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STRUCTURAL PRODUCIBILITY CONSIDERATIONS AT A PRELIMINARY DESIGN LEVEL

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CONTENTS

1. BACKGROUND

The principal objective in designing for production may be stated as reducing production costs to a minimum compatible with functional requirements specified by a shipowner and to a stipulated level of safety.

This simple aim has to be set against the complexity of the ship design process which involves the interaction of a large number of parameters and variables. Consequently a number of feasible solutions can be generated readily from a given set of requirements. This complexity of the process, together with the variety of solutions, leads to a methodology in design in which the problem as a whole is treated at increasing levels of detail - from broad outlines to detail specifications; see Table 1.1. Several studies have been conducted in studying producibility aspects at detail stages of design (1). However, not much has been done with regard to quantifying producibility at early stages of design. Yet it is at this, preliminary stage that maximum impact can be achieved.

Principally due to the information proliferation at successive design stages, the (ship) system is broken down into a number of subsystems such as the hull structure, electrical, engineering, piping/trunking and accommodation/outfit. Decisions have to be made at all design levels and for all subsystems with regard to choice of variables and parameters which define a design. One subsystem, however, is dominant - see Figure 1.1 - and unique from all others. It is the (steel) structural subsystem which specifies the dominant constraints on a shipyard's production capabilities. All other subsystems are, to one degree or another, dependent on the structural design and layout of the ship. For this reason, the present report concentrates on aspects of producibility mainly with respect to the structural subsystem.

2. DEVELOPMENT OF OBJECTIVES

The central feature of research into design for production is to provide designers with improved tools for reaching design decisions with respect to aspects of case of production. These tools may be in the form of general guidance as to good and bad practice, or may be more of a direct evaluation as a step built into the design assessment process. The former of these could be termed a tactical tool, whereas the latter is a strategic tool.

Tactical tools, which to a great extent embody common sense, have been successful in making the greatest initial impact on practical design decision making (2). However, they suffer from a lack of any consistent theoretical basis which could lead to a methodology. Consequently, most research has concentrated upon developing and applying strategic tools. For these, there seems to be little dispute that producibility can most rationally be measured by production cost; the cost including these factors which can be related to influences on design variations. Implicit in this use of production cost is that other factors relating to functional and operational evaluations remain the same. While this may not be so in practice, it nevertheless does permit a study of design for production independently of other complexities.

As argued in Section 1, the impact of the strategic tools is felt most at the preliminary design level. At this stage, the variables under a designers control include:

- Length between perpendiculars (L)
- Length to beam ratio (L/B)
- Beam to draft ratio (B/T)
- Block coefficient (C_B)
- Longitudinal frame spacing (S_L)
- Transverse frame spacing (S_T)

This report outlines the study of production considerations (in terms of costs) on a systematically varied range of general cargo ships with a structural configuration as shown in Figure 2.1 and with particulars as below.

Number of ships in series	:	27
Range of L/B	:	5.0, 6.0, 7.0
Range of B/T range	:	2.0, 2.5, 3.0
Range of C_B	:	0.60, 0.65, 0.70
Constraints	:	L = 110m; D = B/1.8, S_L = S_T = 800mm; Zero camber and rise of floor; Hatch width = B/2; Depth to 'tween deck = 0.60; Hold length = 24m.
Procedure	:	For each L/B value, three variations of B/T are made. Similarly for each B/T value, three variations of C_B are made.

3. OUTLINE OF SOFTWARE USED

3.1 Generation of Structural Designs

A) MIDSCANT (3)

This program was originally developed on a Honeywell 6080 computer and it derives preliminary midship section scantlings for a single 'tween deck general cargo ship. This derivation is made in accordance with Classification Society Rules (4).

The input to the programs comprises preliminary principal particulars. The output, in addition to the scantlings, includes calculated values of:

- Cross sectional area and vertical centre of gravity of longitudinal material;
- Volume per metre and vertical centre of gravity of transverse material;
- Mass per metre and vertical centre of gravity for the complete midship section.

B) CALSCANT (5)

This program is an extension of MIDSCANT and it calculates, from additional input data which too would be known at the preliminary design stage, scantlings for fore and aft ends of a single 'tween deck general cargo ship.

Thus the scantlings for the complete ship are available.

3.2 Assessment of Producibility

This was based on a program written for an IBM PC-XT (6) - see Figure 3.1. The input to the program comprises geometrical details of the structural unit (such as a midship section), the scantlings of the structure and production standards pertaining to a particular yard. Implicit within the program are features pertaining to production sequence and facilities required.

The output from the programs includes the numbers and types of burns, welds and piece-parts, material weight, standard hours for preparation, fabrication and erection and costs for labour, materials and overheads.

4. RESULTS

The 27 ships in the series outlined in Section 2 have been used for the producibility study (7). The scantlings produced by MIDSCANT have been input into the production costing program.

The input to this latter program requires the definition of a "production unit" which indicates the manner in which the structure is to be fabricated. The unit, for this purpose, was assumed to be one half of the midship section. It was further assumed to be out of the way of hatch structure and with a (fore–aft) length of 12m.

After the input of structural geometry and scantlings, shipyard production standards, material rates (@ £250 per tonne) and manning/overhead rates (@ £8 per man hour each), a set of costs pertaining to the various designs are output. Whilst scantlings obviously vary from ship to ship, the material and labour rates have been held constant to allow direct comparison between the various designs.

The output costs are divided into three components – namely material, labour and overhead. However, because overhead costs are calculated as a fixed proportion of the labour component, they are not dealt with separately in the study below.

All costs are divided by volumetric displacement of the ship to which they pertain in order to account for differences in capacities of the ships.

A) Labour cost versus L/B (Figure 4.1)

A line is plotted for each B/T value at $C_B = 0.65$. The three curves exhibit similar trends. Labour costs increase with L/B ratio and with B/T ratio. Over the range plotted, labour cost increases by approximately 40% with B/T and by roughly 50% with L/B.

The implication, as might be expected, is that labour costs increase as the ship becomes longer and narrower and yet as it become wider and shallower. Consequently, for a given beam, the design should be as short and of as large a draft as possible. Due to the relative sensitivities of each parameter, L/B ratio should be optimised with some priority over B/T.

B) Material cost versus L/B (Figure 4.2)

The graphs are of a similar form to Figure 4.1 above. Material costs per unit displacement increase with L/B and B/T. Over the relative ranges shown, cost increases are approximatley 35% with B/T and 30% with L/B.

The conclusion from this graph is that priority between L/B and B/T optimisation is less clear even though the trend is similar to the labour component.

C) Total cost versus L/B (Figure 4.3)

Again the curves are of a similar nature to the labour and material cost components. Cost per unit volume increases with L/B and B/T with the respective changes over the ranges being 43% and 38%.

The conclusion from this is that total costs are minimised by lowering L/B and B/T ratios, i.e. by producing a design of high beam to length, consistent with a high draft to beam. There may be conflict here and although the sensitivity of total cost is greater towards L/B ratio than to B/T, differences are small and both must be considered carefully and in conjunction with other design restrictions.

D) Labour cost versus C_B (Figure 4.4)

The curves for each B/T ratio are similarly shaped and evenly spaced. The costs decrease with increasing C_B and decreasing B/T. Decreases of approximately 14% are shown in labour cost with a 0.1 increase in C_B whilst over the range of B/T, cost increases are around 40%.

The implication is that capacity can be increased at a cost-effective rate by increasing C_B within the range shown. However, cost reductions are small (in order) when compared to increases caused by changes in L/B or B/T. Nevertheless, neglecting other factors, it is evident that maximising C_B produces greater capacity whilst labour costs rise at a progressively lower rate.

E) Material cost versus C_B (Figure 4.5)

The curves for this are almost identical in shape to those for labour costs, i.e. they decrease with increasing C_B. The implications too are the same as in the previous case.

F) <u>Total cost versus C_B</u> (Figure 4.6)

Again the shape is identical to that for the individual labour and material components, i.e. costs decrease with increasing C_B.

It can therefore be concluded that increasing C_B is a cost effective way of maximising capacity. Consequently, in designs where maximum capacity is of prime importance, C_B is large. However, these gains may be outweighed in a typical general cargo design by other factors such as service speed and fuel economy.

G) <u>Total cost versus volume of displacement</u> (Figure 4.7)

Each solid line is for a particular L/B and B/T value and each point corresponds to a C_B value. It is evident that C_B changes cause small increments while B/T and L/B produce progressively larger cost changes.

The implication is that C_B is an effective way of controlling production costs although its effects are limited. L/B and B/T produce greater cost changes but the optima in the two cases conflict with each other; hence care needs to be exercised in the appropriate choices.

H) <u>Total cost versus mass/metre</u> (Figure 4.8)

Nine points have been plotted for one value of C_B (and similar curves can be drawn for other C_B values). The line is almost linear and, as expected, cost increases with mass/metre. As observed in earlier figures, progressively larger mass/metre and total cost steps are taken as B/T and L/B are paired respectively.

The implication is that, for preliminary design purposes, the conventional rule-of-thumb of production costs being directly proportional to steelweight is justified. Consequently, not only is weight itself a feature to be minimised in order to maximise deadweight, but also capital costs can be reduced in the same way. Note that within the overall linear approximation, there are non-linear variations with L/B and B/T. Particularly at lower L/B and B/T values, cost increases more slowly with mass/metre. These non-linearities warrant further detailed investigations and may prove to be significant in minimising production costs.

I) Productivity variations (Figures 4.9 - 4.11)

This will impact upon the labour component principally (8). Such a study is pertinent particularly when considering investments in shipyards. It can be a useful tool to consider potential bonus payments to the labour force for quicker production. (However, this latter requires careful balance against other criteria as well.)

Figure 4.9, for example shows the variation of productivity against labour costs for varying L/B but for particular values of B/T and C_B. The trends in the figure indicate that even small improvements in productivity at very inefficient yards will have a great impact on labour costs; this is not so at yards operating near the ideal standards. This trend is confirmed for varying B/T ratio as well as shown in Figure 4.10. Furthermore, the impact is the same even so far as total (as opposed to labour only) are concerned as is evident from Figure 4.11.

J) Shipyard investment (Figure 4.12)

Consider a prospective investor with a limited amount of money to invest on a ship - as represented by the horizontal line in Figure 4.12.

Assume that there are three shipyards A, B and C having three different productivity values. Shipyard C, which has the highest productivity compared with the other two, could produce a ship having an L/B ratio of 7 and lower. (A high value of L/B means a slender ship with lower fuel bills and operational costs.) Shipyard A on the other hand, having the lowest productivity could only afford to build a ship with L/B of 5. This will imply higher operational costs and may therefore not be preferred by shipowners.

The overall implication here is that design options in shipyards with low productivity are severely restricted.

5. CONCLUDING REMARKS

The work outlined in this report is of an investigative and preliminary nature. It represents a way to build up a comprehensive data bank of producibility and cost information vis-a-vis design variables. The suggested method is through a parametric variation in design variables. In this restricted study the effects of L/B, B/T and C_B variations have been outlined in context of a general cargo ship. An attempt has been made at investigating variations in production criteria as well.

The most important conclusion to emerge from this study is that at a preliminary design level, producibility (as represented in terms of cost) is directly proportional to steelweight. This conclusion reached through the use of work study data inherent in the production costing programs is in line with "traditionally-held" beliefs developed through historically-orientated data.

6. ACKNOWLEDGEMENTS

As is evident from the references cited in the next section, the work outlined here is based on work carried out by students, under the author's supervision, over a number of years. Those most closely involved include Messrs. Kathro, Hamilton, Sanderson and Zainal Abidin.

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	KEY PLANS			WORKING DRAWINGS	
DESIGN STAGE	PRELIMINARY DESIGN	CLASSIFICATION DESIGN	CLASSIFICATION DESIGN	DETAILED DESIGN/WORK STATION DRAWINGS	
SCOPE	TOTAL SHIP	OVERALL STRUCTURE	AREA STRUCTURE	GROUP/UNIT/STAGE	
DOCUMENT-ATION	SPECIFICATIONS	OVERALL STRUCTURE	AREA STRUCTURE	MANUFACTURING INFORMATION	ASSEMBLY/INSTALLATION INFORMATION
HULL STRUCTURE	General Arrangement Midsnips Section Sternframe & Rudder Hull Specification Hull Form Lines Plan	Profile & Decks Girders & Transverses Equipment Requisitioning Numerical Fairing Shell Expansion Seams and Butts Block Breakdown Unit Breakdown	Hold Structure Engineroom Structure Aft End Structure Forward Structure Deckhouse Structure (Process Analysis)	Parts Drawings Group Parts and Material Lists Steel Ordering (N.C. Tapes) (Nesting Drawing)	Assembly Work Station Drawings Work Package Parts Lists (Powder marking) Unit Breakdown

Table 1.1: Information Proliferation in Design

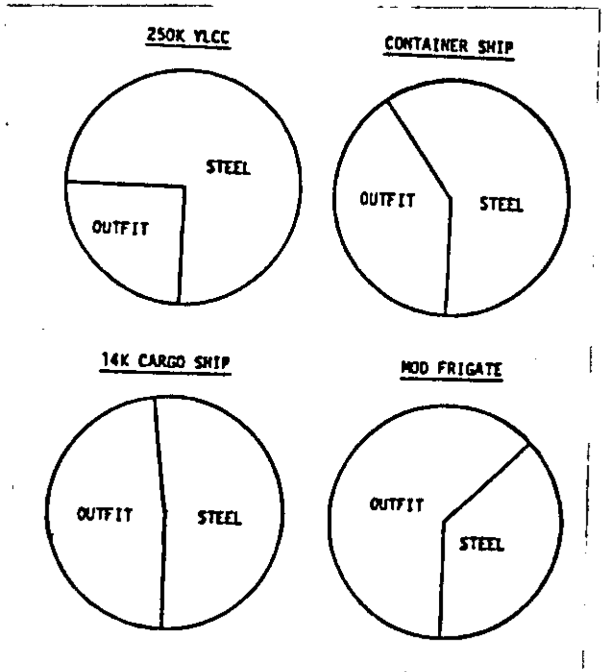

Figure 1.1: Structural Cost Proportions

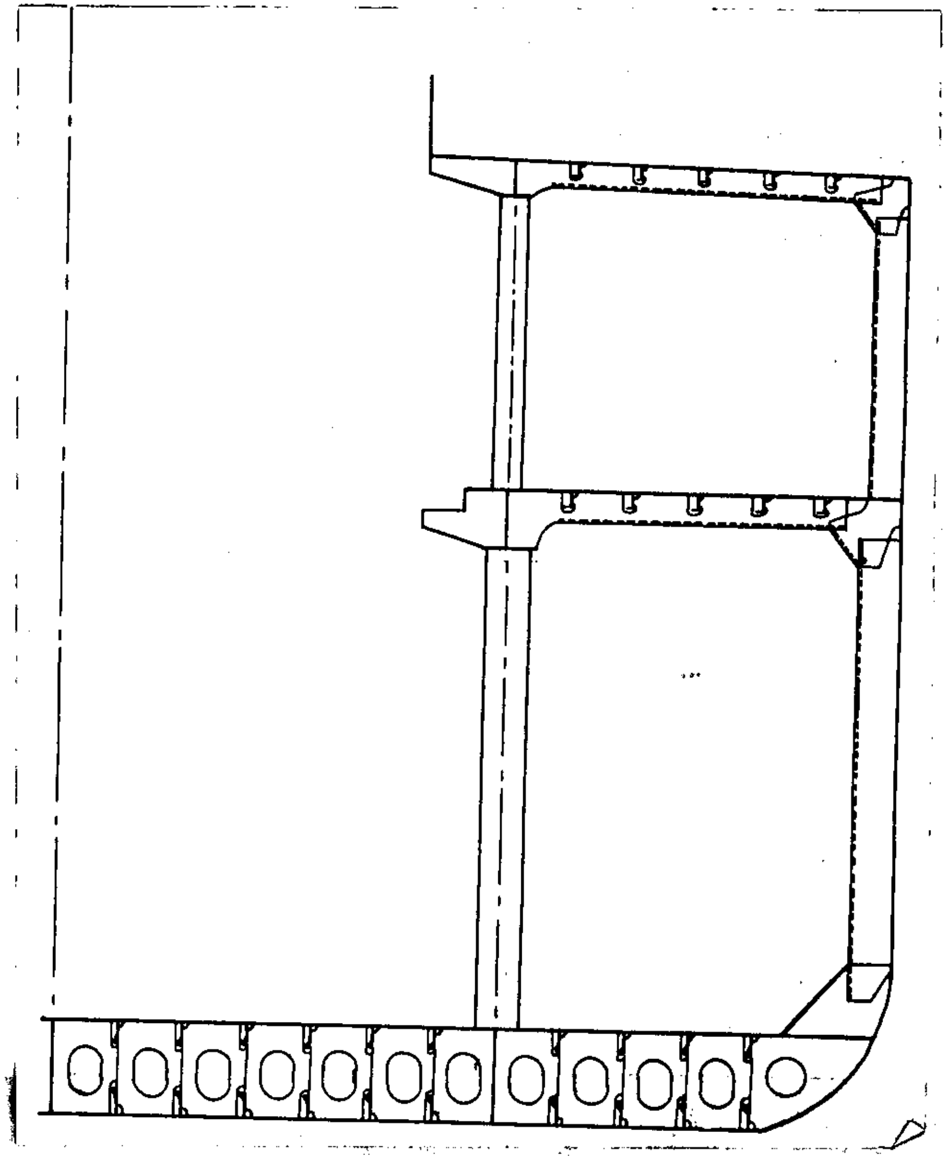

Figure 2.1: Midship Section Arrangement

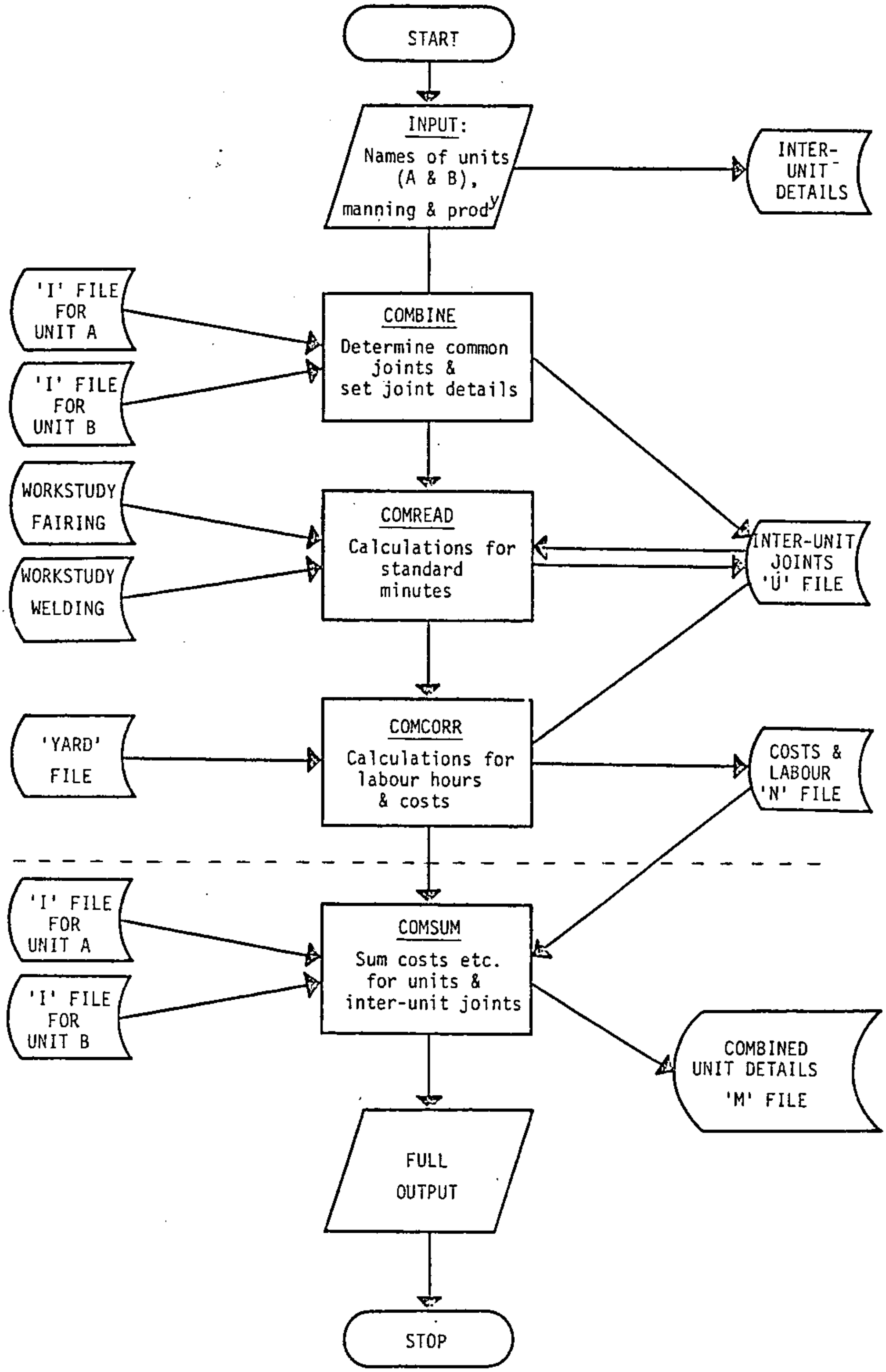

Figure 3.1: Flow Chart of Production Costing Program

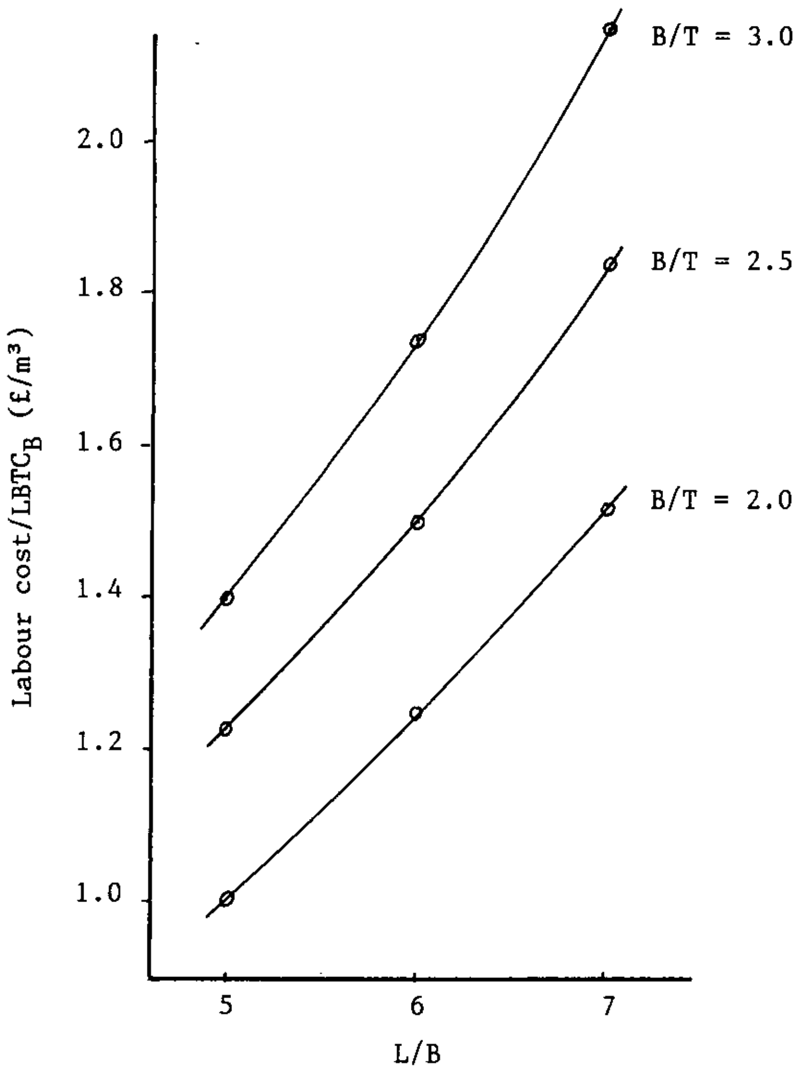

Figure 4.1: Labour cost versus L/B (C_B = 0.65)

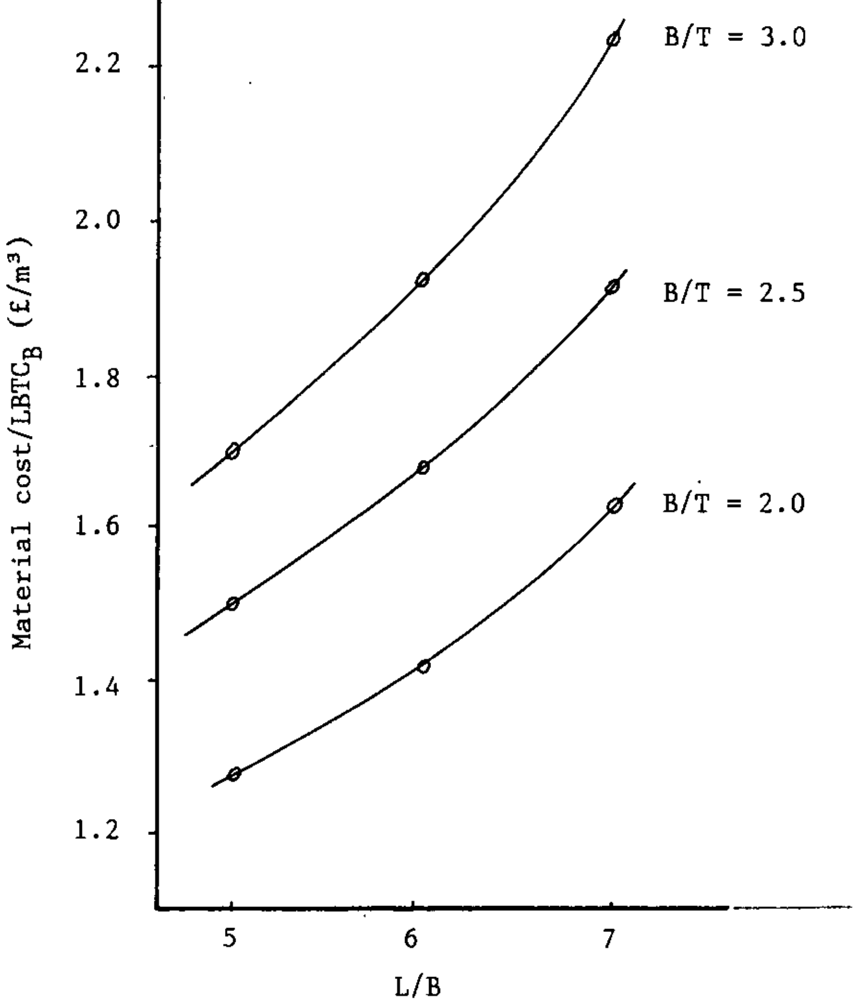

Figure 4.2: Material cost versus L/B (C_B = 0.65)

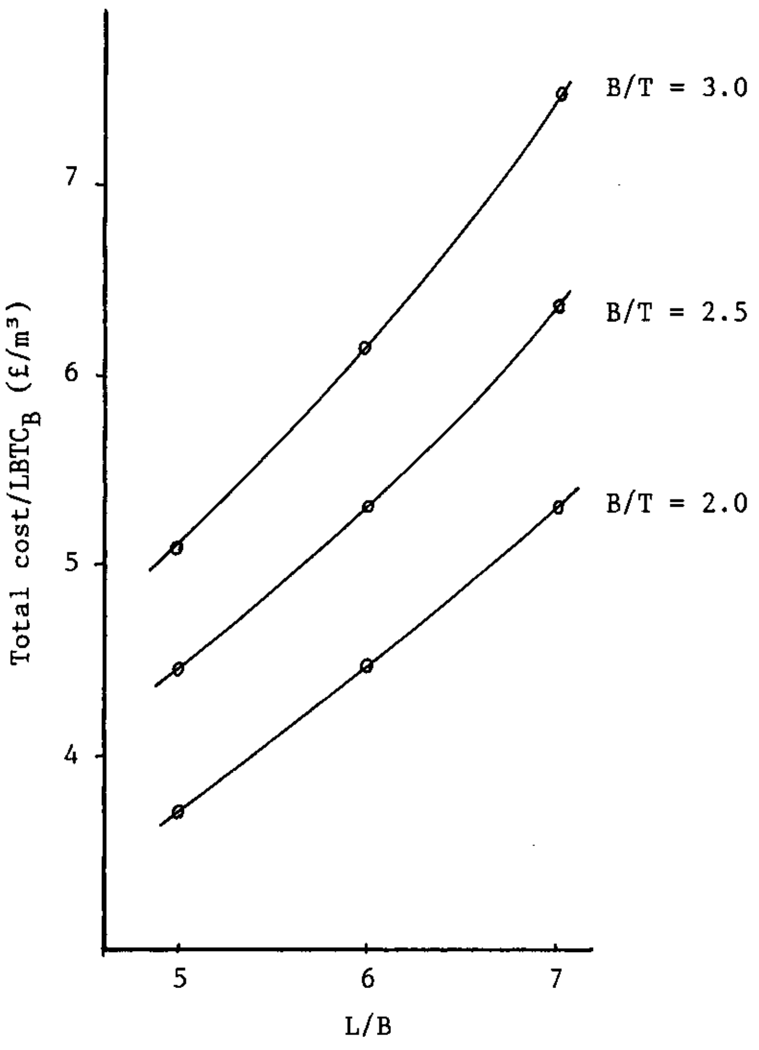

Figure 4.3: Total cost versus L/B (C_B = 0.65)

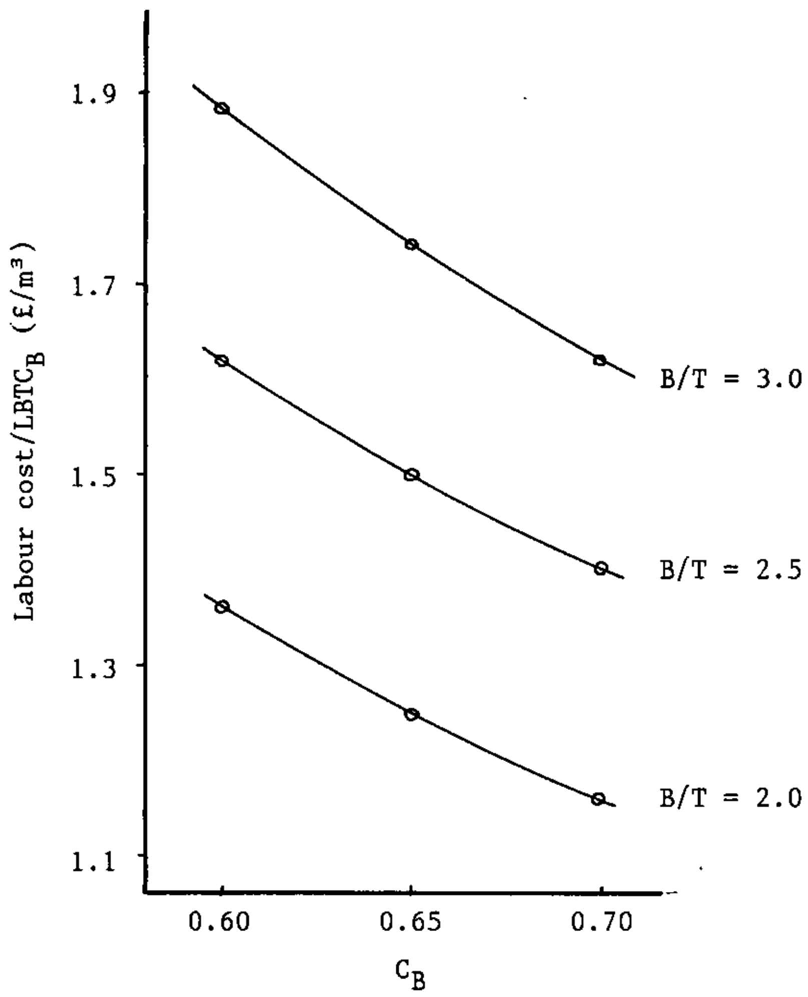

Figure 4.4: Labour cost versus C_B (L/B = 6.0)

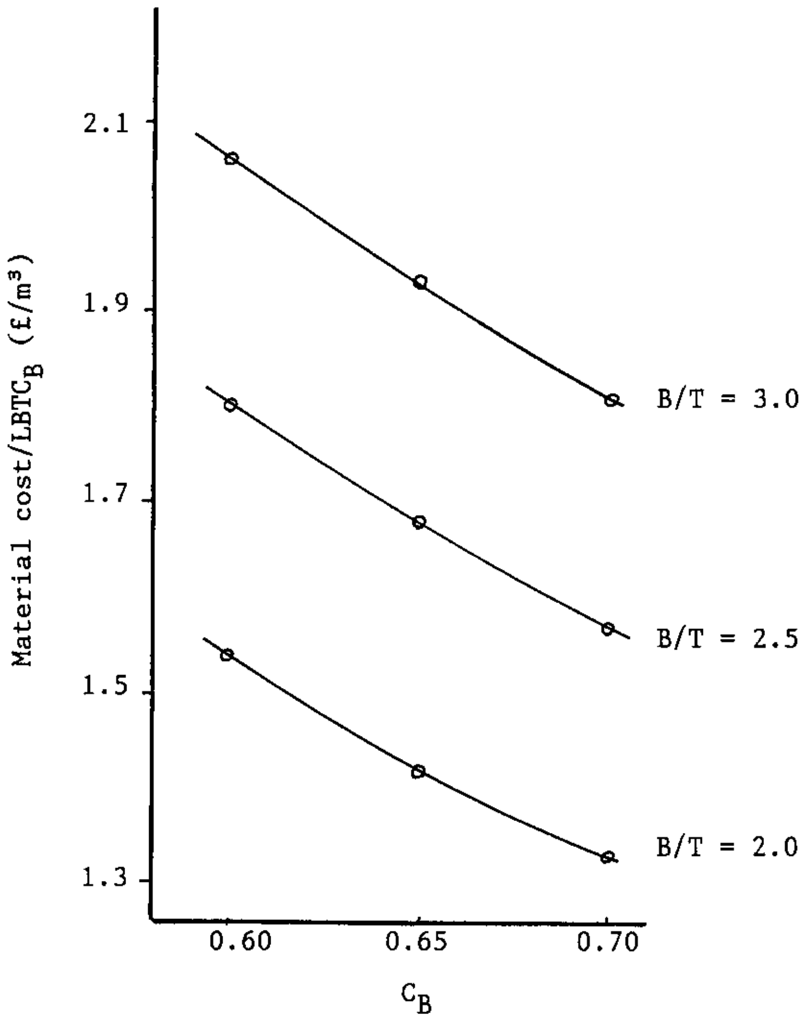

Figure 4.5: Material cost versus C_B (L/B = 6.0)

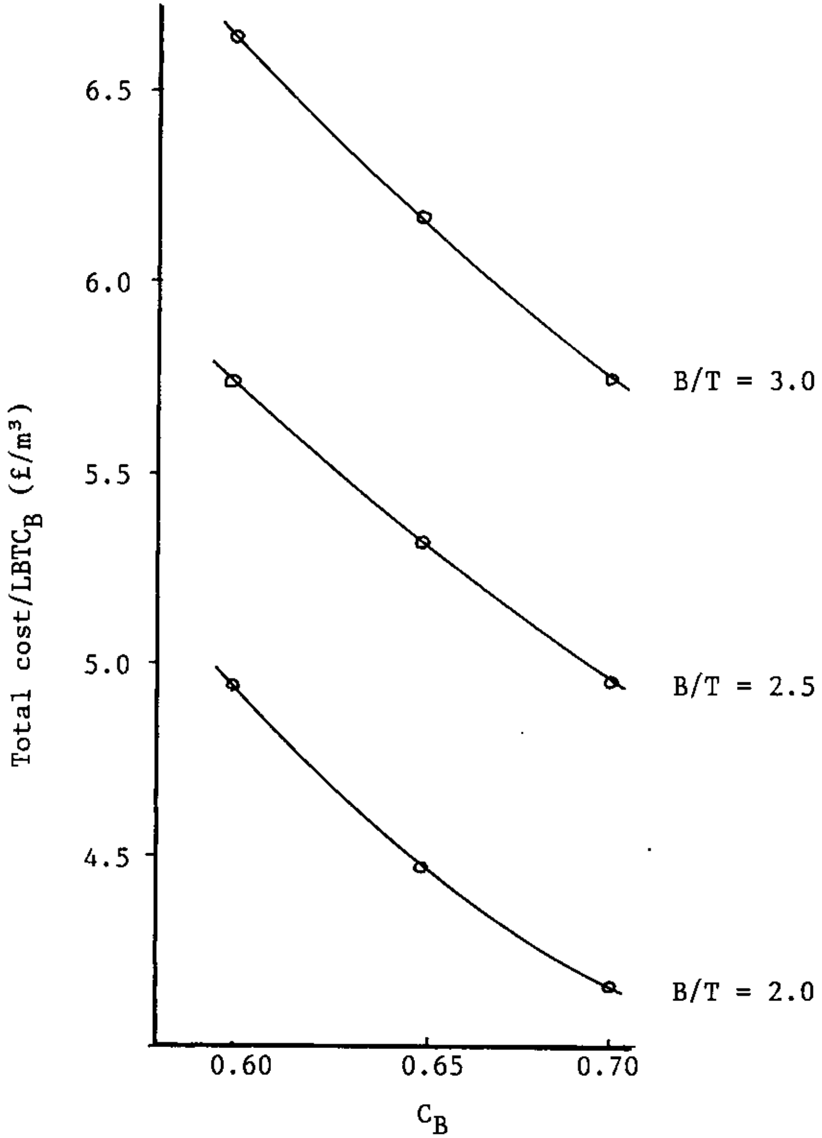

Figure 4.6: Total cost versus C_B (L/B = 6.0)

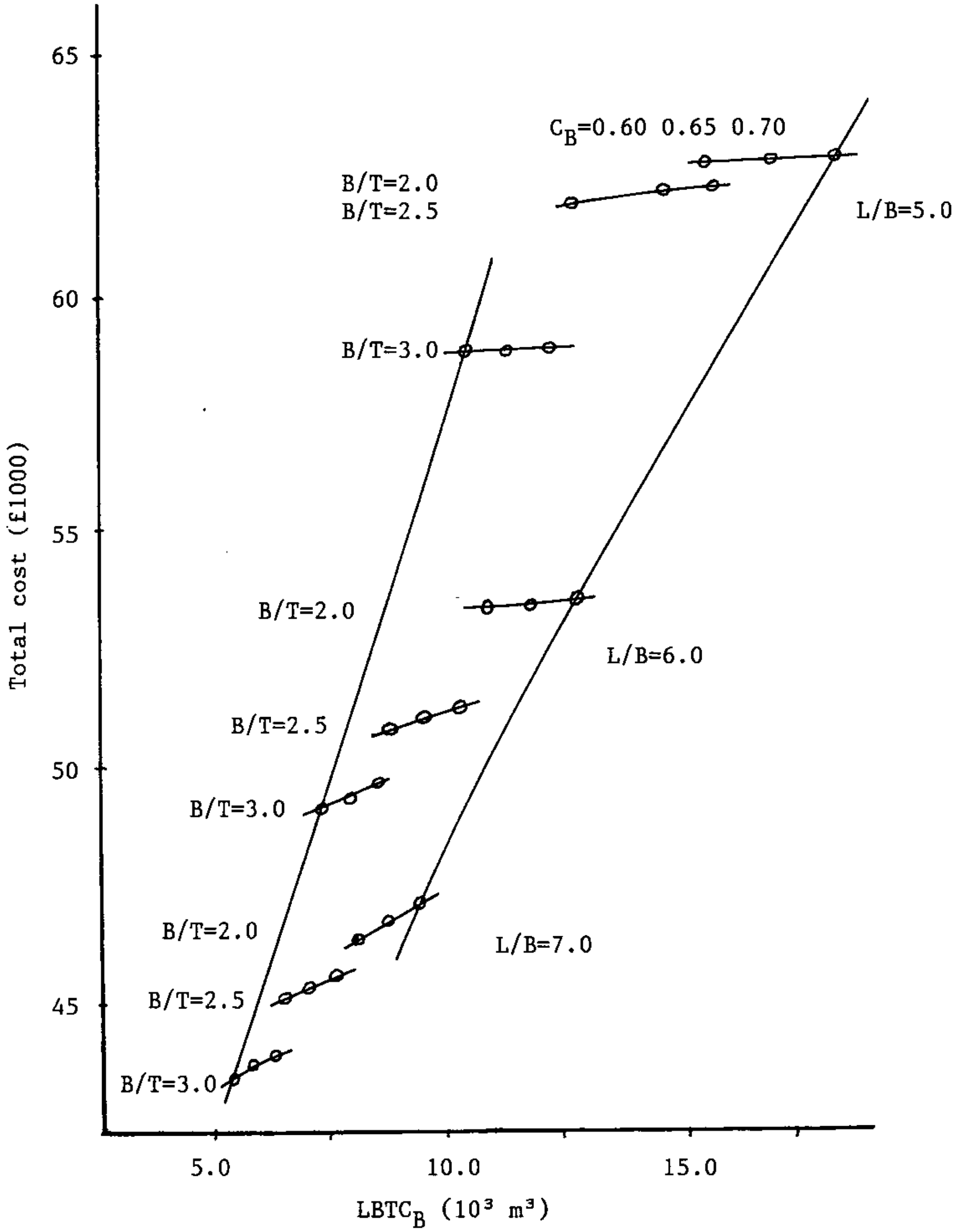

Figure 4.7: Cost versus Volumetric Displacement

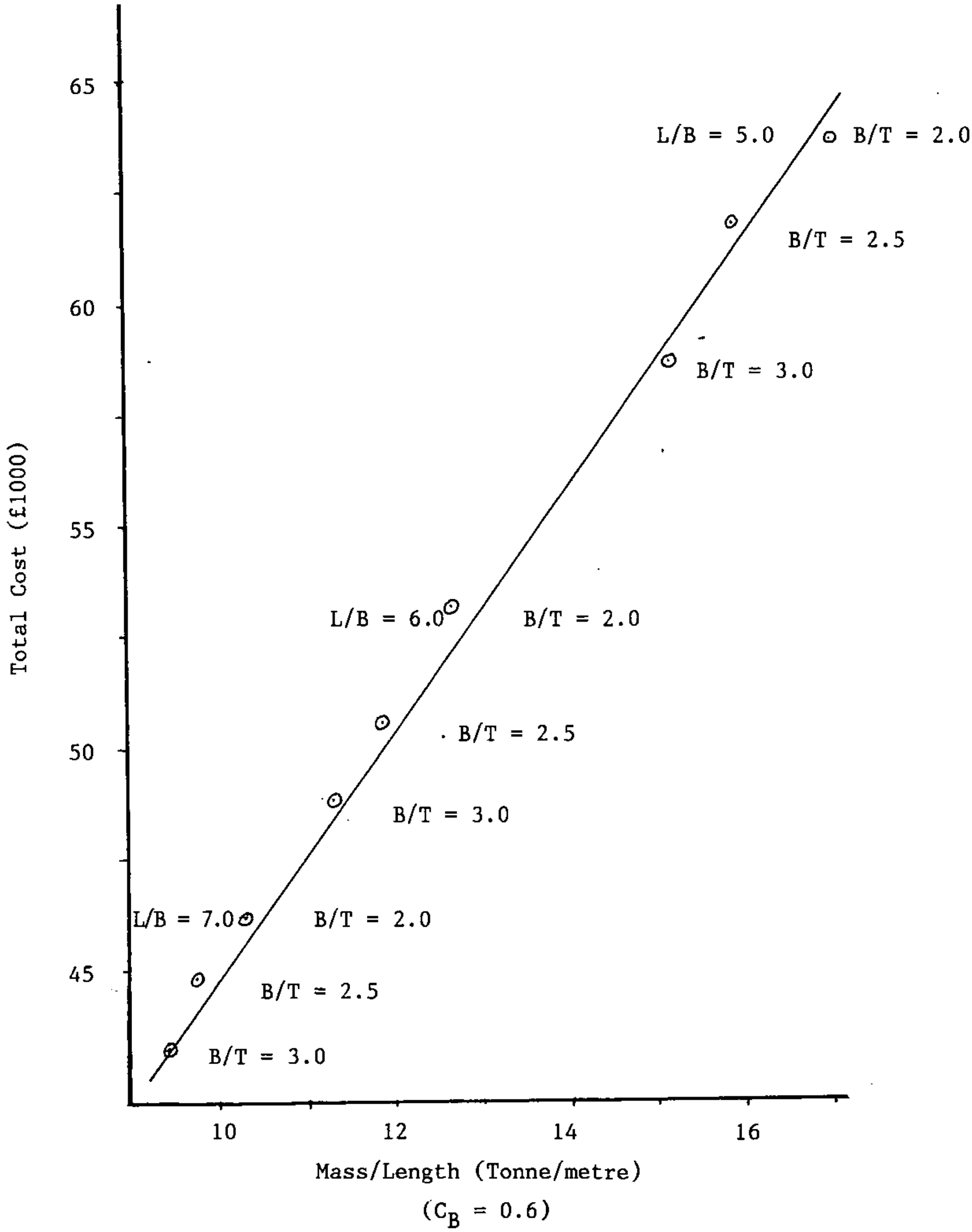

Figure 4.8: Cost versus Weight Relationship

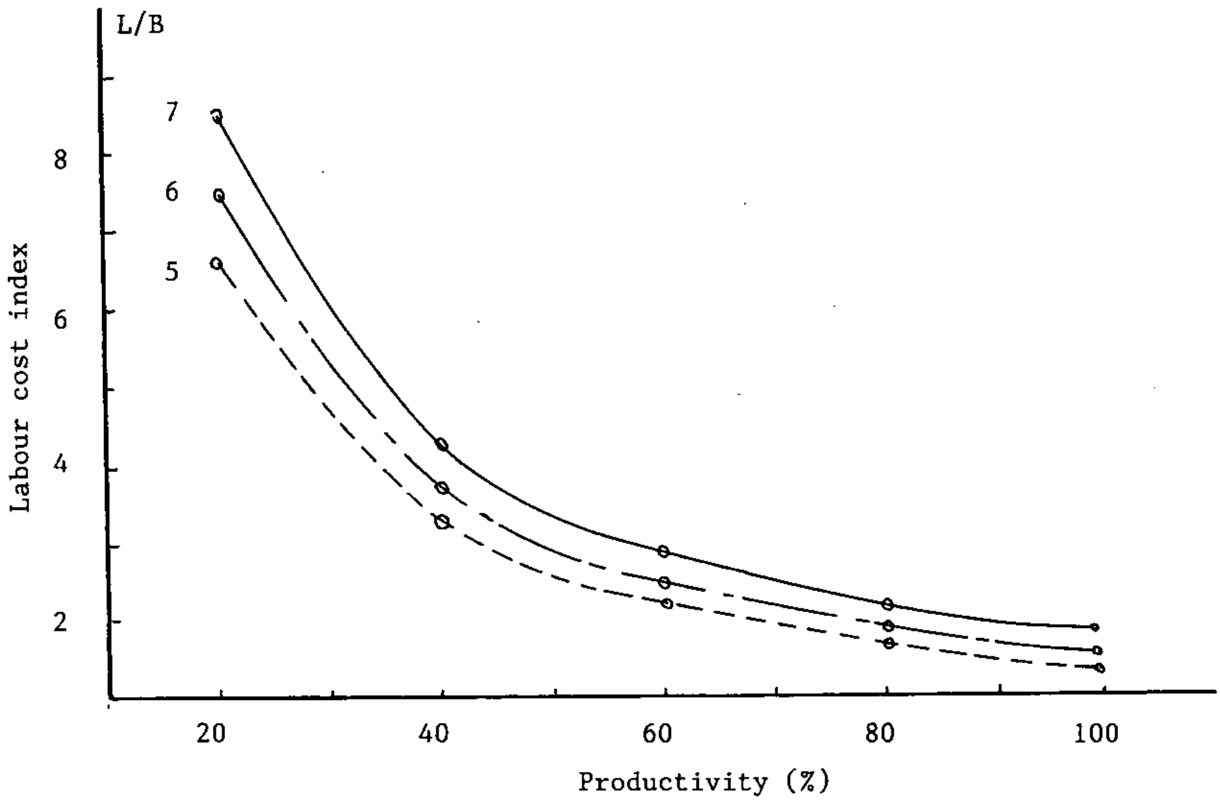

Figure 4.9: Labour Cost Index versus Productivity: Varying L/B

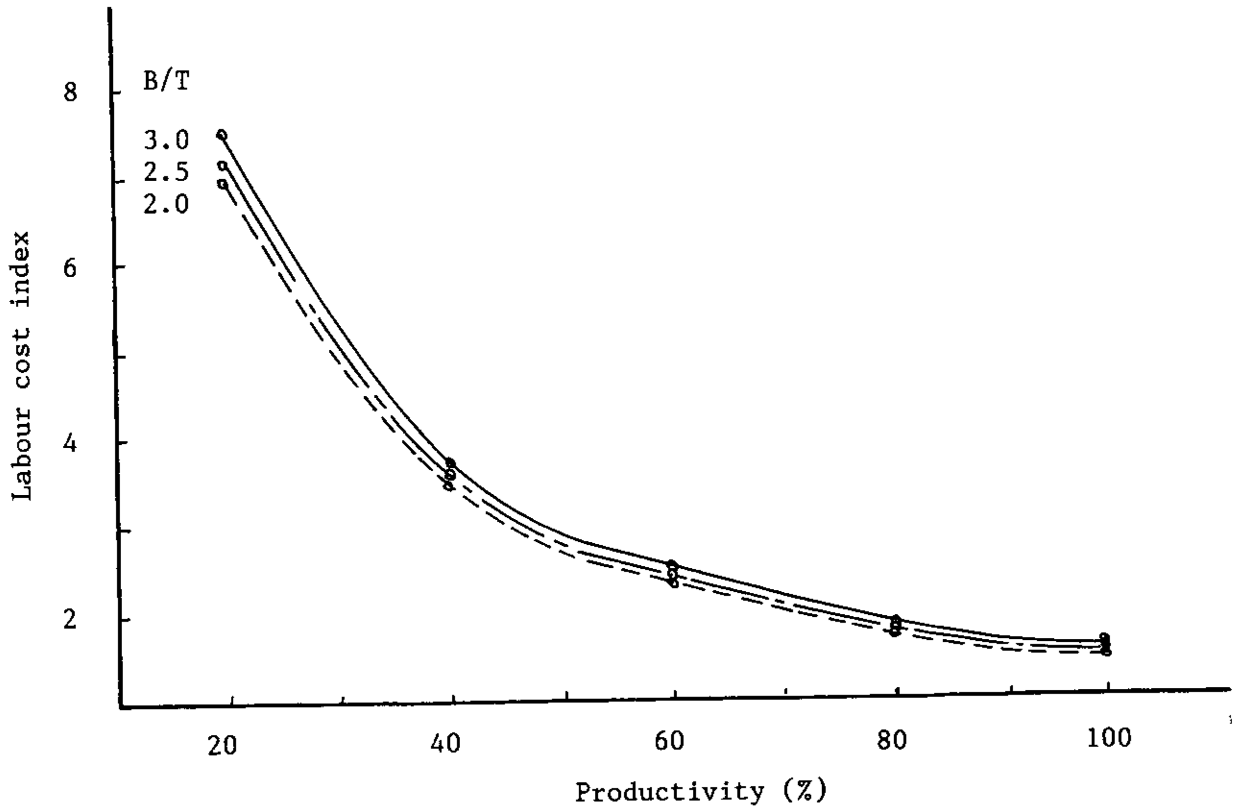

Figure 4.10: Labour Cost Index versus Productivity: Varying B/T

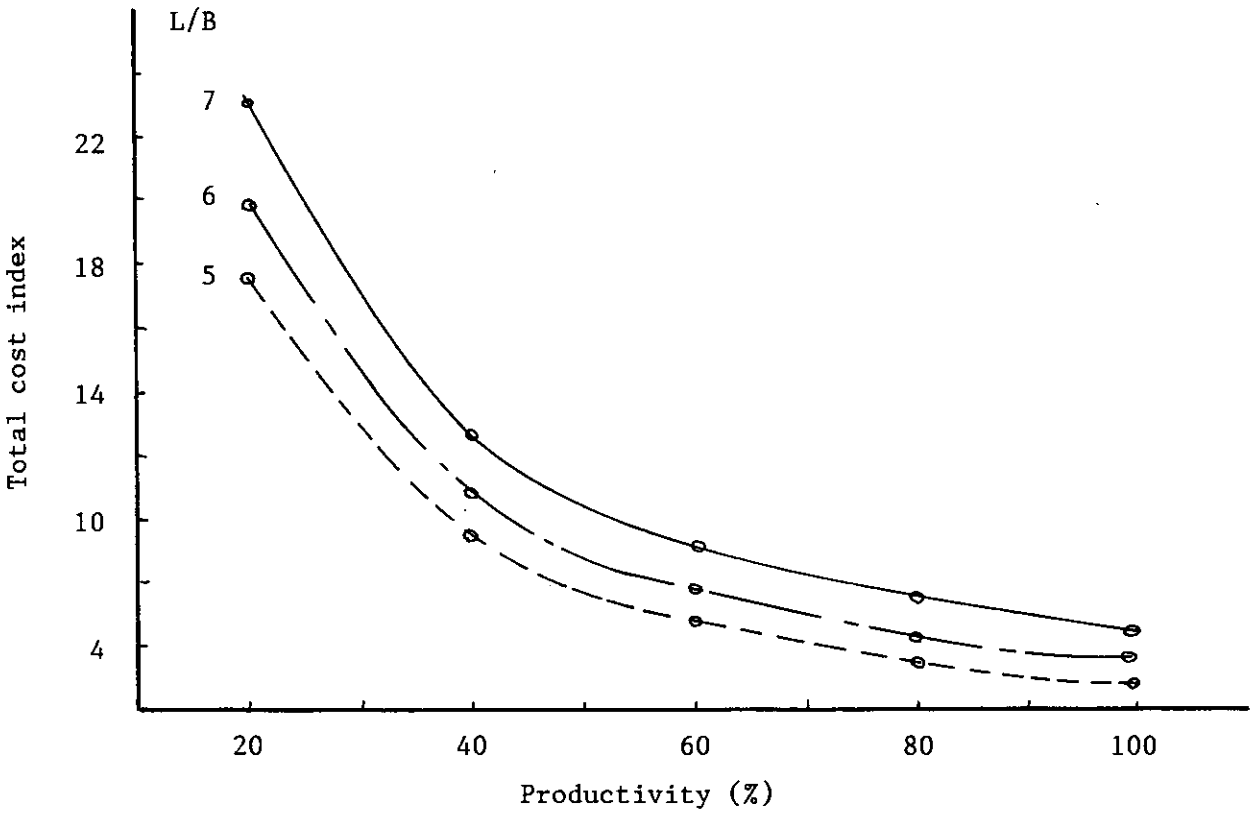

Figure 4.11: Total Cost Index versus Productivity: Varying L/B

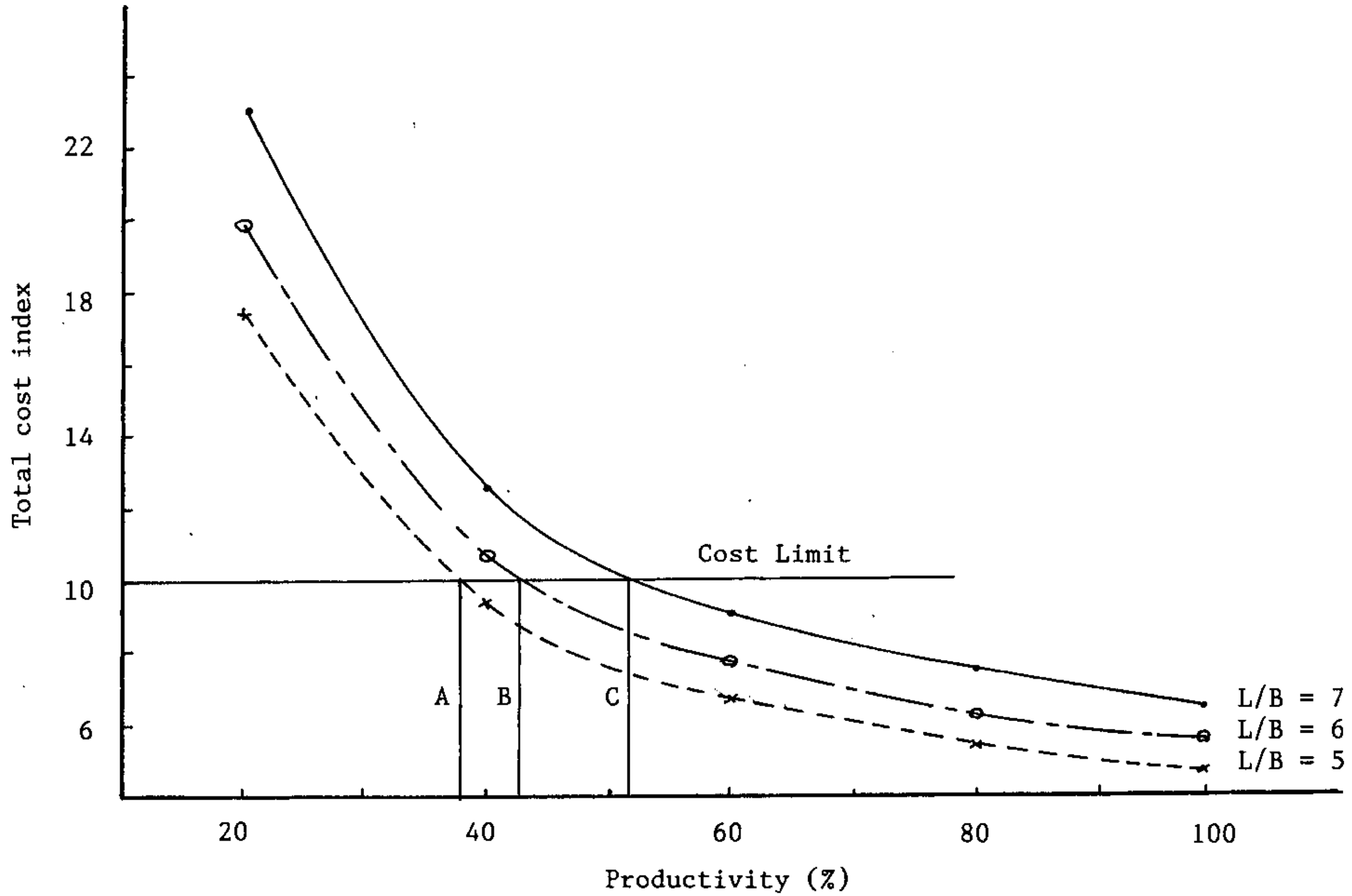

Figure 4.12: Design Choices for Differing Productivity Levels