1																		
Iberia	1			1																	
India	1				1																
Trade/Conference	1	1	1	1	1	1															
Timber	1						1														
Tomato	1							1													
Commodity (Gen.)	1						1	1	1												
General	1	1	1	1	1	1	1	1	1	1											
Large Tankers	1										1										
Other Tankers	1											1									
Mineral Oils	1										1	1	1								
Grain	1													1							
Sugar	1														1						
Vegetable Oils	1															1					
Bulk	1													1	1	1	1				
Container	1																	1			
Ro-Ro	1																		1		
Combi	1																			1	
Deep Sea Traffic	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 8.4 An Escapable Cost Matrix for Cargo Handling

"Trade/Conference" represents the cost that could be saved if the Elbe-Brest and Far East and Iberian and Indian traffic was jointly not accepted. However the combinations, say, Iberia and India or Iberia and Grain have not been included. The implication of these omissions is that some costs will be computed as being joint to more traffic than they ought to be. Consider, for example, an hypothetical case where all ships take one day to load and discharge. A traffic X consists of a ship every second day and a traffic Y consists of a ship on the alternate days. The cost saving in not accepting either traffic separately will be the short-run escapable costs outlined above. In the long-run the cost savings are likely to be small as the same level of cranes, fork-lifts and labour will be required even if one of these traffics is not accepted. However, if both of them are not accepted then these long-run costs could be saved. The matrix in table 8.4 would therefore suggest a low escapable cost for X and Y separately, and the costs which are specifically attributable to X and Y jointly will be "passed on" to the more general category of "Trade/Conference". Thus, the traffic falling under the heading of "Trade/Conference" should be asked to jointly pay for facilities and services which are allocable specifically to X and Y.

The third omission is that it may be possible to consider increments of traffic within a particular trade/conference. This possibility will arise in the case of the larger volume trades and would allow the port to obtain a cost which is closer to long-run marginal cost than the long-run incremental cost obtained when considering the whole trade.

The more important omission therefore is that of not including the various combinations of traffic. In an attempt to resolve this problem, it would be necessary to compute the escapable costs of all the combinations of traffic. Taking for example the end leaves of the diagram in fig 8.3 there are eleven traffics and therefore 2048 different combinations. Given that this list of traffic is incomplete the number of combinations would rapidly become unmanageable. Compounding this problem further is the computation of the escapable cost of each of these combinations of traffic. Given the mobility of some of the factor inputs, a flexibility in the location where the service is performed and the servicing pattern for vessels (including arrival patterns, queueing, service times, and delivery and receiving of goods from the docks) it would be necessary to ascertain the optimum level of resources to employ every time a traffic was deleted from the list in order to compute its escapable cost. Thus in addition to the large number of escapable costs the port would also have a complex simulation problem to solve.

Whilst it may be possible to reduce the number of computations by considering the circumstances of a particular case, it is unlikely that the order of magnitude of these reductions could approach that achieved for conservancy.

It may however be possible to isolate some of the cost items and legitimately attribute them to groups of traffic. In section 8.5 it was noted that some facilities were provided for specific cargo handling operations. It has also been noted that two contributing factors to the above computational problems are mobility of some factor inputs and flexibility in the location where the service is performed. Thus, it would appear appropriate to separate the factor inputs into those which are provided for specific traffic or groups of traffic and those which are more general in nature (that is, mobile between traffic). This separation can occur at both the aggregate level and within groups of traffic.

When considering traffic in aggregate the main factor in the more general category is labour. Assuming perfect mobility of labour then the port would compute the labour force required to meet the total expected demand. The basic rate times the labour force would then be considered as representing the ceiling of total labour costs (excluding the short-run labour costs discussed above) to be recovered from port users. It is however to be noted that this cost is "joint to more traffic than it need be". Thus it is a common cost (that is, not joint due to indivisibility) and it represents an upper bound for cost recovery. If there are constraints on the mobility of labour, then the costs may be attributable to subsets of traffic but within the subset they are common to all traffic. For example, the MDHC Study suggests the establishment of three labour control centres: one at Vittoria to handle Birkenhead general cargo; one at Gladstone to handle general cargo and timber; and one at Seaforth to handle grain and containers. However again within these subsets the costs are only common.

The factors in the more specific category depend upon the cargo handling operation or particular traffic. Thus the facilities at the container terminal, grain terminal and general cargo berths (excluding labour as appropriate) will be common to their respective traffic.

Within these groups of traffic, there may be some costs which are either specific to a particular traffic or joint (in the indivisible sense) to groups of traffic. Before these costs can be attributed to their respective traffic it will be necessary for the port to ascertain whether the facilities are provided as substitutes for, or in addition to the facilities provided generally for all the traffic in the group. If they are additional then they are correctly attributable to the traffic and the "common" costs less these specific costs are common to all traffic. If they are substitutes, then the traffic involved should be treated separately and should not be required to contribute to the common costs.

Consideration of these smaller groups, with similar characteristics, may also make it possible to simulate the escapable costs of particular traffic and combinations of traffic. For example the port could compute these costs at the container terminal by considering the conferences using the terminal as separate traffic and general users as a single traffic. The discussion of the traffic in aggregate is, however also applicable to this case. That is, as the number of different traffics increase the number of computations and simulations of escapable cost increases rapidly.

8.9 Summary and Conclusions

Sections 8.2, 8.3,and 8.4 above outlined the method by which the MDHC computes the revenue rate (price) for handling general cargo. This rate incorporates a complex set of payments to labour which partially consolidate various award payments, dirt allowances, productivity payments and occupational differentials. These payments represent a not insignificant proportion of the present revenue rate (typically 15 per cent) and are directly attributable, in the short-run, to either the commodities handled during the shift or to specific commodities. In other words, if the traffic was not accepted then these costs would not be incurred. Thus, they are allocable either to a commodity or the commodities handled during the shift and represent part of the minimum price that the traffic should pay. If labour works overtime then an overtime premium is payable, these costs are similarly escapable in the short-run. In addition, there are other payments which the port considers as being overheads but which are escapable in the short-run. These include fuel costs and the percentage increases on the above costs represented by national insurance (both employer's and employee's contribution) and other proportional levies. These costs should then be added to the above in order to obtain the minimum price.

The long-run costs may be more difficult for the port to allocate to specific traffic or groups of traffic. The basic question which arises relates to whether it is feasible to adopt the model outlined in chapter 5. If the port has only a small number of different traffics then it is possible, in principle, to ascertain the escapable costs for the vector or matrix. Under these circumstances the procedure is similar to that discussed under conservancy. Thus, the port would estimate demand over a planning horizon then ascertain the level of services and facilities necessary to meet this demand. Certain of the factor inputs will be in existence at the beginning of the planning horizon and thus the port has the problem of ascertaining the opportunity costs or valuation to obtain the lower and upper limits respectively for cost recovery. However, as these assets or contracts become due for renewal their costs become escapable and therefore allocable to the traffic over the relevant time horizon. This applies not only to physical assets such as cranes and fork-lifts, but also to labour, where the "severance schemes" can be introduced. Having computed these costs for the traffic in aggregate over the planning horizon the port can ascertain the escapable costs of not accepting all the appropriate combinations of traffic (that is, it may not be necessary to consider all possible combinations of traffic). Due to the servicing patterns for vessels this exercise will most likely involve a model which simulates the port's traffic. This exercise then provides the data for the escapable cost matrix from which the costs which are directly attributable to the respective traffic can be computed. These costs are then either specific or joint to defined traffic. The port's remaining problem being to ascertain the respective traffic's willingness to pay for the services.

In the MDHC case it was suggested however that such a comprehensive approach may not be feasible. This arose because firstly, it was not believed that the degree of simplification obtained in the conservancy case could be duplicated (In that case, the simplification was obtained because the costs were largely independent of the traffic); secondly, the number of computations of escapable cost (and therefore simulations of costs without particular traffics) would consequently become unmanageable. Therefore the approach adopted was to consider selected traffic and combinations of traffic. These were broadly outlined in the tree diagram in table 8.3. In practice, there would be more end-points in the diagram - these can be incorporated as required. Even this diagram may involve considerable computational difficulties (in particular, the simulations required) and thus, it may be necessary to contract further back along the tree and consider only vessel type. The approach adopted under these circumstances is similar to that outlined in the case where all the escapable costs can be ascertained. The main difference arises in the interpretation of the resulting costs. The directly attributable costs obtained from the escapable costs and the A matrix are still directly attributable to their respective traffic; however they are common to this traffic and consequently using willingness to pay as the criteria for allocating costs within any identified traffic group could lead to cross-subsidisation with respect to the (unidentified) escapable costs.

The advantage of undertaking the computation is that the port knows the total costs allocable to a selective number of traffics; the problem that remains is one of allocating the common costs.

CHAPTER 9

MERSEY DOCKS AND HARBOUR COMPANY (MDHC)

CHARGING SCHEDULES

9.1 Conservancy

In 1979, revenue from conservancy dues represented 4.5 per cent of the Port's total operating revenue of £66m (Table 9.1). On the cost side, operating expenditure on conservancy was 3 per cent of the Port's total operating expenditure of £60m, and if cargo handling is excluded then conservancy represents 8.3 per cent. Within the total figure of £1.8m, contract dredging is the largest single item of conservancy at approximately £700,000. In addition, the MDHC makes a provision for depreciation of fixed assets and allocates interest charges totalling £400,000.

The current pricing practice adopted by the MDHC with respect to conservancy charges is to levy a flat rate per gross registered ton (grt) with different rates being charged according to the vessel's origin or destination. Two origins/destinations are distinguished; the first being broadly defined as the United Kingdom and Ireland, and the second as "all other areas". In terms of the rate, "all other areas" pay approximately three times the rate for the U.K. and Ireland. In the case of vessels loading or discharging petroleum at Tranmere the conservancy charge is incorporated with berth charges. Information on charges for container vessels being subject to inquiry to the Port's Senior Commercial Officer.

There are a number of arguments that the Port could submit in support of this pricing system. Given an accounting requirement that total

Table 9.1 Profit and Loss Account

	Total		Dock Undertaking and Cargo Handling		Conservancy		Pilot Boats	
	1979	1978	1979	1978	1979	1978	1979	1978
	£'000	£'000	£'000	£'000	£'000	£'000	£'000	£'000
OPERATING REVENUE								
Dues - on Ships	11,729	12,155	8,731	9,205	3,003	2,954	-	-
- on Goods	13,461	14,371	13,461	14,371	-	-	-	-
- on Passengers	132	131	132	131	-	-	-	-
	25,322	26,657	22,324	23,707	3,003	2,954	-	-
Cargo Handling	35,973	32,958	35,973	32,958	-	-	-	-
Cranes and Plant	227	210	545	458	52	1	-	-
Warehousing and Storage	298	333	298	333	-	-	-	-
Sundry Services and Facilities	1,370	1,227	228	181	-	-	1,150	1,150
Rents	2,079	1,859	2,079	1,976	-	-	-	-
Other Income	994	1,174	1,086	1,300	-	-	-	-
Total Operating Revenue	66,263	64,418	62,533	60,913	3,055	2,955	1,150	1,150
OPERATING EXPENDITURE								
Operating and Maintenance	10,743	11,312	9,482	9,654	745	977	855	784
Dredging	1,810	1,507	1,107	979	711	632	-	-
Cargo Handling	38,264	34,310	38,392	34,685	-	-	-	-
General Administrative Charges	3,670	3,321						
Levy - National Ports Council	191	173						
Police Expenses	1,070	872	8,549	7,510	340	330	171	135
Local Rates	871	836						
Superannuation and Allowances	3,259	2,755						
Total Operating Expenditure	59,878	55,086	57,530	52,828	1,796	1,939	1,026	919
OPERATING PROFIT	6,385	9,332	5,003	8,085	1,259	1,016	124	231
DEPRECIATION	3,419	3,670	2,969	3,373	274	162	177	135
INTEREST	4,793	4,420	4,724	4,406	126	59	(57)	(45)
(LOSS)/PROFIT BEFORE EXCEPTIONAL ITEM	(1,827)	1,242	(2,690)	306	859	795	4	141
VOLUNTARY SEVERANCE	(5,635)	(2,712)	(5,635)	(2,712)	-	-	-	-
(LOSS)/PROFIT NEFORE TAXATION AND EXTRAORDINARY ITEMS	(7,462)	(1,470)	(8,325)	(2,406)	859	795	4	141

Source: MDHC, Annual report and accounts for the year ended 31st December 1979 revenue equals total cost, the Port could attempt to meet the requirement by estimating total expected expenditure and total expected traffic (in terms of grt), divide the one by the other to obtain an average cost and set price equal to this amount. However, on the cost side the Port may argue that in the longer run, it is the larger ships which impose the higher costs on the Port. Thus, even if the immediately escapable costs are not related to ship size, the Port may argue that they are pricing according to long-run costs. On the demand side, it could be argued that as voyage length increases, the proportion of port costs in total transport costs decreases. Thus, as voyage length decreases the price elasticity of demand for port services increases (The factors influencing the price elasticity of demand for a factor of production will be discussed further in Chapter 10 (Section 10.3)). Therefore, larger ships on longer voyages have a greater ability to pay. The cross-elasticities of one port for another and the port for other means of transport will also tend to be higher for the smaller coastal vessels than the deep-sea vessels. This arises because firstly there are a number of ports in the North West of the United Kingdom capable of handling these smaller vessels, and secondly, within the United Kingdom,the possibility of the commodities being carried by other means of transport. Thus the coastal vessels have a lesser willingness to pay. The port may also take into account that a coastal vessel can make many more entries into the port during a fixed period of time than vessels with longer route lengths. Thus, the port may be considering the willingness to pay of the coastal traffic over a period of time when setting a lower price for this traffic.

Once the port has determined the relative prices of coastal and deep sea traffic the procedure for ascertaining the absolute prices is straightforward.

Let, R = total revenue

C = total cost

AC = average total cost

Q = total traffic volume

P = price

α = relative price of deep sea to coastal traffic

ω = proportion of coastal traffic in total grt

$(1 - \omega)$ = proportion of deep sea traffic in grt

subscript C = coastal traffic

subscript D = deep sea traffic

then,

$$R_C + R_D = C$$

$$P_C \times Q_C + P_D \times Q_D = AC \times Q$$

$$\left(\frac{Q_C}{Q}\right) P_C + \left(\frac{Q_D}{Q}\right) P_D = AC$$

$$\omega P_C + (1 - \omega) P_D = AC$$

and given that,

$$\alpha = \frac{P_D}{P_C}, \quad P_D = \alpha P_C$$

therefore,

$$\omega P_C + \alpha(1 - \omega) P_C = AC$$

$$P_C(\omega + \alpha - \alpha\omega) = AC$$

$$P_C = \frac{1}{(\omega + \alpha - \alpha\omega)} AC$$

and

$$P_D = \frac{\alpha}{(\omega + \alpha - \alpha\omega)} AC$$

Thus for example, if coastal traffic represents one-third of the total traffic (in grt) and the deep-sea rate is three times the coastal rate, then the price for coastal traffic is 3/7ths of the average total cost and the deep-sea rate is 9/7ths of the average total cost.

The two major advantages of this pricing system are the ease of calculation and administration of the rate. Once the port has determined the relative prices they can easily compute the rates. Similarly there are only two rates, based on a measure which is relatively easy to ascertain and check (grt being available in Lloyds Register of Ships and vessels with dual tonnage pay on the higher grt) and therefore the system is easy to adminster. The Port may also claim that the system works in that its application has ensured that on the conservancy account (Table 9.1) the accounting requirement has been met. However this claim raises the question of the cost measure which is used by the Port. In adopting normal accounting practice the operating and maintenance expenditure of £745,000 incurred under the heading of conservancy will include wages and salaries, maintenance and all those items "used up" in the accounting period. The dredging expenditure of £711,000 mainly represents contract dredging of the main channel and the £340,000 represents an apportionment of the Port's general expenses to the conservancy account. In addition there are the depreciation and interest charges of £400,000. Considering firstly the operating and maintenance expenditure; chapter 6 indicated that apart from the buoys that are left on station for two years, and labour, these costs are incurred over a time horizon of a calendar year or less. For example, the buoys are lifted annually in order to overhaul the buoy and flasher unit and to refil the gas bottles. Similarly, fuel and other consumable stores costs are incurred in surveying the approach channels and River, these costs usually being incurred over a time horizon which is less than a year, depending upon the frequency of survey. Due to the contractual agreements with labour their basic pay is not immediately escapable however their overtime payments are escapable. Thus, by including all labour costs in operating expenditure the port is using the upper limit of escapble costs. Secondly, chapter 6 suggested that the basic contract dredging costs are joint to the remaining life of the contract. More specifically, "the present value of contract payments for the standard dredger over the remaining life of the contract less the present value of a settlement which would allow the port to withdraw from the contract" (section 6.5.2). Any payments in excess of the annual contract costs for the standard dredger are attributable to the traffic over one or more years, depending upon the reason for the dredging. In the longer-run the discounted value of the contracted payments at the date of signing the contract are allocable to the traffic over the life of the contract. Thus the port is again using the upper limit of escapable costs and allocating the contract payments to the years in which the cash flows occur. Whilst this approach may be sensible from an accounting point of view, given the nature of the contractual relationship, all that is required is that over the life of the contract the traffic is willing to pay. Thus, if for example demand fluctuates over time then some years may pay more than the actual cash outflow and in other years they may pay less. Thirdly, there is the depreciation which is allocated to the conservancy account. The accounting practice of the Port is to write off fixed assets (excluding land and capital work-in-progress) in equal annual instalments over their estimated remaining economic life. The accounts are prepared on the historic cost basis, modified to include the revaluation of certain fixed assets (revaluation appearing to apply mainly to land and buildings). This approach is clearly at variance with both the opportunity cost principle or valuation formula. The main assets provided under the conservancy heading include the Port Radar Station, the buoys, "Vigilant", the buoy store, surveying boats and Hi-Fix navigation system. Given a planning horizon of, say, ten years then if the asset will not be replaced the escapable cost (lower limit) is,

$$EC = OC(0) - \frac{OC(10)}{(1 + r)^{10}}$$

and if the asset will be replaced the escapable cost (upper limit) is,

$$EC = V(0) - \frac{V(10)}{(1 + r)^{10}}$$

where, EC = escapable cost.

OC(i) = opportunity cost of the asset in year i.

V(i) = valuation of the asset in year i.

This escapable cost is attributable to all the relevant traffic over this time horizon; there being no economic reason why it should be attributed to the traffic in equal annual instalments. Fourthly, the apportionment of £340,000 of general expenses are (assuming that they are a residual after computing the escapable costs of the various services provided by the port) either fixed or joint to all traffic and thus again there is no economic reason why they should be attributed specifically to conservancy.

The discussion of section 6.4.6 suggested that most of the facilities provided under the heading of conservancy were joint to all of the traffic using the Port. The exception being the buoys in the Garston and Eastham channels, and possibly part of the buoy store and one survey launch. In addition, there were some current factor inputs attributable to various areas of the port.

Faced with the problem of jointness of costs over time, the Port has adopted the standard accounting practice of allocating these costs equally to each year, this device being employed for both assets and contracts. Similarly, when faced with the problem of jointness across traffic the Port has allocated costs equally to each grt of traffic during the year (with some allowance being made for coastal traffic). The more generally based rule is that under both circumstances the traffic should pay according to their willingness to pay. However this raises the questions of equity between similar classes of traffic, and how the Port is to ascertain the willingness to pay of different traffic. The above discussion suggested that the distinction between coastal and deep-sea traffic did take the two traffic's willingness to pay into account. However it does raise the question of whether the relative prices of these two traffics reflect history or willingness to pay, and more generally the question of using grt as a charging base for all vessel types. (The charging base will be discussed in more detail in chapter 10).

In chapter 1, three subsidiary objectives of a pricing system were defined. Thus, to what extent does the conservancy schedule meet these objectives? The first objective was to promote the efficient and full use by shippers, shipowners and others of the port's facilities. In the MDHC case, the short-run escapable cost of an extra ship transit through the conservancy area approaches zero. Thus, the optimum price for this transit approaches zero. The effect of the current tariff will therefore be that traffic which was willing to pay a price greater than or equal to the escapable cost but less than the price currently charged will not be accepted. Under these circumstances, the Port can either investigate the extent to which demand is distorted by employing the current tariff or attempt to devise alternative tariffs. Given that a large proportion of the Port's traffic is represented by a small number of large users some form of block tariff may be devised which has a price approaching zero for a traffic's last transit through the port. There will remain however the small volume and one-off traffic which could not be included within such a system. Given an accounting requirement, the pricing systems for such traffic may be limited to average cost pricing or price discrimination.

The second objective was to avoid cross-subsidisation with respect to escapable costs. The methodology of chapter 6 attempted to identify the costs which were attributable to specific traffic in both the short- and long-run. However, as most of the facilities are joint to all of the traffic using the Port (section 6.4.6), it is unlikely that cross-subsidisation will occur. The area where it may be hypothesized that cross-subsidisation could occur is in the maintenance dredging of the main channel. However in section 6.4.3 it was suggested that there is no substantive information to support the hypothesis that it is the deeper draft vessels which impose higher dredging costs on the port. The third objective was to encourage the Port to develop and improve facilities which are justified by demand. In principle, the pricing system should signal to the Port: whether the current provision of buoys, including the characteristics of the lights and spacing of the buoys, is sufficient; whether the vessel's knowledge of water depths is adequate; whether the information provided by the Port Radar Station is adequate; and whether the depths in the channels are warranted by demand.

If one takes the extreme view that port services are demanded jointly then these services consist of a fixed proportions vector;

$$P = (C, B, H, G)$$

where P = port services

C = conservancy services

B = berthing services (lock entrance to quay-wall)

H = cargo handling services

G = goods services (berth to dock gate)

(with each service consisting of further services and facilities, for example, the above list of services provided under conservancy). In practice however the user of port services can trade-off these services, that is, rank different vectors and thus the vector is not one of fixed proportions. If the goods in this bundle were not to a certain extent complementary then the signal received by the Port in reaction to the price would be excess demand, excess supply or equilibrium. Thus the port could react by expanding, contracting, replacing or not replacing capacity. Under these circumstances, the users are in a position to signal their requirements to the Port because they are free to choose whether or not to consume and if they do consume, their equilibrium quantity. In the case of port services however some element of choice is removed and thus the signals received by the port will be imperfect. For example, the Port may provide a particular level of conservancy services and relate their price to escapable costs. This level may be greater than that required by the traffic, however, given the total bundle of port services, the traffic may be willing to pay the required price. If the consumption of conservancy services was voluntary then the port would receive a signal in the form of excess supply and the required adjustments could be made. However, the conservancy will exhibit one of the characteristics of a public good, that is, consumption is not voluntary and the Port will believe that they are providing the correct level of capacity.

In practice, the Port views the provision of some of the conservancy facilities as being an attempt to maintain at least a minimum standard for the safe navigation of vessels into and out of the Port. The assessment of these requirements tend to be based on rules developed by the Port or the subjective assessments of the Pilots. For example, the spacing of buoys in the main channel was based on an assumed minimum visibility of one quarter of a mile. Similarly, the frequency of survey of the various areas of the port will be determined by past knowledge of siltation rates and changes in the regime of the River. None of these "rules" are binding on the Port. For example, if the buoy spacing was increased to more than the current 1.1 km then this may imply that vessel movements were reduced or stopped on those days when reduced visibility occurred. Thus the benefits of the current spacing include reduced delays to ships and cargoes, and improved safety of life and property (including pollution damage). Against these incremental benefits are set the incremental costs of the current buoy spacing compared with an alternative increased spacing. Whilst the port may not have undertaken these calculations, the current spacing represents an implicit subjective assessment of these factors. Thus, in order to ascertain whether they should develop and improve facilities (or even to reduce the facility), it may be necessary for the port to obtain signals other than those obtained directly from the price system. These would have to be obtained by estimating the benefits to traffic in the provision of different levels of service (that is the traffic's willingness to pay) or consultation with user bodies. One of the underlying assumptions of this objective is that the facilities have been correctly costed. The relevant cost measure for these purposes is the upper limit of escapable cost.

9.2 Berth Charges

The presentation of the schedule of charges on vessels is constructed so that conservancy and berth charges appear in the same table. However, whilst the conservancy charges only distinguish two classes of vessel, berth charges include seven classes for "vessels discharging or discharging/loading" and six classes for "vessels loading only" with a rate per grt per day and a minimum and maximum.

"Vessels loading only" pay between 64 and 82 per cent of the rate for "vessels discharging or discharging/loading", except for vessels trading in the area broadly defined as the United Kingdom and Ireland who pay the same rate for both operations. The argument for the difference is that a reduced rate for loading only assists the United

Kingdom's exports.

The class of voyage/vessel distinction essentially breaks down into the two origin/destinations of the conservancy charge (that is, "United Kingdom and Ireland" and "all other areas") with one coastal and four deep-sea exceptions. The basic daily rate for deep-sea traffic is one and a half times the basic coastal rate. For coastal traffic the exception is grain vessels (lower rate). The four deep-sea exceptions are Europe-Finisterre to North Cape (lower rate) - grain vessels (lower rate), open shelter deck/modified tonnage vessels (higher rate) and timber vessels (highest rate). The higher rates for modified tonnage and timber vessels results from the change over from nrt to grt as a charging base. The grt is crudely the total volume enclosed by the ship, not including certain "exempted" spaces divided by 100 if measured in cubic feet (2.83 if in cubic metres). The nrt is then the grt less certain non-earning "deducted" spaces (for example, engine room spaces, crew accommodation).

When the Port used nrt as a charging base, all cargo carried in spaces which were not included in the vessel's nrt (including cargo in open shelter decks and on deck) were measured and charged at the nrt rate. In the case of timber vessels, deck cargo represents a not insignificant proportion of total cargo which is not included in grt. Thus, in order to make allowance for this the Port now charges 33 per cent more for these vessels. In the case of open shelter deck and modified tonnage vessels, the space between the uppermost complete deck and the second deck is not included in the calculation of grt and the port has similarly increased the daily charge on such vessels.

The grain exception appears both for foreign and coastal vessels (both lower than the standard rate). The reason for this would appear to be a marketing exercise to attract grain vessels to Liverpool.

The last distinction in the standard berth charge tariff is the minimum and maximum. If these are converted into days then coastal vessels (including grain) pay for a minimum of 1.5 days and a maximum of 3.75 days. The deep-sea vessels "discharging or discharging/ loading pay a minimum of two days, however their maxima vary. For "all other vessels" the maximum is 5.5 days, modified tonnage vessels 5.6 days, timber vessel 5 days and grain vessels 4 days without separation and 5 days with separation. The minima for "vessels loading only" are also two days, apart from coastal grain vessels for which the minimum is one day. The maxima for these vessels are similar to the above. A noteable exception is the European vessels which have a maximum of just under three days when discharging or discharging/loading and just under four days when loading only.

There are a number of possible interpretations of these minimum and maximum rates. One interpretation is that the structure represents a system of penalty rates. In other words, the port believes that time is important in that one vessel at the berth excludes any other vessel. For this to be the case, coastal and foreign vessels would have to spend at least 1½ and 2 days respectively at the berth, there would not be a maximum and for it to be a true penalty rate it would have to increase after the minimum. Thus, it would appear unlikely that the tariff has been designed specifically as a penalty rate (although it does provide some incentive for a vessel to move off the berth if it completes the cargo transfer operation before the maximum).

A second interpretation is that the schedule is a form of block tariff applied for every entry into the Port. In the case of the conservancy charge, the vessel only makes one arrival and departure, however with berth utilization, time at the berth can vary, thus giving the port a degree of flexibility in devising the tariff. Thus, if the ship enters the port to load or discharge cargo it pays, in the first instance, an amount equal to two days, regardless of whether they are used or not. They then pay the daily rate for the third and fourth day (coastal) and the third, fourth and fifth day (deep-sea) and finally nothing for any further days if cargo continues to be worked.

The advantages of such a system are firstly that it recognises that there are demand constraints to the total level of the charge. In setting their charges the port pays particular attention to its "important" customers (particularly the deep-sea general cargo vessels) who will probably spend on average 5 days working cargo. By placing a maximum, this reduces the uncertainty to the ship in that it at least knows the maximum it will pay. Secondly, the tariff recognises that given no congestion the SRMC of the vessel staying on the berth approaches zero, and thirdly it does provide an incentive to the marginal user who does not require 4/5 days, to move off the berth.

In addition to the main berth charges, the port has a schedule of "Special Berth Charges". These charges include;

(i) Vessels arriving in ballast, etc. and using the graving docks only - rate per grt which includes conservancy.

(ii) Vessels lightening cargo in the River - rate per grt per day for foreign vessels.

(iii) Vessels lying idle because of non-availability of dock labour, discharging/loading berths, adverse weather or repairing,

(a) For vessels intending to work cargo (Saturdays, Sundays and Public Holidays excluded).

(b) For vessels lying idle (Saturdays, Sundays and Public Holidays included)

- rate per grt per day.

(iv) Bunkering ex the Company's Works - rate per tonne of bunkers shipped for vessels which have not previously paid berth charges.

(v) Vessels using River Oil Terminals - rate per tonne of oil discharged/loaded which includes conservancy.

The two more noteworthy special berth charges are for vessels lying idle and vessels using the River Oil Terminals. In the first case, there is no time penalty for vessels lying idle, and in the second case the charging base is the actual quantity of cargo loaded or discharged.

Given the similarities in the construction of the conservancy and berth charge schedules, some of the comments concerning conservancy charges will also be applicable to berth charges.

The revenue from berth charges in 1979 amounted to approximately £8.7m. However from Table 9.1 it is not possible to separate the costs of providing facilities for ships from cargo handling and the facilities between the berth and the dock gate. Thus, it is not clear whether an accounting requirement is met under this heading.

The arguments on the demand side in support of the lower rate for coastal traffic including: the proportion of port costs in landed price ; cross elasticities; and the greater number of entries made by coastal vessels would all appear appropriate to berth charges. Similarly, the comments relating to the ease of calculation and administration of the charge are applicable.

The question of the cost measure used by the port in ascertaining total cost also arises in the berth case. The three main facilities provided between the lock and the quaywall are the locks, dock and the quaywall. In order that these facilities can be used, they are maintained (including the maintenance of the impounded water level, and the dredging and surveying of the locks and docks) and in the case of the locks, they require to be operated. Thus, given an uncongested system the short-run escapable costs of an extra ship (grt) approaches zero. Excluding the facilities and labour, a number of operating and maintenance costs will be incurred over a time horizon of a calendar year or less. Most of these costs tend to be attributable to their respective time horizons and not specific traffic. The exception relates to whether it can be demonstrated that larger vessels impose higher maintenance costs (both use related and stochastic) on the port.

The allocation of depreciation to vessels is again at variance with the opportunity cost principle or valuation formula. The alternative employment of locks, docks and quaywalls tend to be considerably restricted and thus the opportunity cost measure may approach zero. At the other end of the spectrum, it may be particularly difficult to obtain a "replacement cost" for the valuation formula. Thus in the MDHC case a "compromise measure" was suggested which incorporated the estimated replacement cost of the facilities in situ, and an updated historic cost of the assets for which demand exists. Whilst estimating this cost, it may be possible for the port to estimate the cost saving of not accepting particular vessel types, for example, container vessels, grain vessels and general cargo vessels. It may also be possible to estimate the costs of a marginal berth and any size related costs. In a port which is expanding or replacing assets it will be considerably easier to obtain estimates of these costs, particularly that of a marginal berth.

The discussion of chapter 7 suggested that a number of the operating and maintenance costs (including dredging and surveying) were joint to all traffic. Similarly, it may be difficult to isolate the costs of facilities to be attributed directly to specific traffic or groups of traffic. Thus when faced with these difficulties, the port has again averaged over traffic and over time, with an allowance being made for coastal traffic. However, apart from this averaging, there remain the questions of the use of grt as a base for the charge and the relative prices of coastal and deep-sea vessels. In particular the relative berth charges would suggest that coastal traffic has two-thirds of the ability (or willingness) to pay of the deep-sea traffic whereas the conservancy charges suggest that they only have one-third of the ability (or willingness) to pay.

The comments relating to the extent to which the current pricing system meets the objectives outlined in chapter 1 are similar to the conservancy case. Firstly, the use of an average cost based tariff will tend to deter the marginal user, although the use of a maximum charge may moderate the effect. This will however depend upon the number of days that a marginal vessel would spend loading and/or discharging at the Port. If this vessel would spend less than the maximum time, then the tariff would not have this modifying effect. Secondly, given the degree of jointness in the cost of providing facilities for deep-sea traffic it is unlikely that any significant cross-subsidisation with respect to escapable costs will occur. The area where it may be hypothesized that cross-subsidisation could occur in the long-run is with respect to size related costs of locks and quaywalls. This hypothesis would have to be investigated further when attempting to ascertain the replacement costs for the valuation formula. The location and facilities provided for coastal traffic may be different from those provided for deep-sea traffic, thus there may be a case for treating this traffic separately. For example, if it was decided to relocate this traffic at River berths in 1990, it could be the case that they have a prior claim on the berth or that River berths are unsuitable for the deep-sea vessels. Thirdly, the system should encourage the port to develop and improve facilities which are justified by demand. For example, in the case of the coastal traffic which may be transferred to the River berths, the price that they are paying should be signalling whether the necessary improvements and developments should be undertaken. Similarly, the price being paid by container traffic should be signalling whether investment (or disinvestment) in the facilities for these vessels should be undertaken. However, any signal which the port receives is conditional upon the charges levied for other services. For example, if the coastal traffic is willing to pay for the improvements then given the prices of the other services there is a conditional signal to the port to undertake the improvements.

9.3 Charges on Goods

The schedule of charges on goods classifies commodities according to the "Brussels Nomenclature for the Classification of Goods in Customs Tariffs 1955". The charge is on a per tonne basis, with separate rates for goods imported from and exported to a foreign place. In addition there is a separate schedule for coastal traffic which does not use any commodity classification.

In the 1976 foreign traffic schedule there are 131 different commodities or groups of commodities listed (more recent schedules having a similar structure). For imports, there were twelve different rates and for exports there are four different rates (Table 9.2).

Table 9.2 Frequency of Charges on Goods - Import and Export (£/tonne)

Import		Export	
Rate	Frequency	Rate	Frequency
0.32	4	0.47	7
0.70	2	0.70	2
0.83	10	1.28	18
2.00	2	3.29	20
2.16	1		
2.27	19		
2.78	1		
2.90	1		
3.05	14		
3.84	10		
5.04	7		
6.30	44		

Thus, the import traffic has a wider range of rates than export traffic and in general the rate for an imported commodity is higher than the corresponding export rate.

The owner of the goods is liable for the charges, and goods which remain on the dock quays for more than three days are liable for payment of "Quay Rent" or "Special Rent".

The coastal schedule contains a general rate for all commodities and twenty listed commodities or groups of commodities which are exceptions to the general category. Nine of the exceptions pay a rate which is half of the general rate, four pay a rate which is a quarter of the general rate, live animals pay a rate per animal and the balance are exempt from goods charges. The coastal rates are in general considerably less than the foreign rate (the general rate being 68p).

There are a number of exemptions for goods in transit and goods discharged coastwise and then loaded foreign and vice versa. The general purpose of these exemptions is to ensure that goods do not pay twice but at the same time requiring that the revenue that the Port receives is the higher of the two rates.

The discussion in chapter 4 (section 4.6.2) outlined the main supply and demand characteristics of goods. On the supply (cost) side the characteristics included the physical dimensions, the size of the individual unit, the awkwardness of the unit, special properties of the goods and the time for which the service is required. The Port attempts to incorporate the time for which the service is required into the Quay Rents. With respect to the other cost items, it is difficult to ascertain the extent to which the tariff is cost based.

The schedule does not take into account the size of individual units handled except for not including the weight of containers or pallets in the gross weight used for computing the charge. Similarly, whilst awkward units of goods with special properties may incur higher rates, it is difficult to classify them according to these characteristics from the published tariff. One hypothesis that may be investigated however is a relationship between the rate and the physical dimension of stowage factor. Table 9.3 contains the rates, stowage factors and unit values for some of the commodities in the foreign charges on goods schedule. (The reason for the incomplete list being due to problems in matching the Brussels Tariff Nomenclature (BTN) with the Standard Industrial Trade Classification (SITC) [1]). Plotting the stowage factor (specific volume) against the rate, figure 9.1, there is clearly no relationship between these variables. Thus, this data does not support the hypothesis of a relationship between the rate and stowage factor.

On the demand side, section 4.6.2 suggested that the characteristics of the goods included unit value, size of consignment, volume of trade flow, origin/destination and the nature of the transit through the Port. The origin/destination of the commodity is reflected in the lower rate paid by coastal traffic. The arguments submitted in support of this distinction are similar to conservancy and berth charges, and include the proportion of port costs in landed price and cross elasticities. The use of the argument that a single coastal vessel may make many more entries into the port may not however be valid when considering goods. The nature of a good's transit through the Port is incorporated in the exceptions to the schedule whereby the good only pays once. The hypothesized relationship

Table 9.3 MDHC Charges on Goods (Imports)

BTN	Commodity	Stowage Factor (cu.ft./tonne)	Unit Value (£/tonne)	Rate (£/tonne)
01	Live animals	-	339.35	6.30
02	Meat etc.	70	625.42	3.05
03	Fish, crustacea and molluscs	60	920.78	3.05
04	Dairy Produce etc.	66	339.69	3.05
05	Products of animal origin	-	300.45	2.27
07	Edible vegetables	-	131.32	2.27
0801/12	All dried fruit; nuts shelled or not	85	594.79	3.84
09	Coffee, tea, maté and spices	80	507.69	3.05
10	Cereals (excl. breakfast cereals)	50	81.14	0.70
12	Oil seeds and oleaginous fruit etc.	74	139.06	0.70
13	Raw vegetable materials etc.	-	183.64	3.05
15	Animal and vegetable fats and oils	50	261.20	2.90
1501/2	Lard and tallow	82	240.06	2.16
17	Sugars and sugar confectionary (ex. molasses)	54	143.39	2.27
1703	Molasses	-	35.58	0.83
18	Cocoa and cocoa preparations	80	572.67	3.05
1801	Cocoa beans in bags	80	661.22	2.00
22	Beverages, spirits and vinegar	64	59.83	6.30
24	Tobacco	112	950.54	2.78
26	Metallic ores, slag and ash	-	17.40	0.83
2601	Iron ore and bauxite	-	9.85	0.32
29	Organic chemicals	-	370.79	6.30
30	Pharmaceutical Products	52	1,701.70	6.30

Table 9.3 (continued)

BTN	Commodity	Stowage Factor (cu.ft./tonne)	Unit Value (£/tonne)	Rate (£/tonne)
33	Essential oils etc; Perfumery etc.	52	4,197.66	6.30
38	Misc. chemical products	51	313.67	3.05
39	Artififical resins and plastic materials etc.	51	527.51	6.30
40	Rubber, synthetic rubber etc.	72	362.15	3.84
41	Rawhides, skins (excl.) furskins) and leather	104	407.52	3.84
42	Articles of leather	102	1,368.77	6.30
44	Wood and articles of wood etc.	90	114.56	0.83
48	Paper and paperboard etc.	90	342.13	2.27
49	Printed books, newspapers, pictures etc.	-	1,107.65	6.30
51	Man-made fibres (continuous)	104	981.80	6.30
53	Wool and other animal hair	104	903.00	2.27
55	Cotton	104	554.08	2.27
58	Carpets, mats, matting and tapestries etc.	104	914.10	3.84
64	Footwear	-	1202.55	6.30
70	Glass and glassware	73	300.27	6.30
7301/13	Pigiron, scrap, billets, bars, coil etc.	34/39	143.30	0.83
74	Copper and articles thereof	35	899.14	2.27
75	Nickel and articles thereof	35	2,282.11	6.30
76	Aluminium and articles thereof	35	499.91	2.27
78	Lead and articles thereof	35	250.98	2.27

Table 9.3 (continued)

BTN	Commodity	Stowage Factor (cu.ft./tonne)	Unit Value (£/tonne)	Rate (£/tonne)
80	Tin and articles thereof	35	3,339.05	5.04
81	Other base metals	35	1,723.74	6.30
82	Tools, implements, cutlery etc.	52	1,871.20	3.84
84	Boilers, machinery, mechanical appliances etc.	100	1,681.09	5.04
85	Electrical machinery and equipment etc.	78	1,881.87	5.04
89	Ships, boats and floating structures	-	16,804.39	6.30
92	Musical instruments etc.	106	3,126.48	6.30
94	Furniture and parts thereof	106	836.13	6.30
97	Toys, games and sports requisites	106	1,672.15	6.30
98	Misc. manuf. articles	106	1,134.03	6.30

Source: see note [1]

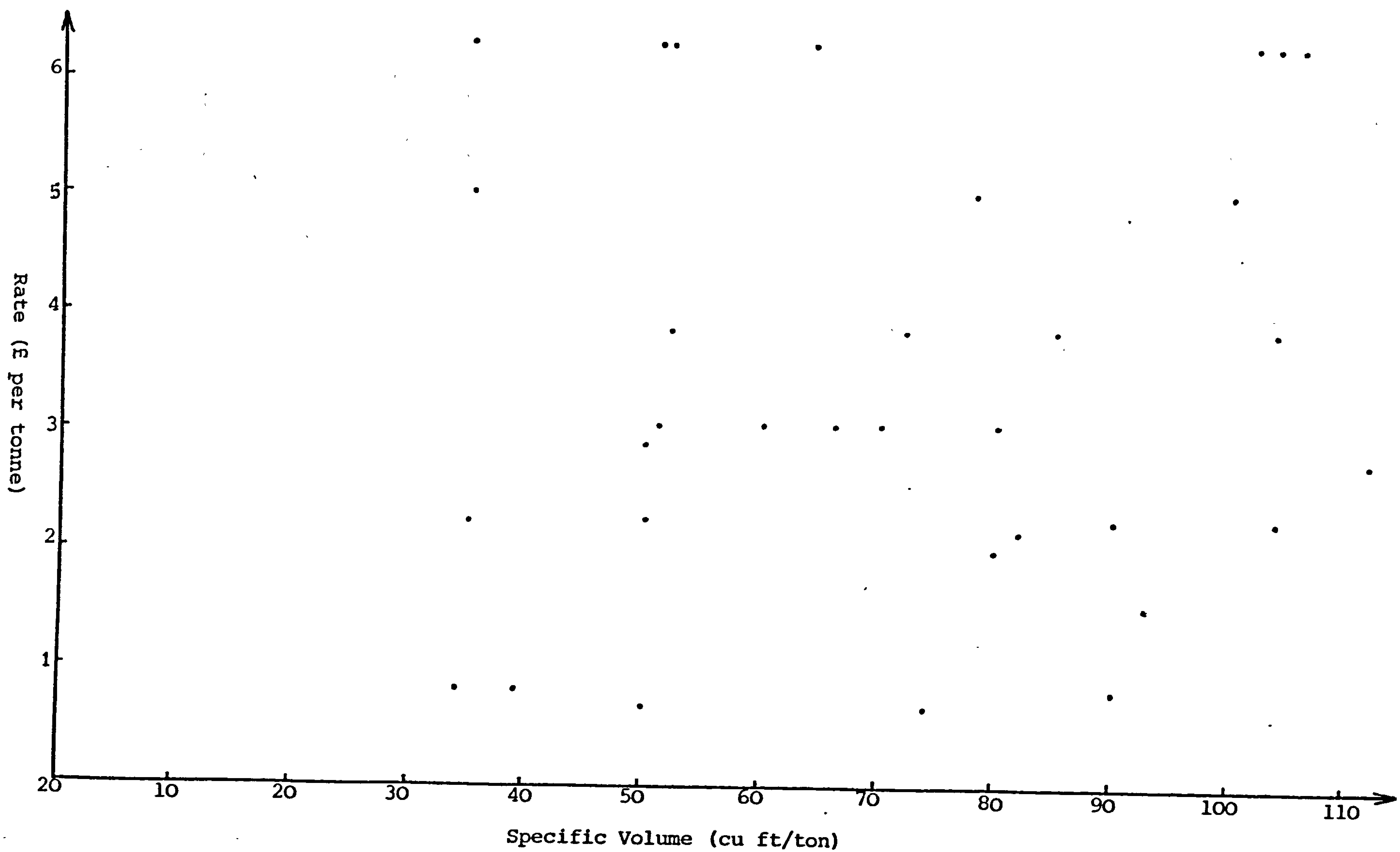


Fig 9.1 Charges on Goods and Stowage Factors

between the rate and unit value is that the higher the unit value the greater the ability of the commodity to absorb higher port charges. In figure 9.2 the logarithm base 10 of the unit value is plotted against the rate using the data in table 9.3. Apart from the five outlying commodities with a low unit value and rate of £6.30, it would appear that the rate increases as the unit value increases. The least squares regression line fitted to all the data is;

$$\text{Rate} = -2.37 + 1.00 \ln UV \quad (r^2 = 0.4427)$$

Thus the logarithm base 10 of unit value explains 44.27 per cent of the variation in the data, a result which partially supports the hypothesis. If the five outlying observations are removed from the data then the regression line becomes;

$$\text{Rate} = -4.01 + 1.22 \ln UV \quad (r^2 = P.6523)$$

which explains 65.23 per cent of the variation in the data. These five commodities are;

Commodity	Unit Value (£/tonne)
Beverages, spirits and vinegar	59.83
Glass and glassware	300.27
Live animals	339.35
Organic chemicals	370.79
Artificial resins and plastic materials etc.	527.51

In the case of spirits, glass and live animals, it could be argued that they require special care and thus impose extra costs on the port (that is, cost factors may partially explain these particular rates).

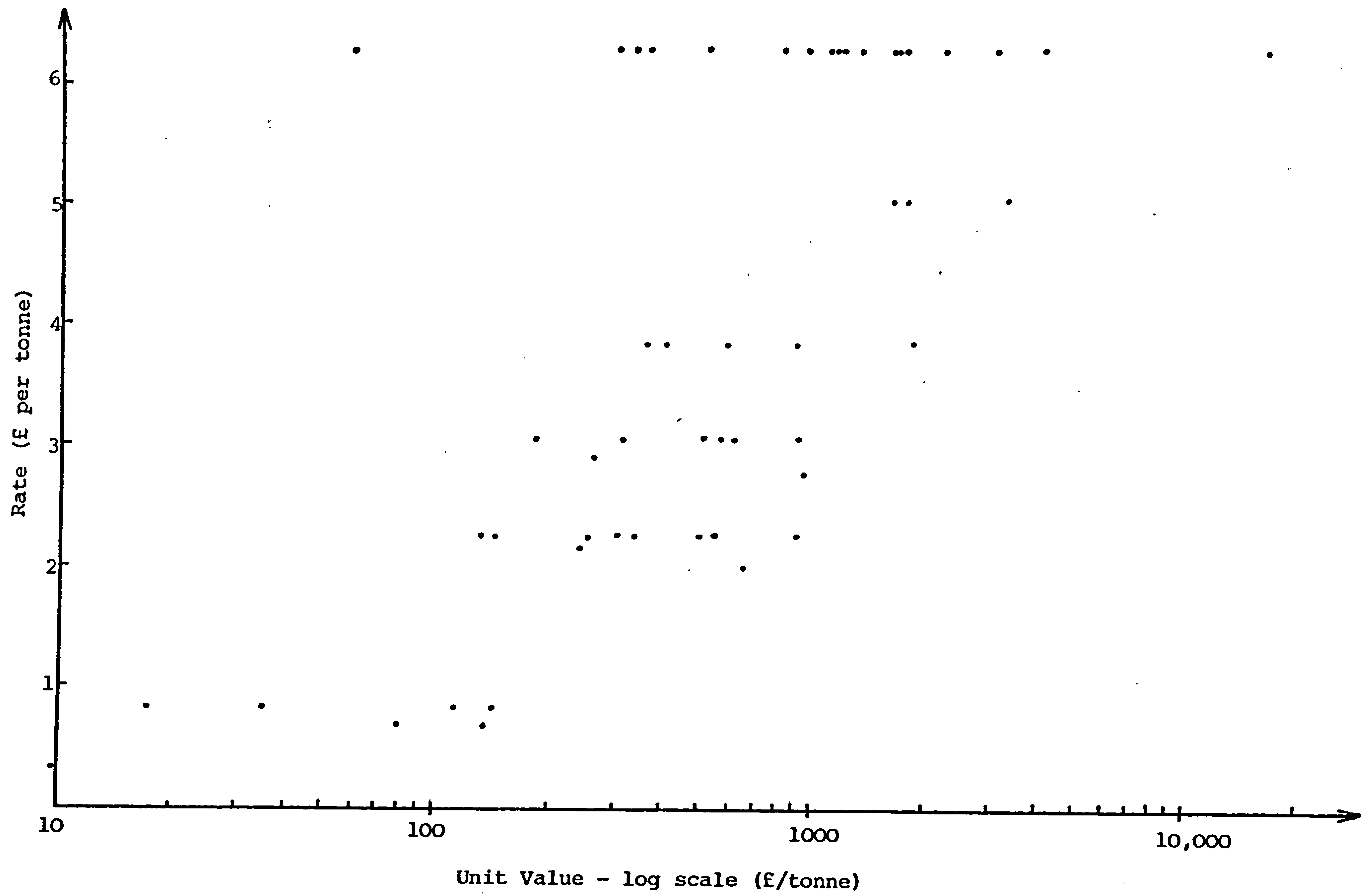


Fig 9.2 Charges on Goods and Unit Value

In the case of organic chemicals and artificial resins, one explanation could be that with technological change the unit value of these commodities has fallen however the rate charged by the port has not been subsequently lowered. One must however be particularly cautious of such an interpretation as the same comment could be made about other commodities that have not been excluded from the analysis. There would however appear to be some evidence to support the hypothesis that charges on goods are to some extent related to demand. But, as was noted in section 4.6.2., high value goods can impose higher costs on the port.

The goods schedule is more complex than both the conservancy and berth schedules. Thus in principle the rates are not as easy to compute and administer. In practice however the rate has been computed by applying "across the board" percentage increases. For example, the rates in the schedule operative from 1st January 1981 are approximately 76 per cent higher than the rates in the schedule operative from 1st January 1976. Thus computation of the rate has been relatively easy. Similarly, given that the structure of the schedule has not changed for some time the Port has considerable experience in its use and therefore its administration is relatively easy.

The revenue from dues on goods in 1979 was just under £13.5m; 54 per cent more than the revenue from dues on ships. Again, however, it is not possible to separate the Port's measure of the costs incurred in the provision of the services associated with charges on goods, as these are consolidated under the heading of Dock Undertaking and Cargo Handling in the Profit and Loss Account (Table 9.1). The main facilities associated with this charge included the surfacing of the of the berth and back-up area, transit sheds, access to the berth and perimeter fences. In addition, it will be necessary for the Port to maintain these facilities. In general, these costs will be allocable to time horizons which are greater than the accounting period of one year. However, the Port again uses the accounting rule of allocating historic cost equally to each of the remaining years of the asset's economic life. The discussion of chapter 7 suggested that the opportunity and replacement costs may be easier to measure for these facilities. Thus the lower and upper limits of escapable costs may be ascertained. Chapter 7 also suggested that berths tend to be "fitted out" for different cargo handling operations and therefore the Port could identify traffic according to vessel type or the cargo transfer facilities required. The procedure outlined was to estimate the aggregate demand for each berth type including container, grain and general cargo; then to estimate the incremental cost (or escapable cost) of providing the basic facilities for this traffic. If a specific traffic requires facilities in excess of the basic facilities then their costs are attributable to that traffic. In order to reduce the number of computations of escapable costs, it was also suggested that the Port attempts to estimate the escapable cost of the marginal basic berth. This cost is then attributable jointly to the traffic requiring a berth of the relevant type.

The view taken by the Port with respect to the different commodity/ vessel types would appear to follow a container, grain, general cargo and timber division of traffic. The main schedule for foreign goods charges does include cereals and wood. However, in the case of grain a separate publication is issued by the Port which lists all of the charges for vessels and goods using the Royal Seaforth Grain Terminal. The rates for both of these commodity groups are lower than the majority of foreign rates - the grain rates are similar to the coastal rates and the timber rates are only slightly higher. Similar comments apply to some of the dry and liquid bulk commodities handled at the port. The rates for containers and container vessels tend to be confidential with information concerning charges being available on request from the Senior Commercial Officer.

In the case of the facilities provided between the berth and the dock gate the Port has "resolved" the problem of jointness in costs over time by allocating the costs equally to each year. When faced with jointness across traffic, a different approach to the averaging process in the conservancy and berth charges is used. In principle the Port would appear to be adoptingthe theoretical solutions suggested in chapters 2 and 3, that is, given that the facilities are supplied jointly the only requirement is that traffic in aggregate should be willing to pay. Thus, the port charges each traffic according to its willingness to pay subject to the traffic in aggregate paying the costs which the Port has allocated (equally) to each year. In practice however it is unlikely that the existing schedule reflects the traffic's relative willingness to pay as the relative prices have not changed over time.

The extent to which this pricing system meets the objectives outlined in chapter 1 tend to be slightly different from conservancy and berth charges. Section 3.4.2.suggested that judicious application of imperfect price discrimination can lead to greater output than a single price monopolist. It may therefore be the case that the level of output is greater under price discrimination than if the Port used average cost pricing. However, given that the short-run escapable cost of an uncongested berth approaches zero there will be traffic which is not willing to pay the scheduled charge, but is willing to make some contribution to longer-run costs, which will not be accepted. Thus again the Port would need to investigate the distortionary effects of the tariff or attempt to devise an alternative tariff structure. The extent to which cross subsidisation with respect to escapable cost may occur in the current schedule is not clear. However if the Port adopts the above procedure of identifying escapable cost according to berth type then any cross subsidation can be minimised.

The signals with respect to the provision of these services and facilities will again be conditional upon the prices of the other services and facilities provided by the Port. In this case however the user may have a choice between the services which he receives. For example the Port may be able to offer berths which have been "fitted out" to different standards and therefore excess supply or demand for different standards of berth would provide a more positive signal to the port when considering whether to develop and improve the facilities. The signal is again however imperfect as it is still conditional upon the other charges levied by the port.

9.4 Cargo Handling

In 1979, the Port's operating revenue and expenditure on the cargo handling account were approximately £36.0m and £38.4m respectively. Thus using the Port's cost measures a loss was made before taking into account the allocation of general expenses, depreciation and interest. These figures represent 57.5 and 66.7 per cent of total operating revenue and expenditure respectively.and thus cargo handling is an important component of the Port's total expenditure. A large proportion of the total expenditure is represented by labour costs, however the exact proportion is not available from the Port's published accounts.

Chapter 8 outlined the four distinct processes in the cargo handling operation. The structure of each of the charging schedules are different and thus the following sections will consider loading, discharging, master porterage and wharfinging separately.

9.4.1 Loading Stevedoring

The loading schedule is a relatively simple schedule with separate rates being quoted for seven different categories of commodity. Of these seven categories there are five "general" and two "specific" rates. Categories 1 to 5 are the general rates, category 6 is for "full cargoes of metals, in pieces, 5 tonnes or over" and category 7 is for containers over 17 m^3 (600 ft^3). The categories are broadly based upon the unit weight or stowage factor of the commodity. Category 1 has the highest unit weights and the lowest stowage factors. Examples of commodities which appear in several categories are shown in table 9.4. The schedule also recognises "palletised cargoes loaded during any 8 hour period or longer with a reduced manning", which are subject to an allowance of 15 per cent off the appropriate tonnage rate.

Table 9.4 Summary of Loading Stevedoring Schedule

COMMODITY / CATEGORY	GENERAL CARGO n.o.s. cu.m/t	BAGS n.o.s. kg/bag	DRUMS kg/drum	PALLETISED OR UNITISED CARGO kg/unit	STANTON PIPES diameter in cm	RELATIVE RATE
1	⩽ 1.133	> 51	> 51	> 762	> 30.5	100
2	> 1.133 to 1.982	> 14 to 51	> 18 to 51	> 508 to 762	-	116
3	> 1.982 to 5.663	⩽ 14	-	-	> 15 to 30.5	158
4	> 5.663 to 8.495	-	⩽ 18	⩽ 508	⩽ 15.2	189
5	> 8.495	-	-	-	-	275

9.4.2 Discharging Stevedoring

The discharging schedule contains 146 listed commodities or groups of commodities with 91 different rates ranging from £2.76 to £23.56 per tonne (schedule effective from 25th April 1977). The unweighted mean of these rates is £9.32 and the standard deviation is £3.05. Figure 9.3 shows the frequency distribution of the rates. The schedule contains four major "not otherwise specified" (n.o.s.) rates which include,

.Cylinders, Drums, Barrels, Casks and Hogsheads.

.Bales, Bundles and Reels

- up to and including 152 kg
- over 152 kg.

.Bags

.Cases, Cartons, Crates and unpacked Machinery

- up to and including 16 kg
- over 16 kg.

Where two weights are indicate, the heavier weight has the lower rate.

Within the remaining 140 "exceptions", there is some division according to unit weight, number of units per tonne and origin of cargo. The commodities where these distinctions are made include,

(a) by unit weight

.Fresh fruit and vegetables in packages, n.o.s.

- up to and including 9 kg
- over 9 kg and including 16 kg
- over 16 kg and including 32 kg
- over 32 kg.

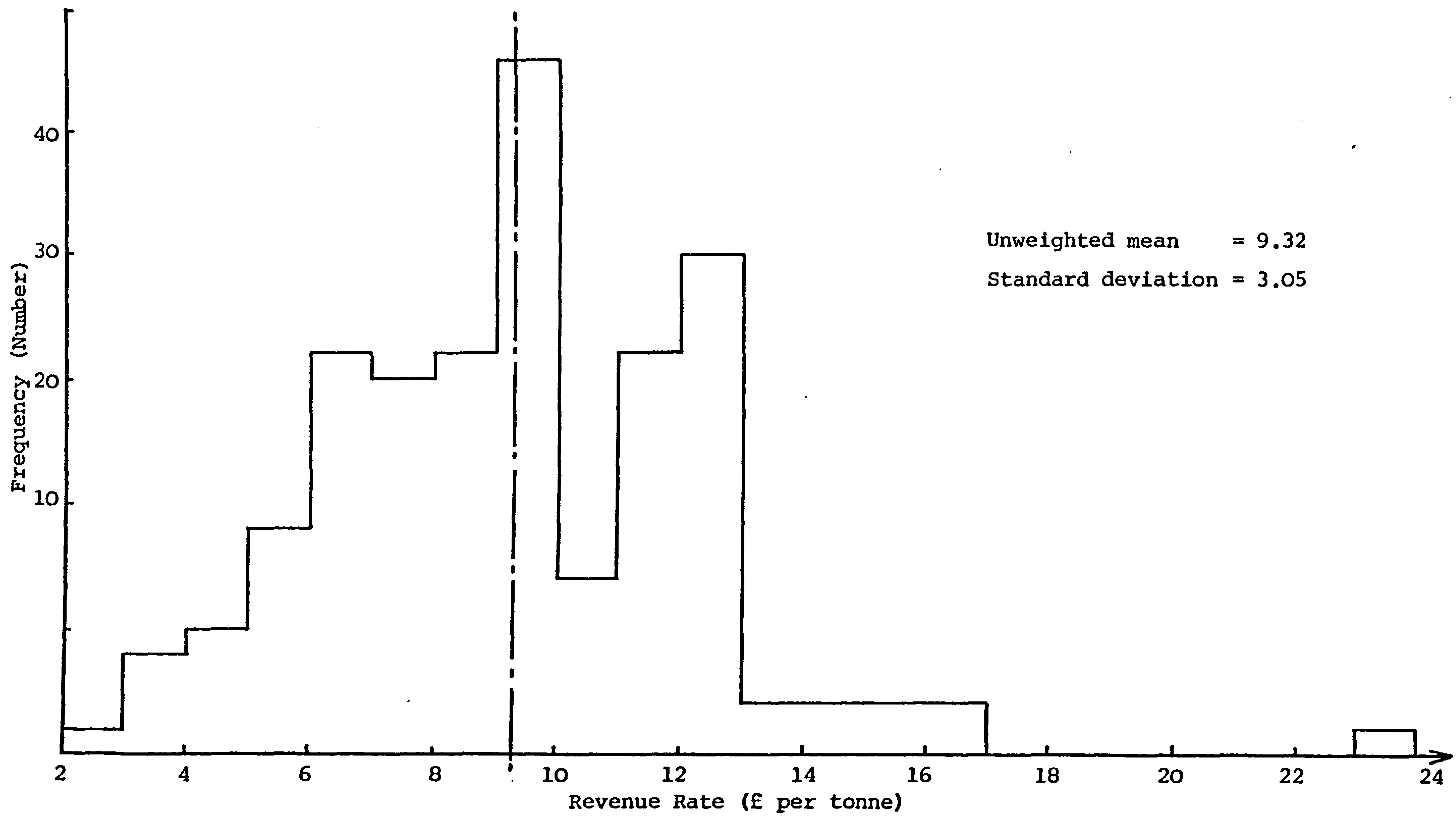


Fig 9.3 Frequency of Discharging Revenue Rates

.Hides and skins

- dry bundles up to and including 254 kg
- dry bundles over 254 kg

.Metals, n.o.s.

- up to and including 27 kg
- over 27 kg and including 305 kg
- over 305 kg and including 1,000 kg
- over 1,000 kg.

In all cases the heavier unit weight has a lower rate per tonne.

(b) by the number of units per tonne

.Timber, if the total shipment of pieces and bundles averages;

- over 1,000 kg per piece
- 1 piece and including 20 pieces per tonne
- over 20 pieces and including 60 pieces per tonne
- over 60 pieces and including 100 pieces per tonne
- over 100 pieces per tonne.

Where, the greater the number of pieces per tonne, the higher the rate.

(c) By origin;

.Mixed general cargo

- ex Elbe to Brest Range (cases, cartons, crates, bundles and baskets)
- ex Far East
  - cartons
  - crates
- ex Iberian Peninsular

.Cargoes originating from

- India, Pakistan and Bangladesh

- discharged at Sandon Dock
- discharged elsewhere.

9.4.3 Master Porterage

The master porterage schedule is composed of twelve categories of commodities mainly according to their method of packaging. In this respect, the structure of the schedule is similar to loading stevedoring. However within each category there are up to 22 different rates so that the similarity to loading is only in the formal presentation of the schedule. Within five of the categories there is a "general classification" (n.o.s.) then a list of exceptions. In the general class, commodities are defined according to their unit weight or origin. The schedule allows rebates on various commodities, these rebates depending upon the total weight of the consignment and the method of delivery. A description of each category is as follows;

(a) Cases, cartons, crates and baskets

General classification

by unit weight,

- up to and including 10 kg
- 10 kg and including 15 kg
- 15 kg and including 30 kg
- 30 kg and including 1 tonne
- 1 tonne and including 5 tonnes

by origin,

- from Far East
- from Iberian Peninsular
- from Elbe to Brest range.

(b) Bales, bundles and reels

General classification

by unit weight,

- up to and including 135 kg
- 135 kg and including 320 kg
- over 320 kg

(c) Drums, barrels, casks and cylinders

General classification

by unit weight,

- up to and including 45 kg
- 45 kg and including 90 kg
- 90 kg and including 180 kg
- 180 kg and including 320 kg
- over 320 kg

Empty drums, barrels, casks and cylinders are charged the general rate plus 50 per cent.

(d) Bags

General classification

by unit weight,

- up to and including 30 kg
- 30 kg and including 55 kg
- over 55 kg.

exceptions,

The dirty cargoes - carbon black, yellow oxide, red oxide and umber - as well as having a rate per tonne also incur a time rate for every hour or part thereof (with a minimum of four hours) which they are worked.

(e) Metals

General classification,

by unit weight,

- up to and including 225 kg
- over 225 kg

(f) Frozen Cargoes

Three specific rates, two of which depend on whether the cargo is to be sorted or not.

(g) Miscellaneous

(h) Heavy lifts over 5 tonnes

Two rates, depending on whether the cargo is delivered direct or landed on the quay. In addition to the rate, the cost of mechanical appliances and extra labour is charged.

(i) Palletised or pre-slung cargo

Unit weight,

- units less than 750 kg charged under the general classification of the commodity composing the unit
- over 750 kg to and including I tonnes
- over 1 tonne to and including 5 tonnes

(j) Containers delivered direct at berths other than container terminal (over 600 cu ft)

Rate per unit, with an additional charge for mechanical appliances and a minimum charge per hatch per working period

(k) Bulk cargoes

(k) Timber

The category is divided into softwood and hardwood at the first level and then logs or loose and bundles at the second level. The loose and bundles have three rates depending upon unit weight

- up to 500 kg
- 500 kg and -ncluding 1,000 kg
- over 1,000 kg

The rebates for the total weight of the consignment range from 5 per cent to 20 per cent. They are made for goods in categories (a) to (e) above and for four specific commodities. The rebates for method of delivery are for direct delivery across the quay and direct delivery.

9.4.4 <u>Wharfinging</u>

The wharfinging schedule does not contain any listed commodities: it consists solely of time rates for labour and mobile plant. Three types of labour are distinguished - staff, labour and clerical - and a rate per man is quoted for each of the shifts worked at the Port, (see section 8.3.1), public holidays and extra hours. In addition there is an "overtime excess cost" which is again quoted for the same types of labour and shifts or hours. The rates for company owned mobile plant are quoted on an hourly basis with different (increasing) rates applying to fork-lift trucks and mobile cranes as capacity increases. The rates for bogies, fork-lifts and mobile cranes exclude the driver. For most of this plant the driver rates are the standard labour rates, however for 30 and 40 ton cranes there are separate (higher) driver rates with two drivers to be charged. Plant hired by the MDHC is charged for at cost plus the cost of the driver's personal injury insurance and reasonable overheads in relation to the hiring.

9.4.5 The Cargo Handling Schedules

In support of these cargo handling schedules, the port would argue that they are all cost based. Apart from wharfinging the broad method of establishing the published revenue rate (price) is to mark-up on direct labour costs and to charge separately for extras. Chapter 8 outlined the main elements of the revenue rate as being:

(i) The basic wages of Registered Dock Workers (RDW). This is a standard rate regardless of the capacity in which the RDW is employed.

(ii) Occupational differentials. When an RDW is allocated to a ship, he is also employed to perform a particular job (for example, deckhand, stevedore, crane driver, checker etc.), each of these jobs receiving an occupational differential in addition to the basic rate.

(iii) Standard manning. The port has a schedule of standard mannings for discharging different commodities.

(iv) Standard productivity. The port has estimated from the experience of their supervisory staff standard productivities (tonnes per net gang hour - TPNGH).

(v) Bonus rate. Again the port has a schedule which for every commodity shows the Bonus Payment per man per tonne.

(vi) The Mark-up. The function of the mark-up is to recover the wage related costs, the district/terminal office costs, various miscellaneous costs and the costs of agreed quayside plant (mainly fork lifts and cranes transferring cargo from the ship's side to the transit shed).

In the case of discharging (stevedoring) the revenue rate was initially computed from the formula,

$$REV = \left[\frac{\sum_{i=1}^{m} W_i/NH}{TPNGH} + b\left(M + \frac{N}{2}\right)\right](1 + \alpha)$$

where, REV = revenue rate (£/t)

W_i = wage plus occupational differential of man i, per shift (£)

NH = net hours worked during a shift

TPNGH = productivity - tonnes per net gang hour

b = bonus plus (where appropriate) dirt allowance (£/man/tonne)

M = ship manning plus half of the checker

N = shore manning (half of bonus payments to the master porters are to the shipowner's account)

α = mark-up

In a second round, slight adjustments were made to incorporate "other" supply and demand factors.

Section 4.6.2 outlined the various supply and demand characteristics of goods. On the supply side, the characteristics which impose costs on the port include;

(i) Those which affect the rate at which cargo is handled. Due to institutional arrangements, the Port incurs its basic labour costs on a temporal basis but charges on a weight basis. Thus, the faster that a cargo is discharged (tonnes per hour) the lower the cost per tonne. The handling rates of a particular commodity will depend upon,

(a) A measure of the relationship between weight and volume. For example, a greater tonnage of copper bars could be discharged per unit time than say bales of cork.

(b) The size of the unit (for example, cartons, pallets and containers). Ceteris paribus, the larger the unit size, the faster the rate at which the cargo can be handled.

(c) The size of the consignment. By the process of specialisation, productivities on large consignments of homogeneous commodities may be greater than the productivities obtained on small consigments of the same commodity.

(d) The "awkwardness of the unit" (for example steel constructional pieces).

(e) The location of the commodity within the ship. Commodities such as explosives, high value commodities and refrigerated cargoes tend to be stowed in lockers. This usually requires manual handling which in turn reduces the rate of discharge (this may however be compensated for - at higher cost - by larger gang sizes).

(f) The "dirty" nature of the commodity. On the cost side, labour is paid a higher rate for handling such cargoes. This extra payment contains two elements: a payment to compensate labour for the disutility of handling such commodities (which is separate from productivity considerations); and a productivity related cost which recognises that extra time must be spent cleaning the ship's hold - which reduces the rate for handling the cargo.

(ii) Those which require the port to provide extra facilities (for example, labour, mobile plant and floating cranes). Some of these facilities are charged for separately and thus they do not enter into the revenue rate. One exception is the standard manning which varies between commodities. Thus some commodities impose different costs on the port according to their required manning.

On the demand side, the characteristics which will influence the user's willingness to pay include;

(i) The unit value of the commodity. The higher the unit value, the more easily the charge can be absorbed.

(ii) The volume of trade flow in the commodity and the size of the consignment. Reduced rates may be offered to shippers presenting large quantities of cargo to the port in order to retain or attract such traffic.

(iii) Origin or destination of the cargo. In the case of conservancy and berth charges it was suggested that as voyage length increases the proportion of port costs in total transport costs decreases and thus the commodities from the more distant ports may have a greater ability to pay. From the published rates this would appear not to be the case. Two more plausible explanations are that either the commodities from the named countries or areas are relatively homogeneous or the rates are an attempt by the Port to retain or attract the trade.

The Port however would explain these factors in terms of costs. High unit value commodities require more care in handling and therefore impose higher costs; high volume trade flows imply that economies of scale can be realised which reduces costs, and the commodities by origin may be homogeneous or the commodity structure stable and thus the Port is able to quote a single rate based on the average productivity for the trade.

The Port suggests that the costs of handling cargo are incurred on both a temporal and tonnage basis. Thus they could attempt to price on either basis.. The discharging, master porterage and loading schedules are tonnage based and the wharfinging schedule is time based. Given that the port adopts standard values for some of the variables used in computing the rate and that some averaging of costs is undertaken, the impact of the cost of deviations from these standards and averages will be different depending upon whether the rate is tonnage or time based.

For the purposes of exposition, the discharging revenue rate can be simplified by assuming an average wage per man per shift of $\bar{W} = \left(\sum_{i=1}^{m} W_i / M\right)$ and ignoring the allocation of half of the bonus payment to the shore labour then,

$$\text{Price/tonne} = \left[\frac{\bar{W}.M}{NH.TPNGH} + b.M\right](1 + \alpha) \qquad \text{(I)}$$

The price/hr = price/tonne x TPGGH, where TPGGH = tonnes per gross gang hour. Thus,

$$\text{Price/hour} = \left[\frac{\bar{W}.M}{NH.TPNGH} . TPGGH + b\,M\ TPGGH\right](1 + \alpha) \qquad \text{(II)}$$

But the total tonnage handled during a shift = NH.TPNGH = GH.TPGGH, where GH = gross hours per shift, and therefore TPGGH = $\frac{NH}{GH}$. TPNGH, thus,

$$\text{Price/hour} = \left[\frac{\bar{W}.M}{GH} + b.M.\ \frac{NH}{GH}\ .\ TPNGH\right](1 + \alpha) \qquad \text{(IIa)}$$

The price per shift = Price/hr x GH, thus,

$$\text{Price/shift} = [\bar{W}.M + b.TPNGH.NH.M](1 + \alpha) \qquad \text{———(III)}$$

and the price per man per shift = (Price/shift) ÷ M, thus,

$$\text{Price/man/shift} = [\bar{W} + b.TPNGH.NH](1 + \alpha) \qquad \text{———(IV)}$$

Alternatively, since b.TPNGH* = K

$$\text{Price/man/shift} = \left[\bar{W} + K.NH.\frac{TPNGH}{TPNGH^*}\right](1 + \alpha) \qquad \text{———(IVa)}$$

In equation I, the first expression in square brackets $(\bar{W}.M)/(NH.TPNGH)$ is the time related cost and the second expression (b.M) is the tonnage related cost. For each commodity the Port knows the manning levels (M) and can therefore compute $\bar{W}$, similarly the value of b is obtained from the Port's labour schedules. In order to determine the rate, it is also necessary for the Port to estimate the net hours per shift (NH) and to assess the standard productivity for the commodity. It is assumed for example that in the two shifts 0800-1200 and 1300-1700 hours there are six net hours. The magnitude of a typical productivity is 12 TPNGH. Thus in equation I, NH is set equal to NH* and TPNGH to TPNGH*. The effect of fixing these variables is that any improvement in productivity per shift above the standard (NH*.TPNGH*) increases the Port's "profit" per tonne and any deterioration in productivity decreases the "profit" per tonne. Differentiating equation I with respect to the TPNGH [2],

$$\frac{\partial\ \text{Price/tonne}}{\partial\ TPNGH} = \left[-\frac{\bar{W}.M}{NH}\left(\frac{1}{TPNGH^2}\right)\right](1 + \alpha)$$

thus if $\bar{W}.M$ = £162.40, NH = 6 hours, TPNGH = 12 and α = 1.75 then,

$$\frac{\partial \text{ Price/tonne}}{\partial \text{ TPNGH}} = -0.52.$$

Thus from a fixed price/tonne of £8.50 (assuming b = 0.0575, M = 14.5 and the other variables in equation I taking the above values) a one unit increase in the TPNGH increases the Port's "profit" per tonne by 52 pence per tonne.

Expressing this as an elasticity [3],

$$\eta = -\text{ proportion of wages plus occupational differentials in direct labour costs}$$

$$= -0.73$$

so that, at the standard productivity, a one per cent increase in the TPNGH leads to a 0.73 per cent increase in the Port's "profit" per tonne. Conversely, a decrease in productivity decreases the Port's profit per tonne by a similar amount.

Thus, with the tonnage based schedule, the direct benefits of increased productivity are passed on to the port and conversely, the cost of decreased productivity must be absorbed by the port.

Similarly, differentiating equation I with respect to the NH [4]

$$\frac{\partial \text{ Price/tonne}}{\partial \text{ NH}} = \left[\frac{-\bar{W}.M}{\text{TPNGH}}\left(\frac{1}{\text{NH}^2}\right)\right](1 + \alpha)$$

and using the same values of the variables

$$\frac{\partial \text{ Price/tonne}}{\partial \text{ NH}} = -1.03$$

Thus a six minute increase, say, in the net hours above the standard increases the Port's "profit" by 10.3 pence per tonne. The elasticity is the same as the productivity case.

Thus, again the impact of the benefit of net hours in excess of the standard lies with the Port whilst the cost of net hours below the standard must be absorbed by the port.

The alternative base for the charge is the temporal basis used for wharfinging. Equations IV or IVa demonstrate how the discharging revenue rate could be converted into a per man per shift rate. This would again require the Port to estimate or assess NH and TPNGH, and some averaging of W and K would be required if the rate was to be applicable to all commodities. This arises because the manning levels vary between commodities and thus the average wage per shift may change due to the wage and occupational differential structure within a gang. Similarly there are six values of K (69, 73, 88, 94, 102 and 109 pence per man per hour) representing the six dirt categories. Assuming that these problems can be overcome (as they have in the wharfinging schedule) then,

$$\text{Price/man/shift} = [\bar{W} + \bar{K}.\text{NH*}](1 + \alpha)$$

If $\bar{W}$ = £11.20, $\bar{K}$ = 0.69p, NH* = 6 and α = 1.75, then

$$\text{Price/man/shift} = £42.19.$$

The effect of fixing these variables is that any improvement in the productivity per shift above the standard decreases the Port's "profit" per man per shift and vice versa. Differentiating equation IVa, with respect to TPNGH [5],

$$\frac{\partial\ \text{Price/man/shift}}{\partial\ \text{TPNGH}} = \left[\frac{\text{K.NH}}{\text{TPNGH*}}\right](1 - \alpha)$$

and using the same values of the variables,

$$\frac{\partial \text{ Price/man/shift}}{\partial \text{ TPNGH}} = 0.95$$

Thus, a unit increase in the TPNGH decreases the Port's "profit" per man per shift by 95 pence and conversely a unit increase in the TPNGH increases the Port's "profit" per man per shift by a similar amount. Expressing this as an elasticity [6],

$$\varepsilon = \text{proportion of bonus in direct labour costs}$$
$$= 0.27$$

so that, at the standard productivity, a one per cent increase in the TPNGH leads to a 0.27 per cent decrease in the Port's "profit" per man per shift.

Thus, the direct benefits of increased productivity accrue to the consumer and conversely the cost of decreased productivity is passed on to the consumer. During overtime hours, this effect will be even less as the overtime rates are quoted on a temporal basis.

This analysis assumes that the Port is using the "correct" measure for costs. The above discussion would suggest that labour costs form a major part of the current revenue rate, however, given the contractual agreements with, and the excess capacity of labour, the short-run escapable cost excludes the fall-back pay of registered dock workers. Section 8.6 suggested that some of these short-run escapable costs are jointly attributable to the commodities handled during a shift (including sundry consumables, fuel for normal plant, occupational differentials, basic bonus, overtime, and the national insurance - both employer and employee-contributions and other compulsory levies based on these labour related costs) whilst others are attributable to specific commodities (including fuel and overtime for extra plant, the bonus in excess of the basic bonus, and the national insurance and levies based on the labour related costs). Thus, these costs represent the lower limit of escapable cost.

With respect to the direct labour costs, the Port is implicitly using the long-run escapable cost of the labour which is warranted by demand, the excess labour being incorporated in the mark-up.

The costs of the extra plant and equipment are again depreciated in equal annual instalments over the asset's life and further averaging is undertaken within a year whereby the annual instalment is converted into an hourly charge.

Thus, when faced with jointness over time the Port allocates costs equally to each year. Labour costs are treated as an operating expenditure and are therefore allocated to the year in which the cash flows occur. When faced with jointness of costs over the commodities handled, the Port has allocated the costs in proportion to the direct labour costs of handling the commodity. It has been suggested that some of the costs included in the mark-up will be related to the direct labour costs and thus the pricing system may be "better than" average cost pricing. However, the pricing system assumes constant long-run elasticities (section 3.4.3) and thus ability to pay. It could however be the case that commodities with higher direct labour costs (for example, "dirty" commodities) have a lesser ability to pay that part of the mark-up which covers the joint costs.

The comments relating to the extent to which the cargo handling tariffs lead to an efficient utilisation of existing assets are similar to the other tariffs. In this case, the short-run escapable costs do not approach zero, however, there is still a divergence between these costs and the price charged by the Port. Thus, again traffic which is willing to pay the escapable cost but less than the price computed by the Port will not be accepted.

The schedule devised by the Port represents a comprehensive attempt to allocate both short- and long-run escapable costs to the traffic imposing the cost. Thus, it would appear that any cross-subsidisation with respect to escapable cost will be minimal.

The conditional signal that the Port has been receiving in the cargo handling operation is that for over a decade there has been excess labour. As a result the number of RDW's on the Liverpool Port Register has fallen from approximately 11,000 in January 1970 to 5,149 in December 1979.

9.5 Summary and Conclusions

In the four tariffs discussed above the Port uses a number of different pricing systems ranging from average cost through full-cost to price discrimination, with some elements of a block tariff being exhibited. The conservancy schedule used average cost pricing combined with discrimination between coastal and deep-sea traffic. The berth charges extended the conservancy schedule by introducing an exception to the coastal rate (grain) and a number of exceptions to the deep-sea rates. Two of these exceptions would appear to be adjustments to the vessel's g.r.t. (modified tonnage and timber vessels) and the grain exception (as in the coastal case) being an attempt to attract traffic to the Port. The tariff is then divided into vessels loading only, and vessels discharging and loading. A lower rate is quoted for the former ostensibly to support United Kingdom exports. A further feature of the schedule is the minimum and maximum rates that the traffic is required to pay which it was suggested is a form of block tariff. The goods schedule distinguishes between coastal and foreign traffic with the rates for the former being much lower. It would appear that this tariff is using price discrimination, as there was some evidence of a relationship between unit value and the rate. The cargo handling schedules use full-cost pricing by marking up on the direct labour costs. The basis for the charge is either tonnage or time. The degree of complexity within the tonnage based schedules varies between loading stevedoring with seven rates, master porterage with twelve categories of commodities distinguished by packaging (with a number of different rates within each category) and discharging stevedoring with 91 different rates. In addition, overtime rates are quoted on a time basis as are the rates for extra plant. Wharfinging is a time based schedule which contains rates for staff, labour and clerical workers which depend upon the day of the week (and public holidays) and shift worked.

The degree of complexity in the tariffs is therefore subject to considerable variation, and consequently computation and administration by the port. In practice, once the schedules have been established their structure becomes ossified and changes are effected by across the board percentage increases in rates. For example, the 1981 goods charges are 76 per cent higher than the same 1976 charges and the 1980 cargo handling tariffs (loading and discharging) are 52 per cent higher than the 1977 tariffs. Thus, it has been relatively easy to administer the systems.

The discussion of the costs used to compute each of these schedules suggested that, particularly in the case of capital assets, the approach adopted by the Port is at variance with both the opportunity cost principle or valuation formula. The Port uses historic cost, whereas it was suggested that in the case where the assets will not be replaced, the lower limit of escapable cost over the planning horizon is the difference in opportunity cost (suitably discounted) at the beginning and end of the horizon. Similarly, if the asset is to be replaced, the upper limit is ascertained by taking the valuation of the asset at the beginning and end of the horizon. Whilst the historic cost may lie within this range it may be inappropriate if replacement is being contemplated.

The problem of jointness in costs over time is approached by "writing off" the historic costs in equal annual instalments over their estimated remaining economic lives. Thus, the Port's solution is to average the costs over time. Whilst this represents an approach to the problem, the only requirement is that the traffic over the life of the asset is willing to pay, which does not necessarily imply averaging the costs. The problem of jointness over traffic was approached by averaging and price discrimination. However, given the joint nature of these costs, the only requirement is again that the traffic jointly pays so that averaging is only one solution.

The question of the charging base used by the Port has been raised in a number of contexts. In the conservancy and berth charge schedules gross registered tonnage is used as a base. However it is not clear whether this base is "equitable" between ship types. In the cargo handling schedule, both tonnage and time were used as bases. However the "optimum" choice of base is again not clear. The charging base will be discussed further in the next chapter.

This chapter has also considered the extent to which the charging schedules meet the objectives outlined in chapter 1. In terms of their own cost definitions, the accounting requirement of the Port has only been met in two of the last five years (1975-1979 inclusive). However, given the cost measures used by the Port it is difficult to assess the significance of this observation.

In general, the short-run escapable cost of the facilities provided by the port are less than the price currently charged and in some cases they approach zero. The implication of this observation is that traffic willing to pay at least this cost but not the price will not be accepted. Thus the systems may not lead to an efficient utilisation of the Port's existing assets. Section 9.1 suggested that under these circumstances the Port can either investigate the extent to which demand is distorted or attempt to devise alternative tariffs. A block tariff was suggested for large regular users, however the problem of the small one-off user remains.

The extent to which cross subsidisation with respect to escapable costs occurs in the conservancy and berth tariffs would appear to be minimal as there is a large degree of jointness in the costs incurred in providing the facilities. In the goods schedule it is not clear whether cross subsidisation is occurring, however identification of traffic according to berth type would minimise its extent. The cargo handling schedule attempts to allocate all of the labour related costs and thus the extent of cross subsidisation is likely to be minimal.

The discussion in this chapter has also suggested that the investment/ replacement signals provided to the Port from the pricing systems are conditional. Thus, they are inefficient with respect to encouraging the Port to maintain and develop assets which are of value of the Port. In the conservancy case for example, an "excess profit" on the conservancy account does not necessarily imply that these facilities should be improved. Conversely if a "loss" is incurred on this account it does not necessarily imply that the facilities should be downgraded. Under these circumstances, it will be necessary for the port to obtain alternative signals, section 9.1 suggesting consultation with port user bodies and assessment using cost-benefit analysis.

Notes

[1] The sources of the statistics in Table 9.3 were;

(i) Rates: MDHC, "Charges on Vessels and Goods" Operative from 1 January 1976.

(ii) Stowage Factors: Arthur D. Little Ltd., "Containerisation on the North Atlantic", Report prepared for the NPC, November 1967.

(iii) Unit Values: HMSO, "Annual Statement of Overseas Trade of the United Kingdom", Vol V, 1975.

[2] Price/tonne $= \left[\frac{\bar{W}.M}{NH.TPNGH} + bM\right](1 + \alpha)$

$$\frac{\partial \text{ Price/tonne}}{\partial \text{ TPNGH}} = \left[- \frac{\bar{W}.M.NH}{(NH.TPNGH)^2}\right](1 + \alpha)$$

$$= \left[\frac{-\bar{W}.M}{NH}\left(\frac{1}{TPNGH^2}\right)\right](1 + \alpha)$$

[3] $$\eta = \frac{\partial \text{ Price/tonne}}{\partial \text{ TPNGH}} \cdot \frac{TPNGH}{\text{Price/tonne}}$$

$$= \left[\frac{-\bar{W}.M}{NH}\left(\frac{1}{TPNGH^2}\right)\right](1 + \alpha)\left[\frac{TPNGH}{\left(\frac{\bar{W}.M}{NH.TPNGH} + bM\right)(1 + \alpha)}\right]$$

$$= \left[\frac{-1}{1 + \frac{b.NH.TPNGH}{\bar{W}}}\right]$$

$$= \left[\frac{-1}{1 + \frac{K.NH}{\bar{W}} \cdot \frac{TPNGH}{TPNGH^*}}\right]$$

$$= \left[\frac{-\bar{W}.TPNGH^*}{\bar{W}.TPNGH^* + K.NH.TPNGH}\right]$$

Setting TPNGH = TPNGH*, then

$$\eta = \left[\frac{-\bar{W}}{\bar{W} + K.NH}\right]$$

= - proportion of wages plus occupational differential per man per shift in direct labour cost per man per shift.

[4]

$$\frac{\partial\ \text{Price/tonne}}{\partial\ NH} = \left[\frac{-\bar{W}.NH.TPNGH}{(NH.TPNGH)^2}\right](1+\alpha)$$

$$= \left[\frac{-\bar{W}.NH}{TPNGH}\left(\frac{1}{NH^2}\right)\right](1+\alpha)$$

[5]

$$\text{Price/man/shift} = \left[\bar{W} + K.NH.\frac{TPNGH}{TPNGH^*}\right](1+\alpha)$$

$$\frac{\partial\ \text{Price/man/shift}}{\partial\ TPNGH} = \left[\frac{K.NH}{TPNGH^*}\right](1+\alpha)$$

[6]

$$\varepsilon = \frac{\partial\ \text{Price/man/shift}}{\partial\ TPNGH} \cdot \frac{TPNGH}{\text{Price/man/shift}}$$

$$= \left[\frac{K.NH}{TPNGH^*}\right](1+\alpha)\left[\frac{TPNGH}{\left(\bar{W} + K.NH.\frac{TPNGH}{TPNGH^*}\right)(1+\alpha)}\right]$$

$$= \left[\frac{1}{\frac{\bar{W}}{K.NH}\cdot\frac{TPNGH^*}{TPNGH} + 1}\right]$$

$$= \left[\frac{K.NH.TPNGH}{\bar{W}.TPNGH^* + K.NH.TPNGH}\right]$$

Setting TPNGH = TPNGH*, then

$$\varepsilon = \left[\frac{K.NH}{\bar{W} + K.NH}\right]$$

= proportion of bonus per man per shift in direct labour cost per man per shift.

CHAPTER 10

THE CHARGING BASE AND TARIFF STRUCTURE

10.1 Introduction

The discussion of the escapable costs has indicated that in some cases costs may be attributed to a traffic or groups of traffic. There remains however the questions of how the tariff is to be structured and which base is to be used for charging this traffic. Chapter 2 (The Port's Pricing and Investment Problem) suggested that where there exists jointness in costs the only requirement is that the traffic should be jointly willing to pay. Willingness to pay however is contrained by considerations of equity - the Acts of Parliament relating to each port usually requiring "no discrimination between users in like circumstances"[1]. The point where the charge initially bears (the impact of the charge) is also of importance to the port as it will influence their negotiating strength. This chapter will therefore discuss the issues of the charging base; the factors influencing the traffic's willingness to pay; equity considerations; and the effects on the port of the impact of a charge.

10.2 The Charging Base

10.2.1 Introduction

The outline of port tariffs and charging bases Chapter 1 (section 1.1) and the dicussion of the MDHC tariffs indicated that there are a number of bases used by ports for charging purposes. Chapter 4 (Port Costs and Traffic Characteristics) further listed the various characteristics of ships and goods, some of which could be used as a charging base. A number of these characteristics (particularly on the cost side) are however related to the structure of the tariff. For example, if a relationship could be demonstrated between cost and size then this may suggest a progressive tariff. Given that there are a number of possible bases, one approach is to devise an output based schedule. In order to use such a base, it is necessary to ascertain its meaning in the port context.

10.2.2 Port Services and Output

The main function of the port is to provide the services and facilities whereby goods can be transferred from one mode of transport (ship) to another (barge, road or rail) and vice versa. Thus at the highest level of aggregation of the services and facilities provided by the port either the tonnage or volume of the goods passing through the port would appear to be an appropriate measure of the output and therefore basis for charging purposes.

In general however, commodities (that is, well defined goods and services) are characterised by a description of their physical properties, their location and their date of delivery (Debreu [2]). In Debreu's discussion, the period of time over which the economic activity is undertaken is divided into equal discrete "elementary intervals" such that, for the purposes of the analysis, any instants within an interval are indistinguishable. Similarly the location of economic activity is divided into "elementary regions". In considering economic services the concept of a commodity is introduced by providing five examples including; labour, a truck, a hotel room, a warehouse and transportation. Labour is described by the task performed, and when the date (the elementary interval at which the service is performed - measured from the present instant) and location (elementary region) are included the service is a well defined commodity. "The quantity of such a service is expressed by the time during which it is rendered." The "use of a hotel room" is described by a list of the facilities available to the occupant. "Its quantity is an integral number of days." In the case of a warehouse, time is included in the description of the commodity and not as a measure of quantity. Thus, the warehouse is described as being refrigerated or not, the security offered, etcetera. The temporal specification requires several dates and "its quantity is expressed, for example, by a real number of cubic feet." Transportation services are described by the mode of transport (rail, road, air, water, pipelines, power lines etcetera) and any other specification necessary to describe the service. The temporal specification will require several dates and the spatial specification at least two locations. "Their quantities are expressed for goods, for example, by the weight or volume transported."

Thus, for a commodity to be "well defined" it must have its physical, temporal and spatial characteristic specified. If any one of these characteristics change then a different commodity results. A noticeable feature of these five examples is also the measure of the quantity used in each case, with time being suggested for labour, the truck and the hotel room, cubic feet for the warehouse and tonnage or volume for transport.

Whilst a coarse specification of port services may suggest tonnage or volume as a measure of quantity, closer examination of the main constituent elements of the port services vector would suggest that the port is providing different types of commodities (services) which have different measures of quantity. The elements of the port services vector consisted of conservancy, berth, cargo handling and goods services. A specification of conservancy services would include in the MDHC case a description of the lights and buoys, the channel depth (including the accuracy of the reported depth) and the services provided by the Port Radar Station. The temporal specification may need to be taken into account as will the state of the tide. The spatial specification is Liverpool and Birkenhead (with further elementary regions being specified if conservancy of the whole River is being considered). The relevant quantity in this case would appear to be the number of ships. The berth services would appear to be similar to Debreu's example of the warehouse. Thus, the specification would include the type of berth (that is, the cargo handling operation performed at the berth), the date and number of elementary time intervals required to perform the service (that is, the duration of the service) and if necessary, where the service is performed within the port (for example, the short-sea passenger traffic may prefer a location closer to the city centre). If the analogy with the warehouse is reasonable, then the quantity will be a measure of the size of vessel that can be accommodated at the berth, for example, length. It should also be noted that a temporal dimension is included in the specification as, for example, the berth service for a vessel for two days is a different commodity from the berth service for the same vessel for three days. The cargo handling service would appear to include elements of both Debreu's labour and truck services. Thus for the labour, its description includes the tasks performed (loading and discharging stevedoring, wharfinging and master porterage), the date and location. In the case of labour, it may be necessary to consider the elementary time intervals as being the shifts worked at the port (which are of unequal length). The description of the plant and equipment will include the task performed by the machines, the condition of the machine, a date and location. In both cases the measure of quantity is expressed in terms of the time worked. On the other hand, it could be suggested that the cargo-handling service more closely resembles transportation services. Thus, it would be specified by the cargo handling operation (container, grain etcetera), the date and location. Under these circumstances, the quantity measure is the tonnage, volume or number of units (in the case of containers).

The facilities provided under the heading of goods include the transit sheds, access roads and perimeter fences. Thus, specification of this service includes a description of the transit facilities, access roads, the date or dates between which the service is rendered and the location. The quantity will therefore include a measure of the area or volume of the transit facilities and also the number of vehicles transporting the goods to and from the berth.

Thus, the relevant quantity measures for each of these services would appear to be: conservancy - number of ships; berth - length; cargo handling - time worked, tonnage, volume or number of units; and goods - area or volume and number of vehicles. In the cases where the duration of the service is included in the specification (berth and transit facilities) it may be possible to remove this from the temporal specification, replace it with a single date and express quantity as a composite measure which includes the linear, square or cubic dimension and the number of elementary time intervals for which the service is rendered (in a similar manner to the hotel room).

It should be noted that these measures do not necessarily relate to the costs incurred by the port (although in the long-run they may). They are submitted as measures of quantity and therefore represent units upon which a charge could be based and schedule structured.

10.2.3 Bases for Conservancy and Berths Charges

A charge based solely upon a vessel's entry into the port would tend to be commercially unacceptable as, apart from cost considerations, it would be claimed that the larger vessels have a greater ability to pay on a per entry basis. Thus some structuring of the schedule may be required (according to size) or the base changed. The base which is widely used is the g.r.t., however it is not clear whether this is "equitable" between users of the port's facilities. The two main measures of vessel size are registered tonnage and deadweight. Both gross and net tonnage are measures of volume. Gross tonnage is found by calculating the total permanently enclosed spaces of the ship, not including certain exempt spaces, and dividing by 100. The net tonnage is the gross tonnage with certain "deducted spaces" subtracted. The philosophy behind the n.r.t. is that cargo cannot be carried in the deducted spaces and thus the measure reflects the potential carrying (earning) capacity of the ship in volume terms. Briefly, the exemptions and deductions include;

Total volume of enclosed spaces,

not including;

1. Double bottoms for water ballast
2. Poop, Bridge and Foc'sle
3. Wheelhouse, galley, pantries and hospitals
4. Hatchways

equals Gross Registered Tonnage

less deducted spaces;

1. Steering gear compartment
2. Chartroom, radio-room
3. Bosun's store
4. Water ballast other than double bottoms
5. Master's and crew accommodation
6. Propelling power allowance

equals Net Registered Tonnage.

Deadweight (dwt) is a measure of weight and represents the difference between the ship's displacement at loaded and light drafts. It is therefore a measure of the ship's capacity to carry: cargo, crew, passengers, stores, fresh water, feed water and bunkers.

Table 10.1 shows the MDHC's examination of the alternative physical dimensions of the ship which could be used as bases for dues on ships.

Table 10.1 Examination of Alternative Bases for the Assessment of Port Rates

Basis of Assessment	Details required	Source of information.	Advantages.	Disadvantages.
1. Net Register Tonnage.	(i) Net Register Tonnage on basis of British or equivalent rules. (ii) Unregistered spaces. (iii) Deducted spaces.	(i)(ii)(iii) Register of Ships Tonnage or Certificate of British Tonnage. (i) only. Lloyds Register.	(i) A universally accepted basis. (ii) Method of calculation may vary as between countries but the varying results either approximate to and are acceptable as equivalent to British tonnage or are capable of simple adjustment. (iii) There is a constant movement towards universal unification of method of calculation. (iv) The resultant measurements are acceptable to ship owners as being fair as between ship and ship.	(i) Though the basis may be equitable between ship and ship as a measure of carrying capacity it is not a good basis on which to charge for the occupancy and usage of port facilities as it is not necessarily a good indication of such use. (ii) Modifications in the rules have to be made from time to time to preserve the fair balance between ship and ship under progressive construction methods and trade requirements. These alterations invariably have the effect of reducing port revenues. (iii) It is nearly always impossible for ports to estimate what the effect of any change in rules will be and almost equally as difficult to determine after a period what the effect has been. It is, therefore, difficult to present a case for the increase in rates on account of these changes in rules. (iv) Nevertheless such losses must be recouped and rates must, therefore, be revised as often as there is a change in rules.
2. Gross Tonnage.	(i) Gross Tonnage as above. (ii) Unregistered spaces.	(i) Register of Ships Tonnage Lloyds Register. (ii) Usually but not always in Register of Ships Tonnages.	(i) Is used as a basis for charging by certain authorities, e.g. Suez, Panama, certain American ports. (ii) Is indication of the size of the ship and might, therefore, be a good basis of charging for the occupancy and use of port facilities.	(i) Though it may be an indication of the size of the ship most of the present rules of measurement provide for the exclusion of certain spaces from the Gross Tonnage. The most important exclusions being open shelter decks and double bottoms (in certain cases). (ii) It is doubtful if shipowners would accept it as a fair method as between ship and ship. Fast passenger vessels would certainly be at a disadvantage, e.g. e.g. — Gross. / Net. / Deadweight. Queen Mary. — 81,237 / 33,073 / 17,000 Sepia. — 42,109 / 23,953 / 65,000 (iii) Might lead to unsafe standards in design.
3. Deadweight	Difference between light displacement and displacement when loaded to summer load line, i.e. weight in tons of cargo, fuel, crew and passengers required to bring vessel down to summer load line.	Ships plans. Lloyds Register (but not in every case)		(i) Not easily obtainable by port authority. (ii) Is not a measure of the size of the ship. (iii) Is not a fair basis for assessment of rates - see comparison above of Queen Mary and Sepia.
4. Displacement Tonnage. (loaded)	Weight of water displaced by ship when loaded down to summer load line.	Ships plans (always given for naval vessels)	(i) Is an accurate measure of the maximum amount of water space occupied in port facilities.	(i) Not easily obtainable by port authority. (ii) Not necessarily related to carrying capacity of ship, e.g. the displacement tonnage of the Sepia is almost certainly greater than that of the Queen Mary. (iii) Might lead to unsafe standards of design.

Table 10.1 (continued)

Basis of Assessment	Details required.	Source of information	Advantages.	Disadvantages.
5. Displacement Tonnage (on arrival or departure)	Weight of water displaced by ship on arrival or departure.	Ships plans	(i) Is a measure of the water space occupied. (ii) Makes allowance for part loaded ships. (iii) Is used by Panama Canal for charging naval vessels.	(i) Not easily obtainable by port authority. (ii) May vary during passage through port area. (iii) Assessment of rates is made on cargo, fuel and ballast. (iv) Might lead to unsafe ballasting. (v) Might lead to unsafe standards in design.
6. Displacement Tonnage (Light)	Weight of water displaced by ship when empty except for boilers filled with water to working level.	Ships Plans.	Is an indication of the overall size of the vessel.	(i) Not easily obtainable by port authority. (ii) Not related to loaded conditions. (iii) Might lead to unsafe standards in design.
7. Weight of cargo (discharged and/or loaded)	Cargo weights	Manifest. Abstract Cocket &c.	(i) May be an indication of (a) the size of the ship. (b) the profitability of the voyage. (ii) Enables charges to be made in relation to volume of traffic. (iii) Attracts shipping to ports for less than full cargoes. Note. At some ports an adjustment of the N.R.T. assessment is made to reduce rates for vessels carrying part cargoes.	(i) There is a great delay in final settlement of rates, awaiting final out-turn of cargo. (The delay in Liverpool is up to two months). (ii) Weight of cargo may not be related to profitability of voyage. (iii) Might ultimately discourage regular liner services which provide a stable income for ports and are the foundation of progressive port planning.
8. Length	(i) Overall length (ii) Registered length. (iii) Tonnage length (U.S. vessels).	(i) Lloyds Register (ii) Ships Register (iii) Ships Register (U.S.)	(i) A charge in proportion to the length of quay occupied might be a satisfactory basis of assessment for many ports. (ii) Where berthage is required the overall length is usually known by port authorities before ships arrival.	(i) There may be a great variation between Overall, Registered and Tonnage lengths. (ii) Length may be no indication of a ship's overall size or carrying capacity. It may operate very unfairly between ship and ship or class and class of ship, e.g. Gross, Net. D.W. Length Ulster Prince. 4,302, 2,301, 911 367. 0 Leinster 4,115, 1,981, 810. 366.10 or c.f. American Laker with general cargo vessel (iii) Length is of little importance in open harbours.
9. Breadth.	(i) Extreme breadth. (ii) Registered breadth. (iii) Tonnage breadth	(i) Lloyds Register. (ii) Ships Register. (iii) Ships Register.	Where berthage is required the breadth is usually known by port authority before ships arrival.	(i) Extreme (i.e. including rubbing strakes or fenders), Registered and Tonnage breadth varies considerably. (ii) Breadth is of little importance to most port authorities in this country.
10. Depth.	(i) Registered Depth. (ii) Overall depth.	(i) Ships plans. (ii) Ships plans.		(i) Depth requires to be carefully defined. At present there is great variation in the rules for measuring registered, moulded and overall depth. (ii) It is no indication of the overall size of the vessel. (iii) Depth alone is of no importance to port authorities – on the other hand draught may be a very important factor.

Table 10.1 (continued)

Basis of Assessment	Details required	Source of information	Advantages	Disadvantages.
11. Draught at summer load line.	Draught at summer load line.	Lloyds Register. Ships plans.	Providing and maintaining depth of water is often a big factor in the cost of operating dredged channels and enclosed docks so that a charge based on draught might well be the most equitable as between ship and ship.	(i) It is not necessarily an indication of the size of ship - again c.f. G. N. L. B. S.D. Queen Mary. 81,237. 33,073. 1,019. 119. 39. Sopia. 42,109. 23,953. 818. 113. 43. (ii) A charge on this draught is based on maximum possible requirements and is not related to actual conditions.
12. Draught on arrival or departure (either maximum or mean)	Draught on arrival or departure.	Ships Log. Reading of scale.	(i) As above. (ii) The measurement is determined in many ports for assessing pilotage charges.	(i) As (i) above. (ii) Determination of draught may not always be easy as the accuracy of readings may be disputed. (iii) Draught frequently alters during the ships passage through the port area.
13. Length x Breadth x Draught.	See 8, 9, & 11.	See 8, 9 & 11.	It is probably a better method than 8, 9 or 11 separately in that it takes into account all factors in ships size affecting accommodation requirements.	(i) See 8(i) and 9(i). (ii) See 11(i) and (ii) (iii) The product may not be an indication of the ships size or carrying capacity, c.f. G. N. D.W. $\frac{L \times B \times D}{1,000}$ Jaladhanya OSD. 6,327. 3,549. 9,550. 836 Salamanca OSD 8,610. 5,141. 9,959. 820
14. Length x Breadth x Draught with a factor or factors.	See 8, 9 and 11.	See 8, 9 and 11.	The introduction of a factor to any of length, breadth or draught or in the calculation of the product for a particular class of ship may give a more equitable basis.	The accompanying schedules will demonstrate the difficulty of discovering a suitable factor.

Table 10.1 (continued)

Vessel		Gross	Net	Dead-weight	Length Ft.	Length Ins.	Breadth Ft.	Breadth Ins.	Summer Draught Ft.	Summer Draught Ins	$\frac{L \times B \times D}{1000}$
Queen Mary		81,237	33,073	17,000	1,019.	6	118.	7	39	4½	4,800
Empress of England		25,585	13,725	8,910	640	0	85	4	29	0	1,586
Accra		11,644	6,447	7,112	471	0	66	2	25	6	795
Caledonia		11,255	6,476	10,417	506	0	66	5	27	5½	924
Ulster Prince		4,302	2,301	911	367	0	52	5	15	1¼	291
Leinster		4,115	1,981	810	366	10	50	2	15	1¼	278
Lady of Mann		3,104	1,258	-	372	4	50	2	13	0¼	243
Brookmount		995	438	1,070	264	6	38	7	12	5	126
Pacific Coast (OSD)		1,188	608	1,703	265	8	38	1	15	2½	154
Edgefield		622	329	930	202	9	31	4	11	6½	73
William Wheelwright		31,320	16,884	48,400	753	6	98	5	38	1½	2,829
Sepia		42,109	23,953	65,000	817	11	112	11	42	10¼	3,982
British General		8,775	5,039	app. 12,150	490	10	62	2	27	6¾	841
Bishopsgate		12,718	5,676	18,060	525	0	70	5	29	6½	1,069
Jaladhanya	CSD	9,487	5523		509.	5	63.	9			
	OSD	6,527	3549	9550					25	9¼	836
Salamanca	CSD	8,610	5,141	9,959	466	4	62	10	28	0¼	820
	OSD	6,704	3,922								
Olivia	CSD	5,396	3,748		424.	8	53	9			
	OSD	3,371	1,867	5,635					21	1	481
Ratzeburg	CSD	3,984	2,639		355	7	48	8			
	OSD	2,143	1,317	4,317					20	8¾	359
Herford	CSD	1,709	1,161	2,760	260	6	40	9	18	3½	194
	OSD	1,085	516								

Notes: CSD = Closed Shelter Dock, OSD = Open Shelter Dock.
Source: MDHC

In orderto further investigate the relationships between these dimensions a survey of vessels entering the Mersey during May 1977 was undertaken. The names of the vessels entering the Port were obtained from the Journal of Commerce and the vessel type, g.r.t., n.r.t., dwt, length, breadth, depth and summer draft were obtained from Lloyd's Register of Shipping. The sample consisted of 633 vessels (some making multiple entries into the Port during the month) and included 338 general cargo vessels (145 to 28,293 dwt), 168 tankers (691 to 227,912 dwt), 50 container vessels (1,043 to 32,753 dwt), 15 bulk carriers (14,860 to 77,774 dwt) and 62 miscellaneous vessels, including naval, fishing, Ro-Ro and ore carrying vessels.

Investigation of the relationships between the ship dimensions for each of the four main vessel types suggested that they are highly correlated. Table 10.2 contains the correlation matrices for each of these vessel types. A natural logarithm transformation of the vessel dimensions yielded higher correlation coefficients (although, further investigation does suggest that the log transformation is too powerful). The corresponding correlation matrices for the transformed data are also included in table 10.2.

Table 10.2 Correlation Matrices of Vessel Dimensions

(a)(i) General Cargo - Untransformed Data

	GRT	NRT	DWT	LTH	BTH	DFT
GRT	1.0000					
NRT	0.9910	1.0000				
DWT	0.9412	0.9570	1.0000			
LTH	0.9332	0.9150	0.9169	1.0000		
BTH	0.9306	0.9186	0.9193	0.9794	1.0000	
DFT	0.9243	0.9139	0.9358	0.9633	0.9685	1.0000

(a)(ii) General Cargo - Transformed Data

	LGRT	LNRT	LDWT	LLTH	LBTH	LDFT
LGRT	1.0000					
LNRT	0.9933	1.0000				
LDWT	0.9722	0.9808	1.0000			
LLTH	0.9678	0.9682	0.9755	1.0000		
LBTH	0.9581	0.9649	0.9750	0.9780	1.0000	
LDFT	0.9761	0.9777	0.9816	0.9623	0.9654	1.0000

(b)(i) Tanker - Untransformed Data

	GRT	NRT	DWT	LTH	BTH	DFT
GRT	1.0000					
NRT	0.9920	1.0000				
DWT	0.9959	0.9948	1.0000			
LTH	0.8792	0.8417	0.8495	1.0000		
BTH	0.9275	0.8956	0.9059	0.9730	1.0000	
DFT	0.9004	0.8709	0.8756	0.9859	0.9752	1.0000

Table 10.2 (continued)

(b)(ii) Tanker - Tranformed Data

	LGRT	LNRT	LDWT	LLTH	LBTH	LDFT
LGRT	1.0000					
LNRT	0.9927	1.0000				
LDWT	0.9922	0.9960	1.0000			
LLTH	0.9825	0.9878	0.9891	1.0000		
LBTH	0.9691	0.9742	0.9791	0.9706	1.0000	
LDFT	0.9890	0.9896	0.9881	0.9772	0.9647	1.0000

(c)(i) Container - Untransformed Data

	GRT	NRT	DWT	LTH	BTH	DFT
GRT	1.0000					
NRT	0.9966	1.0000				
DWT	0.9665	0.9589	1.0000			
LTH	0.9209	0.9064	0.9753	1.0000		
BTH	0.9105	0.8916	0.9654	0.9741	1.0000	
DFT	0.8961	0.8932	0.9389	0.9523	0.9104	1.0000

(c)(ii) Container - Transformed Data

	LGRT	LNRT	LDWT	LLTH	LBTH	LDWT
LGRT	1.0000					
LNRT	0.9939	1.0000				
LDWT	0.9839	0.9849	1.0000			
LLTH	0.9649	0.9516	0.9756	1.0000		
LBTH	0.9163	0.8969	0.9386	0.9760	1.0000	
LDFT	0.9804	0.9770	0.9719	0.9349	0.8861	1.0000

Table 10.2 (continued)

d(i) Bulk - Untransformed Data

	GRT	NRT	DWT	LTH	BTH	DFT
GRT	1.0000					
NRT	0.9800	1.0000				
DWT	0.9826	0.9840	1.0000			
LTH	0.9775	0.9772	0.9819	1.0000		
BTH	0.9600	0.9664	0.9529	0.9582	1.0000	
DFT	0.9233	0.9297	0.9502	0.9478	0.8793	1.0000

(d)(ii) Bulk - Transformed Data

	LGRT	LNRT	LDWT	LLTH	LBTH	LDFT
LGRT	1.0000					
LNRT	0.9850	1.0000				
LDWT	0.9922	0.9886	1.0000			
LLTH	0.9839	0.9677	0.9810	1.0000		
LBTH	0.9784	0.9758	0.9778	0.9577	1.0000	
LDFT	0.9407	0.9370	0.9528	0.9420	0.8950	1.0000

Notes: GRT = Gross Registered Tonnage

NRT = Net Registered Tonnage

DWT = Deadweight

LTH = Length Overall

BTH = Extreme Breadth

DFT = Summer Draft

L prefix = Natural logarithm transformation of Data

The relationships between the dwt and g.r.t. of these four vessel types are shown by the regressions of the untransformed dwt's on g.r.t. in Table 10.3

Table 10.3 Regressions of the Untransformed dwt's on g.r.t.

General cargo:				
	dwt = 518.1	+	1.2255 g.r.t.	R^2 = 0.8859
	(128.1)		(0.0240)	SEE = 1371.5
Tanker:				
	dwt = -1845.2	+	2.0065 g.r.t.	R^2 = 0.9919
	(315.0)		(0.0141)	SEE = 3709.4
Container:				
	dwt = 1438.9	+	0.8890 g.r.t.	R^2 = 0.9342
	(368.8)		(0.0341)	SEE = 2007.7
Bulk:				
	dwt = -1873.7	+	1.7812 g.r.t.	R^2 = 0.9655
	(2370.7)		(0.0933)	SEE = 3832.5

Bracketed numbers are standard errors.

To illustrate the differences between using dwt or g.r.t. as a charging base, consider vessels of, say, 10,000 and 20,000 g.r.t., and let the due be £1.00 per g.r.t. Table 10.4 then shows the corresponding dwt and due per dwt for these four vessel types.

Table 10.4 Dues per dwt for given g.r.t. (Untransformed data)

Vessel type	10,000 g.r.t		20,000 g.r.t.	
	dwt	£/dwt	dwt	£/dwt
General	12,773	0.78	25,028	0.80
Tanker	18,220	0.55	38,285	0.52
Container	10,329	0.97	19,219	1.04
Bulk	15,938	0.63	33,750	0.59

Thus, a charge based upon g.r.t. which does not distinguish between vessel type tends to favour tankers and bulk carriers at the expense of general cargo and container vessels when the charge is considered in terms of dwt. If it is further admitted that tanker and bulk cargoes tend to be weight based and general and container cargoes tend to be volume based then g.r.t. is an even more favourable base for the tankers and bulk carriers (in terms of the actual weight of cargo lifted). In the case of bulk carriers, it could be argued that the unit values of the commodities carried in these vessels is less than those for container and general cargo and thus the bulk carrier has a lesser ability to pay.

Due to the negative constants in the tanker and bulk carrier case, the charge per deadweight decreases with size and due to the positive constants in the general and container equations their charge per deadweight increases with size.

A similar analysis using the transformed data yields the results shown in tables 10.5 and 10.6.

Table 10.5 Regressions of the Transformed dwt's on g.r.t.

General cargo:				
ldwt =	1.1499	+	0.9017 lgrt	R^2 = 0.9452
	(o.0893)		(0.0118)	SEE = 0.2643
Tanker:				
ldwt =	0.5875	+	0.9891 lgrt	R^2 = 0.9845
	(0.0778)		(0.00964)	SEE = 0.1781
Container:				
ldwt =	1.6853	+	0.8272 lgrt	R^2 = 0.9681
	(0.1787)		(0.0217)	SEE = 0.1830
Bulk:				
ldwt =	-0.2445	+	1.0762 lgrt	R^2 = 0.9845
	(0.3721)		(0.0374)	SEE = 0.0683

All variables are natural logarithms.

Bracketed numbers are standard errors.

Table 10.6 Dues per dwt for given g.r.t. (Transformed data)

	10,000 g.r.t.		20,000 g.r.t.	
	dwt	£/dwt	dwt	£/dwt
General	12,770	0.78	23,858	0.84
Tanker	16,276	0.61	32,307	0.62
Container	10,983	0.91	19,486	1.03
Bulk	15,798	0.63	33,311	0.60

Thus, there are no marked differences in the dues per dwt when using the transformed and untransformed data.

The discussion of the quantity for berth services suggested that a measure of the size of vessel which can be accommodated at the berth is the relevant measure. Both length and g.r.t. are used and thus the question of "equity" between users arises again. The relationships between length and g.r.t. for the four vessel types are shown in table 10.7.

Again, to illustrate the differences between using length or g.r.t. as a charging base the dues per unit length are compared between vessel type and size for vessels of 10,000 and 20,000 g.r.t. and a rate of £1.00 per g.r.t. (Table 10.8).

Whilst the rank order changes for the two vessel sizes the least favourably treated vessel for both sizes is the tanker. When comparing sizes for each vessel type the general cargo vessel is least sensitive to changes in g.r.t. (this arises because it is the most sensitive to changes in g.r.t. - table 10.7). Thus a flat rate per

Table 10.7 Regressions of the Untransformed lengths on g.r.t.

General cargo:			
length = 59.8	+	0.009450 g.r.t.	R^2 = 0.8709
(1.059)		(0.0001985)	SEE = 14.77
Tanker:			
length = 89.3	+	0.002650 g.r.t.	R^2 = 0.7730
(2.491)		(0.0001115)	SEE = 29.34
Container:			
length = 80.8	+	0.005662 g.r.t.	R^2 = 0.8480
(3.747)		(0.0003460)	SEE = 20.40
Bulk:			
length = 129.8	+	0.002900 g.r.t.	R^2 = 0.9555
(4.411)		(0.0001737)	SEE = 7.13

Bracketed numbers are standard errors.

Table 10.8 Dues per unit length for given g.r.t. (Untransformed data)

	10,000 g.r.t.		20,000 g.r.t.	
	lth (m)	£/lth	lth (m)	£/lth
General	154.3	64.81	248.8	80.39
Tanker	115.8	86.36	142.3	140.55
Container	137.4	72.77	194.0	103.07
Bulk	158.8	62.97	187.8	106.50

g.r.t. will be a progressive tariff per unit length (because length is a linear measure and g.r.t. is a cubic measure) however for different vessel types the rate per unit length will vary.

Given the non-linear nature of this relationship tables 10.9 and 10.10 examine the corresponding models for the transformed data.

Table 10.9 Regressions of the Transformed lengths on g.r.t.

General cargo:			
llength = 1.953	+	0.3341 lg.r.t.	R^2 = 0.9366
(0.0357)		(0.00474)	SEE = 0.1058
Tanker:			
llength = 2.134	+	0.3131 lg.r.t.	R^2 = 0.9653
(0.0372)		(0.00461)	SEE = 0.0852
Container:			
llength = 2.089	+	0.3207 lg.r.t.	R^2 = 0.9310
(0.1038)		(0.0126)	SEE = 0.1063
Bulk			
llength = 1.949	+	0.3340 lg.r.t.	R^2 = 0.9681
(0.1673)		(0.0168)	SEE = 0.0307

All variables are in natural logarithms.

Bracketed numbers are standard errors.

Table 10.10 Dues per unit length for given g.r.t. (Transformed data)

Vessel type	10,000 g.r.t.		20,000 g.r.t.	
	lth (m)	£/lth	lth (m)	£/lth
General	153.0	65.36	192.8	103.73
Tanker	151.1	66.18	187.7	106.55
Container	154.9	64.56	193.5	103.36
Bulk	152.2	65.70	191.9	104.22

Thus, for a given g.r.t. the differences of the untransformed data are not present. The non-linear relationship is reflected in the progressive nature of the tariff. The elasticity of the due per unit length with respect to g.r.t. is approximately $\frac{2}{3}$rds [3]. That is, a one per cent increase in g.r.t. increases the due per unit length by $\frac{2}{3}$rds of one per cent, regardless of the vessel type.

10.2.4 Bases for Cargo Handling and Goods

The two main alternative quantity measures for cargo handling are time and units of the commodity (that is tonnage, volume or number of units of the commodity). Section 9.4.5 investigated time and tonnage based charges at the Port of Liverpool and the results of the investigation are summarised in table 10.11.

The two main observations from that analysis relate to the sign and magnitude of the results. If the port sets a rate based upon a standard productivity (TPNGH) then the benefit of a productivity in excess of the standard accrues to the user - in the case of a time based charge - and to the port if the charge is tonnage based. This

Table 10.11 The Sensitivity of Time and Tonnage Based Cargo Handling Charges

Time Based		Tonnage Based	
$\frac{\partial P/M/S}{\partial TPNGH}$	ε	$\frac{\partial P/T}{\partial TPNGH}$	η
0.95	0.27	-0.52	-0.73

where P/T = Price/tonne; P/M/S = Price/man/shift

TPNGH = Tonnes per Net Gang Hour

η = Elasticity of P/T with respect to TPNGH

ε = Elasticity of P/M/S with respect to TPNGH

arises because the cost of factor inputs are related to both time and tonnage. Thus in the time based case the port will have to pay more per man per shift if a greater than standard productivity is achieved. However the revenue rate per man per shift is fixed so that the port is required to absorb the increased cost. In the tonnage based case the port will have to pay labour less per tonne as the fixed wage per man per shift is spread over the higher than standard tonnage. Thus, given a fixed revenue rate per tonne the "profit" from increased productivity accrues to the port.

The magnitudes of the elasticities would suggest that a time based schedule is less sensitive (by a factor of approximately three) to deviations from the standard productivity than a tonnage based schedule. This arises because the tonnage based costs represent a smaller proportion of direct labour costs. (Note that the time based elasticity, ε, is calculated from the tonnage based labour costs).

Consider, for example, the port's revenue per shift when the tariff is time and tonnage based. From equation III (section 9.4.5), with $\bar{W}$ = £11.20; M = 14.5 men; b = £0.0575/man/tonne; NH = 6 hours; TPNGH* = 12; and α = 1.75, then

$$\text{Revenue/shift} = [\bar{W}.M + b.NH.TPNGH.M](1 + \alpha)$$
$$= £611.68$$

If the tariff was time based then this is the revenue which the port would receive regardless of the productivity. If however the actual productivity was, say, 13 TPNGH then (substituting 13 instead of 12 in the above equation) the port should have charged £625.44. Thus the port has to absorb £13.76 of the increased "costs" (Note that this is approximately equal to $\frac{\partial \; P/M/S}{\partial \; TPNGH} \times M$).

If the tariff was tonnage based then from equation I (section 9.4.5)

$$\text{Price/tonne} = \left[\frac{\bar{W}.M}{NH.TPNGH^*} + bM\right](1 + \alpha)$$
$$= £8.50.$$

So that if the actual productivity was 13 TPNGH (= 78 tonnes per gang per shift) then the port's actual revenue per shift would be £662.66 (£8.50 x 78) whereas £625.44 should have been charged. Thus the port's "profit" increases by £37.44 . (Note that this is approximately equal to $\frac{\partial \; P/T}{\partial \; TPNGH} \times TPNGH^*$). Given the impact and magnitude of the costs and benefits the port then has to decide upon the appropriate charging base.

If the charge was tonnage based, then it could be argued that this would provide an incentive to the port to achieve productivities in excess of the standard (and provide a positive disincentive to productivities below the standard). Whilst the shipowner would pay more per shift for an increased productivity, he would also benefit by being able to complete discharging or loading in a shorter period of time. If on the other hand, the charge was time based then there is a disincentive for the port to achieve productivities in excess of the standard. The shipowner may also argue that such a charge is sensitive to a factor (namely the productivity) over which he has no control. For example, if the port is experiencing "labour difficulties" then it is the shipowner who bears the cost of the resulting low productivities. If however, the reason for a reduced productivity is "bad stowage" then it may not be unreasonable for the ship to pay. Thus, a time based schedule does provide an incentive to the shipowner to stow the cargo in such a manner that rapid discharge is facilitated.

The balance of these arguments would appear to favour a tonnage based charge. However, given that a time based charge is less sensitive to changes in productivity it does merit further consideration by the port.

The quantity measures relevant to the services provided under the heading of goods included area or volume and the number of vehicles. In the case of a container terminal, the homogeneous nature of the "commodity" would suggest that the twenty foot equivalent unit (TEU) may be a suitable unit of quantity. If the temporal dimension was removed from the description of the service then the charging base can incorporate both the area occupied by the container and the time that it is in the stacking area. In the case of other homogeneous commodities the quantity measure which is used by the Port for transit facilities is the tonne (for example, the capacity of the grain silos).

The tonne is also the base which is used extensively for the heterogeneous general cargo. Clearly, tonnage is a measure of quantity for transit facilities, however, with general cargo its use tends to favour those commodities with high stowage factors (volume per unit weight). A similar problem exists for the ship carrying these commodities and as a result the shipowner (or liner conference) reserves the right to charge on either basis.

The access provided for road vehicles is subject to similar considerations to those of access for ships (that is, conservancy). Following the logic of that case, the port could charge each vehicle for an entry into the port. If this was not acceptable because of different vehicle sizes then a measure of the vehicle's gross weight, carrying capacity or other relevant physical characteristics. In practice, ports tend not to charge vehicles, thus the charging base moves back to the goods.

10.3 Willingness to Pay

Whilst the assessment of a specific traffic's willingness to pay a particular charge is related to demand, and thus beyond the scope of this thesis, there are a number of demand based considerations which are of general applicability.

Apart from the demand for cruise liners, the demand for shipping services, and thus port services is a derived demand. In other words, it is not required for its own sake, it is demanded because there exists a demand to change the spatial location of commodities.

Marshall [4] discussed four "conditions under which a check to the supply" of a factor of production "may cause a very great rise in its price" (that is, the conditions under which the demand for the factor are inelastic). These conditions include;

1. "the factor itself should be essential, or nearly essential to the production of the commodity, no good substitute being available at a moderate price"
2. "the commodity in the production of which it is a necessary factor should be one for which the demand is stiff and inelastic"
3. "only a small part of the expenses of production of the commodity should consist of the price of this factor"
4. "even a small check to the amount demanded should cause a considerable fall in the supply prices of other factors of production"

Layard and Walters [5] restate these conditions as;

"Within an industry, the (absolute) elasticity of demand for a factor i (ε_{ii}) varies directly with;

1. The (absolute) elasticity of demand for the product the factor produces ($|\eta^D|$) (2 above).
2. The share of the factor in the cost of production (v_i) (3 above).
3. The elasticity of supply of the other factor (η^S) (4 above).
4. The elasticity of substitution between the factor in question and the other factor (S_{ij}) (1 above)".

Layard and Walters decompose the elasticity (ε_{ii}) into an output effect (with constant factor proportions and a substitution effect (with output remaining constant and factor proportions changing). The first three conditions are analysed in terms of the output effect then the substitution effect is introduced when considering the fourth condition. Thus, given constant factor proportions (that is, no substitution effect), the relationship between the first three factors is [6];

$$\varepsilon_{ii} = v_i \left[\frac{\eta^S \eta^D}{\eta^S - (1 - v_i)\eta^D} \right]$$

The interesting cases embodied in this formulation can be examined by investigating the limiting cases. Rearranging the equation, by dividing the numerator and denominator of the expression in brackets by η^S,

$$\varepsilon_{ii} = v_i \left[\frac{\eta^D}{1 - (1 - v_i)\eta^D/\eta^S} \right]$$

Thus, as $\eta^S \to \infty$, $\varepsilon_{ii} \to v_i \eta^D$. The condition under which $\eta^S \to \infty$ is that the prices of other factors are fixed. Thus for example, if one is considering import and export elasticities in the range [-2,0], and given that port costs may only represent a small proportion of the total through transport costs, then the elasticities of demand for port services will tend to be very low. This formulation also demonstrates the relationship between elasticity and unit value of the commodity [7]. Let t_i be the port costs incurred by the commodity and p_i be the c.i.f. price of the commodity. Then $v_i = t_i/p_i$, and

$$\varepsilon_{ii} = \frac{t_i}{p_i} \eta^D$$

Thus, ceteris paribus, as the unit value of the commodity (c.i.f. price) increases, the elasticity of demand for port services decreases (that is, it becomes less sensitive to price changes).

At the other extreme, as $\eta^S \to 0, \varepsilon_{ii} \to 0$. η^S can be interpreted as either the supply of other factors or the supply of the commodity itself. In this second case, the commodity is considered as being a factor input in the exporting country which is combined with transport services to produce the output in the importing country - the place where the demand elasticity is relevant. Thus, if the supply is inelastic then so also is the demand for the factor.

If the elasticity of substitution is admitted into the analysis then it can be shown that the substitution effect is equal to [8],

$$-(1 - v_i)S_{ij}$$

where,

S_{ij} = percentage change in factor proportions resulting from a unit percentage change in relative factor prices.

Thus, assuming perfectly elastic supply of the other factor input, and combining the output effect with this substitution effect,

$$\varepsilon_{ii} = v_i \eta^D - (1 - v_i)S_{ij}$$

or

$$|\varepsilon_{ii}| = v_i |\eta^D| + (1 - v_i)S_{ij}$$

This formulation suggests that there is a direct positive relationship between ε_{ii} and v_i if and only if $|\eta^D| > S_{ij}$. That is, for a given η_D and S_{ij}, if;

$$|\varepsilon_{ii}|^* > |\varepsilon_{ii}|$$

then,

$$v_i^*|\eta_D| + (1 - v_i^*)S_{ij} > v_i|\eta_D| + (1 - v_i)S_{ij}$$

or,

$$v_i^*(|\eta_D| - S_{ij}) > v_i(|\eta_D| - S_{ij})$$

and since $0 < v_i < 1$, for this condition to hold, $v_i^* > v_i$ and $(|\eta_D| - S_{ij}) > 0$. The formulation also suggests that long-run elasticities may be greater than short-run elasticities. In the short run, it may not be possible to change factor proportions and thus the value of S_{ij} will be low. In the long-run however it may be possible for ships or goods to substitute other ports,and for technological change ot occur (for example, substitution of the capital intensive container and Ro-Ro vessels for the labour intensive general cargo ships). The discussion of the reasons for a lower rate for coastal vessels could possibly be explained in terms of these smaller vessels having higher short-run elasticities of substitution than the deep-sea vessels.

Thus, the elasticity of demand for the factor will vary directly with the share of port costs in the c.i.f. price (assuming that $|\eta^D| > S_{ij}$), the price elasticity of demand for the commodity handled and the supply elasticity of other factors (including the commodity). The relationship involving the share also suggests that the demand elasticity will vary inversely with the unit value of the commodity.

Whilst these factors may give the port authority a qualitative indication of the elasticity of demand for the port's services, there remains the problem of obtaining quantitative estimates of their values. Batchelor and Bowe [9] estimated the relative price elasticities of UK imports and exports for 44 and 48 commodity groupings respectively. Their estimates, together with the unit values [10] for each commodity group are shown in Tables 10.12 and 10.13. The positive signs of some of the elasticities and the observation that over half of the estimates are not significantly different from zero

Table 10.12 United Kingdom Import Elasticities and Unit Values (Port of Liverpool)

Commodity	SITC(R)	Unit Value	Price Elasticity
Food and Live Animals			
Live animals	01,941	339	-
Raw meat	011	575	-1.60
Meat preparations	012,013	905	-1.42
Dairy produce	02	340	0.29*
Fish and preparations	03	921	-0.20*
Wheat	041	86	0.05*
Maize	044	67	-2.37
Other milled cereals	042,043,045	114	-2.85
Milled cerals and preparations	046-048	604	-0.88
Fresh fruit	051	539	-0.31*
Vegetables	054	123	-0.87
Fruit and vegetable preparations	r.05	264	0.01*
Sugar and preparations	06	126	0.21*
Animal feeding stuffs	08	87	-1.06*
Beverages	11	60	0.49
Tobacco	12	951	1.07
Other Food	07,09	418	-0.53*
Basic materials			
Textile fibres and waste	26	692	-0.59*
Crude fertilisers	271	-	-0.69*
Crude minerals	r.27	32	-0.17*
Iron ore	281	10	-0.21*
Other ores and scrap	r.28	220	-0.48*
Oil-seeds and nuts	22	139	-1.23
Crude rubber	23	362	-0.05*
Wood, lumber and cork	24	102	-0.58*
Pulp and waste paper	25	159	-0.05*
Animal and vegetable oils and fats	4	263	-0.03*
Other basic materials	21,29	284	-0.36*

Table 10.12 (continued)

Commodity	SITC(R)	Unit Value	Price Elasticity
Chemicals			
Chemical fertilisers	56	-	-1.13
Plastics	58	418	-0.57
Organic chemicals	512	371	-9.23
Inorganic chemicals	r.51 ex 515	-	-12.19
Other chemicals	515,52-5,57,59	256	0.34*
Machinery and Transport Equipment			
Non-electrical machinery	71	1,581	-2.70
Electrical machinery	72	1,882	-0.14*
Transport equipment	73	1,439	-0.94*
Miscellaneous manufacturers			
Wood and cork manufacturers	63	195	-1.13
Paper and products	64	342	-0.46*
Textiles	65	1,225	-1.18
Cement	661.2	-	-0.95*
Other mineral manufactures	r.66	166	-0.04*
Iron and steel	67	151	-0.67*
Non-ferrous metals	68	865	-0.17*
Metal manufactures n.e.s.	69,951,961	853	0.19*
Other manufactures	61,62,8,911	1,875	-2.32

Source: See [9],[10]

*Not significant at the 5 per cent level.

Table 10.13 United Kingdom Export Elasticities and Unit Values (Port of Liverpool)

Commodity	SITC(R)	Unit Value	Price Elasticity
Food and Live Animals			
Meat and dairy produce	01,02	330	-1.36
Fish and preparation	03	617	-1.16
Milled cereals and preparations	046-048	504	-0.05*
Fruit and vegetables	05	230	-1.26
Sugar and preparations	06	323	0.37*
Spirits	112.4	751	-3.03
Tobacco, food, n.e.s.	07,09,12	549	-0.02*
Live animals	001,941	4,005	-2.00
Unmilled cereals	041-045	-	-0.76*
Animal feeding stuffs	08	188	-0.74*
Beverages n.e.s.	11 ex 112.4	144	-1.06*
Basic Materials			
Textile fibres and waste	26	634	-0.59*
Clay	276.21	37	-0.45*
Salt	276.3	13	-0.30*
Crude minerals n.e.s.	r.27	-	-
Stone, sand and gravel	273	-	-
Other basic materials	21-25,29,4	280	-0.38*
Ores and scrap	28	692	-0.75*
Chemicals			
Organic chemicals	512	425	-0.68*
Caustic soda	513.62	-	-0.53*
Soda ash	514.28	92	0.31*
Inorganic chemicals n.e.s.	r513,514	127	-1.16
Mineral tar etc.	52	102	-1.14
Dye stuffs etc.	53	723	-0.89
Essential oils etc.	55	401	-0.92
Plastics	58	487	-1.64
Other chemicals	54,57,59	732	-0.46
Chemical fertilisers	56	94	-0.75*

Table 10.13 (continued)

Commodity	SITC(R)	Unit Value	Price Elasticity
Machinery and Transport Equipment			
Non-electrical machinery			
Power generating	711	1,980	-4.10*
Agricultural	712	788	-1.39*
Metal working	715	985	-3.10*
Other	714,717-9	1,551	-4.20
Electrical machinery			
Power generating	722	1,627	-0.38*
Other	r.72	1,266	-1.63*
Road vehicles n.e.s.	732.2-5,.7,.9	930	2.13*
Vehicle parts n.e.s.	732.8	1,118	-0.97*
Other vehicles and parts	731,3,4.92, 5.93	260	-10.97
Motor cars	732.1,.6	1,077	-2.66*
Miscellaneous Manufactures			
Wood and cork manufactures	63	-	-1.39*
Textiles	65	1,607	-1.18
Cement	661.2	-	-5.30
Glass and pottery	664-666	235	-0.55*
Other mineral manufactures	r.66 ex. 667	131	-1.27
Iron and Steel	67	163	-0.68*
Non-Ferrous metals	68	867	-0.21*
Finished structures	691	389	-1.19
Other metal manufactures	r.69,951,961	645	-1.35
Rubber manufactures	62	832	-1.18*
Other manufactures n.e.s.	61,8,911	1,406	-1.34
Paper and products	64	406	-3.06

Source: See [9],[10]

*Not significant at the 5 per cent level.

reflect the difficulties involved in attempting to obtain quantitative estimates of the price elasticities.

The price elasticity, whilst giving an indication of the sensitivity of the quantity to changes in price, does not necessarily indicate the commodity's ability to pay. Provided that any relationship which may exist between the price elasticity of demand for the commodity and its unit value can be established, a better measure of a commodity's ability to pay a charge may be its unit value (for example, a charge of £1.00 on a commodity with a unit value of £1,000 is insignificant when compared with the same charge on a commodity with a unit value of £10.00). Figures 10.1 and 10.2 (derived from the data in tables 10.12 and 10.13) do not support an hypothesis that there is a relationship between the price elasticity of demand for the commodity and unit value (for example, it cannot be stated that low unit value commodities are more sensitive to price changes or vice versa). Thus, given that there is no discernable pattern in a commodity's elasticity as its unit value increases and that a charge (in absolute terms) decreases in significance as unit value increases there may be a case for using unit value as a measure of ability to pay.

A similar problem is encountered in the pricing of liner shipping services. The approach adopted by liner conferences, when fixing a rate on a new commodity or reducing the rate on an existing commodity, is to require the shipper to provide them with the following information [11];

"(a) Stowage and handling - this includes also the properties of the cargo, such as whether it is hazardous, or likely to contaminate other cargo;
(b) Movement of the commodity - where a reduction in the existing rate is requested, the expected

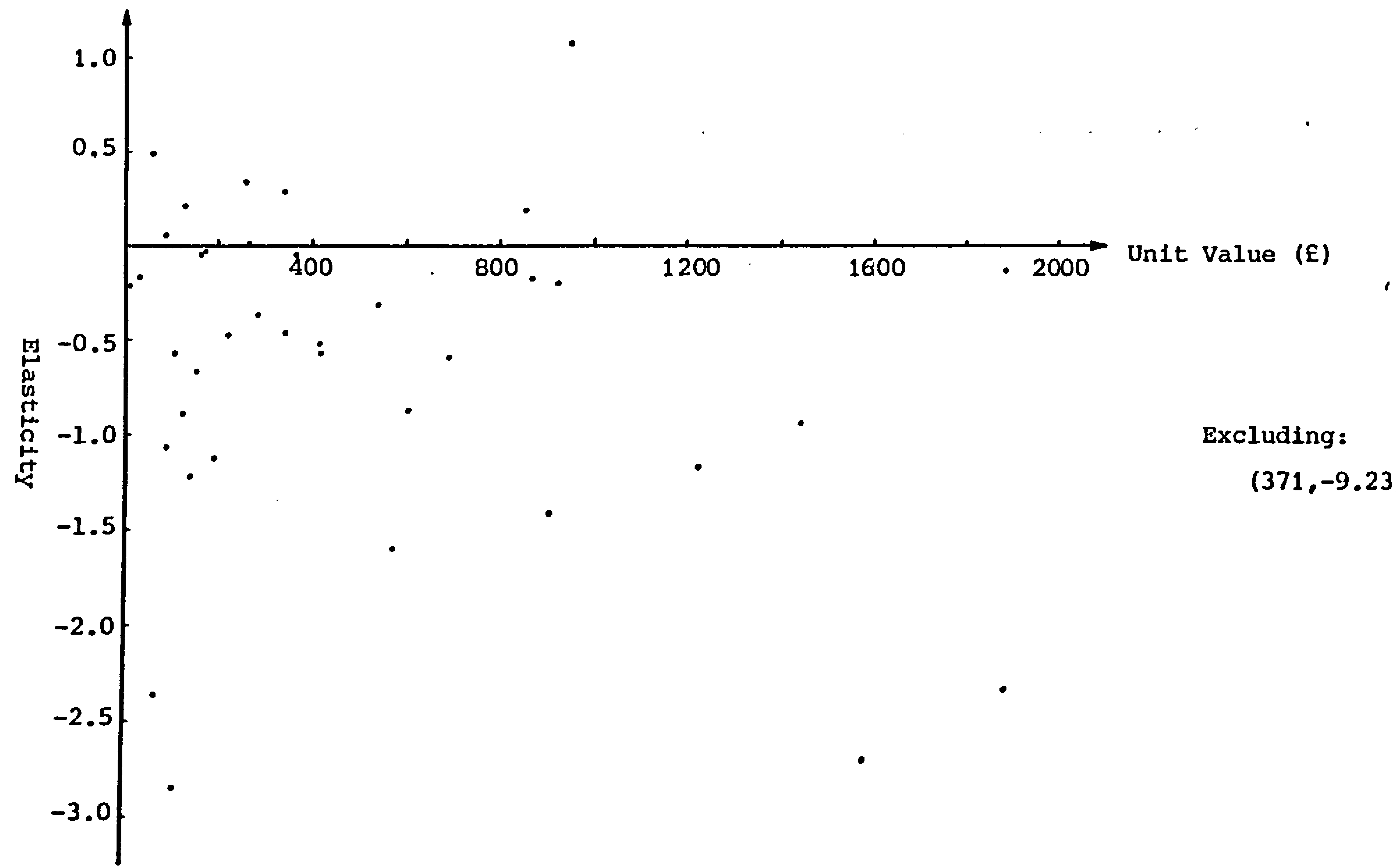
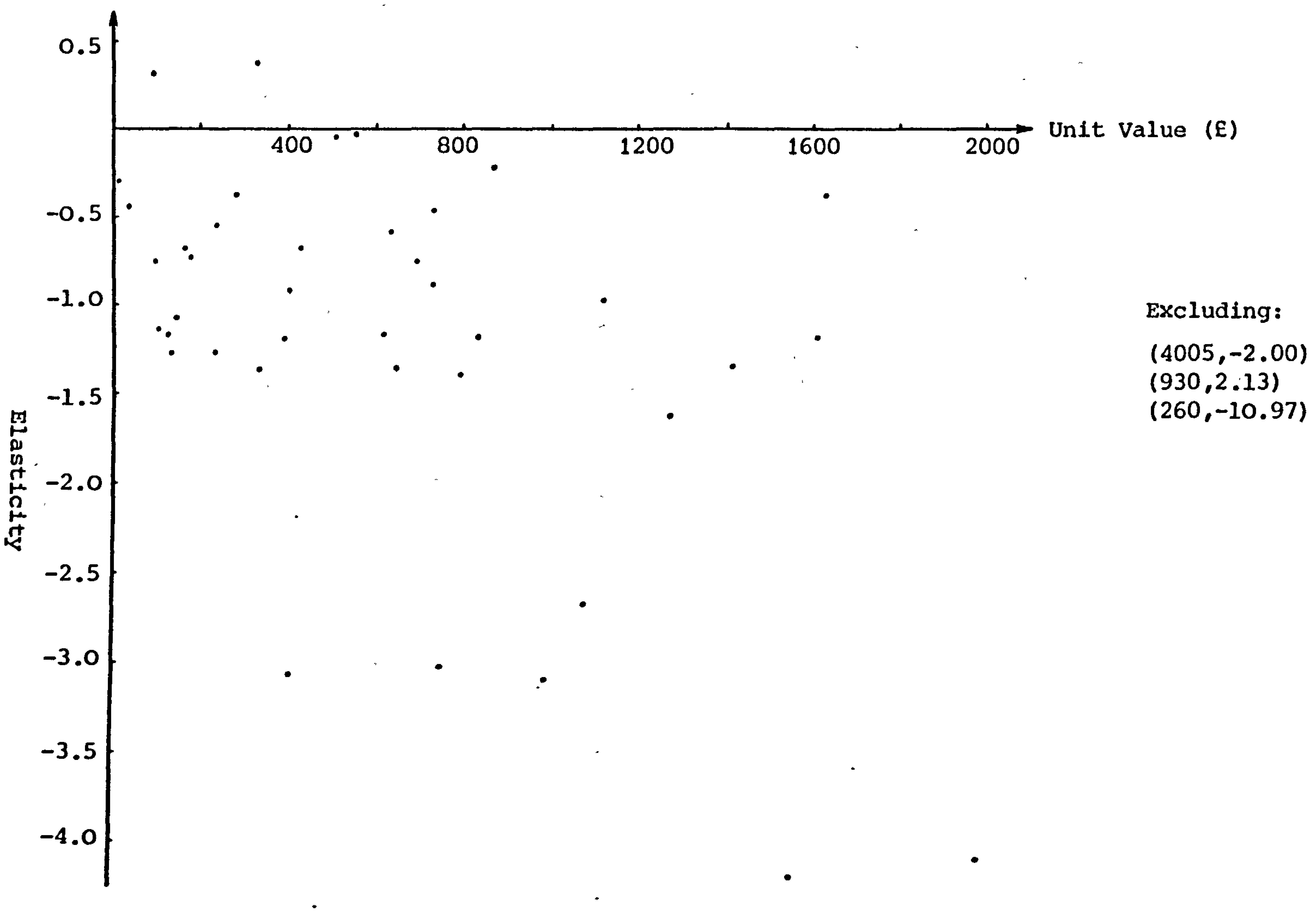


Fig 10.1 United Kingdom Import Elasticities and (Liverpool) Unit Values

Figure 10.2 United Kingdom Export Elasticities and (Liverpool) Unit Values



increase in the movement of the commodity is asked for;
(c) Capacity of the commodity to bear a particular rate - in this context, information relating to the export incentives received by the shipper and the f.o.b. value and rate charges in respect of identical or similar commodities moving from other areas to the same market is also collected."

Thus the liner conference would appear to be combining partial information of a qualitative and quantitative nature to estimate the user's willingness/ability to pay.

10.4 Equity Considerations

One of the statutory principles to be applied to pricing in United Kingdom Ports is that users in equal positions should be treated equally. Rochdale's summary [12] of the statutory control of port charges states that;

> "Charges at the major independent ports are generally controlled by the provision of the Private Acts of Parliament relating to the individual ports... The port authority is free to vary charges within the prescribed maxima, provided there is no discrimination between users in like circumstances."

If the port wishes to increase charges then it can apply to the Minister. One of the principles that will be borne in mind when considering the application is;

> "that charges should be shared equitably by all users of the port." [13]

Thus, the first quotation requires horizontal equity whilst the second is suggesting vertical equity (that is, the relative positions of users in different circumstances). Given that it is not possible for the port to undertake the required comparisons of interuser utility it will be necessary for them to develop various "rules of thumb" which are accepted by the users (or can be "sold" to the users).

From the port's tariff schedules a number of measures of horizonal equity are used. In the conservancy schedule coastal vessels are treated as equals as are the deep sea vessels. With respect to cargo handling a measure of equity is productivity - commodities with equal productivities paying the same rate (with adjustments made for the dirty nature of the commodity). The underlying measure is however the labour cost per shift, with the tariff being designed so that (apart from differences in the dirty nature of the cargo and different manning scales) all commodities pay the same amount per shift. In the goods schedule there is some evidence to suggest that the unit value of the commodity is a measure of horizonal equity.

The measures of vertical equity are directly related to those of horizonal equity. In the conservancy and berth cases traffic is separated vertically into coastal and deep-sea traffic. This separation was explained (sections 9.1 and 9.2) in terms of voyage length, cross elasticities between ports and the number of entries into the port. Whilst these factors may explain the differences qualitatively they do not explain quantitatively why the coastal rate is only one third of the deep-sea rate (conservancy). With respect to cargo handling it has been suggested that the prices are related to cost and thus vertical equity is obtained with measurable differences in productivity, manning and dirt allowances. However it has been suggested that the system assumes constant long-run elasticities and a greater ability to pay of the commodities with higher direct labour costs. In the goods schedule, if there is a relationship between unit value and the charge, then the port again has measurable differences with which the schedule can be structured.

Another issue related to the structure of the port's schedules is whether they should be progressive. To a limited extent the conservancy schedule at Liverpool is progressive with respect to vessel size (given that coastal vessels tend to be smaller than deep-sea vessels). Given also that berth charges are based on g.r.t. they will be progressive with respect to length. Other ports, for example, Tees and Hartlepool used to have progressive conservancy and dock dues according to the vessel's n.r.t. (Table 10.14)

Table 10.14 Charges on Vessels - Tees and Hartlepool Port Authority (1st August 1973)

Conservancy (All Ships)		Dock Dues (Dry Cargo Ships)	
Size Range (n.r.t.)	Due (relative)	Size Range (n.r.t.)	Due (relative)
0-500	100.0	0-500	100.0
501-1000	101.7	501-2000	130.0
1001-2000	123.5	2001-5000	170.5
2001-5000	127.9	5001 plus	185.9
5001-10000	132.7		
10000-40000	169.6		
40001 plus	187.6		

It appears however that the port may experience some difficulty in obtaining a measurable demand factor which reflects the traffic's willingness to pay and can therefore be used to structure the tariff vertically. The Tees and Hartlepool charges do not appear to be based upon any other vessel dimension which when converted to an n.r.t. basis yields a progressive tariff. For example, the survey of vessels at Liverpool (section 10.2.3) suggests that both g.r.t. and dwt increase less than proportionately with n.r.t. - Table 10.15 (length, breadth and draft will also increase less than proportionately as they

Table 10.15 Regressions of Transformed g.r.t. and dwt on n.r.t. - General Cargo

lg.r.t.	= 0.6867	+	0.9838 ln.r.t.	R^2 = 0.9867
	(0.0434)		(0.00623)	SEE = 0.1403
ldwt	= 1.6738	+	0.9010 ln.r.t.	R^2 = 0.9621
	(0.0681)		(0.00976)	SEE = 0.2200

All variables are in natural logarithms.

Bracketed numbers are standard errors.

are linear dimensions). Distance, on the hypothesis that the proportion of port costs in total transport costs decreases with distance (which in turn implies a lower demand elasticity and thus greater ability to pay) could be used as a measurable demand factor. An extension of Walter's "development model for road investment" [14] to the case where productivities increased with distance could turn the rent pyramid (with apex at the final market place) into a figure whose altitude increases with distance. Under these circumstances the good's ability to pay transport costs may increase with distance.

In some circumstances, it may be the case that unit value is a function of distance, however in general, unit value is likely to be so variable both within and between ship types that such a relationship would be inappropriate for general application. The remaining measure, in conservancy and berth charges, for vertical equity is cost. The use of this measure presupposes that the port can undertake the required computation (section 6.4.3) and/or that some formula has been adopted to allocate the (fixed) capital dredging costs.

Questions of equity also arise if the port is considering whether to base charges upon a traffic's actual physical characteristics, its maximum physical characteristics or the capacity provided by the port. For example, should conservancy charges be related to vessel size (g.r.t. or dwt) or tonnage discharged/loaded at the port? Should berth charges be related to quay length or to the actual vessel length? Should the charge on containers be related to the T.E.U. or the number of tonnes in the container? Given that the main function of a port is to act as a transfer point then it could be argued, for example, that actual weight should be the basis of the charge. On the other hand, it may also be argued that such a system is "inequitable" because a 10,000 dwt general cargo ship which only enters the port to discharge 100 tonnes of general cargo, would pay the same as a 100 dwt coaster which also discharged 100 tonnes. In table 10.1 the Port's view of the advantages and disadvantages of weight of cargo as a basis of assessment of port rates are listed (item 7). The major disadvantage would appear to be the time taken (up to two months) for the final out-turn of cargo - as a measure of profitability of the voyage, the case is not proven, as weight is not necessarily related to profitability. The Port recognises that such a charging base would attract vessels with part cargoes however it also believes that in the long-run such a base would encourage liner operators to adopt multiport itineraries which may reduce the Port's traffic. The Port does however note that some other ports do use the actual tonnage handled to adjust their rates. For example, the Tees and Hartlepool Port Authority used to quote conservancy dues for vessels discharging or loading "full cargoes". A "full cargo" was defined as a cargo discharged or loaded which exceeds 70 per cent of the vessel's n.r.t. The dues for vessels discharging or loading less than a "full cargo" are 50 per cent of the quoted dues.

10.5 Effect on the Port of the Impact of the Charge

The impact of the port charges (who initially pays the charge) can lie with either the shipowner or the goods owner. At Liverpool the impact of the various charges is as follows;

Shipowner

- conservancy
- berth charges
- loading stevedoring
- discharging stevedoring (plus half the master porter's bonus)
- wharfinging

Goods owner

- goods charges
- quay rents
- master porterage (excluding half of the bonus)

The impact of the charges may be of some importance to the port. If the port is dealing with a large number of small users, it can exercise some monopoly power, whilst if it is dealing with a small number of large users its power may be reduced. In the extreme case of bilateral monopoly (figure 10.3) the port acting as a monopolist would produce that level of output (Q_1) where marginal cost equals marginal revenue (A) and set price (P_1) from the corresponding point on the user's demand curve (B). However the user acting as a monopolist sets his marginal revenue product (the demand curve) equal to his marginal expense of the port's services (D) (the change in total cost of purchasing one extra unit of port services) and offers to purchase the services at a price (P_2) equal to the port's marginal cost at the level of output corresponding to the intersection of these two curves (C). Under these circumstances the final price and quantity are indeterminant and will depend upon the bargaining skills of the two parties.

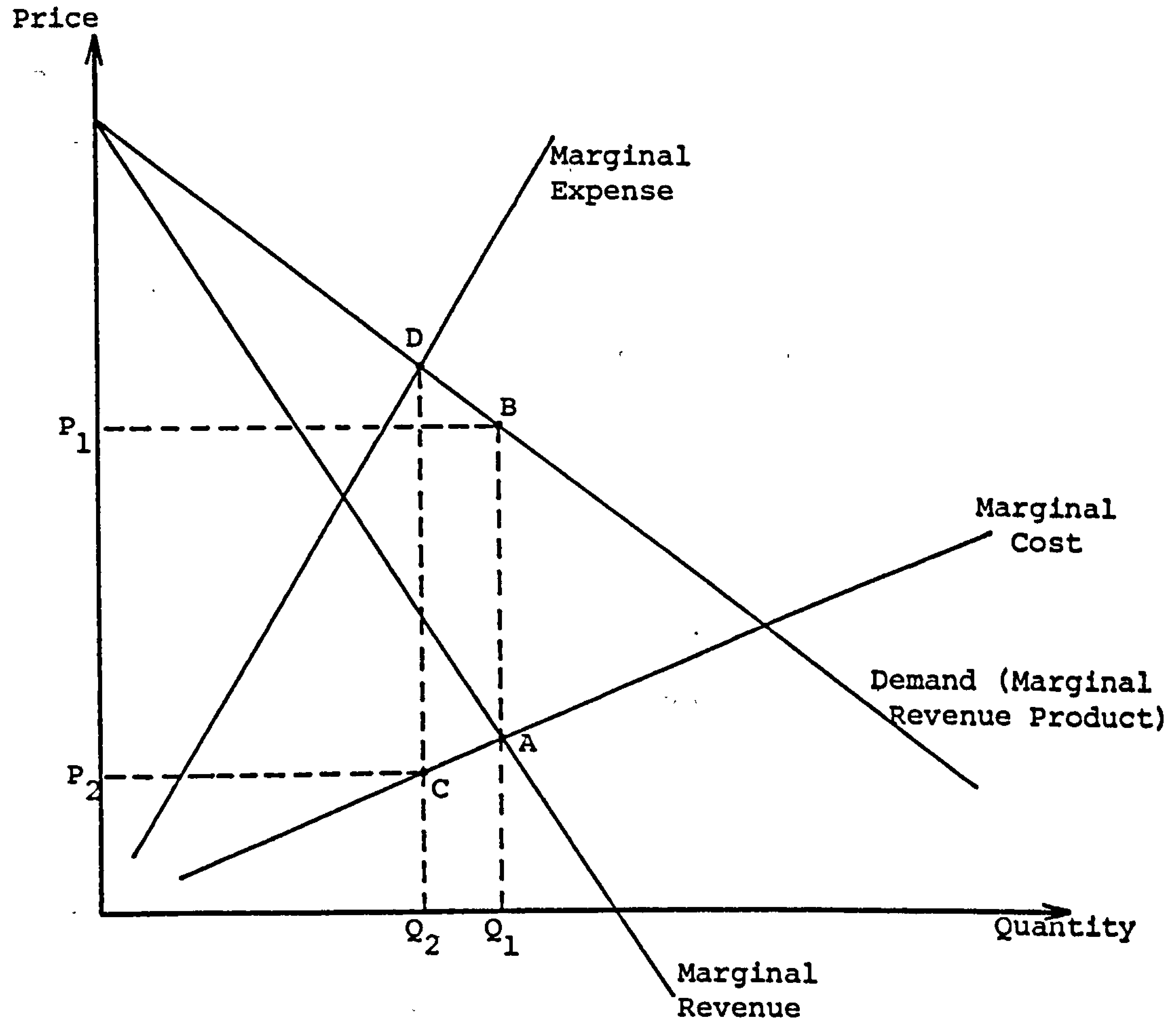


fig 10.3 Bilateral Monopoly

Whilst the port will not be operating under the conditions of this extreme case, some of the elements of indeterminancy, may be present. This situation is more likely to arise in the Port's dealings with the shipowner as the Port argues that a large proportion of their general cargo trade is represented by a small number of users (liner conferences or trades). Table 7.3 (Chapter 7) indicates, in the last column, whether the berth is a "single or various user berth". Given the number of single user berths (and their corresponding tonnages) there is some evidence to support this argument. On the other hand there tends to be a considerably larger number of goods owners, so that the port may find itself in a relatively stronger bargaining position with the goods owner than with the shipowner. Thus, it may be in the Port's interest to maintain the separate responsibility for paying charges between the shipowner and the goods owner.

10.5 Summary and Conclusions

This chapter has considered the charging base, willingness to pay, equity and the impact of a charge. Following Debreu, different measures of quantity were suggested for each of the four main services provided by the port. These included: conservancy - number of ships; berth - length; cargo handling - time worked, tonnage, volume or number of units; and goods - area or volume and number of vehicles. In the case of the berth and transit facilities it was further suggested that time could be removed from the physical description of the service and included in a composite measure of the quantity.

The choice of any charging base inevitably involves considerations of equity and given that the port cannot compare interuser utility it is difficult to judge which is the "best" base. As Prest states, "the abstract meaning of equity is a problem for the moral philosopher rather than the economist" [15]. However, it is possible to outline some of the bases which could be used and to indicate the differences which may arise if they were employed. One of the functions of port management will then be to choose bases which are acceptable to, or can be "sold" to, the user.

It was suggested in the conservancy case that the use of the ship as a charging base may be commercially unacceptable because, ceteris paribus, the larger ships will have a greater ability to pay. Assuming that ability to pay is related to the carrying capacity of the ship then either a volume or weight measure suggest themselves. The vessel's g.r.t. is used extensively and this was compared with deadweight. The analysis suggested that the g.r.t. base favours bulk carriers and tankers at the expense of container and general cargo vessels. If however the unit values of tanker and bulk commodities are less than those for the commodities carried on general cargo and container vessels then this may not be particularly important.

The quantity measure suggested for the berth was length however g.r.t. is a widely used base for these charges. It could be argued that the vessel has an ability to pay which increases more than proportionately with length and consequently g.r.t. may be the "better" base. The analysis suggested that the elasticity of a due per unit length with respect to g.r.t. was $^2/_3$rds, there being no significant difference between vessel types.

The two bases discussed under cargo handling were time and tonnage.

Given that the costs of factor inputs are both time and tonnage based either base could be used. On balance, tonnage is preferred as it provides a positive incentive to the port to increase productivity, however it is also noted that at Liverpool a time based schedule is less sensitive to changes in productivity.

In the case goods, T.E.U.s (containers) and tonnage (other "commodities") were suggested as alternatives to the quantity measures. For heterogeneous cargo this tends to favour commodities with high stowage factors. From the practice of ports not to charge vehicles delivering and receiving cargoes tonnage would also appear to be an appropriate basis.

Section 10.3 considered the various factors influencing the price elasticity of demand for transport services including: the supply and demand elasticities of the commodity transported, the share of transport costs in c.i.f. value of the commodity and the elasticity of substitution. It was indicated however that it may be difficult to obtain reliable quantitative estimates for these factors, and unit value was submitted as a possible base for incorporating the user's willingness/ability to pay.

Section 10.4 introduced the problem of obtaining suitable measures which may be considered to be both horizontally and vertically equitable. For cargo handling, the measurable differences are productivity, manning and dirt allowances and for the goods charges there is some evidence to suggest that unit value could be used for this purpose. For conservancy and berth charges, whilst vertical structures are adopted by ports (for example, by voyage type or vessel size) it would appear more difficult to obtain a quantitative demand measure which reflects the user's willingness or ability to pay.

Finally section 10.5 suggested that it may be in the port's interest to separate the responsibility for paying charges between the goods owner and the shipowner.

Notes

[1] Rochdale, Viscount "Report of the Committee of Inquiry into the Major Ports of Great Britain", Cmnd 1824, p66, London, HMSO.

[2] Debreu, G. "Theory of Value", Yale University Press, New Haven and London, 1959, pp28-32.

[3] $$\text{Charge/metre} = \frac{\text{g.r.t. x charge/g.r.t.}}{\ell^2 \text{ x g.r.t.}^{1/3}}$$

$$= (\ell^{-2} \text{ g.r.t.}^{2/3}) \text{ charge/g.r.t.}$$

$$\therefore \text{Elasticity} = \frac{2}{3}$$

[4] Marshall, A. "Principles of Economics", Macmillan, London, 8th ed., 1949.

[5] Layard, P.R.G. and Walters, A.A. "Microeconomic Theory" McGraw-Hill, New York, 1978.

[6] Decomposing the elasticity of demand for a factor into an output and substitution effect implies that the output elasticity measures the proportionate change in the quantity of the commodity which is transported resulting from a unit percentage change in transport costs. Thus if factor proportions are constant, the substitution effect is zero and the elasticity of demand for transport with respect to transport costs is equal to the elasticity of demand for the commodity transported also with respect to transport costs.

Thus, following Bennathan, E. and Walters, A.A.,("The Economics of Ocean Freight Rates",Praeger, New York, 1969),

Let,

x = output of commodity

t = price of transport services per unit of x (assumed to be independent of x)

$p_s(x)$ = supply (f.o.b.) price of commodity

$p_d(x)$ = demand (c.i.f.) price of commodity

ε_{trans} = ε_{ii} in text

$$v = \frac{t}{p_d}$$

Then,

$$\varepsilon_{trans} = \frac{dx}{dt} \cdot \frac{t}{x}$$

but,

$$p_d(x) = p_s(x) + t$$

and differentiating with respect to t,

$$\frac{dp_d(x)}{dx} \cdot \frac{dx}{dt} = \frac{dp_s(x)}{dx} \cdot \frac{dx}{dt} + 1$$

$$\frac{dx}{dt} = \left[\frac{dp_d(x)}{dx} - \frac{dp_s(x)}{dx}\right]^{-1}$$

so that,

$$\varepsilon_{trans} = \frac{t}{p_d}\left[\frac{x}{p_d} \cdot \frac{dp_d}{dx} - \frac{x}{p_d} \cdot \frac{dp_s}{dx}\right]^{-1}$$

now,

$$\frac{x}{p_d} = \frac{x}{p_s + t} = \frac{x}{p_s}\left(\frac{1}{1 + \frac{t}{p_s}}\right) = \frac{x}{p_s}\left(\frac{p_d - t}{p_d}\right)$$

$$= \frac{x}{p_s}\left(1 - \frac{t}{p_d}\right)$$

Thus,

$$\varepsilon_{trans} = \frac{t}{p_d}\left[\frac{x}{p_d} \cdot \frac{dp_d}{dx} - \left(1 - \frac{t}{p_d}\right)\frac{x}{p_s} \cdot \frac{dp_s}{dx}\right]^{-1}$$

$$= v\left[\frac{1}{\eta^D} - (1 - v)\frac{1}{\eta^S}\right]^{-1}$$

$$= v\left[\frac{\eta^S \eta^D}{\eta^S - (1 - v)\eta^D}\right] .$$

[7] Deakin, B.M. "Shipping Conferences", C.U.P., Cambridge, 1973.

[8] Layard and Walters [5], Appendix 8, p 413.

[9] Batchelor, R.A. and Bowe, C. "Forecasting UK international trade: a general equilibrium approach", Applied Economics, 1974, 6, 109-141.

[10] H.M.S.O. "Annual Statement of Overseas Trade of the United Kingdom", Vol 5, 1975.

[11] UNCTAD, "The Liner Conference System", United Nations, New York, 1970, TD/B/C.4/62/Rev.1.

[12] Rochdale [1], p 66.

[13] Rochdale [1], p 66.

[14] Walters, A.A. "A Development Model of Transport", Papers and Proceedings of the American Economic Association", Vol 58, pt 2, May 1968, pp 360-377.

[15] Prest, A.R. "Public Finance in Theory and Practice", Weidenfeld and Nicolson, London, 1960, p 111.

CHAPTER 11

SUMMARY AND CONCLUSIONS

11.1 Problems and Solutions

The pricing and investment problem facing the port was outlined in Chapter 2 as being one of indivisibilities leading to jointness. In other words, the problem arises because costs in particular are difficult to separate (that is, indivisible) which implies that they are shared (that is, joint). On the supply side, table 2.1 suggested that the production of a good for one consumer implied that the same or other goods were produced for other consumers, whilst on the demand side, the consumption of one good implied the consumption of one or more other goods. At the simplest level, the problem is manifest as being one of recovering the port's capacity costs. The discussion of Chapters 6, 7 and 8 suggested however that the degree of severity of the problem varied between the services and facilities provided by the port and depends upon the extent of the indivisibilities in these services and facilities. For example, in the conservancy case, it was concluded that the majority of the facilities provided were joint to all of the traffic. It was further suggested that the level of service provided would be unlikely to be altered for moderate changes in the traffic volume. In the berth case however it was suggested that, in principle, incremental changes in capacity could be made and in the cargo handling case, even smaller incremental changes could be effected by altering the size of the labour force. An additional feature of cargo handling was that the short-run escapable costs represented a not insignificant proportion of the service's costs.

The general solution to these problems consists of a pricing and investment rule, namely;

1. Set price equal to marginal cost.
2. Invest if the traffic is willing to pay the cost of the extra capacity.

If the port is able to make small capacity adjustments and if decreasing costs are not exhibited over the range in which the decision is being made then an accounting requirement that total revenue equals total cost can be met (that is both the capacity and operating costs can be recovered). This is achieved by setting price equal to the marginal capacity plus operating costs. In the case where there exists temporal jointness with fluctuating demand, and given the same assumptions with respect to small capacity adjustments and no decreasing costs, then an accounting requirement can again be met. In terms of costs and prices this can be demonstrated by considering the programming problem:

$$\text{Max. } W = \sum_{i=1}^{n} D^i \int_0^{x_i} p_i(x_i)\,dx_i - \sum_{i=1}^{n} D^i c_i(x_i) - g(y)$$

Subject to:

$$x_i \leqslant y, \; i = 1, \ldots , n$$

where:

W	=	Welfare (consumers' plus producers' surplus)
$p_i(x_i)$	=	Demand function in time period i
$c_i(x_i)$	=	Total operating costs in time period i
$g(y)$	=	Capacity cost
D^i	=	Discount operator = $1/(1 + r)^i$
r	=	Discount rate

n = life of asset

y = capacity

Forming the Lagrangian expression;

$$W_\lambda = \sum_{i=1}^{n} D^i \int_0^{x_i} p_i(x_i)dx_i - \sum_{i=1}^{n} D^i c_i(x_i) - g(y) + \sum_{i=1}^{n} D^i\lambda_i(y - x_i$$

The Kuhn-Tucker conditions are;

(1) $\frac{\partial W_\lambda}{\partial x_i} = D^i p_i(x_i) - D^i c_i'(x_i) - D^i\lambda_i \leq 0, \quad x_i \frac{\partial W_\lambda}{\partial x_i} = 0$

(2) $\frac{\partial W_\lambda}{\partial \lambda_i} = D^i(y - x_i) \geq 0 \qquad , \lambda_i \frac{\partial W_\lambda}{\partial \lambda_i} = 0$

(3) $\frac{\partial W_\lambda}{\partial y} = - g'(y) + \sum_{i=1}^{n} D^i\lambda_i \leq 0 \qquad , y \frac{\partial W_\lambda}{\partial y} = 0$

Assuming that all $x_i > 0$ and that some capacity is provided (that is, $y > 0$), then the complementary slackness conditions imply that $\frac{\partial W_\lambda}{\partial x_i} = 0$ and $\frac{\partial W_\lambda}{\partial y} = 0$, and therefore,

$$D^i p_i(x_i) - D^i c_i'(x_i) - D^i\lambda_i = 0$$

or,

(1a) $\qquad p_i(x_i) = c_i'(x_i) + \lambda_i$

Now, from (2), if $x_i < y$ then, $\frac{\partial W_\lambda}{\partial \lambda_i} > 0$ and $\lambda_i = 0$.

Thus, price equals marginal operating cost in those time periods when capacity is not fully utilized. When capacity is fully utilized, $y = x_i$, $\frac{\partial W_\lambda}{d\,\lambda_i} = 0$ and $\lambda_i > 0$. Now, from (1a),

(1b) $\qquad \lambda_i = p_i(x_i) - c_i'(x_i)$

and from (3), since $y > 0$,

$$\text{(3a)} \qquad \sum_{i=1}^{n} D^i \lambda_i = g'(y)$$

Thus, from (1b) and (3a),

$$\text{(4)} \qquad \sum_{i=1}^{n} D^i (p_i(y) - c_i'(y)) = g'(y), \text{ for all } i \text{ where } y = x_i$$

or the present value of the excess of price over marginal operating cost is equal to the marginal capacity cost.

Thus, as long as the relevant demand and cost functions for each time period are known, equation (4) is solved for the optimum capacity level (y) and price is set such that,

$$p_i(x_i) = \begin{cases} c_i'(x_i) & , x_i < y \\ c_i'(x_i) + \lambda_i, & x_i = y \end{cases}$$

This would ensure that over the life of the asset the marginal capacity cost is recovered since,

$$\sum D^i \lambda_i = g'(y)$$

It should also be noted that the pricing rule implies that if demand is fluctuating over time then prices will be subject to similar fluctuations.

If however the port can only make discrete adjustments to capacity then it will be necessary to compute W_λ for each of the capacity levels. The investment criterion is the same as the general case, that is, continue investing as long as $W_\lambda \geqslant 0$. The pricing rule does not however guarantee that an accounting requirement will be met. This arises because in the Lagrangian expression g(y) and y are constant for

for each level of capacity that the port is considering. Thus the third Kuhn-Tucker condition is no longer relevant, that is, it is not required that,

$$\sum D^i \lambda_i = g'(y)$$

The pricing rule is the same as in the above case, that is,

$$p_i(x_i) = \begin{cases} c_i'(x_i) & , x_i < y \\ c_i'(x_i) + \lambda_i & , x_i = y \end{cases}$$

However $\Sigma D^i \lambda_i$ could be less than, equal to or greater than the incremental capital cost. Under the circumstances where the accounting requirement is not met ($\Sigma D^i \lambda_i < g'(y)$) it will therefore be necessary for the port to find alternative means to extract some of the surplus.

11.2 Escapable Costs

The general solutions to the port's pricing and investment problem have inter alia assumed a single identifiable traffic. In the port case however it may be necessary to provide facilities which are different in quality or nature for different traffic. Thus, when the port is considering the investment, reinvestment or disinvestment decision they will need to know the longer-run costs specifically associated with these separate classes of traffic. It has been suggested that the relevant cost for these purposes is the escapable cost. This cost is ascertained by defining the class of traffic then asking the question "which costs could be escaped if the traffic was not accepted?". The principles of the measurement of escapable cost were outlined in chapter 5 and included the reformulation of Foster's methodology in terms of matrices and an extension to the temporal case. The subsequent attempt in chapters 6, 7 and 8 to apply the methodology to

Conservancy, the Docks and Cargo Handling respectively indicated further the importance of classifying traffic according to "an essentially different quality or nature of the services and facilities provided". Apart from relatively minor differences in the quality of the services provided within a class of traffic they are treated as being homogeneous and the general solutions suggested above are applicable. In the Conservancy case, traffic was identified according to area of destination. This classification was used because the MDHC is providing services and facilities for traffic proceeding to ports other than the Port of Liverpool (including Birkenhead). Apart possibly from some size related costs the traffic proceeding to Liverpool (including Birkenhead) should be treated as a single traffic. In the Docks case, the services and facilities provided were divided into the lock gate to the quaywall and the berth to the dock gate. The general conclusion for the lock gate to the quaywall was that apart possibly from some size related costs the facilities tend to be provided for traffic in general. For the berth to the dock gate however, berths tend to be fitted out for particular cargo handling operations. Thus, given that the nature of the facilities are essentially different the cargo handling operation could be used to define a homogeneous class of traffic. This distinction can be carried forward into the cargo handling case itself.

The implication of such an approach for say a liner conference which requires sole use of a number of general cargo berths is that the port should supply the facilities if the conference is willing to pay the long run incremental costs of the required capacity including berths, transit sheds, cargo handling equipment and access roads.

The pricing rule is as outlined in section 11.1, namely,

$$p(x) = \begin{cases} c'(x) & , x < y \\ c'(x) + \lambda, & x = y \end{cases}$$

which may or may not meet an accounting requirement depending upon the port's overall utilization of general cargo berths. When considering the long-run costs, the conference may also be required to make a contribution to the joint costs of conservancy, lock gate to quaywall, berth to dock fate and cargo handling - the requirement with respect to these costs being that all the relevant traffic should be jointly willing to pay for these facilities.

11.3 The Overall Approach

The outline of the port's pricing and investment problem, and the discussion of the services and facilities provided under the heading of Conservancy, the Docks and Cargo Handling suggest that devising a tariff structure for ports is a complex problem. Given the degree of complexity, it will be necessary for the port to place the various pricing, investment, cost, demand and financial aspects into context by considering the overall problem. Turvey [1] suggests in the public enterprise case, that;

> "In principle, of course, the optimal price-output combination should be fixed in the light of predicted demand and cost functions. But when only point predictions of demand and rough guesses about elasticities are possible the only practical procedure is to proceed in steps:
>
> 1. Choose the relationship of prices to marginal costs which is most probably optimal;
> 2. Forecast demand in quantity terms;
> 3. Re-optimize production and investment plans;
> 4. Calculate marginal costs with output matching forecast demand;
> 5. Fix prices unless it is too soon since the last change;

6. Wait, while getting on with other tasks;
7. Go to step 2.
With this cycle there is a feedback from prices to forecast demand, but this is not instantaneous. Since things change during step 6, no equilibrium or optimum may ever be reached. Life is like that, however, and one might as well try to adjust to it."

Thus, this approach recognises the difficulties in estimating demand and outlines a step-by-step approach. Whilst Turvey does suggest that "the study of costs of a public enterprise ..... may have to apply to point output forecasts, ignoring feedback via prices", it may also be possible to re-examine the demand forecast (step 2) before fixing prices (step 5).

The approach adopted in the 1971 White Paper "The Nationalised Industries" was discussed in chapter 1; figure 11.1 reproducing the flow diagram of figure 1.1. This approach is based on the 1967 White Paper's recommendation that prices should cover long-run marginal costs and it attempts to interrelate the pricing, investment and financial objectives laid down by government. In order to be able to use this approach, it is necessary for the industry to have an "investment programme" which can be used as a "yardstick". The current position at the Port of Liverpool is such that no new investments are planned for at least ten years - one of the objectives of the MDHC Study being to "minimise capital investment". If there exists decreasing costs then this approach may also lead to an accounting deficit. It was suggested however, in the case of the Docks, that the Port could attempt to use this approach by considering an hypothetical investment in a "basic" berth and access using ex-post data.

A third approach which attempted to incorporate the valuation of assets was outlined in fig5.2. This approach suggested that the port

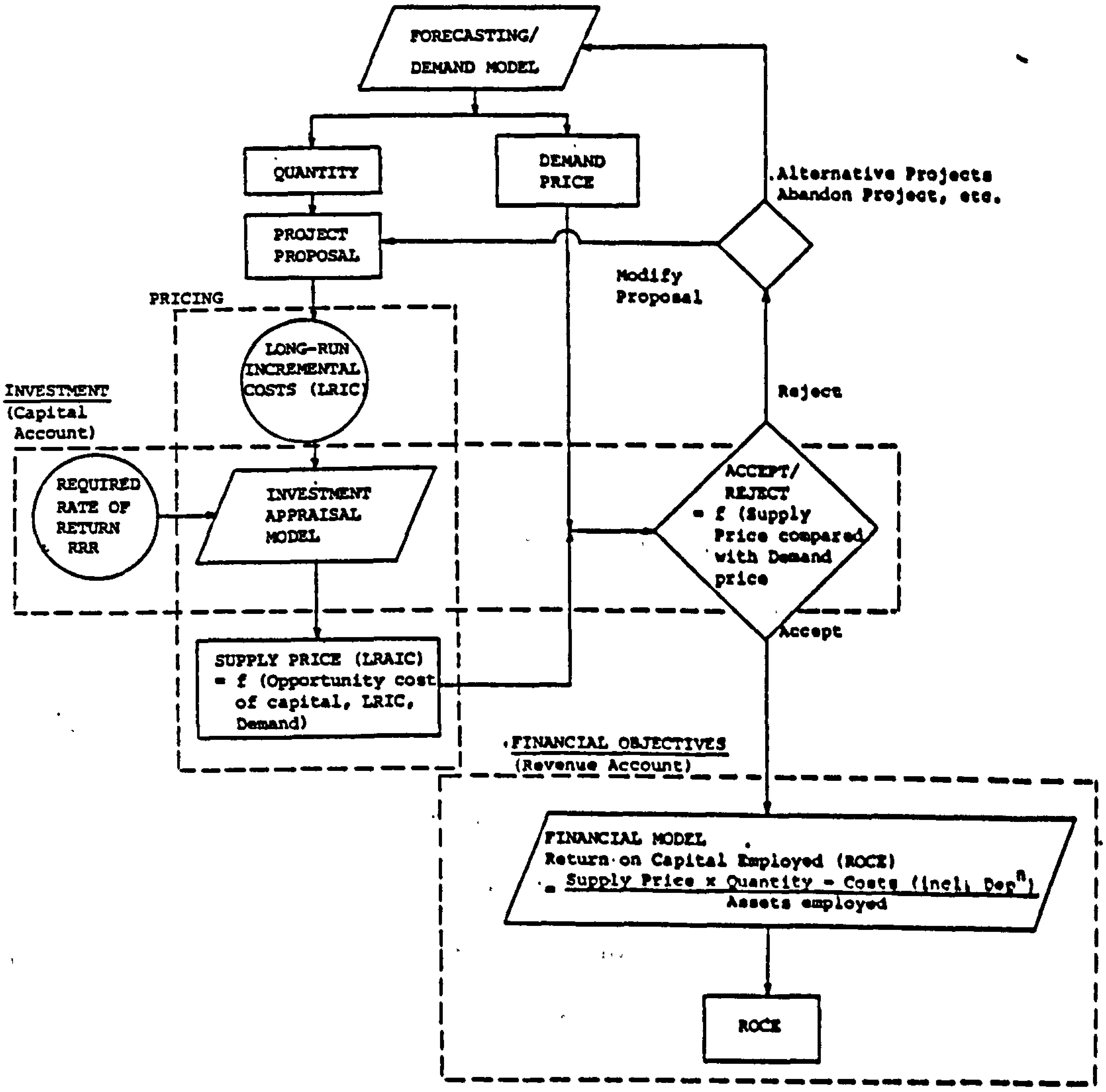


Fig.11.1 Schematic presentation of the recommendations in the 1978 White Paper "The Nationalised Industries"

computes an upper and lower limit to "escapable" costs which reflect the opportunity cost and replacement cost of the asset respectively.

In an attempt to synthesize these approaches, the following is a step-by-step approach (which can also be converted into a flow diagram) for the berth to the dock gate.

1. Choose a set of prices which are believed to be optimal. (In the absence of any other information, the port may have to use the current price.)
2. Forecast demand in quantity terms over the planning horizon. This would involve an investigation of each commodity, trade or liner conference. (In a second round, this would also involve investigation of trades that may find the port attractive if a "suitable" pricing system was available.)
3. Group traffic according to the cargo handling operation required (and size if it can be demonstrated that the port provides an essentially different nature or quality of service for vessels of differing sizes).
4. Ascertain the facilities required, over the planning horizon, to meet the demand from each of the traffic groups. For example, the port could have an "asset planning chart" (see Table 6.5) which included a description of the asset, its age and expected replacement date or dates. In addition, the chart would include the operational requirements of the traffic and facilities including labour and maintenance.
5. Ascertain the facilities required jointly for any relevant combination of these groups (including all traffic jointly).
6. Go to step 7a if adopting the total cost approach. Go to step 7b

if adopting the marginal cost approach.

7a (i) Value the assets in steps 4 and 5. Assets and other operational requirements which will be replaced are valued by reference to their replacement cost which is incorporated in the valuation formula. For assets which will not be replaced, because either replacement is not warranted by demand or the asset is durable, it will be necessary to compute a lower and upper value represented by the opportunity cost and the valuation formula.

(ii) Compute the directly attributable costs. If the degree of jointness between the cargo handling operations is not severe then the matrix approach may not be necessary. However if it is, the matrix method may be found useful.

Whilst valuing the assets, the port may also find it useful to consider step 7b.

7b. Use an actual or hypothetical investment programme to generate the incremental costs of different types of cargo handling operations.

8. Devise pricing system, noting that over the time horizon discounted revenue should at least equal discounted costs.

9. Go to step 2 and investigate whether the proposed pricing system is likely to affect the demand forecast. One area where adjustments may be made is in step 7. If a pricing system cannot be devised whereby a cost as computed from the valuation formula is not recovered then the valuation can be reduced down to the opportunity cost if necessary and the asset not replaced. If the new pricing system is "suitable" go to step 10.

10. Investigate whether the accounting requirements are met (according to the "accounting policy of the day"). The 1978 White Paper [2]

states that; "Changes in an industry's accounting policies e.g. in calculating depreciation or valuing assets, would not necessitate any changes in prices or outputs". The situation could arise however where the accounting practice is such that depreciation is charged to assets for which there is little demand and consequently the accounting requirements may not be met. Under these circumstances it may be necessary for the port to revise its accounting policy.

Whilst this approach illustrates the berth to dock gate case, its basic structure can be applied to other cases.

11.4 Devising a Pricing System

The pricing and investment rules;

1. Set price equal to marginal cost
2. Invest if the traffic is willing to pay the cost of the extra capacity.

will in most cases faced by the port lead to an optimal allocation of resources. Deviations from these rules will (again in most cases) represent a compromise or trade-off between allocative efficiency and an accounting requirement. For example, in the conservancy case at the Port of Liverpool there would need to be considerable changes in the traffic volume before changes in the level of capacity would be required. Thus conservancy would appear to fall into the discrete case considered in section 11.1, with the capacity constraint not binding (that is, with the excess capacity, the Lagrangian multiplier λ is always zero). Given then that the marginal cost approaches zero the pricing rule is clear, namely price approaches zero. Now, even if the port was considering whether to purchase, say, a new buoy the rule is still clear, namely, invest if consumers are willing to pay (measured by compensating variation, areas under Hicksian Compensated Demand Curves or areas under Ordinary Demand Curves - if this is the only available information) and set price equal to short-run marginal cost (which still approaches zero). Any other pricing rule will distort demand, that is, consumers who were willing to pay short-run marginal cost (that is, the cost that they impose on society by proceeding along the channel) but not the alternative price will not be accepted. Thus, in devising a pricing system one is also searching for a system which leads to the least distortion in demand. There is however a second trade-off that the port must consider - this is the trade-off between allocative efficiency and equity. For example, it may be the case that a pricing system based upon price discrimination (according to, say, unit value) distorts demand to a lesser extent than average cost pricing. However, according to the value judgements of the day or statutory obligations price discrimination may not be an acceptable pricing system.

Chapter 3 outlined the theoretical properties of a selection of pricing systems, however there remains the practical aspects of computing the price under each of these systems. The starting point in developing any system is the accounting identity;

$$\sum_{i=1}^{n} P_i Q_i = TR$$

where,

P_i = price per unit for commodity "i"

Q_i = quantity of commodity "i" passing through the port during the pricing period

TR = total revenue.

The commodity "i" could be defined as number of ships, g.r.t., tonnes etcetera, depending upon the charge which is being investigated. Given an accounting requirement that total revenue equals total cost then prices under the different systems can be obtained as follows;

1. Average Cost Pricing

The price under this system is relatively easy to compute. Given that TR = TC (total cost) then,

$$\sum_{i} P_i Q_i = TC$$

but the price is the same for every commodity, so that,

$$P = \frac{TC}{\sum Q_i}$$

If time is introduced, then the costs incurred over the defined time horizon (which may be a fixed period of time or it may be related to the asset's life) can be allocated either directly to the forecast traffic over the period of time under consideration or they can be allocated to years, then the traffic. In the first case, the requirement is that,

$$\sum_{i=1}^{n} \sum_{t=1}^{\tau} D^t P_{it} Q_{it} = \sum_{t=0}^{\tau} D^t C_t$$

where,

i = traffic

t = time

C_t = cost incurred in time t

D^t = discount operator $(1 + r)^{-t}$.

If the prices are to be the same for all commodities at each point in time, then,

$$P = \frac{\sum_t D^t C_t}{\sum_i \sum_t D^t Q_{it}}$$

Inflation can be incorporated into the computation by suitably adjusting prices, costs and discount factors. For example, if all costs are subject to the same inflation rate then the above formula can be used by imputing the real costs, computing P then in any year t, $P_t = P(1 + k)^t$, where k is the rate of inflation of costs.

The second case usually applies to capital costs. These costs can be converted into an annuity (Annual Equivalent Capital Costs - AECC) using the Capital Recovery Factor that is

$$AECC = C_o \times CRF$$

$$= C_o \left[\frac{r}{1 - (1 + r)^{-n}} \right]$$

where,

C_o = capital cost (incurred in year zero)

r = discount rate

n = life of the asset.

Then in any year t,

$$P_t = \frac{AECC + OC_t}{\sum_i Q_{it}}$$

where,

OC_t = operating costs in year t.

2. Price Proportional to Marginal Cost, Average Variable Cost or Unit Value

Baumol and Bradford [3] investigated "Optimal Departures from Marginal Cost Pricing" where the welfare maximisation problem is subject to a "profit constraint" (accounting requirement that total revenue equals total cost). Following Morrison [4], this rule can be derived by forming the Lagrangian expression,

$$W_{\mu} = \sum_{i=1}^{n} \int_{0}^{Q_i} P_i(Q_i) - C(Q_1, \ldots, Q_n) - g(y)$$

$$+ \mu \left[\sum_{i=1}^{n} Q_i P_i(Q_i) - C(Q_1, \ldots, Q_n) - g(y) \right]$$

where,

$P_i(Q_i)$ = port charge per unit for commodity "i"

Q_i = quantity of commodity

$C(Q_1,..,Q_n)$ = total operating costs

$g(y)$ = total capacity costs (fixed).

The Kuhn-Tucker conditions are:

$$(1) \quad \frac{\partial W_{\mu}}{\partial Q_i} = P_i - \frac{\partial C}{\partial Q_i} + \mu \left[P_i + Q_i \frac{dP_i}{dQ_i} - \frac{\partial C}{\partial Q_i} \right] \leq 0, \; Q_i \frac{\partial W_{\mu}}{\partial Q_i} = 0$$

$$(2) \quad \frac{\partial W_{\mu}}{\partial \mu} = \sum_{i=1}^{n} Q_i P_i(Q_i) - C(Q_1, \ldots, Q_n) - g(y) \geq 0, \; \mu \frac{\partial W_{\mu}}{\partial Q_i} = 0$$

Assuming that some of every commodity passes through the port $Q_i > 0$, so that $\frac{\partial W_{\mu}}{\partial Q_i} = 0$.

Defining $\varepsilon_i = -\frac{dQ_i}{dP_i} \cdot \frac{P_i}{Q_i}$ to be the price elasticity of demand for the services with respect to the charge, then condition (1) can be solved to yield [5],

$$P_i = \left[\frac{1}{1 - \frac{\mu}{(1 + \mu)\varepsilon_i}} \right] \frac{\partial C}{\partial Q_i}$$

(where ε_i is expressed in absolute terms.) Since prices will be required to be positive, $\frac{\mu}{1 + \mu} < \varepsilon_i$, for all i. Thus the value of $\frac{\mu}{1 + \mu}$ must be less than the smallest elasticity. For a specified commodity, if ε_i is known, and given that μ is constant for all commodities the pricing rule that emerges is to set prices proportional to marginal cost. The proportion however is a function of the elasticity - the higher the elasticity (in absolute terms) the lower the mark-up on marginal cost. Under these conditions the computation of $k = \frac{\mu}{1 + \mu}$, and therefore μ is particularly difficult. Given the requirement that TR = TC then,

$$\sum_i P_i Q_i = TC$$

$$\sum_i \left[\frac{1}{1 - \frac{k}{\varepsilon_i}} \right] \frac{\partial C}{\partial Q_i} \cdot Q_i = TC$$

One approach is to use Taylor's expansion of the term in square brackets,

$$\sum_i \left[1 + \frac{k}{\varepsilon_i} + \frac{k^2}{\varepsilon_i^2} + \ldots \right] \frac{\partial C}{\partial Q_i} \cdot Q_i = TC$$

$$\sum \frac{\partial C}{\partial Q_i} \cdot Q_i + k \sum \frac{\partial C}{\partial Q_i} \cdot \frac{Q_i}{\varepsilon_i}$$

$$+ k^2 \sum \frac{\partial C}{\partial Q_i} \cdot \frac{Q_i}{\varepsilon_i^2} + \ldots\ldots = TC$$

then to truncate the expression and solve the polynomial for k. However one may encounter convergence problems particularly if the values of $\frac{k}{\varepsilon_i} \rightarrow 1$. An alternative method is to find a starting value of k from the linear Taylor approximation, that is,

$$k = \frac{TC - \sum \frac{\partial C}{\partial Q_i} \cdot Q_i}{\sum \frac{\partial C}{\partial Q_i} \cdot \frac{Q_i}{\varepsilon_i}}$$

then to use an iterative approach until the accounting requirement is met.

This formulation of the problem assumes that the port has knowledge of the elasticities. It has however been suggested in chapter 10 (sect. 10.3) that elasticities are notoriously difficult to estimate. Thus it may be necessary to assume constant elasticities which in turn implies a constant proportionality factor (α). This can be computed as follows;

$$P_i = \alpha \frac{\partial C}{\partial Q_i}$$

therefore,

$$\alpha \sum \frac{\partial C}{\partial Q_i} \cdot Q_i = TC$$

$$\alpha = \frac{TC}{\sum \frac{\partial C}{\partial Q_i} \cdot Q_i}$$

This formulation is similar to full cost pricing, where price is set proportional to average variable cost (AVC) that is,

$$P_i = \alpha \, AVC_i$$

therefore

$$\alpha \sum AVC_i \cdot Q_i = TC$$

$$\alpha = \frac{TC}{\sum AVC_i \cdot Q_i}$$

In chapter 10 (section 10.3) one of the estimates obtained for ε_i was,

$$\varepsilon_i = \left[\frac{P_i}{P_i + UV_i}\right] \eta_i$$

where,

P_i = port charge per unit for commodity "i"

UV_i = c.i.f. value of commodity "i" excluding port charges.

(this estimate assuming fixed factor proportions and perfectly elastic supply of other factor inputs.) Following Morrison [6], this estimate can be substituted into the pricing solution of the welfare maximisation problem to yield [7],

$$P_i = \frac{\frac{\partial C}{\partial Q_i} + \frac{k}{\eta_i} UV_i}{1 - \frac{k}{\eta_i}}$$

where,

k = as defined above = $u/(1 + \mu)$

η_i = the absolute value of the import/export elasticity for commodity "i".

Now, since k must be less than the smallest ε_i and assuming an average value of η_i of 1. Then $1 - \frac{k}{\eta_i} \cong 1$, so that,

$$P_i \cong \frac{\partial C}{\partial Q_i} + \frac{k}{\eta_i} UV_i$$

Thus, price is approximately equal to marginal cost plus a proportion of the unit value. Thus k can be computed as follows,

$$\sum \left[\frac{\partial C}{\partial Q_i} + k \frac{UV_i}{\eta_i} \right] Q_i = TC$$

$$k \sum \frac{UV_i}{\eta_i} \cdot Q_i = TC - \sum \frac{\partial C}{\partial Q_i} \cdot Q_i$$

$$\therefore k = \frac{TC - \sum \frac{\partial C}{\partial Q_i} \cdot Q_i}{\sum \frac{UV_i}{\eta_i} \cdot Q_i}$$

Again however, it may be difficult to obtain estimates of the elasticities. If it is believed that commodities fall into defined categories with plausible average elasticities then the port could use this formulation. If however this cannot be attempted then it may again be necessary to assume constant elasticities.

The price is then set such that,

$$P_i = \frac{\partial C}{\partial Q_i} + \alpha\, UV_i$$

and

$$\alpha = \frac{TC - \sum \frac{\partial C}{\partial Q_i} \; Q_i}{\sum UV_i \cdot Q_i}$$

This method could lead to high charges for high valued commodities and the port may find that this traffic is not willing to pay these high charges. It may therefore be necessary to "reduce" this effect with a tranformation of the unit value. A general transformation which could be used is,

$$UV^* = \frac{UV^{\lambda} - 1}{\lambda} .$$

One of the properties of this transformation is that as $\lambda \to 0$, $UV^* \to \ln UV$. The actual value of λ would have to be decided by the port by taking into account vertical equity and the traffic's willingness to pay the resulting charge.

Extending this analysis to the temporal case yields similar results to those obtained above. The welfare maximising Lagrangian expression becomes,

$$W_\nu = \sum_{t=1}^{\tau} \sum_{i=1}^{n} \int_{0}^{Q_{it}} D^t P_{it}(Q_{it})\, dQ_{it} - \sum_{t=1}^{\tau} D^t C_t (Q_{1t}, \ldots, Q_{nt})$$

$$- \sum_{t=0}^{\tau} D^t g(y_t) + \nu \left[\sum_{t=1}^{\tau} \sum_{i=1}^{n} D^t Q_{it} P_{it}(Q_{it}) \right.$$

$$\left. - \sum_{t=1}^{\tau} D^t C_t (Q_{1t}, \ldots, Q_{nt}) - \sum_{t=0}^{\tau} D^t g(y_t) \right]$$

Differentiating with respect to Q_{it},

$$\frac{\partial W_\nu}{\partial Q_{it}} = D^t P_{it} - D^t \frac{\partial C_t}{\partial Q_{it}} + \nu D^t \left[P_{it} + Q_{it} \frac{dP_{it}}{dQ_{it}} - \frac{\partial C_t}{\partial Q_{it}} \right] = 0$$

The discount operator D^t divides out and the pricing rule becomes;

$$P_{it} = \left[\frac{1}{1 - \dfrac{\nu}{(1 + \nu)\varepsilon_{it}}} \right] \frac{\partial C_t}{\partial Q_{it}}$$

The computation of the constants required to find the price proceeds as above. Define the total costs to be the present value of the operating plus capacity costs, that is,

$$TC = \sum_{t=1}^{\tau} D^t \left[C_t(Q_{1t}, \ldots, Q_{nt}) + g(y_t) \right]$$

then, the accounting requirement is that the present value of the revenue equals the present value of operating plus capacity costs. Thus,

$$\sum_t \sum_i D^t P_{it} Q_{it} = TC$$

$$\sum_t \sum_i D^t \left[\frac{1}{1 - \frac{m}{\varepsilon_{it}}} \right] \frac{\partial C_t}{\partial Q_{it}} \cdot Q_{it} = TC$$

where,

$$m = \frac{\nu}{(1 + \nu)} < \min \varepsilon_{it}$$

A starting value for m in an iterative approach is,

$$m = \frac{TC - \sum_t \sum_i D^t \frac{\partial C_t}{\partial Q_{it}} \cdot Q_{it}}{\sum_t \sum_i D^t \frac{\partial C_t}{\partial Q_{it}} \cdot \frac{Q_{it}}{\varepsilon_{it}}}$$

If one assumes constant elasticities between commodities and over time then,

$$P_{it} = \alpha \frac{\partial C_t}{\partial Q_{it}}$$

and,

$$\alpha = \frac{TC}{\sum_t \sum_i D^t \frac{\partial C_t}{\partial Q_{it}} \cdot Q_{it}}$$

The substitution of $[P_{it}/(P_{it} + UV_{it})]\eta_{it}$ for ε_{it} yields the approximation,

$$P_{it} \cong \frac{\partial C_t}{\partial Q_{it}} + \frac{m}{\eta_{it}} UV_{it}$$

with the value of m being computed from the formula,

$$m = \frac{TC - \sum_t \sum_i D^t \frac{\partial C_t}{\partial Q_{it}} \cdot Q_{it}}{\sum_t \sum_i D^t \frac{UV_{it}}{\eta_{it}} \cdot Q_{it}}$$

However the substitution would require further investigation as it assumes fixed factor proportions and perfectly elastic supply of other factor inputs.

If constant elasticities are assumed them,

$$P_{it} = \frac{\partial C_t}{\partial Q_{it}} + \alpha\, UV_{it}$$

where,

$$\alpha = \frac{TC - \sum_t \sum_i D^t \frac{\partial C_t}{\partial Q_{it}} \cdot Q_{it}}{\sum_t \sum_i D^t\, UV_{it} \cdot Q_{it}}$$

and if the traffic with relatively high unit values are not willing to pay the implied higher charge then it will be necessary to reduce the effect with a suitable transformation of the unit value.

These formulae are applicable to the case where there is a single identifiable traffic with non zero marginal cost. If the port is considering groups of traffic jointly (for example grain and container) then there may be costs which are marginal or incremental in both the

the short- and long-run. Under these circumstances it may be necessary for the port to resort to average incremental costs as a proxy for marginal cost. Alternatively it may be necessary for the port to use the marginal cost for the constituent traffic as a basis for recovering both the short- and long-run joint costs. It must also be borne in mind that these costs may be "common costs which, though not truly joint, and therefore not entirely arbitrary in incidence, involve sensitivity in allocation". [8].

3. Two-Part/Block Tariff

Chapter 3 suggested that from an allocative viewpoint, a two-part or block tariff may be better than the systems discussed above. The spectrum of traffic demanding port services ranges from the frequent users to the one-off users. It is the traffic located towards the frequent user end of this spectrum which is relevant when considering this type of tariff. Chapter 3 further suggested that there are a number of ways in which this system can be applied, however, a major problem in each case is to ascertain the total amount to be extracted in the form of a lump sum or from the blocks.

If there was only a single user of a particular facility the lump sum payment could be ascertained by firstly estimating the level of demand (given this pricing system), secondly estimating the total cost at this level, thirdly deciding upon the follow-on price (for example, marginal cost at the forecast level of demand or average variable cost) then,

$$\text{Lump sum} = TC - f \times Q$$

where,

f = follow-on price.

If the port is going to "spread" the lump-sum over a number of units, then it must decide upon the size of this first block (Q^*) - fig 11.2.

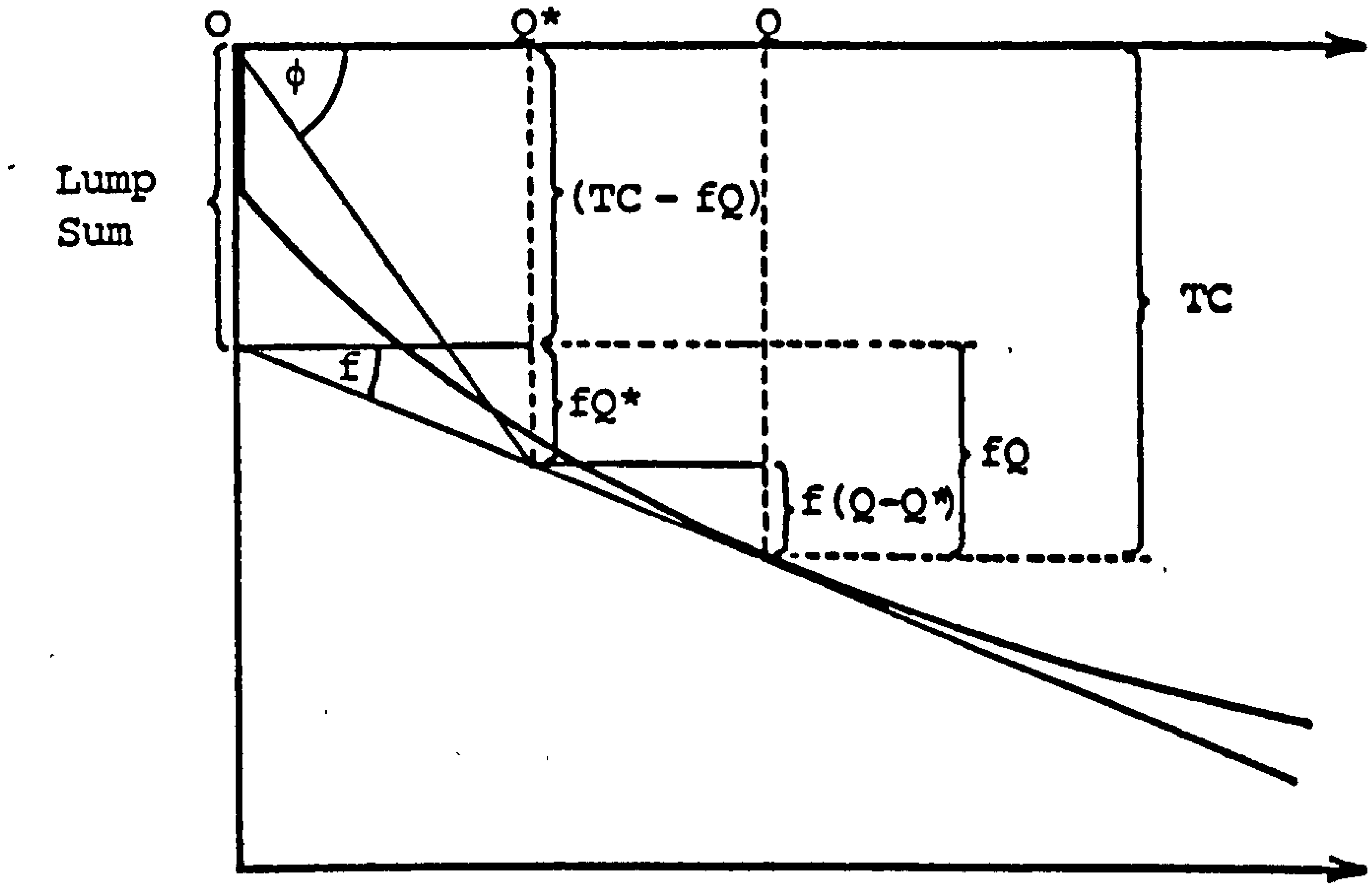


fig 11.2 The Two-Part Tariff Structure

The price per unit in the first block (ϕ) is then,

$$\phi = \frac{TC - f(Q - Q^*)}{Q^*}$$

and the follow-on price is again f. Whilst this approach attempts to take cost and demand into account, it will be necessary to iterate back through demand to ascertain whether the consumer is willing to pay the lump-sum or block prices (see section 11.3). It could, for example, be the case that consumers are not willing to pay the total costs regardless of the pricing system. Under these circumstances revisions will be necessary which may imply that capacity is not replaced. It may also be necessary for the port to "adjust" the initial structure of the tariff to make it attractive to the frequent users. For example, if there are indivisibilities in demand whereby an operator has a fixed number of sailings during the pricing period then the port may "negotiate special rates for guaranteed throughput" [9]. A two-part or block tariff could be used to perform this function.

In general, the port will again have a number of users with some of the costs being joint to groups of users. If a lump-sum type of system is to be adopted then the approach again follows the steps outlined in section 11.3. Firstly, choose prices which it is believed will be optimal (similar to the final prices), secondly estimate demand, thirdly estimate the traffic's directly attributable and those directly attributable costs to which the traffic may be required to contribute, and fourthly decide upon the follow-on price. To the extent that capacity costs are directly attributable to the traffic then they can be included directly in the lump-sum (or the block structure of the tariff). There remains however the joint, common and "fixed" costs which will have to be attributed to the traffic by some means if an accounting requirement is to be met. The basic theoretical investment rule developed in chapter 2 was that,

$$\int_0^{x^*} MRS \; dx - \int_0^{x^*} MRT \, dx - F > 0$$

and the various "means" adopted in 1 and 2 above to extract consumers' surplus from the benefit measure in this criteria included the use of average cost, average variable cost, marginal cost, elasticities and unit value. Thus, if a two-part or block tariff is to be adopted then one method of obtaining the lump sum is to work backwards from the methods in 1 and 2.

(a) Average Cost

In general, the total cost "allocable" to a traffic or commodity i is,

$$TC_i = \sum_{\substack{I=0 \\ i \in I}}^{n} DAC^i_{P(I)} + F^i$$

where,

TC_i = total cost allocable to traffic i

I = set of n traffics which has been identified separately

P(I) = power set of I, that is, the class of all subsets of I

DAC^i = directly attributable costs of a subset of I which are allocated to traffic i

F^i = "fixed" costs which are allocated to traffic i

$\sum_{I=0}^{n} DAC_{P(I)}$ = $DAC_0 + DAC_1 + DAC_2 + DAC_{1x2} + \ldots\ldots + DAC_{1x2x\ldots xn}$

(note that in the formula for TC_i, only the DAC's which have i in the subscript are included)

Under a system of average cost, traffic i "participates" in each "pool" of directly attributable costs (and the fixed costs) according to the proportion of its quantity to the total quantity in the pool. For example,

$$\sum_{i=1}^{3} \pi^i_{1x2x3} \cdot Q_i = DAC_{1x2x3}$$

But the directly attributable cost per unit, π, is the same for the three traffics, thus,

$$\pi = \left[\frac{DAC_{1x2x3}}{Q_1 + Q_2 + Q_3}\right]$$

and traffic 1, for example, contributes,

$$DAC^1_{1x2x3} = DAC_{1x2x3}\left[\frac{Q_1}{Q_1 + Q_2 + Q_3}\right]$$

The lump-sum for any traffic i is,

$$LS_i = \sum_I DAC^i_{P(I)} + F^i - f_i Q_i$$

and the follow-on price is f_i.

If this is converted into a block tariff, the port decides upon the size of the first block, Q_i^*, then the price for each block, ϕ_i, is,

$$\phi_i = \begin{cases} \dfrac{LS_i + f_i Q_i^*}{Q_i^*} & , Q_i \in [0, Q_i^*] \\ f_i & , Q_i > Q_i^* \end{cases}$$

(b) Lump Sums Based Upon Marginal Cost and Unit Value

The formula derived for prices proportional to marginal cost was,

$$P_i = \left[\frac{1}{1 - \frac{k}{\varepsilon_i}}\right]\frac{\partial C}{\partial Q_i}$$

If this is to be converted into a lump-sum plus marginal cost, then,

$$TR_i = LS_i + \frac{\partial C}{\partial Q_i} \cdot Q_i$$

But,

$$TR_i = P_i Q_i$$

$$= \left[\frac{1}{1 - \frac{k}{\varepsilon_i}} \right] \frac{\partial C}{\partial Q_i} \cdot Q_i$$

$$= \left[\left(\frac{1}{1 - \frac{k}{\varepsilon_i}} \right) - 1 \right] \frac{\partial C}{\partial Q_i} \cdot Q_i + \frac{\partial C}{\partial Q_i} \cdot Q_i$$

$$= \left[\frac{1}{\frac{\varepsilon_i}{k} - 1} \right] \frac{\partial C}{\partial Q_i} \cdot Q_i + \frac{\partial C}{\partial Q_i} \cdot Q_i$$

Thus,

$$LS_i = \left[\frac{1}{\frac{\varepsilon_i}{k} - 1} \right] \frac{\partial C}{\partial Q_i} \cdot Q_i$$

and the marginal cost at Q_i is the follow-on price.

If this is to be converted into a block tariff then the port again decides upon Q^*, and the price for each block, ϕ_i, is,

$$\phi_i = \begin{cases} \dfrac{\left[\frac{1}{\frac{\varepsilon_i}{k} - 1} \right] \frac{\partial C}{\partial Q_i} \cdot Q_i + \frac{\partial C}{\partial Q_i} \cdot Q^*}{Q^*} & , Q_i \in [0, Q^*] \\ \dfrac{\partial C}{\partial Q_i} & , Q_i > Q^* \end{cases}$$

If it is assumed that the elasticities are constant then,

$$TR_i = \alpha \frac{\partial C}{\partial Q_i} \cdot Q_i$$

$$= (\alpha - 1) \frac{\partial C}{\partial Q_i} \cdot Q_i + \frac{\partial C}{\partial Q_i} \cdot Q_i$$

so that,

so that,

$$LS_i = (\alpha - 1) \frac{\partial C}{\partial Q_i} \cdot Q_i$$

and for a block tariff,

$$\phi_i = \begin{cases} \dfrac{(\alpha - 1) \dfrac{\partial C}{\partial Q_i} \cdot Q_i + \dfrac{\partial C}{\partial Q_i} \cdot Q^*}{Q^*} & , Q \in [0, Q^*] \\[2ex] \dfrac{\partial C}{\partial Q_i} & , Q > Q^* \end{cases}$$

The approximate formula which related price to unit value was,

$$P_i \approx \frac{\partial C}{\partial Q_i} + \frac{k}{\eta_i} UV_i$$

This can be converted into a lump-sum plus marginal cost as follows,

$$TR_i = LS_i + \frac{\partial C}{\partial Q_i} \cdot Q_i$$

But,

$$\begin{aligned} TR_i &= P_i Q_i \\ &= \left[\frac{k}{\eta_i} UV_i + \frac{\partial C}{\partial Q_i}\right] Q_i \end{aligned}$$

Thus,

$$LS_i = \frac{k}{\eta_i} UV_i Q_i$$

with marginal cost as a follow-on price.

If this is to be converted into a block tariff then,

$$\phi_i = \begin{cases} \dfrac{\dfrac{k}{\eta_i} UV_i Q_i + \dfrac{\partial C}{\partial Q_i} Q^*}{Q^*} & , Q_i \in [0, Q^*] \\[2ex] \dfrac{\partial C}{\partial Q_i} & , Q_i > Q^* \end{cases}$$

If again this produces an unacceptably high lump-sum for commodities with high unit values then the port will have to investigate a suitable transformation of unit value.

In both of these cases, adjustments may be necessary to make the tariff attractive to frequent users.

11.5 Conclusions

The pricing policies of ports have been subject to criticisms which centre around their relationship to costs. On the one hand it is suggested that comprehensive cost accounts are not kept, whilst on the other hand it is argued that even when the information is available, prices are not necessarily related to costs. In particular it is suggested that the tariffs are governed by custom, how the users would react or what-the-traffic-will-bear.

The port however has a number of problems when devising a tariff structure which extend beyond a "first best world". The introduction outlined an amalgam of factors which influence the port's pricing and investment decisions including, inter alia, the requirements of the financial backers and expected reactions of other ports and port users. Chapter 2 further outlined the economic problems facing the port in terms of indivisibilities and jointness. Given these deviations from a first best world, the port is faced with the problem of maximising welfare subject to a number of constraints. The main constraints that have been considered include indivisibilities in demand, indivisibilities in supply in both a technical and temporal sense, an accounting requirement and equity considerations. Under these conditions, various pricing rules emerge which include elasticities and unit values. In other words, optimisation within this second best world does include an element of pricing according to the traffic's willingness to pay (tempered by equity considerations). It is therefore suggested that outright dimissal of tariff structures because they contain this element is not particularly helpful.

These observations do not condone the current pricing practices of ports: they emphasise the importance of the responsibility placed on the port to obtain reasonable approximations for these demand factors. The estimation of elasticities either quantitatively or qualitatively is not however a particularly easy task. Similarly the wide range of unit values of the commodities passing through the port may necessitate a qualitative assessment of an appropriate transformation for the unit values. Thus, given that the port is required to exercise some judgement they will also be open to criticism.

The examination of costs in chapter 5 and subsequent chapters high-lighted further the difficulties in defining and attributing costs to traffic. The relevant cost measure is the escapable cost, that is, the cost that "would be saved if production were curtailed and the resources released for use elsewhere". However even this relatively simple concept is particularly complex in practice. The implication of the application of the concept is that costs for some assets may tend to be low. However, returning to the demand side this does not imply that the assets are of no value to their users. Thus it was suggested that in some cases it may be appropriate to compute limits to a range of costs. The lower limit representing the foregone opportunities by not employing the asset in its next best feasible alternative and the upper limit reflecting the replacement cost of the asset (using the valuation formula). In spite of the complexity of these problems, the information is required by the port in order to maie pricing, traffic accept/reject and invest/disinvest decisions.

Given the measurement problems faced by the port (in both costs and demand), and the resultant subjective nature of some of the estimates it is not surprising that port pricing systems have been questioned. However, criticism is important, as the pricing structures become ossified if they appear to work, and if an accounting requirement is met, there is a tendency to place less emphasis on ascertaining costs.

Notes

[1] Turvey, R., "Economic Analysis and Public Enterprises", Allen and Unwin, London 1971, p54.

[2] H.M.S.O., "The Nationalised Industries", Cmnd 7131, London, 1978.

[3] Baumol, W.J. and Bradford, D.F., "Optimal Departures from Marginal Cost Pricing", American Economic Review, Vol 60, June 1970, pp 265-283.

[4] Morrison, S.A., "The Structure of Landing Fees at Uncongested Airports", Journal of Transport Economics and Policy, Vol 16, No. 2, May 1982, pp 151-159.

[5]
$$P_i - \frac{\partial C}{\partial Q_i} + \mu \left[P_i + Q_i \frac{dP_i}{dQ_i} - \frac{\partial C}{\partial Q_i} \right] = 0$$

But,
$$\varepsilon_i = - \frac{dQ_i}{dP_i} \cdot \frac{P_i}{Q_i}$$

so that,

$$P_i - \frac{\partial C}{\partial Q_i} + \mu \left[P_i - \frac{P_i}{\varepsilon_i} - \frac{\partial C}{\partial Q_i} \right] = 0$$

$$P_i \left[1 + \mu - \frac{\mu}{\varepsilon_i} \right] = (1 + \mu) \frac{\partial C}{\partial Q_i}$$

$$P_i = \left[\frac{(1 + \mu)}{1 + \mu - \frac{\mu}{\varepsilon_i}} \right] \frac{\partial C}{\partial Q_i}$$

$$= \left[\frac{1}{1 - \frac{1}{(1 + \mu)\varepsilon_i}} \right] \frac{\partial C}{\partial Q_i}$$

[6] Morrison, [4].

[7] Rearranging the first equation in [5],

$$P_i - \frac{\partial C}{\partial Q_i} + \mu \left[P_i - \frac{P_i}{\varepsilon_i} - \frac{\partial C}{\partial Q_i} \right] = 0$$

$$(1 + \mu) \left[P_i - \frac{\partial C}{\partial Q_i} \right] = \frac{\mu P_i}{\varepsilon_i}$$

$$\frac{P_i - \frac{\partial C}{\partial Q_i}}{P_i} = \frac{\mu}{(1 + \mu)} \frac{1}{\varepsilon_i}$$

Substituting $\varepsilon_i = \left[\frac{P_i}{P_i + UV_i} \right] \eta_i$

$$P_i - \frac{\partial C}{\partial Q_i} = \frac{\mu}{(1 + \mu)} \left[\frac{P_i + UV_i}{\eta_i} \right]$$

Let, $k = \mu/(1 + \mu)$

$$P_i \left[1 - \frac{k}{\eta_i} \right] = \frac{\partial C}{\partial Q_i} + \frac{k}{\eta_i} UV_i$$

$$P_i = \frac{\frac{\partial C}{\partial Q_i} + \frac{k}{\eta_i} UV_i}{1 - \frac{k}{\eta_i}}$$

[8] Munby, D. (ed.), "Transport", Penguin, 1968, p 13.

[9] Lloyds List, "Liverpool charges rise by up to 17%", 17th November 1980.

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