CHAPTER EIGHT.

THE LOCATION OF MANUFACTURING.

Industrial Location Theory.

There have developed two main bodies of theory relating to the location of manufacturing activities. One, with Weber its most notable exponent, is based oh the least-cost principle; the other, with which Hotelling and Lösch in particular are associated, is founded on the market-area approach.[1] Formulated in terms of perfect competition, Weberian theory incorporates the axiom that profits are largest where costs are lowest. The optimum location for a manufacturing enterprise is therefore the point where it will be possible to minimize costs. The alternative school of thought, which is concerned with market-area analysis and the locational inter-dependence of firms, is framed in terms of monopolistic competition and spatial rivalry. It focuses more directly on the maximization of profits, which is taken to result from maximizing sales rather than minimizing costs, and the optimum location is regarded as that point which will enable a manufacturer to command the largest share of the market possible.

1. See :.F.E. Ian Hamilton, "Models of Industrial Location", chap.10 in Models in Geography, ed. Richard J. Chorley and Peter Haggett, London, 1968; D.M. Smith, "A Theoretical Framework for Geographical Studies of Industrial Location", Economic Geography, Vol.42 (1966), pp.98-99; Melvin L. Greenhut, Plant Location in Theory and in Practise, Chapel Hill, U.S., 1956, chaps. 1-3 and 11; Walter Isard, Location and Space-Economy, Cambridge, Massachusetts, 1956.

The market-area approach, as formulated by Lösch,[1] begins by postulating a uniform plain on which resources are evenly distributed, and the only element of the delivered price free to vary is the transport charge for conveying the good in question from producer to consumer. Other costs are constant, regardless of the location of the producer. The market is taken to be dispersed rather than concentrated. A manufacturer seeks to maximize his profits by maximizing the market area he controls, and hence his sales. Limits are set to his capacity to do so by the fact that if a good has to travel more than a certain distance, and transport costs rise above a certain level, consumers will turn to alternative suppliers who can deliver it at a lower total cost.

There are disadvantages in this approach to industrial location which do not recommend its adoption in the present context. In particular the initial abstractions tend to be too restrictive. For example, the premise that resources are of a uniform character throughout a region is grossly unrealistic when industries that use raw materials of a highly irregular occurrence are being studied. Again, Weber's concept of the market is more relevant than Lösch's to the study of basic industries, which dominated manufacturing on Teesside. Most of the demand for the produce of such industries emanates from places outside the region, and

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1. Hotelling's work on inter-dependence may be thought of as a special and limited case, in that the market is considered as a line rather than an area. See Greenhut, <u>op.cit.</u>, pp.37-41.

transportation and other commercial economies invariably mean that external demand is channelled through one point, or a small number of points, where goods are collected for despatch.

Effectively, therefore, the market is concentrated rather than dispersed, and there is no question of a manufacturer attempting to control a market area in the sense suggested by Lösch. Rather, the manufacturer is concerned with minimizing the cost of producing his goods and delivering them to the regional market or shipment point. These considerations also apply to non-basic industries which do not have scattered final consumers as their market. The Lösch-type model is therefore most appropriate for market-oriented manufacturing when the market is areal rather than punctiform.[1]

The Weberian model is also based on simplifying assumptions which are open to criticism, but it is better suited to the needs of the present study. In a sense, this model is the antithesis of Lösch's construct. Perfect competition is assumed and there is consequently only one market price, rather than a series of delivered prices. There is only one market point, or a small number of such points, instead of a host of consumers scattered throughout the region. Resources and costs vary spatially, and the predominant concern of

1. See : Greenhut, op.cit., p.268; and Edwin von Böventer, "Towards a United Theory of Spatial Economic Structure", Papers of the Regional Science Association, vol.10 (1963), p.173.

the manufacturer is to find that location which will allow costs to be minimized and profits thus maximized.

In Weber's scheme,[1] the optimum or least-cost location is defined with reference to three factors : transportation costs, labour costs, and agglomeration economies and diseconomies. The first of these, transportation costs, is believed to have the most fundamental influence on industrial locations, the other factors being regarded almost as causes of abberration. This is an attitude which is common to location theories in general. Thus, Isard concluded that "... only the transport factor and other transfer factors whose costs are functionally related to distance impart regularity to the spatial setting of activities."[2]

For simplicity, and to confine his analysis to purely economic matters, Weber regarded transport costs as the product of the weight of a good and the distance it had to be moved.[3] He was concerned not with transport rates as such, which are affected by political, social and other considerations, but with the true economic cost of transportation in terms of the resources needed to move a good from one place to another. Determining the location where transport costs will be lowest is, therefore, a matter of identifying the point at which production will entail the smallest aggregate movement of raw materials and product. To take account of

1. A translation, with annotations, of Weber's work is available : Carl Joachim Friedrich, Alfred Weber's Theory of the Location of Industries, Chicago, 1929, 256 pp.

2. Isard, op.cit., p.140.

3. Friedrich, op.cit., chap.3.

real transport rates, as many critics of Weber have urged, would be to remove the general base from the theory.

The materials used in manufacturing may be classified as either ubiquitous or localized, as suggested by Weber.[1]. Those in the former category are to be found everywhere in sufficient quality and quantity; those in the latter have irregular spatial distributions. Localized materials may be further defined as 'gross' or 'pure', according to whether they do or do not lose weight during processing. The types of materials used by a particular industry, and the proportions in which they are required, are important determinants of its basic orientation.

If transport costs alone are considered, there is a range of possible solutions to the location problem. For an industry which uses only ubiquitous materials, the optimum location is at the market, where transport costs will theoretically be zero. In contrast, an industry requiring one gross material can minimize its transport costs by locating at the source of that material; the material loses weight during processing, and it is consequently preferable to take the factory to its source than to the market. A third hypothetical case is provided by the industry using just one pure material. Here, the location problem is theoretically insoluble, since the material weights the same amount as the pro-

1. Loc.cit. Also see : Greenhut, op.cit, pp.8-17 and 254-57; Isard, op.cit., chap.5; and Stuart Daggett, "The System of Alfred Weber", in Readings in Economic Geography, ed. Robert H.T. Smith, Edward J. Taafe and Leslie J. King, Chicago, 1969, pp.58-64.

duct, and transport costs will be the same whether production takes place at the source of the material, the market or some intermediate point.

These examples, however, are all comparatively simple. Solutions to the location problem are more difficult to obtain for industries using more complex packages of inputs. For this reason, Weber devised a material index, which consists of the weight of the localized material inputs divided by the weight of the product.[1.] An index value smaller than unity occurs when the product is heavier than the localized materials combined, and indicates that the optimum location is at the market. If the product is equal in weight to the localized materials, then the material index has a value of one and the optimum location is still at the market, unless only one pure material is required, in which case it is indeterminate. If the index value is larger than unity, the optimum location depends on the number and weights of the localized materials used. When only one such material is required, the optimum location is at its source, when more are involved but one is heavier than the others plus the product, the source of the dominant material is the optimum location; otherwise, the optimum location is at some intermediate point which can only be determined by more rigorous analysis.

As Weber pointed out, the solution to the last problem, when the optimum location is an intermediate point, can be

1. Friedrich, <u>op.cit.</u>, pp.59-61.

found mathematically or by the use of a physical analogue such as the Varignon frame.[1] The market and the sources of the localized materials can be represented in a location figure. In a simple form, this may be a triangle, with the market and the sources of two materials providing the corners. Each corner exerts a locational attraction on the industry concerned which is commensurate with the relative weights of the materials and the product and the distances between them. As Isard has said, "... the problem is one of the equilibrium of forces...."[2]

Deane showed that it is not impossible for the equilibrium position to be at a corner of the location figure when no single weight exceeds the others in combination.[3] Further, in certain circumstances the source of a pure material may provide the optimum location[4] despite Weber's assertion that this could never be the case.[5] The solution depends on just how the conflict between opposing forces is resolved in a particular example. It is even possible for the equilibrium point to lie outside the location figure, in which case the nearest corner may be adopted as an approximation to the best solution.[6]

1. Ibid., pp.53-58.
2. Isard, op.cit., p.121.
3. Loc.cit.
4. Loc.cit.
5. Friedrich, op.cit., p.61.
6. Isard, op.cit., p.122.

The second factor Weber considered ih determining the optimum location for an industry was the effect of variations in the cost of labour.[1] By this, he meant not the crude differences in wage levels, but differences between places in the cost of labour per unit of output,[2] though there are practical difficulties in dealing with this type of variation. While labour costs vary spatially, they do so in an irregular manner; some plases have high and others low labour costs, but there are not smooth gradients between them. Hence, the critical "... question is whether industry should operate at the point of minimum transportation costs or be moved to the (cheapest) labour location".[3] It may only be possible for an entrepreneur to minimize his overall costs by neglecting the location where transport costs are lowest and choosing one where labour is inexpensive.

Weber argued that movement to a cheap labour point will only occur if "... the savings in the cost of labour which this new place makes possible are larger than the additional costs of transportation which it involves".[4] Further, if there is more than one cheap labour location, then that one will be selected which allows the largest saving in total costs. For there to be an advantage in such a movement, the proportion of total costs attributable to labour must be relatively high; otherwise, variations in labour costs would

1. Friedrich, op.cit., chap.4.
2. Ibid., p.95.
3. Ibid., p.102.
4. Ibid., p.103.

be less significant than those in transport costs. Hoover and Isard, as well as others, have shown that other production costs may be treated in the same manner that Weber dealt with labour costs.[1] For example, an industry with large water requirements, or one needing extensive tracts of land, may be able to obtain overall savings by departing from the location where transport costs are lowest in order to take advantage of a local abundance of water, or land.

Finally, Weber attempted to find a place in his model for the forces of agglomeration and deglomeration.[2] In practice, these are difficult to measure, but they certainly have an important bearing on costs. Weber dealt rather vaguely with this subject, but, following Ohlin and Hoover,[3] agglomeration economies may be sub-divided into three components : scale economies internal to the firm or plant, localization economies for all firms in one industry, and urbanization economies for all firms in all industries. Agglomeration economies encourage industrial concentration by resulting in a lowering of costs as production becomes more centralized. Conversely, the forces of deglomeration, which stem from diseconomies of scale and concentration, encourage industrial dispersal.

Internal scale economies mean that the larger plant has lower unit costs, and therefore they stimulate the central-

1. See Isard, op.cit., chap.6; and Edgar M. Hoover, Location of Economic Activity, New York, 1948, chaps.5 & 7.

2. Friedrich, op.cit., chap.5. For a discussion of this subject see Isard, op.cit., chap.8.

3. Isard, op.cit., p.172.

ization of resources into plants which are smaller in number but larger in size than would otherwise be the case. Localization economies result from the congregation of a number of firms in the same industry at one point. Weber cited joint technical developments, the specialization of labour and the growth of knowledge in relevant fields as some of the advantages, but many more come readily to mind. Urbanization economies arise from the complex and sophisticated nature of the urban economy, and they also appear in many forms. Commercial facilities in general tend to be in a more advanced state in and around the city, which is also the repository of capital and usually the hearth of invention and innovation.

All of these factors influence the cost structure of a particular industry or firm. It may be the case that agglomeration economies offer sufficient savings to persuade an entrepreneur to ignore, or abandon, the point where transport costs are lowest and choose a location where total costs are lower, despite an increase in the costs associated with transportation. Conversely, though more rarely perhaps, there may be diseconomies resulting from agglomeration which require a firm to seek a location some distance from an urban-industrial centre if it is to minimize its costs.

Economic Growth and the Location of Manufacturing

Theoretically, at least, it is possible for a region to undergo economic growth without any contribution other than a larger aggregate output from the manufacturing sector. If growth were based on the rising productivity of agriculture or mining, this could be the case. An expansion in the supply of manufactured goods, for both industrial and final consumption, would be required but this need not prompt innovation in the secondary industries. Indeed, it would not necessarily affect domestic manufacturers at all; the many examples of colonial economies, and areas of new settlement, indicate that the additional demand for secondary goods could be satisfied by raising the level of imports. Even so, a certain amount of locational change amongst domestic manufacturing industries would be expected, with the establishment of new activities and the decline of some of those already represented. Such changes, however, are of marginal interest in the present context. The major concern is with locational adjustment during the phase of rapid economic growth which accompanies industrialization, a phase in which manufacturing industries play a leading rather than a subsidiary role.

It is convenient to begin by assuming that the economy is in a state of equilibrium, with stable levels of supply and demand, a static technology, and plants operating at the current optimum scale. This position may be disturbed by change internal or external to a particular industry, or industries. In the case of internal change, an innovation which results in a lowering of unit costs of production - assuming that there is a measure of demand elasticity for the good in question - will be followed by an expansion of demand. In turn, output will rise. New plants may be needed, since those in existence were already working at the optimum level. However, innovation often makes possible greater scale economies, and thereby reduces or removes the need for additional plants.

The nature of the industry concerned, and the extent of the increase in demand, determine whether the expansion of output will be achieved through more plants of the same size as those already established, more of a larger size, or fewer of a larger size. Innovation must permit scale economies to grow at a faster rate than demand if there is to be a reduction in the number of plants. In reality, the process is normally step-like, with innovations which allow a rise in scale economies occurring at irregular intervals, and with demand catching up or taking the lead in the intermediate periods. After surmounting some particularly awkward problem, an industry tends to experience a series of innovations which takes it to a new technical ceiling relatively quickly. Subsequently, further scale economies may have a long gestation period.

Amongst the external influences on an industry's development, demand conditions are obviously of great importance. One aspect of them is the elasticity of demand, which controls the extent to which an industry can benefit from internal innovation. A relatively high elasticity for a particular commodity means that there are great opportunities for expansion if the industry producing it can lower its costs. At the other extreme, demand may be resolutely inelastic, which will limit the opportunities for expansion and probably tend to discourage invention and innovation.

Rising productivity in other sectors of the economy may aid an individual manufacturing industry by reducing its unit costs, much as an internal advance does. Improvements in the transport sector have historically played a crucial role in this respect. Another external influence of great significance is the growth of education, knowledge and skills which normally accompanies rapid economic development. By improving the economic quality of labour, this is a change which can contribute to the lowering of real costs of production in many industries. Finally, the effect of a rise in demand independent of changes in production costs should not be under-estimated. It may occur as a result of higher living standards, the development of external trade or the discovery of a new use for a particular commodity. Its immediate effect is to prompt the expansion of production, but in the longer term it may act as a catalyst for innovation.

The nature and extent of industrial change will obviously vary according to the interplay of internal and external conditions in a given situation, and ultimately it is a problem for empirical investigation. One industry may find itself under overwhelming pressure to expand its output and productive capacity, as internal productivity increases combine with external developments to lower costs, and as demand grows under the influence of falling prices and rising per capita incomes. These are circumstances favouring the construction of more plants, larger plants, or some combination of both. On the other hand, an industry may find its opportunities for expansion limited by a scarcity of raw materials. Another, perhaps with a fine record of innovation, may be restricted by the inelasticity of the demand for its product. These are situations in which modest expansion may be all that is possible, despite the propitious circumstances.

It is also possible that there will be industries faced with the imminent prospect of decline. Some may be traditional industries producing goods for which cheaper or technically superior substitutes have been found. Others may be industries which have raised their productivity, and lowered their costs, but are still unable to compete any longer, even in domestic markets, with foreign producers who have superior resources at their disposal. One of the striking paradoxes of economic development is that the improvement of transport facilities and the expansion of external trade which normally accompany it are just as great a source of danger to some domestic industries as they are one of opportunity to others.

Growth and Materials-Oriented Manufacturing.

It is convenient to consider the locational effects of growth by referring separately to the industrial categories distinguished by Weber. The industries to be included in the materials-oriented group generally have a value higher than unity on Weber's materials index, have a relatively low labour coefficient - that is, labour costs are a small part of total costs -, and are not affected to a significant extent by agglomeration economies of diseconomies. Normally, too, the orientation is towards gross materials : those which have a localized distribution and lose weight during processing. When one material input is heavier than the product plus the other localized materials, then its source represents the optimum location. When no single weight is dominant, then the optimum location is normally at some intermediate point. As explained earlier, however, there are special circumstances in which a localized material, pure or gross, may provide the equilibrium position even though it is not dominant.

In reality, other industries may be added to the group; for a straightforward consideration of weight alone can give a misleading picture of a material's attractiveness. For example, transportation rates have seldom, if ever, been directly related to the weight alone of a commodity. The charge the cargo can bear is usually taken into account. Valuable commodities consequently have higher rates levied on them than their weight justifies, while very heavy and, or, bulky goods of low value tend to be carried at relatively low rates.[1] In general, too, finished products are charged higher rates than raw materials. In applying Weber's model to real situations, therefore, use should be made of the 'economic' rather than the 'crude' weight of the commodities involved.

1. See Hoover, op.cit., chaps.2, 3 and 4.

An additional consideration is that transfer payments are rarely directly proportional to distance.[1] Longer hauls tend to be less expensive, per ton per mile, than short hauls. One reason is that there are certain fixed charges, including terminal and insurance costs, which must be met regardless of the length of the journey involved, and over short distances these loom disproportionately large. Over long distances, they constitute a negligible part of the overall cost per ton-mile. Another factor is that railway companies, in particular, often tend to encourage long-distance traffic by setting progressively lower rates.

For these and other reasons, Hamilton has suggested a broader definition of materials orientation. Thus :

> Industries, ... , will tend to be located nearer the sources of their materials and fuel (or dominant input) the greater the proportion of unusable waste, the greater the bulk (perishability or fragility), the higher the freight charges, and the lower the value - weight for weight - of the raw materials compared with the products.[2]

A rider may usefully be inserted at this point concerning the term 'materials'. In works concerned with industrial location theory, it is usually implied, at least, that 'materials' are raw materials. At best, this is a gross over-simplification, since even metallic ores are normally given some processing prior to their sale. More important, the raw materials used by many industries are in fact the

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1. Loc.cit.

2. Hamilton, op.cit., p.374.

finished products of others. In principle, this distinction between 'raw' and 'manufactured' materials is not perhaps very significant : both may be ubiquitous or sporadic in occurrence, and gross or pure in type, and both are equally at home in Weber's model. In practice, however, confusion may arise in determining the orientation of an industry which uses other than crude materials. Most manufactured materials are obtainable only, or mainly, in and near to industrial towns and cities. These are the locations which are most likely to offer agglomeration and labour economies and major markets. For some industries it may be very difficult to discover whether materials or one of these other factors is the dominant attraction.

If a region has only one source of a material which is dominant for a particular industry, and the economic climate favours expansion, then the industry in question will expand at that source. Existing plants will be enlarged, as necessary, to ensure the full realisation of current scale economies, a limit being set by the prospect or actual onset of diminishing returns. Beyond that limit, any additional increase in output will require the establishment of new plants.

New plants should be installed at the same location as those already in existence, since that is the location where overall costs for the industry are at a minimum. This, however, raises a theoretical problem; for if one plant occupies the optimum location, then another cannot. Indeed, even one plant requires an area rather than a point for its location. If, as is logical, a location is accepted as an area, then it is clear that new plants can only be built within a certain radius of the centre of that area. Beyond that radius, increased transport costs will prevent the earning of a normal profit, and this is unacceptable in a competitive economy.

To some extent, however, the area within which it is possible to earn a normal profit - the optimum location - may be enlarged by the localization economies which normally accompany industrial expansion in one place. Although of small importance to a material-oriented industry, these, and possibly urbanization economies too, may still serve to widen the areal extent of the optimum location by partially offsetting the rise in transport costs.

If demand remains in excess of supply once the optimum location is fully occupied, then the price of the good concerned will rise, giving existing producers the opportunity to earn excess profits. In this situation new producers will be attracted, even though they will be obliged to accept non-optimum locations, and will consequently bear relatively high costs, providing that they can still earn what are normal profits in the context of the economy as a whole. Hence, there will be a widening of the area of production. Further, it may also become possible, with the new price and cost structure, to develop a second area of production, perhaps based on a resource body which was previously not worth working. A limit is set to the spatial expansion of production by foreign competition; once a certain cost and price level is reached, further rises will be ruled out by the development of an import trade. In the event of external competition forcing the price level downwards, the domesticn industry would be obliged to contract. Ideally, the last plants to be established would be the first to succumb, since they would have the poorest locations. Ultimately, however, even the firms with the best locations might be forced out of business.

As well as these predictable patterns of expansion and contraction, there is another aspect of the impact of economic growth to be considered. In addition to simply lowering production costs, technical innovations can transform the orientation of an industry quite fundamentally. Thus, modifications to the manufacturing process may mean that one material ceases to be dominant in the material index, or even that the localized materials as a whole come to weigh less than the product. Historically, the reduction of the fuel inputs for various metal-making industries has been especially notable in this context. In a rather different category, progress in the transportation sector may so reduce transport costs that labour or aggregation economies become the main determinant of locations equilibrium.

Growth and Market-Oriented Manufacturing.

According to Weber, the industries to be included in this category are those with a material-index value not greater than unity. In addition, as described earlier, there are special circumstances in which the market may be the optimum location, when neither the weight of the product nor that of any material is dominant. Finally, there is the condition to be met that neither labour nor agglomeration economies should be capable of luring the market-oriented industry away from the location where transport costs are lowest. Because of Weber's simplified interpretation of transport costs, however, Hamilton has suggested the following description of market orientation.

> ... The greater the gain in weight, bulk, perishability, or fragility, the higher the costs of transport, and the lower the value of the product, the greater is the tendency for entrepreneurs to locate an industry as near the centre of the market as possible to minimize distribution costs.[1]

The expansion of market-oriented industries is governed by much the same rules as apply to those industries tied to the sources of their materials. The output of existing plants can be raised to the optimum level, which may itself be raised by innovation. Above that level, the further expansion of production requires the establishment of new plants, which should be built as close to the optimum location as possible. Again, however, new plants must be confined to the area within which normal profits can be earned. This area may well be extended by the agglomeration economies which accrue to producers located at an urban market.

1. Hamilton, op.cit., p.374.

If the upsurge of demand outstrips the pace of innovation and cost reductions, prices will rise and give existing producers the opportunity to earn excess profits. They will also allow new producers to locate their plants at a greater distance from the centre of the market than would have been feasible at the original price level. Similarly, secondary markets which were previously untenable locations could become viable. Again, competition from external producers will set limits to these types of development; the growth of imports will prohibit further expansion once a certain cost and price level is reached.

For some industries, expansion may create a different problem. Those using materials from wasting resource deposits may find that they cannot obtain adequate supplies, because of the limited physical capacity of the resources or because the production of the materials concerned is becoming more costly. One possible solution is for them to turn to alternative domestic sources, which will be poorer or more distant from the market; another is to import the requisite materials. Either policy is likely to involve additional expense, and consequently to threaten the competitive position of the industries concerned. The use of materials from new sources may also affect the material index and lead to locational re-orientation, since there can be considerable variations in the weight of a material drawn from different places.

A change in the locational orientation of an industry can also be brought about by technological advance or the improvement of transportation facilities. While it is unlikely that either of these factors could convert a market-oriented industry into one tied to the source of a raw material, it is quite possible that one or the other could result in labour or agglomeration economies becoming the dominant locational attraction. In practice, however, little or no change in an industry's distribution would occur if this took place. Apart from the matter of industrial inertia to consider, there is also the point that labour and agglomeration economies tend to be greatest at the market, especially when the market is the regional capital.

Growth and Industries Oriented to Labour and Agglomeration Economies.

Industries belonging to these two separate categories may conveniently be considered together, since they are generally attracted to urban-industrial locations. Transport, and related, costs are only of marginal significance in both cases. One group is primarily concerned with the cost savings, direct and indirect, to be obtained from locating in a complex and sophisticated industrial environment, with extensive commercial facilities. The other group is most influenced by the opportunities for drawing upon a large pool of specialised and highly efficient labour, and these are concentrated in large urban centres. Economic growth and industrial expansion will merely confirm the city's advantages for both groups. It is probable, however, that they will also result in some marginal adjustments to the various industrial distributions. In particular, industries with relatively large land requirements will tend to shift towards the urban periphery, as land at the centre becomes more expensive.

Manufacturing Industries in the Teesside Region.

The industries which have been selected for empirical study do not include all the types of manufacturing established on Teesside in the nineteenth century, but collectively they constituted the major part of the manufacturing sector. Most of them were basic industries, in the sense that they were essentially export oriented, so far as the region was concerned. Most were also either involved with iron making or used iron as a material. Consequently, few had antecedents in the pre-1850 era. In general, the study seeks to reconcile the actual distributions of these industries with the theoretical patterns suggested by Weber's model and the foregoing discussion of locational change during rapid economic growth.

The Iron-Smelting Industry.

It was the iron-smelting industry which was primarily responsible for the transformation of the Teesside economy that took place in the third quarter of the nineteenth century. Other industries were soon involved, some to play important parts once development was under way, but the iniative came from the pig-iron makers. For many years the smelting industry remained the keystone of the regional economy, the number of furnaces in or out of blast providing as important an index of economic activity as unemployment figures do today.

A necessary pre-condition to the establishment of the smelting industry was that there should be adequate supplies of raw materials, particularly iron ore and coking coal, available. The Durham coalfield could supply all the fuel needed for smelting, but prior to 1850 there seemed to be little prospect of local ironstone resources proving sufficient. The Eston discovery, which was made by a firm of iron manufacturers and not a mining company, changed that situation and ushered in a new era. Large amounts of new capital were subsequently invested in the mining, smelting and finishing industries, dramatically raising the region's employment capacity and leading to the establishment of a great variety of other industries, as well as to economic growth. Nationally, it was in the field of pig-iron production that Teesside first came to notice as an iron district.[1]

Less prosaically, iron smelting quickly developed a social prominence to match its role as economic leader. The process by which stone from the Cleveland Hills was converted into iron, and through which so much else became possible, grasped the popular imagination and fired the enthus-

1. As Dr. Kenneth Warren has pointed out, one reason why Teesside concentrated on pig iron production in the early years was that it was more difficult for new districts to break into the finishing trades, since they were handicapped by a shortage of the necessary skills. See his The British Iron and Steel Sheet Industry since 1840 : An Economic Geography, London, 1970, pp.14-15.

iasm of writers to whom Teesside had previously meant little. As Briggs has expressed it, "... the 'magic'of industry' fascinated the Victorians,"[1] and contemporaries found much to marvel at in the blast furnaces which sprouted along the banks of the Tees.

National Developments.

At the national level, the iron-smelting industry was one of the most dynamic parts of the economy for much of the nineteenth century. There were fluctuations, sometimes wild ones, in the production of pig iron but the general trend was upwards at a high rate until the 1870's, when expansion was checked.[2] Subsequently, the upward course was resumed, but it became more erratic. Deane and Cole examined the pattern of expansion, using five-year averages in order to smooth out short-run variations. They found that the United Kingdom's output of pig iron trebled, at least, every twenty years between the early 1820's and the early 1860's. Peak growth rates were attained between 1830-'34 and 1850-'54, when production quadrupled. Moderate expansion, entailing at least a doubling of output every two decades, was sustained throughout the first three-quarters of the century. Later, growth slowed; production rose by only 50 per cent between 1870 and 1900.

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1. Asa Briggs, Victorian Cities, Harmondsworth, 1968, p.242

2. See P. Deane and W.A. Cole, British Economic Growth, 1688-1959, 2nd. ed., London, 1967, p.224. Unless otherwise stated, this work has been drawn upon in the subsequent discussion.

During the first half of the nineteenth century it was primarily the upsurge of home demand that gave the national industry its opportunities for expansion.[1.] A growing familiarity with the properties of iron, which meant that it was increasingly accepted for more and more uses,[2.] combined with cost reductions to boost demand. Part of the output was converted into machinery, and part into building structures, but the largest element destined for the home market was made into railway iron.[3.] It has been calculated that 156 tons of iron were used in building one mile of single-track railway about 1841.[4.] In the heady days of 1845, during the railway boom, some 2,000 miles of new track were projected,[5.] which gives an indication of the level the demand for railway iron could reach.

In 1850, it has been estimated, 44 per cent of the United Kingdom's output of pig iron was destined for export, in one form or another.[6.] The proportion rose to 50 per cent in 1856, declined slightly from then until 1861, and subsequently increased again to reach 60 per cent by 1870.[7.] From mid-century, exports of iron and iron products grew faster

1. Ibid., p.225.

2. See Alan Birch, The Economic History of the British Iron and Steel Industry, 1784-1879, London, 1967, chap.II.

3. Ibid., p.222.

4. Loc.cit.

5. Loc.cit.

6. J.C. Carr and W. Taplin, History of the British Steel Industry, Oxford, 1962, p.7. The proportions given are estimates, with exports of the various types of iron product converted into their pig-iron equivalents.

7. Loc.cit.

than home consumption, and the export trade provided the main base for the expansion of the smelting industry.[1]

The United States was the most important foreign market for British iron in this period, taking 30 per cent of the exports in 1840 and more than 50 per cent in 1853.[2] As at home, the main demand in America was for railway iron, but there was also a substantial demand for pig iron suitable for castings.[3] A financial crisis in the United States in 1857 and subsequently the American Civil War disrupted trade until the late 1860's. There was then a recovery of the demand for railway iron which gave a fillip to British exports, but by that time the American iron industry was growing rapidly and the country was becoming less dependent on imports.[4] The United States still purchased 30 per cent of British exports,[5] but the proportion was declining steadily.

During the 1860's, despite the disruption of the American trade, the United Kingdom's output of pig iron rose, and the export trade in iron products continued to provide the main stimulus. The European countries were becoming increasingly important buyers of British iron. Railway construction was the main source of their rising demand,[6] but there was also a growing market for crude pig iron, especi-

1. Deane and Cole, op.cit., p.225.
2. Carr and Taplin, op.cit., p.7 and p.36.
3. Birch, op.cit., p.227.
4. Carr and Taplin, op.cit., pp.36-37.
5. D.L. Burn, The Economic History of Steelmaking, 1867-1939, Cambridge, 1940, p.20.
6. Ibid., pp.19-21.

ally in Germany, which benefited producers in North East England and Scotland in particular.[1]

After a long period of virtually continuous expansion, pig iron production in the United Kingdom reached a new peak of 6¾ million tons in 1872.[2] Exports of pig iron, alone, totalled 1,331,000 tons - which would have accounted for the entire output in 1840 -, and the pig-iron equivalent of all iron exported represented 60 per cent of the national output.[3] The country produced half of the world output of pig iron at that time.[4]

Subsequently, the fortunes of the British iron industries changed abruptly and substantially. A series of monetary crises extending across Europe in 1872 and 1873, and later reaching further afield, shook business confidence and resulted in the suspension of investment programmes, which in turn cut the demand for key materials such as railway iron.[5] Many overseas railway projects were in any case unsound, and financial difficulties coupled with operating problems further encouraged a period of retrenchment. A severe trade depression began to appear; the prices of most categories of iron began to fall from the inflated levels they had reached during the peak of the boom, and production started to slacken.

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1. Carr and Taplin, op.cit., p.37.
2. Ibid., p.36.
3. Ibid., p.37.
4. Deane and Cole, op.cit., p.227.
5. See Burns, op.cit., chap.2; and Carr and Taplin, op.cit., pp.38-39.

For the British iron trade, the fall of demand in overseas markets was particularly serious, since it was the export sector which had previously provided so much of the buoyancy. The wrought iron industry, which was so dependent on the demand for railway iron, suffered most severely. Exports of railway iron fell by half between 1872 and 1879; those to the United States dropped from 500,000 tons in 1871 to zero in 1876.[1.]

Exports of crude pig iron also fell, from 1,331,000 tons in 1872 to 776,000 tons in 1874.[2.] Subsequently, they recovered, however, and in 1879 they were only slightly below the level of 1872. On the whole, the smelting industry was affected less severely than the finishing trades. Production of pig iron dropped below 6 million tons for a brief period in 1874, but by 1880 it stood at 7¾ million tons, which was higher than ever before.[3.] Nevertheless, the depression marked the end of a long period of rapid expansion for the smelting industry. Although output recovered and resumed its upward trend, expansion was slower and more irregular. Moreover, the British share of the world production of pig iron had declined to 42 per cent by 1880, and it was to grow steadily smaller in subsequent years.[4.] This was a relative decline, of course, but it was indicative of the

1. Burns, <u>op.cit.</u>, pp.27-28.

2. <u>Loc.cit.</u>

3. Annual statistics for the national output of pig iron from 1870 are conveniently given in T.H. Burnham and G.O. Hoskins, <u>Iron and Steel in Britain, 1870-1930</u>, London, 1943, Appendix 1.

4. <u>Ibid.</u>, p.28.

speed with which foreign industries were developing, and a sign that British producers could expect growing competition in overseas markets.

Another important change occurred during the 1870's. This was the emergence of mild steel as a serious rival to wrought iron . After a slow and rather disappointing beginning, many oftthe technical problems associated with the Bessemer method of producing steel had been overcome by 1870, and in that year steel rails were not much more expensive than rails made of wrought iron.[1.] The price differential subsequently narrowed still further and parity was achieved in 1878.[2.] This gave a final blow to the wrought iron industry, which was heavily dependent on the rail trade.[3.]

These developments affected the smelting industry quite fundamentally; for pig iron made from British iron ore was generally unsuitable, then, for use in the Bessemer converter. Phosphorous-free iron was required for that purpose, and the only substantial British deposits of ore which could yield suitable pig iron were those in Cumberland and north-west Lancashire. Their output was consequently increased, but insufficiently to keep pace with the growth of demand. In 1873 Cumberland and Lancashire haematite had a market value of 33s.6d. per ton, which was more than twice as high as six years earlier.[4.]

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1. Carr and Taplin, op.cit., p.29.
2. Loc.cit.
3. Burns, op.cit., p.28.
4. M.W. Flinn, "Scandinavian Iron Ore Mining and the British Steel Industry, 1870-1914", Scandinavian Economic History Review, Vol. 2 (1954), p.32.

There was a need for larger supplies of phosphorous-free ore, if prices were to return to a more normal level. The best alternative source of haematite known at the time was in northern Spain, where highly concentrated ore occurred near the coast.[1.] A small traffic in Spanish ore had begun in the 1860's, but the price inflation of the early 1870's sent a wave of British prospectors to the Bilbao area, and a number of companies were floated in Britain to develop its resources. By 1882, one million tons of Spanish ore were being imported into the United Kingdom annually. A quantity of haematite was also imported from Sweden,[2.] but Spain supplied 90 per cent of British imports, and about 5 per cent of all the iron ore used in Britain.[3.]

Development on Teesside.

The rapidity with which the iron-smelting industry grew on Teesside is emphasised by the fact that there were no blast furnaces at all in the region in 1850.[4.] Indeed, the North East as a whole had remarkably few at that date, considering the long history of iron working in the area and the immense wealth of its coal resources.[5.] This was largely due to the North East coalfield's deficiency of the clayband and

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1. Idem., "British Steel and Spanish Ore, 1871-1914", Economic History Review, Vol.8 (1955), pp.84-90.

2. Idem., "Scandinavian Iron Ore Mining ... .", op.cit., pp.31-46.

3. Idem., "British Steel and Spanish Ore...", op.cit., p.89; and Burnham and Hoskins, op.cit., p.116.

4. See Isaac Lowthian Bell, "On the Manufacture of Iron in Connection with the Northumberland and Durham Coalfield" Transactions of the North of England Institute of Mining Engineers, Vol.13 (1863-64), pp.109-155.

5. The North East was the third most important area in the country for finished iron in 1800, according to : A.G. Kenwood, "Capital Investment in North Eastern England, 1800-1913", unpublished Ph.D. thesis, University of London, 1962, p.46.

blackband iron ores which had provided the material for smelting in other British coalfields.[1] There were seams of ironstone associated with the Coal Measures and the Carboniferous Limestone in the North East, but they were all comparatively meagre.[2] Certainly, they were poorer than their equivalents in Central Scotland and South Staffordshire. In the latter district, for example, the Coal Measures yielded 1½ to 2 million tons of ore annually between 1850 and 1880.[3]

Despite the handicap of a chronic shortage of local ore, the smelting industry was continuously represented in the North East from the mid-eighteenth century, and on an occasional basis it was older still. I. Cookson built the first coke-fired blast furnace the area had known at his Whitehill Works, near Chester-le-Street, in 1745.[4] The furnace was small, capable of producing a mere 25 tons of pig iron per week, but even so the local resources of ore soon proved insufficient. Supplies were supplemented with stone drawn from the beaches of the Cleveland coast, an expedient adopted by most of the North East's ironmasters prior to 1850.

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1. Bell, op.cit., p.109; and L.R. Jones, "A Geographical Study of Localisation and Migration of Iron and Steel Manufacture in the North East of England (Northumberland, Durham and the North Riding)," unpublished Ph.D. thesis, University of London, 1925, pp.31-33.

2. Bell, op.cit., passim.

3. Jones, op.cit., p.32.

4. Bell, op.cit., p.120.

The industry thus had a difficult infancy - it would almost be more accurate to say gestation, for its existence was always precarious before the middle of the nineteenth century. It was expensive to use other than local ores, because of the high transportation costs, especially when the areas to be served or tapped were inland and remote from railways. On the other hand, there was generally little alternative; local resources were almost invariably found to be inadequate or near exhaustion within a short time. The North East was consequently a marginal district for iron smelting. A great deal depended on the price of pig iron, and this was decided by events elsewhere. When the price was high, new furnaces were built and old ones restored; when it was low, furnaces were left to stand idle, perhaps to be demolished eventually. For long periods, the production of pig iron in the North East was probably barely worthwhile, but occasional shortages and high prices kept an interest in it alive.

Prices rose steeply during the Napoleonic Wars and the Tyne Iron Company was one firm to take advantage of this. The company built two blast furnaces at Lemington, on Tyneside, about 1800.[1] In 1812, pig iron was being made there at a cost of £5.5s.6d. per ton, which was well below the current market price of £8, even though much of the ore had to come from the Cleveland coast.[2] The 1840's were a period of exceptional development for the smelting industry in

1. <u>Loc.cit.</u>

2. <u>Loc.cit.</u>

the North East, largely because of the greatly increased demand for railway iron.[1] Of the thirty-eight blast furnaces working in Durham and Northumberland in 1850, the majority had been built during the previous decade. The largest group of furnaces belonged to the Derwent Iron Company, which had seven at Consett and another seven nearby at Crook Hall.[2] Coal-Measures ore was unusually plentiful in that locality, but it was still necessary to supplement it with ironstone from Stanhope in Weardale. It has been argued that both works would have been obliged to close shortly afterwards if the Derwent Iron Company had been unable to secure a stake in the Cleveland orefield in 1851.[3]

Lowthian Bell estimated that the North East's annual output of pig iron did not exceed 150,000 tons prior to 1850.[4] Until the late 1840's, however, production must have been well below that ceiling. Birch has examined the various statistical series pertaining to the period before 1854, when official returns first became available, and he suggests the following estimates for production in Durham and Northumberland[5] :

1806	-	2,500 tons.
1823	-	2,379 "
1830	-	5,327 "
1839	-	13,000 "
1840	-	11,000 "

1. See Kenwood, op.cit., chap.5.
2. Bell, op.cit., p.124.
3. Jones, op.cit., p.42.
4. Bell, op.cit., p.124.
5. Birch, op.cit., p.135.

1843	-	25,750 tons.
1847	-	99,840 "
1848	-	94,380 "
1852	-	145,000 "

In 1848, the national output was 2,093,736 tons.[1] Just before the discovery of iron ore in Cleveland, therefore, the North East was responsible for making about 4.5 per cent of the country's pig iron.

Following the decision to begin working ironstone at Eston, the first blast furnaces to be built on Teesside were put into operation in 1852. Two years later, in 1854, there were already 9 separate works, with a total of 29 furnaces, in the region.[2] By 1861, the number of works had risen to 14, and the number of furnaces to 49, of which 37 were in blast and the remainder either still under construction or undergoing repairs.

In 1861, the 26 working furnaces in the North Riding, all of which lay within the Teesside region, produced 234,656 tons of pig iron. Since returns were published only on a county basis, it is not possible to obtain an official figure for the output of those Teesside furnaces in Durham.

1. Ibid., p.124. The figures given for national output in later years have been taken from this source, from Burnham and Hoskins, op.cit., Appendix 1., and from B.R. Mitchell, Abstract of Historical Statistics, Cambridge, 1962.
2. Unless otherwise stated, the figures given for numbers of works and furnaces and for county outputs have been taken from : Robert Hunt, Mineral Statistics, Mining Records, Memoirs of the Geological Survey of Great Britain and the Museum of Practical Geology, London. This publication appeared annually.

However, a useful estimate of their contribution can be formed by multiplying their number by the average output of Cleveland furnaces in that year. There can be little objection to this procedure as the furnaces and general working conditions were the same on the north as on the south bank of the Tees. The estimate arrived at by this means is 99,240 tons.

The combined output of the Teesside furnaces in 1861 was thus approximately 334,000 tons of pig iron. This was equivalent to more than half the North East's total of 620,000 tons, and to 11 per cent of the United Kingdom's total. If Hunt's figure of £2.17s.0d. per ton is accepted as the mean market price for Cleveland pig iron in 1861,[1] then Teesside's production was worth more than £950,000 in that year. It is important to note that this position had been built up in a mere ten years.

The North East had traditionally retained the great bulk of its output of pig iron for local use. Even in 1854, only 6,383 tons were exported or sent to other parts of the country, while 91,666 tons went to local foundries and 183,334 tons to local forges.[2] With the discovery of Cleveland ore, however, ironmasters in the North East, particularly those on Teesside, acquired a comparative advantage and their pig iron began to find markets in other areas. In

1. Ibid., (for 1862).

2. Ibid., (1855). Subsequent references to shipments for various years are also from Hunt's publication.

1855, 17,611 tons of pig iron were exported from the Teesside ports. In the following year, the figure was nearly 50,000 tons, with 21,000 tons going to Germany alone. Middlesbrough was the principal port for exporting iron from the region. Hartlepool was much less important and Stockton played a role of negligible significance. Exports continued rising, and in 1861 93,662 tons of pig iron were shipped abroad - most of it from Middlesbrough -, which was almost as much as the amount used by the Teesside wrought iron industry.[1.]

Unlike some earlier periods, the years in which the Teesside smelting industry was established were not marked by high prices for pig iron, even though the demand for that material was rising on all fronts by the middle of the nineteenth century. During the first quarter of the century, the price of English pig iron usually varied between £5.10s. and £6.10s. per ton, although it rose higher for short periods and even touched £25 in 1825.[2.] In Wales the price ranged between £4.10s. and £9 in the 1830's.[3.] The expansion of the Scottish smelting industry forced the level down somewhat and the Glasgow price was £3.12s.6d. in 1840, but the railway boom took it up again to £5.10s. in 1845.[4.] In 1850, however, the Scottish price was only £2.5s.[5.], and it was

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1. See section below on wrought iron production.

2. Isaac Lowthian Bell, <u>Principles of the Manufacture of Iron and Steel</u>, London, 1884, p.16.

3. <u>Idem</u>., "On the Manufacture of Iron...", <u>op.cit</u>., p.122.

4. <u>Loc.cit</u>.; and <u>idem</u>., <u>The Iron Trade of the United Kingdom</u>, London, 1886, p.7.

5. Carr and Taplin, <u>op.cit</u>., p.10.

then, when the price was perhaps as low as it had ever been, that the Teesside industry had its origin.

Between 1850 and 1870, pig iron prices remained comparatively low and stable. Cleveland pig- which was iron made from Cleveland ore - fluctuated in price between £2.10s. and £3 per ton.[1] One reason for the stability and the low level of prices was that the expansion of the Teesside industry helped the national output to keep pace with the growth of demand.[2] Inflation no longer occurred quite so readily as it had done during the notorious railway booms of the first half of the century.

The main factor to stress in accounting for the rapid expansion of the smelting industry on Teesside is the relatively low cost of production, which was due mainly to the cheapness of Cleveland ore. However, this point requires qualification. The comparatively low costs incurred by Teesside producers did not ensure them access to all markets. Many of the traditional British markets must have remained beyond reach, because the cost of transporting the finished product would have outweighed the savings on working costs. Again, areas such as the Black Country had reserves of skill and experience which must have stood them in good stead for producing higher quality iron.

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1. See Hunt, op.cit., for various years.
2. Carr and Taplin, op.cit., p.38.

As a result of these and other factors, South Wales produced as much pig iron in 1880 as it had done twenty years earlier, even though local deposits of ore had become exhausted in the meantime.[1] In South Staffordshire, where both coal and ore resources had dwindled, output did fall in this period, but neither steadily nor substantially. Scotland, too, produced no less in 1880 than in the late 1850's. It is improbable, therefore, that Teesside captured a significant part of the older districts' domestic markets. Apart from the North East itself, the natural outlets for Teesside pig iron lay overseas and in the coastal districts of Britain, where the region's producers were able to consolidate their advantages because they had immediate access to water transport. In this context, it seems significant that the emergence of Teesside as an iron producing region coincided with the displacement of home demand by exports as the main driving force behind the smelting industry's growth at the national level.

Teesside quickly developed a thriving trade in pig iron with various European countries, and with Germany in particular.[2] The demand for crude iron in Germany was running at a higher level than the domestic smelting industry could satisfy. A tariff was levied on pig iron imports, and this and the cost of transportation meant that Teesside pig sold for £4 per ton in 1860.[1] Even so, Germany still provided a

1. Birch, op.cit., chap.7, has output series for the various districts.

2. See Burns, op.cit., p.20.

3. Bell, Principles of the Manufacture of Iron and Steel, op.cit., pp.461-63.

large and growing market for Teesside producers.

Expansion continued unabated during the 1860's. In 1871 the region had 23 smelting plants, which together had 95 working furnaces plus some not in blast. The number of furnaces in production was thus three times as large as in 1861, and, at 1,270,545 tons,[1] the output was four times as large. In 1871, too, Teesside was responsible for 70 per cent of the North East's output of pig iron, and 19 per cent of that of the United Kingdom. The North East as a whole was the foremost of the iron producing districts usually given separate recognition.

In 1871, according to Lowthian Bell, the average market price of Cleveland pig iron in the Middlesbrough district was £2.9s.3d. per ton.[2] On the basis of this figure, Teesside's output in that year was worth approximately £3,124,000. This is almost certainly an under-estimate, however; for a small and unknown proportion of the iron produced in the region was made from Cumberland haematite , and had a market value of £4.9s.6d. per ton.[3]

There is insufficient statistical information to permit a detailed description of the marketing arrangements made for Teesside pig iron. It may be noted, however, that in

1. This figure is an estimate which has been made on the basis outlined earlier for 1861. An additional step required for 1871 was the elimination of four blast furnaces in the Goathland area.

2. Bell, The Iron Trade of the United Kingdom, op.cit.p.17.

3. Loc.cit.

1871 about 269,000 tons were exported from Middlesbrough.[1] This quantity constituted a quarter of the United Kingdom's exports of that commodity, and it indicates the importance of overseas trade to the region. A further 214,000 tons were sent by sea from Middlesbrough to other parts of the country.[2] The total tonnage of pig iron shipped from Middlesbrough was thus equivalent to 38 per cent of the Teesside output. It may have included the produce of one or two works outside the region, but, on the other hand, no mention has been made of shipments from the Hartlepools.

The smelting industry's high rate of growth, at both national and regional level, was checked in 1873. As demand had overtaken supply, the price of Cleveland pig at Middlesbrough had risen from £2.9s.8d. per ton in 1871 to £4.17s.1d. in 1872 and £5.9s.2d. in the early part of 1873.[3] The onset of the depression in 1873 caused a sudden fall in prices, and they continued falling for the remainder of the decade. The lowest point came in 1879, when Cleveland pig sold for £1.17s.4d. per ton at Middlesbrough.

Despite the troubled nature of the 1870's, however, the Teesside pig iron makers managed to hold their own. One or two firms were forced into liquidation,[4] but that was due to

1. Data from the Quarterly Reports of the Middlesbrough Chamber of Commerce given in Kenwood, op.cit., Appendix 1.

2. Loc.cit.

3. Prices for the 1870's are given by Bell in The Iron Trade of the United Kingdom, op.cit., p.17.

4. Eg. Thomas Vaughan and Swan-Coates. See William Lillie, The History of Middlesbrough, Middlesbrough, 1968, p.101.

their interests in the wrought iron trade.[1] Most were able to survive until the market recovered. In 1881 there were actually four more smelting works in the region than there had been a decade earlier. Altogether, there were 27 smelting plants in 1881, with a total of 122 blast furnaces, 99 of which were at work. However, there were only 4 furnaces more in production then than in 1871. The increase in capacity during the 1870's was due to the buoyancy of the early part of the decade, when most of the new furnaces were built.

Using the methods described earlier, the output of pig iron in the Teesside region was estimated to have been 2,190,557 tons in 1881. This was nearly a million tons higher than in 1871, and indicates an expansion in output of about 72 per cent during the intervening decade. By 1881, Teesside contributed 83 per cent of the production of the North East, and 27 per cent of that of the United Kingdom. These statistics place the 1870's in a more realistic perspective than many contemporary reports did. Relatively and absolutely, the Teesside smelting industry was far stronger in 1881 than in 1871, despite the difficulties experienced during the years between those two dates.

The figures for pig iron shipments from Middlesbrough suggest that during the 1870's, the Teesside smelting industry owed its expansion more to the growth of external than internal demand, and more to an increase in coastwise

1. See Burns, op.cit., pp.28-29.

than export trade. Exports of pig iron from Middlesbrough rose from 269,000 tons in 1871 to 430,000 tons in 1881.[1] Coastal shipments, in the same period, increased from 214,000 to 501,000 tons.[2] The total shipments from Middlesbrough in 1881 were equivalent to 43 per cent of the region's output in that year, which was a higher proportion than a decade earlier. The total shipments from the region may well have constituted an even larger proportion of the regional output, but data for the other Teesside ports are not available. Germany and the United States, in that order, were the most important overseas customers, together taking about half the exports.[3] Scotland received the great bulk of the coastwise shipments.[4]

Teesside was affected quite as severely by the shift from wrought iron to steel in the 1870's as most districts. As elsewhere, the rail trade, long a staple source of demand for pig iron, was transformed by the development of mild steel. So far as the Teesside ironmasters were concerned, an important obstacle to the speedy adoption of mild steel was that Cleveland pig was unsuitable for conversion by the Bessemer process. This meant that they would have had to resort to imported phosphorous-free ore, and abandon the advantages conferred by the region's own orefield, had they switched from wrought iron to mild steel immediately. So long as it seemed possible that the wrought iron trade might

1. Kenwood, op.cit., Appendix L.

2. Loc.cit.

3. Richard Meade, The Coal and Iron Industries of the United Kingdom, London, 1882, p.398.

4. Loc.cit.

recover, most firms preferred to postpone the decision that would have committed them to that step. A few companies, however, correctly forecast the future and prepared to meet the challenge of steel. Bolckow and Vaughan began constructing a steelworks with its own special blast furnaces as early as 1874.[1]

A certain amount of Cumberland haematite had long been used on Teesside, largely as an admixture, and little more was demanded with the growing interest in steel production. Although 500,000tons of Bessemer pig were made in the region in 1880,[2] only 58,000 tons of Cumberland and Lancashire ore were used, and that was little more than in 1872.[3] Most of the ironstone consumed in the Bessemer furnaces came from Spain, where Teesside firms were active in opening mines, building railways and developing port facilities.[4]

The Location of Smelting Plants
on Teesside in the 1850's.

John Vaughan, of the firm of Bolckow and Vaughan, was the first to appreciate something of the commercial significance of the Cleveland orefield, and he was instrumental in establishing the smelting industry on Teesside. As was true of many contemporary firms, Bolckow's and Vaughan's partnership exemplified the union of merchant capital and technical

1. Burns, op.cit., p.23.
2. Meade, op.cit., p.396.
3. Ibid., p.403.
4. See Burns, op.cit.

experience so important to the iron industry in the nineteenth century.[1] The early years of the partnership provide an interesting picture of the foundation of smelting on Teesside.[2]

Henry Bolckow was from Mecklenburg, and had been trained to follow a commercial career - at first in Rostock and later in Newcastle upon Tyne, where he joined a firm owned by family friends and compatriots that was engaged in the corn trade. It was while he was living in Newcastle that Bolckow met John Vaughan, who was then a manager at Walker Ironworks but had learned his trade at Dowlais in South Wales. Vaughan interested Bolckow in the iron industry, and the two decided to go into business together, the former to supply the technical knowledge and the latter the capital and commercial experience.

Initially, however, the partners' interests lay in the finishing trades rather than smelting. Vaughan had the task of selecting a suitable location for a works, and he eventually chose a site at Middlesbrough which consisted of six acres of land fronting on the river. The reasons for this choice are not known but they do not appear to have been overwhelmingly strong; for an earlier and unsuccessful attempt had been made to buy land at Stockton.[3] Joseph Pease's

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1. See Birch, op.cit., p.8.

2. Unless otherwise indicated, the information relating to Bolckow and Vaughan has been drawn largely from: J.S. Jeans, Pioneers of the Cleveland Iron Trade, Middlesbrough, 1875; and R. Gott, Henry Bolckow : Founder of Teesside, Middlesbrough, 104 pp.

3. That was in 1839. See Gott, op.cit., p.24.

influence, resulting from his dual role as a director of the Stockton and Darlington Railway and one of the Owners of the Middlesbrough Estate, may well have been the most important factor which steered the partners towards Middlesbrough.

Pease was anxious to persuade industrialists to establish themselves in Middlesbrough. The town was still only a coal-shipping port, without an industrial base, and a decline in the coal trade could have led to it disappearing almost as quickly as it had grown. Such an event would have been disastrous for the Stockton and Darlington Railway, which was already in difficulty as a result of losing traffic and revenue to the railway company promoting Hartlepool as a port. Whatever his motives, and they may have amounted to little more than a paternal interest in the town he had been so largely responsible for creating, Pease was ready and able to support new ventures in Middlesbrough.[1] Bolckow and Vaughan were sold the land they required at a low price, and Pease gave them letters of introduction to businessmen with whom they were likely to deal. He was also quick to extol the virtues of Middlesbrough, pointing to the advantages conferred by its railway and shipping facilities in particular.

Bolckow and Vaughan opened their first works in Vulcan Street, Middlesbrough, in 1841. Shortly afterwards, the

1. See J.S. Jeams, op.cit., pp.128-48, and Jubilee Memorial of the Railway System, London, 1875, pp.231-45.

high and fluctuating price of Scottish pig iron persuaded them to consider smelting their own metal. On the strength of an assurance of adequate local supplies of iron ore, blast furnaces were built at Witton Park in 1845. It was soon found, however, that the local reserves of ore were insufficient, and had to be augmented with stone from Whitby. This was not a satisfactory solution to the problem. Iron ore had to be shipped to Middlesbrough and then forwarded by rail to Witton Park, and pig iron and coal had to be sent to Middlesbrough. The transport costs thus incurred were high enough to place the firm in jeopardy,[1] and it was this factor which made the search for alternative sources of iron ore a matter of great urgency.

Fortunately, the Main Seam was discovered at Eston in 1850. In the following year Bolckow and Vaughan began constructing three blast furnaces at the Vulcam Street works.[2] These were the first to be built in the Teesside region, and they were blown in during 1852.[3] Six more furnaces were put to work at Bolckow and Vaughan's new Eston Ironworks in 1853.[4] Other firms were quick to follow this lead, acquiring mineral royalties in the neighbouring hills

1. Gott, op.cit., p.28.

2. John Gjers, "A Description of the Ayresome Ironworks, Middlesbrough, with Remarks upon the Gradual Increase in Size of the Cleveland Blast Furnaces", Journal of the Iron and Steel Institute (1870-71), No.2, p.202.

3. John Marley, "Cleveland Ironstone : Outline of the Main or Thick Stratified Bed : Its Discovery, Application and Results in Connection with the Iron-Works in the North of England", Transactions of the North of England Institute of Mining Engineers, Vol.5 (1856-57), p.212.

4. Loc.cit.

and purchasing land for works. As early as 1854, there were already nine smelting plants in the region (Table 8.1).

Table 8.1

Blast Furnaces on Teesside in 1854.[1]

Works	Location	Firm	Number of Furnaces	Number of Furnaces in Blast.
Clarence	Port Clarence	Bell Brothers	3	3
South Durham.	Darlington.	South Durham Iron Co.	2	2
Eston	South Bank.	Bolckow & Vaughan	6	6
Cleveland	" "	T. Elwon and Co.	2	2
South Bank	" "	Bernhard Samuelson	2	2
Middlesbrough.	Middlesbrough	Bolckow & Vaughan	3	3
Tees	North Ormesby	Gilkes, Wilson, Leatham and Co.	4	4
Ormesby	" "	Cochrane & Co.	4	2
Stockton+	Stockton	Stockton Iron Co.	3	-

+still under construction.

Within the region, the early ironworks were relatively widely dispersed, with one at Darlington, one at Stockton, one at Middlesbrough and another opposite at Port Clarence, and the remainder strung along the southern bank of the Tees to the east of Middlesbrough. An attempt has been made to compare this seemingly random distribution with the pattern to be expected in the light of location theory.

There is no doubt that transport costs were of the utmost importance to the smelting industry, and that ironmasters were aware of the principles underlying location theory.

1. Data from Hunt, op.cit. (1855).

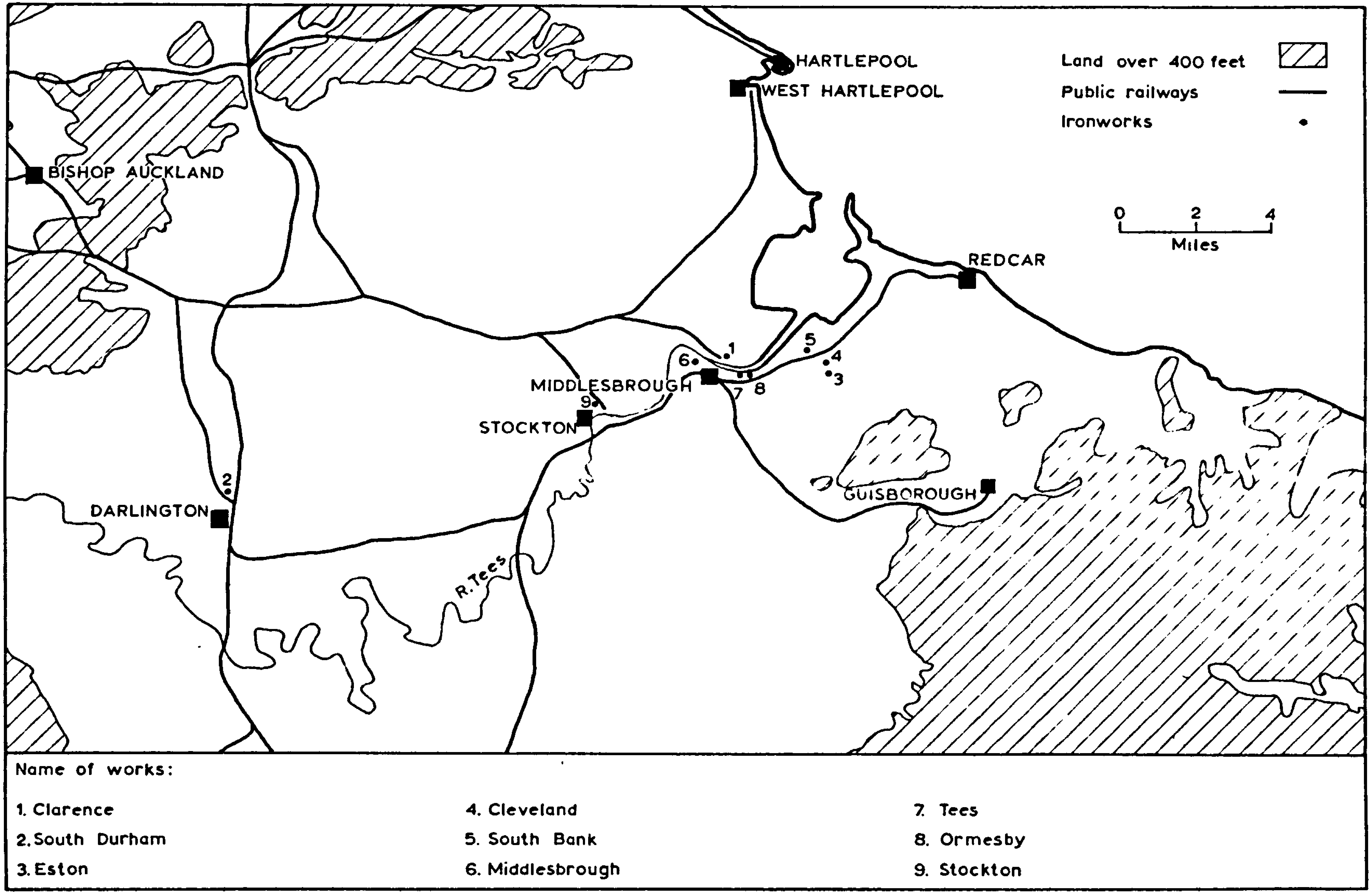

Figure 8.1 Distribution of Iron Smelting Works, 1854

As Bell commented,

> when the raw material weighs five or six times as much as the marketable product, and when the quantities dealt with are so large as in the case of iron in its various forms, the item of transport occupies a very important place in the cost of production.[1]

In the early part of the nineteenth century, approximately ten tons of coal were required to produce one ton of pig iron.[2] The amount of iron ore used varied according to the iron content of different ores, but it was always much less than the fuel input. Small quantities of chalk or limestone were also needed, to act as a flux, but these were of little significance locationally. The overwhelming weight of the fuel dominated the smelting industry, and confined it to coalfield districts. However, transport costs were also high for iron ore, particularly in areas without railways, and they prevented the industry from establishing itself in coalfield districts which did not have resources of ore as well as fuel.

By 1840, technical progress - including the introduction of the 'hot-blast' - had so reduced fuel consumption in the blast furnace that the quantities of coal and ironstone required to produce one ton of pig iron were approximately equal in most parts of Britain.[3] Theoretically, at least,

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1. Bell, <u>Principles of the Manufacture of Iron and Steel</u>, <u>op.cit</u>., p.595.

2. Howard G. Roepke, <u>Movements of the British Iron and Steel Industry, 1720 to 1951</u>, Urbana, Illinois, 1956, p.27. Others have put the figure lower, but this is not important; there is no doubt that the fuel input was dominant. See Walter Isard, "Some Locational Factors in the Iron and Steel Industry Since the Early Nineteenth Century", <u>Journal of Political Economy</u>, Vol.56 (1948), pp.203-205.

3. Roepke, <u>op.cit</u>., p.30 and p.48.

the smelting industry had thereby obtained greater locational freedom; it was now no longer dominated by one material. The optimum location might therefore be thought to have been some intermediate point between the sources of the various raw materials and the market. In fact, however, this was not the case, and there was no significant alteration in the industry's distribution in Britain. Smelting remained highly concentrated in certain coalfield areas, because it was there that the major known deposits of iron ore occurred. The fuel and the ore were in that sense spatially coincident, and together they dominated the location figure.

The discovery of iron ore in Cleveland marked a significant turning-point, in that a major body of ore had been found which was not in a coalfield. The smelting industry was thus free to test its theoretical locational independence of fuel sources. In order to determine its optimum location, it is necessary to examine the technical proficiency of the industry at that time in the North East. The earliest blast furnaces built on Teesside were modelled on the most modern designs which the older iron-producing districts, such as South Staffordshire, had to offer.[1] The Teesside ironmasters consequently had the advantage of being able to draw upon a great wealth of experience and practical knowledge, but there were also disadvantages to this policy. Conditions varied between one district and another, and the

1. Gjers, op.cit., p.202.

design which was best suited to Staffordshire was not necessarily the best for Cleveland.

The first blast furnaces built in the Teesside region were the three begun in 1851 at Bolckow and Vaughan's Middlesbrough Ironworks. They were 42 feet in height and 15 feet in diameter at the boshes, the widest part, and they had a capacity of 4,566 cubic feet.[1] For the North East, these were comparatively large. At Wylam on Tyne, for example, Bell Brothers had been operating a furnace since 1844 which was a mere 2,300 cubic feet in capacity.[2] However, when it came to building the Clarence works, at Port Clarence, in 1853, Bell Brothers also decided in favour of larger furnaces. The original Clarence furnaces were 47½ feet high, 16½ feet in diameter, and 6,174 cubic feet in capacity.[3] Very similar designs were adopted by other firms in the region.

In addition to being lafge, the early Teesside furnaces were also of an advanced style in that they had fitted tops and made use of a heated blast, innovations which had still not been accepted in many districts.[4] Under the prevailing conditions, the weekly output of such furnaces was about

1. Ibid., p.203.

2. Greville Jones, "A Description of Messrs. Bell Brothers' Blast Furnaces from 1844-1908", Iron and Coal Trades Review, Oct.2, 1908, p.1423.

3. Gjors, op.cit., p.203.

4. Carr and Taplin, op.cit., pp.50-55; and Birch, op.cit, pp.178-89.

100 tons.[1] The amount of fuel used varied considerably between works, according to furnace design, the quality of the coke and the system of management. Under John Vaughan, and later under equally able managers, Bolckow and Vaughan's furnaces were generally considered to be amongst the best and most economical on Teesside, and in the early 1850's they used about 40 cwts. of coke to make one ton of pig iron.[2] Slightly lower figures were recorded at some works, but over a period of several months 40 cwts. was probably quite representative of the average consumption in well-managed works. The coal-equivalent of this amount of coke was approximately 67 cwts.[3]

Cleveland iron ore had an average iron content of 30 per cent.,[4] the proportion being rather higher at the northern edge of the field and rather lower to the south. Bell stated that a mere 0.5 per cent of the iron was lost during the smelting process.[5] On the basis of these figures, approximately 67 cwts. of ironstone would have been consumed in making one ton of pig iron. The weight of the ore required

1. John Gjers, "A Short Historical Sketch of the Rise and Progress of the Cleveland Iron Trade...", Transactions of the Chesterfield and Derbyshire Institute of Mining, Civil and Mechanical Engineers, Vol.3 (1875), p.70.

2. Loc.cit. This figure was also given by many of Gjers's contemporaries.

3. Only 60 per cent of the coal's weight was normally retained by the coke made in Durham. See Bell, Principles of the Manufacture of Iron and Steel, op.cit., pp.47-50.

4. Gjers, "A Short Historical Sketch of the Rise and Progress of the Cleveland Iron Trade", op.cit., pp.68-69.

5. Isaac Lowthian Bell, "On the Development of Heat and its Application in Blast Furnaces of Different Dimensions", Journal of the Iron and Steel Institute, (1869-70), p.37.

was thus equal to that of the coal. Furnaces of the dimensions normal in the region at that time also used about 14 cwts. of limestone per ton of pig iron made.[1] If transport costs alone are considered, then it would appear that the smelting industry's optimum location must have been at some intermediate point; neither the weight of the product nor that of any localized raw material was dominant. However, account must also be taken of the partial processing to which the various materials were subjected prior to being charged to the blast furnace.

Durham coal was unsuitable for direct use in the blast furnace and coke was consequently the only fuel employed for smelting on Teesside.[2] For metallurgical purposes, the best coking coal was that found in the Shildon-Crook area of south-west Durham.[3] It contained volatile materials, and other unwanted substances, equivalent to 30 per cent.of its weight, and hence had a coke potential of 70 per cent.[4] However, the beehive ovens, which were traditional in the North East, were comparatively wasteful, and in practice

1. This figure is a composite one, but it is of the correct magnitude. See Bernhard Samuelson, "Description of Two Blast Furnaces Erected in 1870 at Newport, near Middlesbrough", Proceedings of the Institution of Civil Engineers, Vol.32 (1871).

2. See R.A. Mott (ed.), The History of Coke Making and of the Coke Oven Managers' Association, Cambridge, 1936, chap.7.

3. J.S. Jeans, Notes on Northern Industries Written for the Iron and Steel Institute of Great Britain, London, 1877 , p.68.

4. Bell, Principles of the Manufacture of Iron and Steel, op.cit., p.49.

only 60 per cent of the weight of the coal was actually converted into coke.[1] Coking was normally undertaken at the pit-head,[2] since no attempt was then made to recover the waste products, and this practice meant that the attractions of the coalfield for the smelting industry were less than would otherwise have been the case. Only 40 cwts. of coke, as opposed to 66.6 cwts. of raw coal, had to be carried to the smelting works per ton of pig iron made.

It was also normal for Cleveland ironstone to be calcined prior to its being charged to the blast furnace. This process, which amounted to a slow roasting at a relatively low temperature, had the intended effect of ridding the ore of quantities of unwanted oxygen, water, carbonic acid and sulphur.[3] It reduced the weight of the ironstone by 25 per cent, or expressed in another way, the process raised the iron content to an average of 40 per cent.[4] The main advantage gained from calcination was that it allowed more efficient use to be made of the blast furnace, which was an

1. Loc.cit. This was true even in 1884, when Bell wrote this work.

2. This continued to be the case until integrated works, with by-product recovery ovens, began making their own coke towards the end of the nineteenth century. See S.H. Beaver, "Coke Manufacture in Great Britain : A Study in Industrial Geography", Papers and Transactions of the Institute of British Geographers, No.17 (1951), pp.133-48.

3. See Isaac Lowthian Bell, Chemical Phenomena of Iron Smelting, London, 1872, Section 38.

4. Ibid., p.304; and Gjers, "A Short Historical Sketch of the Rise and Progress of the Cleveland Iron Trade", op.cit., p.69.

expensive piece of capital equipment.[1] If the ore was partially reduced beforehand, then there was less work to be done in the blast furnace, which could consequently produce more pig iron in a given period of time. In addition, there were savings in labour and fuel costs; calcination required the attention of fewer men than smelting, and it could be done with poorer quality and cheaper fuel. Finally, it was also found that there was an improvement in the quality of the iron once this practice was adopted.

Calcination could be undertaken without benefit of any special facilities, and in Scotland and some other districts the traditional method of roasting the ore in heaps in the open-air was retained, even into the twentieth century in some cases.[2] In Cleveland, however, early use was made of special kilns, which were inexpensive to build and operate and gave better control over the calcining process.[3] The cheapest slack coal could be used quite satisfactorily in the kiln, whereas coke was necessary in the blast furnace. Slack coal was usually regarded by the Durham colliery managers as so much rubbish to be disposed of, and in the early

1. A detailed account is available in : Bell, Chemical Phenomena of Iron Smelting, op.cit., Section 38. Most of the information concerning calcining has been abstracted from this source.

2. Dorman, Long and Co. still practised the method at the firm's open-cast mines in Rutland in the 1930's. Information from : H. Palmer, "A Talk on Ironstone and Limestone Delivered to Members of the Head Office Staff, Dorman, Long and Co. Ltd., at Brunswick Street", (mimeographed), October 12th, 1936.

3. It was important to avoid overheating the stone, since that tended to fuse it and hence obstruct the passage of the blast in the furnace.

years of the Teesside iron industry it was given away without charge.[1] Later, when it was realised to be not entirely useless, it was sold at one-third the price of coke.

It is difficult to determine when the calcining kiln came into general use on Teesside. Certainly, it was not adopted immediately, but it was a standard piece of equipment by 1864, and probably quite common by the late 1850's.[2] Generally, however, calcining did not affect the location issue. Although there were kilns adjacent to a few mines in Cleveland, the great majority were built at the ironworks. The full weight of the raw ironstone therefore had to be transported from mine to blast furnace. This meant that transport costs were higher than they need have been, but not from inattention. When it had been calcined, the ironstone was in a very friable condition and tended to deteriorate in transit, crumbling under the pressure and incessant jolting. On balance, the wastage and deterioration sustained outweighed any savings in transport costs which accrued from locating the kilns near the mines.[3] By incorporating them in the smelting plants, the ironmasters may also

1. Evidence of I.L. Bell to the "Commissioners Appointed to Inquire into the Several Matters Relating to Coal in the United Kingdom", Report, Vol.1, 1871, p.96.

2. See J.G. Beckton, "Construction of Blast Furnaces in the Cleveland District", Proceedings of the Institution of Mechanical Engineers, (1864), p.250.

3. This was an old problem. When the Walker Ironworks, on Tyneside, began using Whitby stone, Lowthian Bell arranged for the ore to be calcined at the mines to save transport costs. This practice was abandoned once it was found that other costs arose. See Joseph Bewick, Geological Treatise on the District of Cleveland in North Yorkshire : Its Ferruginous Deposits, Lias and Oolites, with Some Observations on Ironstone Mining, Newcastle, 1861, p.26.

have entertained hopes of cutting overall fuel costs, since there was a possibility of burning waste gas from the furnaces in the kilns. Initially, however, coal was used, and about 2.2 cwts. were required to calcine sufficient ore to yield a ton of pig iron.[1]

It was also customary to calcine the limestone, again to reduce the amount of waste materials fed into the blast furnace. As with the iron ore, the limestone was roasted in kilns, often together with the ore, and this was usually done at the works rather than the quarry. The quantity of fuel required was very small; perhaps 0.75 cwts. of small coal would be used in calcining the limestone needed to produce a ton of pig iron.[2]

The elements of the location equation may now be summarised for the average Teesside smelting works in the 1850's. To produce 20 cwts. of pig iron, the following quantities and types of localized materials were required : 40 cwts. of coke, 3 cwts. of small coal, 14 cwts. of limestone, and 66.7 cwts. of iron ore. With a materials index of approximately 124 : 20, the materials, together, were clearly much heavier than the product. The iron ore was the heaviest individual input, but it was not dominant; the other materials plus the product had a greater weight. It would appear, therefore, that the optimum location for the smelting industry was at a point intermediate between the market and

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1. Bell, Chemical Phenomena of Iron Smelting, op.cit., p.324.

2. See Samuelson, op.cit., p.332.

the sources of the various materials. This could be approximated by using the iterative technique developed by Kuhn and Kuenne.[1]

Effectively, however, the location problem is amenable to simpler solution, because of the disposition of materials and markets and the system of transport on Teesside. As indicated earlier, the coke used by the smelting industry was obtained from south-west Durham. The limestone came from Weardale, in the same area. Iroh ore was initially obtained from the Eston and Upleatham Hills, and later from the Cleveland Hills. There was more than one market, since there were finishing works and shipping facilities in various places on Teesside, but Middlesbrough may be regarded as the main market centre to simplify the discussion. The only practicable means of transporting materials and produce within the region was provided by the railway network, which had not been built to serve the needs of the smelting industry exclusively. The location problem was, therefore, essentially one-dimensional; the choice of sites for a smelting works was restricted to points on the existing railway network or near enough to it to be connected at very little cost.

Coal, coke and limestone for the industry originated from south-west Durham, and ironstone from Cleveland. Bet-

1. H.W. Kuhn and R.E. Kuenne, "An Efficient Algorithm for the Numerical Solution of the Generalized Weber Problem in Spatial Economics", Journal of the Regional Science Association, Vol.8, (1962), pp.21-33.

ween these two areas lay the market for pig iron. The three points in the location figure were inter-connected by two railway systems : the Stockton and Darlington, and the West Hartlepool lines. The former ran from Crook, via Darlington, to Stockton, Middlesbrough and Redcar. The latter, which had been built by the Clarence Railway Company but was operated in the 1850's by the West Hartlepool Harbour and Railway Company, began in the Bishop Auckland district and ran from there to Port Clarence, with a branch to Stockton and another to the Hartlepools.

Effectively, therefore, the sources of the materials used in smelting and the market for the product were points on a line rather than points in two-dimensional space.[1.] The point of minimum aggregate movement, or least transport cost, must also have been on that line. Determining its exact location is analagous to finding the point of minimum aggregate travel, which is a well-known problem in the context of shopping studies.[2.] In its one-dimensional form, that problem has a simple solution ; the point of minimum aggregate travel

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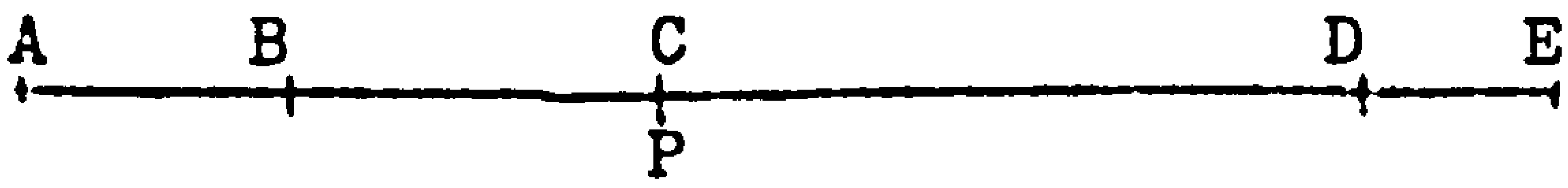
1. This type of situation is described by Martin Beckmann, in his Location Theory, New York, 1968, pp.21-22.

2. The problem usually takes the form of finding the point at which a shop, or similar facility, can be located in such a manner as to minimize aggregate consumer travel.

is the median point of a linear distribution.[1] This solution may be applied to the problem of finding the point on a line where transport costs will be minimized.[2]

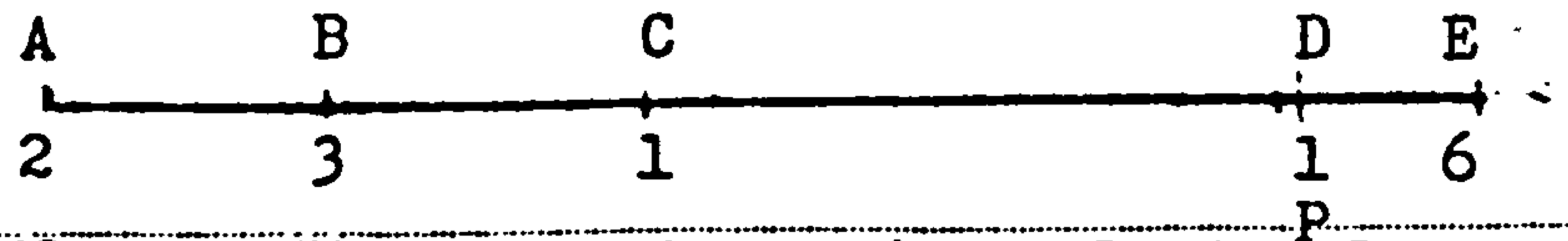
The line AE, in Figure 8.2 , has five points on it, with unequal distances between each successive pair. If another point, P, is sought, such that the aggregate distance between it and each of the original points is at a minimum, it will be found to be at C, which is the median of the distribution. In the context of the location

Figure 8.2



problem, however, points A, B, C, D and E are of unequal weight, as in Figure 8.3 . Because of these weightings, P is now located at D, the new median position. It is at D that

Figure 8.3



1. W. Alonso, "Location Theory", in <u>Regional Development and Planning</u>, ed. J. Friedmann and W. Alonso, Cambridge, Massachusetts, 1964.
In two-dimensional space, however, the median can only be approximated,. See : P.W. Porter, "What is the Point of Minimum Aggregate Travel?" <u>Annals of the Association of American Geographers</u>, Vol.53(1963), pp.224-32, and "A Comment on 'The Elusive Point of Minimum Travel'", <u>Annals of the Association of American Geographers</u>, Vol.54(1964), pp.403-406; and A.Court, "The Elusive Point of Minimum Travel", <u>Annals of the Association of American Geographers</u>, Vol.54(1964), pp.400-403.

2. A general discussion of the significance of the median point in a spatial distribution is contained in : James A. Quinn, "The Hypothesis of Median Location", <u>American Sociological Review</u>, Vol.8 (1943), pp.148-56.

there is an equal 'weight' of points on either side, and that defines the median. This solution is valid regardless of the distances between the various points.

Applying these findings to the Teesside smelting industry, it can readily be seen that transport costs would have been minimized if the blast furnaces were located at the market. It is worth repeating that this was not because the market was dominant, in Weber's sense, but because the material sources and the market were effectively points on a line and the market represented the median location. Figure 8.4 illustrates this situation diagrammatically. The figures below the line are the weightings attached to L (limestone), C (coal and coke), M (market) and O (iron ore). They are, of course, the

Figure 8.4

respective weights of the various materials and the product, expressed in cwts. per ton of pig iron. If each cwt. is regarded as one point, then it can be seen that the median point is one of those at M. The least transport cost location, the point where total movement was minimized, was therefore at M.

This conclusion is interesting in that it has been shown how a 'vertex solution' to the location problem can arise when no single corner of the location figure is dominant. More immediately, it has also been demonstrated that the market was the optimum location for Teesside pig-iron makers in the 1850's, if transport costs alone are considered. This was true whether Middlesbrough or some other place - Stockton or Darlington, for example - is taken as the market, so long as it lay between the coalfield and the orefield. Similarly, either the orefield or the coalfield would have been the optimum location had it been situated between the other point and the market.

So far. it has been implicitly assumed that the optimum location was the point where production would have involved the minimum total movement of the materials and the product, and there is no need to alter this assumption. Neither differential labour nor agglomeration economics can have been sufficient to have placed the optimum location for the smelting industry at any other point.

By the standards of the 1850's, iron smelting was a highly mechanized industry, more capital - than labour - intensive, and labour costs were of relatively small importance.[1.] In 1878, labour contributed only 4s. per ton to the total cost of producing pig iron,[2.] and the figure cannot have been much higher twenty years earlier. More important, the direct cost of labour probably did not vary

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1. See Isard, "Some Locational Factors in the Iron and Steel Industry Since the Early Nineteenth Century", op.cit., p.203.

2. Burnham and Hoskins, op.cit., p.152.

spatially within the region for the smelting industry - which would have meant that there was no advantage in seeking a location other than at the point where transport costs were lowest -, while the indirect cost may well have been higher away from the market. The industry was new to Teesside and, initially at least, it depended on immigrants to the region for its skilled, and even much of its unskilled, labour. This meant that wages had to be comparable with those in other iron-producing districts, regardless of where a smelting plant was located on Teesside. Moreover, if the iron-masters had adopted locations in rural areas, they would have been obliged to make larger investments in housing and other facilities, which would indirectly have added to the cost of labour.

Similarly, agglomeration economies, though impossible to measure, must have tilted the balance of advantage even further in favour of the towns. The smelting industry had extensive land requirements, which often necessitate a non-urban location, but the Teesside towns were then so small and compact that large, cheap sites were available within a few minutes' walk of their respective centres. As a positive attraction, the main towns were the nuclei of the transportation system. They all had railway terminals, and all except Darlington were located on tidal water and already had shipping facilities. In addition, such manufacturing industries, and skills, as the region possessed were located in the main towns, which meant that at least some of the ancillary trades and crafts required by the ironmasters were close at hand.

Finally, account must be taken of the fact that transport rates varied according to the distance of the journey and the type of good being carried. The evidence available suggests, however, that this does not require any alteration to the initial conclusion concerning the optimum location of the smelting industry. During the 1880's, and presumably earlier, minerals were carried at uniform rates on the railways on Teesside, and the rate for pig iron was about 50 per cent higher than that for minerals.[1] This can be allowed for by raising the weight of the pig iron in the location figure by 50 per cent. Thus, in terms of transport costs, one ton of pig iron 'weighed' 30 cwts.

By referring again to Figure 8.4, it can be seen that this adjustment does not affect the position of P, the median or optimum location. Indeed, if L, C and O retain their original values - as they must, since raw materials were carried at the same rate -, then only a decrease of more than 10 cwts. in the value of M would require the relocation of P. Any increase for M would merely serve to confirm it as the location of P. In other words, the fact that a higher rate was charged for transporting pig iron than raw materials gave the former a greater economic weight. By doing so, it reinforced the market's attraction for the smelting industry. If the differential in transport rates had been

1. This was true in the early 1880's, according to figures given by Bell and by Samuelson. See : Bell, The Iron Trade of the United Kingdom, op.cit. pp.102-108, and Principles of the Manufacture of Iron and Steel, op.cit. pp.596-97.

sufficiently large, of course, the economic weight of the product would have exceeded that of all the raw materials together, and the market would have been dominant in its own right.

The actual distribution of blast-furnace plants in the region in 1854 compares favourably with the theoretical optimum pattern, once it is recognised that there was more than one market. At first glance, however, the location of the South Durham Ironworks at Darlington appears anomalous. The works was about twelve miles, by rail, from the nearest shipping facilities, at Stockton. To the extent that pig iron was sent to places outside the region, therefore, Darlington was a poor location for a smelting works, since transportation costs must have been unnecessarily high. On the other hand, Darlington was the best location for a works intended to supply a market within the town itself.

In 1854 there could have been very little demand in Darlington for pig iron, since the town's first finishing works - a small forge - was not opened until that year,[1.] and the South Durham Iron Company must have built its smelting plant largely in the hope that a market would develop there. The situation changed considerably in 1858, when the South Durham Company came to an agreement with William Barningham under which the latter was sold some land adjacent to the blast furnaces, for a low price, as a site for a fin-

1. Jeans, Jubilee Memorial of the Railway System, op.cit. p.280.

ishing works.[1] This agreement was advantageous to both parties; Barningham obtained a good site cheaply for his Darlington Ironworks, and was assured of a supply of cheap pig iron, while the South Durham Company acquired a guaranteed market which must have removed some of the disadvantages Darlington had as a location for blast furnaces.

Construction of the Stockton Ironworks also began in 1854. If the intention was to market crude pig iron outside the region, then Middlesbrough would have been a better location, since overland transport costs would have been lower. In this context, it should be pointed out that so long as the input of iron ore exceeded the total input of coal, coke and limestone, then the best possible location for export production was the market nearest to the orefield. This was because it was cheaper to transport the requisite quantities of coal, coke and limestone than it was that of the ironstone over a given distance. However, Stockton, with its small but various engineering industries,[2] had long provided a market for pig iron, and the Stockton Iron Company may well have been looking to its future expansion. Certainly, it was cheaper to supply the Stockton market by assembling the materials and manufacturing pig iron there rather than elsewhere. This remained true so long as none of the raw materials was dominant in Weber's sense.

1. Ibid., pp.282-84.

2. See Henry Heavisides, The Annals of Stockton-on-Tees, Stockton, 1865, pp.151-55.

The other smelting works within the Teesside region in 1854 were all located close to Middlesbrough, though only Bolckow and Vaughan's original blast furnaces were actually in the town itself. Bell Brothers' Clarence Ironworks was situated on the north bank of the Tees at Port Clarence, immediately opposite Middlesbrough. It had an extensive site, with a river frontage, and virtually unlimited scope for expansion, since there had been no other industrial development on that side of the Tees. However, the site had obvious disadvantages too. One was that the land was very low lying and even more susceptible to flooding than land on the southern bank of the river.

More important, the Clarence works, which had good rail connections with the coking district of south-west Durham, was separated from the Cleveland orefield by the Tees. In the absence of a bridge, it was necessary to ferry the ore across the river by keel boat, a procedure attended by both difficulty and expense. Rather ingenuously, Jeans commented that

> to one of less penetration than Mr. [Isaac Lowthian] Bell, the site selected would have seemed anything but congenial for such an enterprise. But the new firm were [sic] alive to advantages that did not altogether appear on the surface.[1]

If Jeans was aware of any hidden advantages possessed by the Port Clarence site, he did not reveal them, and it is doubtful if there were any. While coke probably had less

1. Jeans, Pioneers of the Cleveland Iron Trade, op.cit. p.167.

far to travel than it had to works on the south bank of the Tees, because the Clarence Railway was more direct than the Stockton and Darlington line, this was outweighed by the difficulty of obtaining iron ore.

Bell Brothers selected the Port Clarence site as part of a wider agreement, and its disadvantages should be set against other considerations. The firm's main preoccupation at the time was with obtaining an adequate supply of iron-stone. In 1852 or 1853, when Lowthian Bell began contemplating the establishment of a works on Teesside, there were doubts about the extent of Cleveland's iron ore resources. Bolckow and Vaughan had already leased the mineral rights over the greater part of the Eston Hills, and the Derwent Iron Company had done similarly at Upleatham. This left only small royalties, of which that at Normanby was the best, to the north of the vale of Guisborough. At that stage, Bell seems to have had little interest in exploring the district to the south, perhaps feeling like Henry Bolckow that

> ... it was not enough to discover iron [ore] - people were always doing that in Cleveland - the thing was to discover it where and when it could be of use - to discover it near some convenient place for using and shipping, or railwaying it.[1]

The Normanby estate was owned by Ralph Ward Jackson, who was also the principal of the West Hartlepool Harbour and Railway Company, which operated the Clarence line.

1. Landor Praed, A History of the Rise and Progress of Middlesbrough, Newcastle, 1863, p.7.

Jackson wanted to ensure that his railway company obtained some of the traffic being generated by the development of the iron industry on Teesside, and to that end he made it a condition of the lease to the Normanby royalty that the lessee should build blast furnaces at Port Clarence.[1] Bell Brothers accepted this condition, presumably thinking that it would be a comparatively simple matter to build a short railway from Normanby to the Tees, from where the ore could be ferried to Port Clarence. However, the Stockton and Darlington Railway rigorously opposed Jackson's schemes for constructing railways south of the Tees, and for a bridge across the river,[2] with the result that iron ore from Normanby had to be sent on a circuitous journey via the Middlesbrough and Guisborough Railway, and a number of lines in the vicinity of Middlesbrough, before it could be ferried across the Tees.

It was not until 1860 that Parliament gave permission for the building of a short railway north from Normanby to the river, and for the establishment of a private ore jetty at Cargo Fleet. The construction of these facilities must have cut transport costs substantially, but there remained the expense and difficulty of ferrying ironstone across the river. It is difficult to avoid the conclusion that the Clarence works would have been better located on the southern bank of the Tees, a conclusion supported by the fact

1. See Robert Wood, West Hartlepool, West Hartlepool, 1967, p.72.

2. For an account of the struggles between the rival railway groups see Tomlinson, op.cit., pp.563-76.

that no other firm chose the north bank, even when land became scarce at Middlesbrough.

Of the other works in existence in 1854, two were located at Cargo Fleet, to the east of Middlesbrough Dock. These were the Ormesby and the Tees Ironworks, both of which had river-front and otherwise admirable sites. The South Bank, Eston, and Cleveland works were all further east still, in the area later to become Grangetown and South Bank. All three drew their supplies of iron ore from Bolckow and Vaughan's Eston mines,[1.] to which they were connected by a private railway, and they all had private wharves for shipping that part of their output not used locally.

On the whole, therefore, the actual distribution of smelting works in the Teesside region in 1854 seems to have approximated quite closely to the optimum pattern. The location of a works at Darlington was premature, perhaps, and the Port Clarence site was poor, but these were minor aberrations. Whether or not the ironmasters consciously sought to minimize their transport costs is a question which cannot be properly answered without access to personal records, but their actions suggest that they did, so far as that was possible.

1. Even before it was built, John Vaughan offered to supply Samuelson's South Bank works with ore from Eston, an offer which was readily accepted. See Jeans, Pioneers of the Cleveland Iron Trade, op.cit. p.220. Not long after it was opened, the Cleveland Ironworks was purchased by Bolckow and Vaughan, and became dependent then on the Eston mines, if it had not been so earlier. The Eston works, of course, was owned by Bolckow and Vaughan.

The Location of Smelting
Plants on Teesside in 1881.

Between the early 1850's and 1881, the terminal date of the present study, immense changes affecting the Teesside smelting industry occurred. In origin, some were internal and others external to the regional industry. So far as the industry itself is concerned, economies resulting from technical progress and increasing returns to scale grew rapidly, until the 1870's at least, and gave lower real unit costs. In turn, falling costs further stimulated demand, which was already rising independently, both locally and outside the region.

Demand, indeed, outstripped the growing scale of production, and the industry was able to establish more as well as larger plants. To some extent, this resulted in adjustments to the distribution of the smelting industry, since new sites were required. Much more significant in this context, however, were changes in blast-furnace technology, notably those which contributed to a reduction in fuel consumption per unit of output. As they had a fundamental influence on the industry's locational requirements, these changes demand a detailed examination.

Contemporary observers and historians alike have stressed the importance of the contribution made to the lowering of fuel consumption by the increasing size of the blast furnace. Even during the 1850's there was a tendency on Teesside to build rather larger furnaces than normal, though the initial object was to obtain scale economies, by raising the productivity of the furnace.[1] Prior to 1858, however, this tendency was not very marked; some ironmasters were ready to experiment in that direction, but a lack of experience and the amount of capital already invested in their plants made them proceed cautiously. At the time, the largest blast furnace in the region was one at Cochrane's Ormesby Ironworks, which was 55 feet high and 16 feet in diameter at the boshes.[2] This was capable of the 'extraordinary' feat, as it was then considered, of producing 150 tons of pig iron in one week.[3]

Opinions on the subject were divided, but some of the ironmasters claimed that the larger furnaces used relatively less fuel than those of more traditional dimensions. John Vaughan believed this to be the case, and in 1858 he rebuilt one of Bolckow and Vaughan's furnaces at Witton Park to a height of 61 feet.[4] Gjers regarded this step as the first deliberate attempt to obtain fuel economies by increasing the size of a furnace.[5] The results were evidently satisfactory; for in 1861 Vaughan rebuilt two furnaces at the

1. See Bell, <u>Principles of the Manufacture of Iron and Steel</u>, <u>op.cit.</u>, p.23.

2. Gjers, "Description of the Ayresome Ironworks", <u>op.cit.</u>, p.204.

3. <u>Idem.</u>, "A Short Historical Sketch of the Rise and Progress of the Cleveland Iron Trade ...", <u>op.cit.</u>, p.70.

4. This and subsequent references to the dimensions of blast furnaces, unless otherwise indicated, are from the chronological tables in Gjers, "Description of the Ayresome Ironworks...", <u>op.cit.</u>, pp.204-207.

5. <u>Ibid.</u>, p.203.

Middlesbrough Ironworks, making them 75 feet high. These were then a full 15 feet taller than any others on Teesside.

Whitwells had more capacious furnaces at Thornaby, where the diameter had been increased more than the height, but Vaughan considered extra height alone to be the origin of fuel economies. Lowthian Bell was inclined to agree with him at that time, although later his views changed, and he made plans to build two furnaces to a height of 80 feet at the Clarence works.[1] Other ironmasters followed suit, placing their trust in the judgement of Vaughan and Bell rather than making their own assessments. Thomas Vaughan, John's son, built furnaces 81-feet high at his own works in South Bank in 1864, and his father's company went as far as 95½ feet a year later at the Cleveland works.

By 1871, there were only two blast furnaces remaining of all those erected on Teesside prior to 1859. The others, not all of which were worn out, had been replaced by larger versions.[2] The trend of enlargement reached its most extreme manifestation at Ferryhill, which was actually outside the region, where furnaces were constructed to a height of 103 feet in 1868, and others of 105 feet were planned.[3] By then, however, those ironmasters who had not found reason to alter their faith in the efficacy of greater height were running out of the courage of their convictions. More cautious attitudes had come to prevail generally.

1. Bell, Chemical Phenomena of Iron Smelting, op.cit. p.xxii.

2. Gjers, "Description of the Ayresome Ironworks....", op.cit., p.208.

3. Jeans, Pioneers of the Cleveland Iron Trade, op.cit. p.211

Two separate but related issues dominated the technical discussions of Teesside ironmasters during the 1860's : the origin of fuel economies and their potential limits. Both affected blast furnace design. According to Edward Williams, who became the manager of Bolckow and Vaughan's works when the company turned public in 1864, John Vaughan was a great believer in the virtues of tall furnaces.[1.] Williams, himself, was of the same opinion, and he pointed to the results obtained at Bolckow and Vaughan's works as proof of its correctitude.

Charles Cochrane, on the other hand, after some early hesitation,[2.] tended to favour increasing the diameter of the furnace. In 1870 he built two blast furnaces at his Ormesby works which were 90 feet in height and 30 feet in diameter, and had a capacity of 41,149 cubic feet each. He thought that even larger furnaces were desirable,[3.] on the grounds of fuel economy, and disagreed with Edward Williams, who resolutely maintained that "no economy of coke resulted from increasing the capacity of a furnace in any direction other than in its height".[4.] Cochrane found an ally

1. See the discussion following Isaac Lowthian Bell's paper : "On the Development of Heat and its Appropriation in Blast Furnaces of Different Dimensions", <u>Journal of the Iron and Steel Institute</u>, (1869-70), No.1, pp.128-29.

2. In 1864, he declared that it was questionable whether there was any value in increasing the diameter of a furnace beyond 21 feet. See his paper : "On the Working and Capacity of Blast Furnaces", <u>Proceedings of the Institution of Mechanical Engineers</u>, (1864), p.171.

3. <u>Idem</u>, "On the Further Utilisation of the Waste Gas from Blast Furnaces, and the Economy of Coke Due to Increased Capacity of Furnace", <u>Proceedings of the Institution of Mechanical Engineers</u>, (1869), pp.21-44 and 45-76; and see Cochrane's contribution to the discussion following Samuelson's paper (<u>op.cit.</u>) in 1871.

4. Discussion following Samuelson, <u>op.cit.</u>, p.364.

in Bernhard Samuelson, who was engaged in building very large blast furnaces at Newport.[1] Twelve years later, Samuelson was unrepentant, declaring that in his experience wide furnaces had always proved more efficient users of fuel than narrow ones.[2]

To add greater complexity to the cross-currents of the debate, Williams was in agreement with both Cochrane and Samuelson when he argued, in 1871, that the larger the furnace, the better from the viewpoint of fuel consumption.[3] He was concerned, like they were, only with the practical limit to fuel economies from larger furnaces; there obviously was a theoretical limit, but it was believed to be far in excess of what could be achieved in practice. Cochrane went so far as to calculate the theoretical minimum figure for coke consumption in a blast furnace producing Cleveland pig. This, he found to be rather less than 7½ cwts. for a furnace of optimum size,[4] which suggested that the Teesside ironmasters had much scope for improvement, as they used three or four times that amount.

By 1869, however, Lowthian Bell had come to the conclusion that no more advantage was to be gained from still

1. Ibid., pp.367-69.

2. Discussion following R. Howson, "On Blast Furnace Economy in Relation to Design", Journal of the Iron and Steel Institute, (1883), No.2, p.633.

3. Discussion following Samuelson, op.cit., pp.349-69.

4. Cochrane, "On the Further Utilisation of the Waste Gas from Blast Furnaces....", op.cit., p.33.

larger furnaces.[1] He considered Cochrane's giants to be quite 'extraordinary', and rejected his suggestions on the optimum size of a blast furnace as well as those on the minimum figure for fuel consumption. Bell also impugned the accuracy of some returns for coke consumption at the Newport works of Bernhard Samuelson, saying that his own calculations left him with the opinion that they were impossibly low even in theory.[2] In addition, Bell thought Williams to be mistaken in attributing so much importance to the height of a furnace, arguing that it was the cubic capacity which was critical, not height or diameter.[3] For practical purposes, he believed that a cubic capacity of 11,000 to 15,000 feet was quite sufficient, regardless of the other dimensions of the furnace.

There was, therefore, a considerable measure of disagreement amongst the ironmasters. All, however, were in agreement on some points. The problems arose from the fact that a large amount of heat, which should have been used to warm the incoming materials, was lost, with the escape of waste gases, from even the best of furnaces. Fuel economies

1. Bell, "On the Development of Heat...", op.cit., p.43.

2. Discussion following Samuelson, op.cit., pp.349-53.

3. Bell, "On the Development of Heat...", op.cit., pp.130-31. However, it must be said that Bell's recorded comments at various meetings of the Iron and Steel Institute suggest that he was not altogether consistent on this point. In the discussion following a paper by Gjers ["Description of the Ayresome Ironworks...", op.cit., p.239.], for example, he appeared to support Williams!

could only be maximized if waste gases were no warmer than the surrounding air when they left the furnace; that would mean that they took no heat with them. It had been demonstrated that the gases leaving a larger furnace were cooler, at the time of exit, than those from a smaller one. From that observation, as well as the records of coke consumption, arose the view that fuel economies were related to furnace size.

Cochrane seems to have assumed virtually constant relationships between the variables. He concluded his theoretical analysis with the statement that the optimum size for a blast furnace was 124 feet in height, 36 feet in diameter and 80,546 cubic feet in capacity. With a furnace of such dimensions, the waste gases would be reduced to the temperature of the surrounding atmosphere by the time they left it.[1] Bell countered this analysis by producing graphs of his own to show that the relationship between furnace size and the temperature of the escaping gases was not in fact constant.[2] Rather, the temperature curve flattened out beyond a certain point, so that a quite disproportionate addition to furnace capacity was required if even a very small further reduction in temperature was to be achieved. Hence, in Bell's view, there was no practical justification for building furnaces larger than about 12,000 cubic feet in capacity.

1. Cochrane, "On the Further Utilisation of the Waste Gas from Blast Furnaces....", op.cit., pp.31-32.

2. Bell, On the Chemical Phenomena of Iron Smelting, op.cit.

It was the onset of the trade depression in the 1870's rather than Bell's theoretical discourse that halted the construction of still larger furnaces. Cochrane felt obliged to admit, in 1875, that his largest furnaces had not justified his expectations, but he blamed their shortcomings on matters of design and management rather than erroneous analysis.[1] In addition, he pointed out that fuel consumption tended to rise the longer a furnace was in blast, due to leakages.[2] In keeping with his reputation as an innovator, Cochrane suggested that this defect might be prevented by casing furnaces in cast iron. Nevertheless, Cochrane believed that the results from his furnaces of 33,000 cubic feet capacity matched his theoretical predictions very closely.[3] Bell, however, was to some extent vindicated; for fuel consumption did not fall below the level he considered practicable, and a ceiling to furnace size was reached in the early 1870's.[4]

There, the debate was left, for a variety of reasons. Fatigue on the part of the participants was possibly one reason; their respective positions were well known, little new information was forthcoming, and the various arguments

1. Charles Cochrane, "On the Ultimate Capacity of Blast Furnaces", Proceedings ofthe Institution of Mechanical Engineers (1875), pp.334-40.

2. Ibid., pp.353-54.

3. Ibid., pp.353.

4. See Jeremiah Head, "On Recent Developments in the Cleveland Iron and Steel Industries", Proceedings of the Institution of Mechanical Engineers, Vol.45 (1893), pp.230-32.

seemed to have been exhausted. By then, too, other problems had become more pressing - notably the depression and the serious threat to wrought iron presented by mild steel. There was also a growing awareness that innovations other than greater furnace size deserved credit for part of the reduction in fuel consumption. For example, the introduction of Cowper's brick stove, and Whitwell's modification of it, had accompanied the growth of furnace dimensions. So, too, had the adoption of more efficient means of utilizing waste gas for heating the boilers. In combination, these innovations had permitted the raising of a hotter blast, without the use of any fuel other than that charged to the blast furnace itself, than had previously been possible, and had thereby lowered overall fuel consumption.

By these and other means, fuel consumption had in fact been cut quite dramatically by about 1870. Whereas 40 cwts. of coke had been needed to produce one ton of pig iron in the early 1850's, Gjers stated that the equivalent figure in 1875 was between 20 and 25 cwts. in Cleveland.[1.] He considered the reduction to be due in equal parts to the greater size of the furnace and the higher temperature of the blast, a view which was echoed in 1882 by Jeans.[2.] Some years earlier, Samuelson had revealed that fuel consumption in his

1. Gjers, "A Short Historical Sketch of the Rise and Progress of the Cleveland Iron Trade...", <u>op.cit.</u>, p.69

2. J.S. Jeans, "On the Consumption and Economy of Fuel in the Iron and Steel Manufacture", <u>Journal of the Iron and Steel Institute</u>, (1882), No.1, p.130.

works had fallen from 40 cwts. of coke, per ton of pig iron, in 1854 to 20.35 cwts. in 1871.[1] He also attributed the improvement to the same factors as Gjers.

During a discussion in 1883,[2] a number of Teesside ironmasters laid records of fuel consumption before a meeting of the Iron and Steel Institute, and these shed further light on the subject. Cochrane stated that the average coke consumption per ton of pig iron made had fallen at his Ormesby works from 39.64 cwts. in 1855 to 21.18 cwts. in 1882. In the latter year, his larger furnaces alone had used only 19.38 cwts. of coke per ton of pig iron. He attributed the reduction, in equal proportions, to the introduction of a hotter blast and the building of larger furnaces.

On the other hand, Edward Williams, who said that the equivalent figure for coke consumption at Bolckow and Vaughan's works had dropped from 33 cwts. in 1865 to 23 cwts. in 1882, maintained that in his experience the reduction was entirely due to the building of higher furnaces. He argued that this must have been so, since the temperature of the blast had not been raised at the works in his charge. Use was still made of the old-fashioned iron stoves, instead of either Whitwell's or Cowper's brick versions, and these permitted only relatively low temperatures in the blast.

To complete a confused picture, Hugh Bell described

1. Samuelson, op.cit., p.331.

2. Discussion following Howson, op.cit., pp.593-633.

the progress made at the Clarence works. There, coke consumption had been cut from 32.44 cwts. in 1857 to 22 or 23 cwts. in 1882. This had been achieved, it could be said, without altering either the dimensions of the furnace or the temperature of the blast. The Clarence furnaces were of different sizes, but two of them used air heated to relatively low temperatures by old iron stoves, were only 11,500 cubic feet in capacity, and yet consumed an average of 21 cwts. of coke over an entire year. The improvement was believed to have resulted from careful management of the furnaces in this case.

It is clearly not possible to draw any detailed conclusions from these apparently contradictory statements on the origin of fuel economies. Larger furnaces, improved ancillary equipment, a hotter blast, and better systems of furnace management all seem to have played important parts. It is clear, however, that fuel consumption had been virtually halved, with the major advances coming before the depression of the mid-1870's. Despite the impressive progress made in this field, it is arguable that the Teesside ironmasters were unreasonably obsessed with fuel consumption; more attention could perhaps have been given to raising the productivity of the blast furnace, an area in which American producers were later to excel. However, the interest and achievements in lowering fuel consumption did have important consequences for the smelting industry in a locational context.

The reduction of the quantity of fuel used in making pig iron is the most important new factor to be considered in determining the optimum location of the industry in 1881. Despite the growth of imports of haematite, three-quarters of the iron made on Teesside was still from Cleveland ore. The practice of calcining this ore had been retained, but it was no longer thought worthwhile to treat limestone in the same manner, which meant that slightly less small coal was required.[1] Rather less limestone per ton of pig iron was needed than had been the case in the 1850's, apparently because the larger furnaces were more efficient in that respect too, and this calls for another adjustment to the figures in the material index.

On average, therefore, the following quantities of materials were required in 1881 to make 20 cwts. of Cleveland pig iron : 22 cwts. of coke, 2.2 cwts. of small coal, 12 cwts. of limestone, and 66.7 cwts. of ironstone. The figure for coke consumption may be a little too low for some firms, but it was undercut by a number of the more efficient producers. There is no doubt, however, that by 1881, and probably almost a decade earlier, iron ore had become the dominant weight in the location equation, being considerably heavier than the other materials and the product combined.

This conclusion refers simply to the physical weights involved, and on the basis of it, the orefield should have

1. Bernhard Samuelson, "Notes on the Construction and Cost of Blast Furnaces in the Cleveland District in 1887", Journal of the Iron and Steel Institute, (1887), No.1, p.92.

provided the optimum location for the smelting industry. A rather different picture emerges if account is taken of the 'economic weights' of the various commodities : that is, if allowance is made for the differential transport costs to which they were subject. Although there were no differences between the rates charged for conveying the various raw materials by rail, manufactured goods, such as pig iron, bore higher tariffs and were therefore effectively 'heavier' than is suggested by their physical weights. Lowthian Bell, in one of his publications, listed the various railway rates charged in Cleveland, and this list has been used to compile Table 8.2.

The rate charged for carrying pig iron was consistently higher than that for minerals, though the differential was not constant over distance. Both rates tended to decline, the longer the distance involved. The differential was relatively consistent, though changing, over distances of up to about 20 miles, with the rate for pig iron being between 61.1 and 64.7 per cent higher than that for minerals. Over longer distances, however, the differential declined quite sharply, and at 40 miles it was only 35.2 per cent. What has been termed the 'economic weight' of pig iron thus ranged between 27 and 33 cwts., depending on how far the commodity had to be carried.

If the economic weight of pig iron is substituted for the physical weight, then iron ore is no longer dominant in the general index, other than when pig iron has to be hauled

Table 8.2

Railway Rates on Teesside in 1883[1]

Distance (in miles)	10	12	15	18	20	22	30	40
Rate for Minerals (in d. per ton-mile)+	1.10	0.97	0.95	0.88	0.85	0.83	0.78	0.74
Rate for Pig Iron (in d. per ton-mile)+	1.80	1.60	1.53	1.44	1.40	1.36	1.23	1.00
Rate for Pig Iron as % of Rate for Minerals.	163.6	164.9	161.1	163.6	164.7	163.9	157.7	135.2
'Economic Weight' of 20 cwts. of Pig Iron (in cwts.).	32.7	33.0	32.2	32.7	32.9	32.8	31.50	27.0

+ The rates include a charge for returning empty waggons.

1. Data from Bell, Principles of the Manufacture of Iron and Steel, op.cit., p.597.

more than 30 miles to market. Over distances of less than 30 miles, the higher cost of carrying pig iron offsets the greater weight of the ironstone. The optimum location for the smelting industry would therefore normally be at an intermediate point. In the particular case of Teesside, however, the arguments used earlier may be invoked again to put the optimum location at the market, as in the 1850's. Thus, the system was linear and the median point was at the market, which happened to lie between the coalfield and the orefield. It may be concluded, therefore, that while technical innovations within the industry had allowed working and transport costs to be cut between 1851 and 1881, mainly through fuel economies, they had been prevented from making as great an impact on the optimum location pattern as they might have done by the structure of transport rates within the region.

As at the earlier date, there is no reason to suppose that either labour or agglomeration economies were such as to outweigh the influence of transport costs on the optimum location in 1881. The incentive to minimize transport costs was very strong. In 1883, for example, the average cost of conveying the materials necessary to make a ton of pig iron at a Teesside works was about 8s.6d.[1] That, alone, was equivalent to more than 20 per cent of the selling price of Cleveland pig, and probably accounted for nearer 30 per cent of the total costs. In contrast, labour payments represen-

1. Burnham and Hoskins, op.cit., p.140.

ted only 6 to 9 per cent of the total costs.[1] More important, in so much as labour costs varied spatially, they would have been lowest in the urban-industrial centres of the region. Similarly, that is where agglomeration economies would have been highest. In all respects, therefore, the market was the optimum location for the smelting industry.

There is, however, one qualification to be made to this conclusion : it applies only to the production of pig iron from Cleveland ore. A new development on Teesside in the later 1870's was the beginning of the manufacture of Bessemer pig for conversion into steel. Prior to the introduction of the Gilchrist-Thomas process, this required phosphorous-free iron ore. As was said earlier, Cleveland ore was consequently unsuitable. A small quantity of haematite from Cumberland and Lancashire was used, but the great bulk of the ore for this purpose was imported from Spain.

Where the market for Bessemer pig - in the form of finishing works or shipping facilities - was coincident with the unloading point for imported ore, then the combined weight of the product and the ore would have defined that point as the optimum location for blast furnaces engaged in this work. Where the market was inland, however, the optimum location would have been at the median point on the transport system, whether that happened to be the coalfield, the

1. See G.T. Jones, Increasing Return, Cambridge, 1933, p.133.

market or the docks which were effectively the source of the imported ore.[1]

Table 8.3 comprises a list of the region's twenty-six smelting works in 1881. With one or two exceptions, the distribution of works was little different to what it had been a decade earlier; for the 1870's had been essentially a period of consolidation. Five of the smelting plants were located within Middlesbrough, the four which had been added since 1854 lying inside the 'Ironmasters' District'. This was an area of reclaimed marshland to the north west of the residential part of the town. It was particularly good for industrial purposes since it lay within a meander loop of the Tees, and the lengthening of the river's course, which the loop entailed, meant that most of the works in the area could have a water frontage. The need to ship finished goods, the growing imports of iron ore, and the increasing resort to disposing of slag at sea made wharf facilities very advantageous.[2]

In addition to the works actually within Middlesbrough, there were others nearby, including Bell Brothers' Clarence

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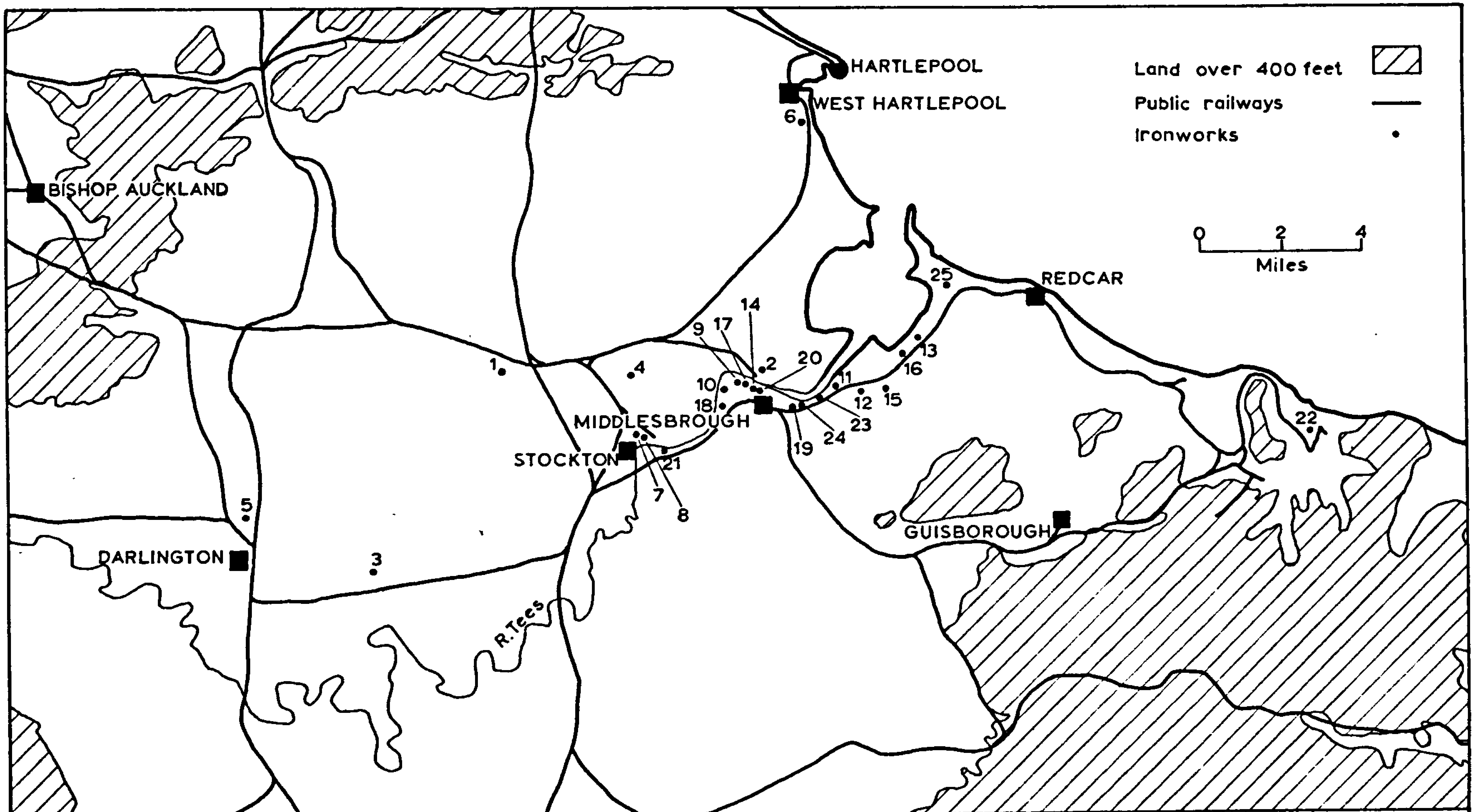
1. Only about 40 cwts. of imported haematite was required to make a ton of pig iron, but that endorses, rather than contradicts, the observation that no single corner of the location figure was dominant.

2. By the 1880's, slag disposal was becoming a serious problem for firms with works inside Middlesbrough. The original solution of simply tipping it on adjacent land was no longer feasible. Samuelson recommended the building of facilities for running slag directly into waiting barges from the furnaces. See his "Notes on the Construction and Cost of Blast Furnaces in the Cleveland District in 1887", op.cit., p.96.

Table 8.3

Blast-furnace Plants on Teesside in 1881.

Works	Location	Proprietor	Furnaces	Furnaces in Blast
Carlton	Carlton.	Carlton Iron Co.Ltd.	3	3
Clarence	Port Clarence.	Bell Brothers Ltd.	12	12
Middleton	Fighting Cocks.	George Wythes and Co.	4	2
Norton.	Norton.	Norton Iron Co.Ltd.	6	0
South Durham.	Darlington.	South Durham Iron Co. Ltd.	3	0
West Hartlepool.	West Hartlepool.	West Hartlepool Iron Co. Ltd.	3	0
Stockton.	Stockton.	Stockton Iron Furnace Co.	3	0
Tees Bridge.	Stockton.	Tees Bridge Iron Co. Ltd.	3	3
Acklam.	Middlesbrough.	Stevenson, Jaques and Co.	4	4
Ayresome.	"	Gjers, Mills & Co.	4	4
Cargo Fleet.	Cargo Fleet.	Cargo Fleet Iron Co.	5	4
Clay Lane.	Grangetown.		6	3
Coatham.	Redcar.	Downey and Co.	2	2
Middlesbrough.	Middlesbrough.	Bolckow, Vaughan and Co. Ltd.	3	3
Cleveland) Eston)	South Bank-Grangetown.	" "	11	11
Lackenby.	South Bank.	Downey and Co.	3	3
Linthorpe.	Middlesbrough.	Edward Williams.	6	4
Newport.	"	Bernhard Samuelson and Co.	8	8
Tees.	Cargo Fleet.	Wilson, Pease & Co.	5	5
Tees-side.	Middlesbrough.	Hopkins, Gilkes and Co. Ltd.	4	4
Thornaby.	Thornaby.	William Whitwell and Co.	3	3
Skinningrove.	Skinningrove.	Skinningrove Iron Co. Ltd.	2	2
Normanby.	Grangetown.	Jones, Dunning and Co.	3	3
Ormesby.	Cargo Fleet.	Cochrane and Co.	4	4
Redcar.	Redcar.	Robson, Maynard and Co.	4	4



Name of works:

1. Carlton
2. Clarence
3. Middleton
4. Norton
5. South Durham
6. West Hartlepool
7. Stockton
8. Tees Bridge
9. Acklam
10. Ayresome
11. Cargo Fleet
12. Clay Lane
13. Coatham
14. Middlesbrough
15. Cleveland/Eston
16. Lackenby
17. Linthorpe
18. Newport
19. Tees
20. Tees-Side
21. Thornaby
22. Skinningrove
23. Normanby
24. Ormesby
25. Redcar

Figure 8.5 Distribution of Iron Smelting Works, 1881

Ironworks. A number of plants had been built along the southern bank of the river to the east of the town, filling some of the gaps left by development in the 1850's. In the vicinity of Cargo Fleet, for example, the Ormesby and the Tees works had been joined by the Normanby and the Cargo Fleet works. Further east, the original group in the Grangetown -South Bank district had been augmented by the Clay Lane and Lackenby works. Further east still, the Coatham and the Redcar works had been built almost at the mouth of the river.

Thus, sixteen of the region's smelting works were located along the southern bank of the Tees, between Middlesbrough and the coast. All of these had finishing departments or facilities for shipping pig iron, or both together, and all might therefore be said to have had market locations, in keeping with the pattern postulated on theoretical grounds. All of them were also close enough to Middlesbrough, by then the largest urban-industrial centre in the region, to take full advantage of any agglomeration or labour economies which might have been available.

In 1881, the South Durham Ironworks was still the only smelting plant in Darlington, which suggests that the immediate market for pig iron was too small to justify the construction of additional works. However, Hetherington has stated that the Middleton Ironworks at Fighting Cocks supplied Darlington with pig iron.[1] Confirmation for that

1. Joseph Hetherington, "A Physical and Economic Geography of Northern Tees-Side," unpublished Ph.D. thesis, University of Durham, 1958, Vol.1, pp.166-67.

statement has not been found, but, if correct, it would seem to indicate that the South Durham Company left part of the demand unsatisfied. In that case, the Middleton works would have been better built at Darlington, instead of several miles to the east.

There was also a number of works in the vicinity of Stockton which were concerned with the production of pig iron. Two of these were actually in the town, and a third was located at South Stockton or Thornaby, the industrial satellite which was developing on the southern bank of the Tees. It may be surmised that they supplied a mainly local market, and that they exported very little of their produce. This would be in keeping with the fact that Stockton never shipped very much pig iron. The Norton and the Carlton works were in the same category, though their respective locations, to the north of Stockton, must have meant that transport costs were somewhat higher than necessary.

During the early 1870's, a smelting works had been built at West Hartlepool by Thomas Richardson, who also had interests in marine engineering and shipbuilding.[1] Ownership was transferred to the West Hartlepool Iron Company, a new organisatioh, in 1874, but the time was inopportune for new ventures in this field and the company went into liquidation almost before it began production. It was not until the mid-1880's, after several more changes of ownership, that the works found a secure footing. Nevertheless, even

1. See Wood, op.cit., pp.72-74.

though fraught with difficulty, the extension of iron smelting to the Hartlepools was a pointer to an important aspect of the industry's future on Teesside. With its shipbuilding and marine engineering, the district had a substantial market for iron. It also had good shipping facilities for exporting its produce and for importing iron ore, which was to increase in importance in later years.

Skinningrove Ironworks is perhaps the most interesting of the smelting plants in existence in 1881, in that it was the only works to be successfully established on the ore-field in the Teesside region. During the 1850's, the Victoria Ironworks Company had built two blast furnaces near Runswick - to the south of Skinningrove and on the coast -[1] but they had been abandoned within a few months, because of damage sustained during a landslide.[2] The Skinningrove works was established in 1874, though it was known as the Loftus Ironworks until 1880, when ownership passed to the Skinningrove Iron Company.[3]

This works was supplied with iron ore from local mines, most of it coming from the Loftus or Skinningrove mine which was owned by Pease and Partners, a firm with interests in the ironworks.[4] Without details of the operations of the Skinningrove works, it is not possible to evaluate its loc-

1. Marley, op.cit., p.198.

2. S.K. Chapman, "Gazeteer of Cleveland Ironstone Mines", Dorman Museum Research Report, No.1, Middlesbrough, 1967, p.8.

3. Meade, op.cit., p.394.

4. Burns, op.cit., p.273.

ation with much confidence. Certainly,however, any advantages the location held for smelting must have been very finely balanced. The distance by rail from Skinningrove to Middlesbrough was approximately 20 miles, and, according to the calculations presented earlier, the economic weight of a ton of pig iron would therefore have been 32.9 cwts. The combined weight of the product, fuel and limestone was approximately 69 cwts., which should have meant that there was a small advantage to be gained from locating at Middlesbrough rather than Skinningrove. However, the weight of the ironstone required may have been a little higher than the hypothetical figure of 66.7 cwts. adopted here, since the iron content of Cleveland ore declined with distance to the south, and this would have reduce the advantage of a Middlesbrough location.

Indeed, in practical terms, there was little to choose between the market and the orefield, if transport costs alone are considered, in the region as a whole. Using the economic weights for pig iron that were listed in Table 8.2 and the generalized values for limestone and fuel consumption, the combined weight of the product and the localized materials, other than iron ore varied between 69.2 and 67.7 cwts. This has been compared with a weight of 66.7 cwts. for Cleveland ore. However, particularly,in southern areas of the orefield, the weight of the ore may have been nearer the 70 cwts. referred to by some contemporary writers.[1.]

1. Eg. Meade, op.cit., p.402.

This would have meant, of course, that the orefield held a slight advantage as a location for the smelting industry.

That more firms did not follow the example of the Skinningrove firm, and build plants on the orefield, can be attributed to several factors. One was that the orefield did not become a viable alternative to the market, assuming that it eventually did in some cases, until about 1870, and by that time most of the region's works had already been established. More important, in most cases it is probable that agglomeration and labour economics were sufficient to restore, or confirm, the advantages of the market. Finally, the growth of the import trade in iron ore placed a premium on waterside locations almost as soon as other factors had cleared the way for inland locations. With time, as foreign ores became more important to the Teesside smelting industry, the Skinningrove location grew less tenable.

Summary.

Following the discovery of commercially-viable deposits of iron ore at Eston in 1850, the production of pig iron began in the Teesside region. Technical progress in iron smelting during the first half of the nineteenth century had been such that the industry was no longer confined to coalfield locations. Indeed, neither the product nor any of the localized materials used was locationally dominant. However, the spatial format of the Teesside region meant that there, at least, the optimum location for the smelting industry in the 1850's was the market rather than some intermediate point. This conclusion is seemingly paradoxical, since pig iron production was then, as it is still, a materials-oriented industry if notice is taken of Weber's materials index.

There was a multiple system of markets on Teesside, but all of the recognisable market points - distinguished as places where there were finishing works and, or, shipping facilities for sending pig iron overseas or to other parts of the United Kingdom - were situated between the orefield and the coalfield, and were on the railway network. It has been demonstrated that the determination of the optimum location in such circumstances is essentially a linear rather than an areal problem. It has also been shown that the point where the smelting industry's transport costs could be minimized in the 1850's was the median point on the transport system, which was the market. Consideration of other influences, including differential labour and agglomeration economies, did not suggest that the point of least transport costs was not also the optimum location for the industry.

Because of the multiple-market system, no single location in the Teesside region was the best possible for all purposes. Rather, there was a series of viable alternatives, despite cost differences between them. At Darlington, for example, transport costs must have been higher that at Middlesbrough, but both towns were feasible locations for smelting. Darlington producers had to haul coal, coke and limestone a shorter distance than their Middlesbrough counterparts, but the distance saved on those commodities had to be covered by iron ore, which was heavier than the three of them together. Total transport costs were therefore higher. Even so, it was cheaper to make pig iron for the local market at Darlington than to produce it at, and transport it from, Middlesbrough. This did not apply, however, if the metal was intended for export or coastwise shipment, since the additional cost of carrying it to navigable water had then to be borne. Darlington could only be justified as a location for the smelting industry if production was aimed at the local market.

Similarly, other places in the region with local markets were alternative optimum locations for the industry. For export production - inter-regional as well as international -, however, the best location was the area stretching eastwards from Middlesbrough along the southern bank of the Tees. Coal, coke and limestone had further to travel to reach that area, but iron ore, which was heavier, had less far to travel. Overland transportation costs could therefore be minimized. The north bank of the Tees must be dismissed because of the difficulty and expense of ferrying ore across the river.

In practice, the distribution of smelting plants accorded quite closely with what would be expected on theoretical grounds. There were works built at Darlington and Stockton to supply an essentially local market for pig iron, but many more were located in the vicinity of Middlesbrough, all but one of these being on the southern bank of the Tees. Most of the pig iron for export was produced by this second group, although a little was despatched from, and presumably made at, Stockton.

During the following twenty years, until 1873, the smelting industry on Teesside had all the hallmarks of a classic growth industry.[1] The regional and external demand for pig iron rose substantially and virtually continuously, as new uses were found for iron and as the Teesside region gained entry to wider markets. Innovation within the regional industry contributed to the expansion of demand by lowering production costs, notably through fuel and scale economies. The results were seen in the form of a growing output from more and larger blast furnaces.

It was the relative reduction of the industry's fuel requirements that was most significant in a locational context. Between the early 1850's and the early 1870's, the fuel consumption per ton of pig iron made was halved. The coalfield's attractive power was consequently also reduced by half. Other things being equal, this would have had the effect of making the orefield the optimum location for the smelting industry. However, the local structure of railway freight rates, which were heavier for manufactured goods than raw materials, offset this development. When the eco-

1. The remainder of the 1870's probably belonged to the period which followed. Between 1883 and 1925, according to G.T. Jones, the Cleveland pig iron industry stagnated and "... yielded an almost constant return to human effort." See G.T. Jones, op.cit., p.145.

nomic, as opposed to physical, weights of the various goods are considered, then it would appear that no single commodity, product or material, was dominant. The market therefore remained the optimum location in 1881, because of its central position between coalfield and orefield, and to a lesser extent because of its greater potential for labour and agglomeration economies. Nevertheless, the balance of advantage was small.

A distinction should again be drawn, however, between the optimum location for a plant designed to serve an immediate local market and that for one oriented to export production. In the former case, a market point anywhere was adequate. In the latter, as in the 1850's, it was the area to the east of Middlesbrough and south of the Tees that was best. It should be added that the growing use of imported ore during the 1870's served to strengthen the advantages of market locations alongside navigable waterways.

The actual distribution of works in 1881 matched the ideal pattern sufficiently closely to warrant the conclusion that the ironmasters had a good, if pragmatic, understanding of the principles underlying location theory. Most of the plants which had been built since 1854 were located in the vicinity of Middlesbrough and were on the southern bank of the Tees. No other firm had emulated Bell Brothers by siting a works on the north shore. Again, only one small works had been built near Darlington, indicating an appreciation of how unsuitable a location that was for export production, and how limited the local market for pig iron. On the other hand, novelty had been added to the distribution pattern by the building of one works at Skinningrove, presumably in recognition of the narrowing of the gap between the respective claims of the orefield and the market as a location, and another at West Hartlepool, which was well suited to development based on imported ore.

The Wrought Iron Industry.

It was not until the late 1880's that the British output of steel surpassed that of wrought iron,[1.] and for most of the nineteenth century the great bulk of the pig iron produced and used at home was consumed by the wrought iron industry. As late as 1880, the tonnage of wrought iron made in Britain was equal to 26 per cent of the national output of pig iron,[2.] and it represented a still larger share, since a certain amount of pig was lost during processing. In the same year, production of wrought iron was half as large again as that of steel.[3.]

The basis of the puddling process, by which pig was converted into wrought iron, had been established by Henry Cort with his famous patent of 1783.[4.] Cort showed how pig

1. Data from Burnham and Hoskins, op.cit., pp.26-27.

2. Loc.cit.

3. Loc. cit.

4. For descriptions of the process see: Carr and Taplin, op.cit., pp.55-57; Birch, op.cit. chap.9; W.K.V. Gale, Iron and Steel, London, 1969, chaps. 3, 4 and 5, and The British Iron and Steel Industry : A Technical History, Newton Abbott, 1967. chaps.3, 4 and 5.

iron could be decarburized in a reverberatory furnace heated by coal, which was kept in a separate compartment from the charge. With Cort's furnace as the model, a number of modifications were made in the early part of the nineteenth century which helped to reduce the consumption of both fuel and pig iron. By about 1830, however, the puddling process had attained the essential state it was to keep, with surprisingly little alteration, until the demise of the wrought iron industry.

To the irritation and despair of many of the more scientifically minded ironmasters, puddling remained a strenuous manual craft despite all efforts to reform it. The puddler was consequently something of an aristocrat amongst the ironworkers. He could command a high wage, since it was mainly upon his skill, strength and diligence that the quality of the finished product depended. In an era of increasing mechanization, it is not surprising that the process should have been regarded by many as primitive, and yet it stood up well to all attempts to introduce a mechanical substitute for the puddler.

The conventional puddling furnace took a charge of from 2½ to 5 cwts. of pig iron, the capacity being limited by the physical capability of the puddler. The growth of pig iron production in the nineteenth century was consequently matched not by an increase in the size of the puddling furnace but by a very large expansion in its numbers. The rudimentary nature of the process for making wrought iron meant that labour, fuel and pig iron were all used rather wastefully. In addition, maintenance costs were relatively high, and the furnace required complete rebuilding, at a cost of £130 in the 1860's, twice each year.[1]

Particularly after 1860, a great effort was made to mechanize puddling. In the period from 1867 to 1876, 389 patents were registered in Britain which represented attempts to improve the process by one means or another.[2] Some of the minor modifications gained wide acceptance, but none of the major mechanical innovations found universal approval. Fuel consumption was too high, maintenance too costly, or the quality of the finished iron thought to be inferior in virtually every case. Summarising the results of this wave of experimentation, Jeans said in 1882 that not more than one per cent of the puddling furnaces extant in the United Kingdom were different to the traditional model.[3] Even the once-vaunted Danks mechanical puddling apparatus had been dismissed as an 'unlucky machine'.[4] Jeans added:

> It will not probably be denied that the skill, experience, and inventiveness of practical men have seldom been so barren of useful results as in the matter referred to. The ordinary puddling process has outlived all attempts to improve it out of existence. The puddling furnace of a generation

1. Carr and Taplin, op.cit., p.55.

2. Jeans, "On the Consumption and Economy of Fuel in the Iron and Steel Manufacture", op.cit., p.143.

3. Ibid., p.144.

4. [Idem.] "Cleveland Finished Iron Trade", Colliery Guardian, 17 December, 1880, p.971.

> ago is in all its essential features the puddling furnace of today. Both have been condemned as crude, barbarous, and wasteful, and yet both continue to enjoy a measure of vitality and appreciation to which their merits have certainly not entitled them.[1]

From the puddling furnace, the iron was taken to be hammered - or 'shingled' - into a rough bloom , which was then given a preliminary rolling in the forge train. The outcome was the puddled bar, and that represented the culmination of the processes which took place in the forge. Further working occurred in the finishing mill, which was usually, though not necessarily, adjacent to the forge and a part of the same works. There, the puddled bars were reheated, in furnaces not unlike those used for puddling, and re-rolled. The number of reheatings and re-rollings determined the quality of the iron, as repetition of these processes gave the metal added refinement.

Like the blast furnace, but unlike the puddling furnace, the forge hammer and rolling mill were subject to virtually continuous improvement during the nineteenth century. The steam engines which drove the machinery became increasingly powerful and efficient, and methods were devised of utilizing waste heat from the furnaces to provide steam to drive the engines. Major improvements were also made to the mills themselves, which became more sophisticated and versatile as well as more efficient and reliable. In these departments,

1. Idem., On the Consumption and Economy of Fuel in the Iron and Steel Manufacture," op.cit., p.144.

at least, innovation kept pace with the changes in smelting.

The Optimum Location of the Industry.

The locational requirements of wrought iron production are more difficult to assess than those of the smelting industry. One reason is that there was a great variety of products, and different qualities of iron and different types of finished goods demanded varying quantities of fuel and other materials. In addition, there were differences between firms in their degrees of vertical integration, which must be taken into account. Some companies spanned the whole range of activities, from producing pig iron to making the highest quality wrought iron goods. Others had no smelting plant, and some were even without puddling facilities. Clearly, therefore, the optimum location for a firm with one set of interests would not necessarily be the same as that for one with another.

There is also the more mundane problem of data availability to consider. No official statistics pertaining to wrought iron production, or the industry's consumption of materials, were collected for the period under study. Although the technical literature is relatively wealthy with figures relating to the consumption of the various materials used, these often refer to a small part of the overall process or to the production of some specialised good. The high rate of experimentation during the 1860's and 1870's adds to the problem, since many of the data quoted in the technical journals referred to new and unrepresentative processes. A mitigating factor is that despite the great interest in new techniques and equipment, there was very little change in the basic method of puddling. It was on the old-fashioned furnace that the ironmasters relied as businessmen, whatever their predilections as scientists and engineers.

It was reported in 1850 that 3 tons of coal and coke were used in the post-smelting operations to make one ton of wrought iron rails in South Wales.[1] This figure included the fuel used directly in the puddling and reheating furnaces and that employed to raise steam for the rolling mills and ancillary machinery. No comparable data have been found for Teesside works at that time, but it is probable that their fuel consumption was a little higher than that of their Welsh counterparts, if only because coal alone, rather than a mixture of coal and coke, seems to have been preferred in the former.

Subsequently, there was a reduction in the amount of fuel used in manufacturing iron rails. Writing in 1882, Jeans gave some contemporary data for individual works. One manufacturer said that 40 cwts. of coal was the average quantity of fuel consumed at his works in making one ton of rails from pig iron.[2] Another, who, like the first, was

1. This figure appeared in an American report in 1850 and is quoted by Isard in his article : "Some Locational Factors in the Iron and Steel Industry Since the Early Nineteenth Century", op.cit., pp.207-208.

2. Jeans, "On the Consumption and Economy of Fuel in the Iron and Steel Manufacture", op.cit., pp.144-45.

probably from Teesside, gave a figure of 46 cwts.[1] This was disaggregated thus :

	Cwts.	Qrs.	Lbs.
Puddling.	26	3	21
Reheating.	3	1	14
Heating and Reheating Rail Piles.	9	2	0
Steam-raising.	6	1	0
	46	0	7

The fuel savings which had been obtained were not the result of improvements in puddling technique; the consumption figure given above for puddling was little different from the 25 cwts. reported for South Wales in 1850.[2] The main advance had come from the utilization of waste heat from the furnaces for raising steam to drive the forge hammers and rolling mills. The more efficient works of the day, including Dowlais in South Wales and many on Teesside, had reached the stage where additional fuel to heat the boilers was unnecessary.[3] Sufficient heat was generated in, and could be channelled from, the puddling and reheating furnaces for that purpose .

In addition to the figure quoted above of 26 cwts. of coal, there are other records and estimates of fuel consump-

1. Loc.cit.

2. Isard, "Some Locational Factors in the Iron and Steel Industry Since the Early Nineteenth Century", op.cit., pp.207-208.

3. See Jeans, "On the .Consumption and Economy of Fuel in the Iron and Steel Manufacture", op.cit., p.144, and Jeremiah Head's comments on pp.167-68.

tion during the actual puddling process. One observer said in 1872 that on the average, 24 cwts. of coal were used on Teesside in making one ton of puddled iron by the conventional method,[1] a view echoed by others at the time.[2] There were, however, variations between works, which resulted in part from the use of coal of differing quality. Ten years later, in 1882, Jeans gave figures for coal consumption which ranged upwards from 21 cwts.,[3] and Head gave it as his opinion that the average was between 22 and 27 cwts.[4] So far as it is possible to judge, Teesside producers seem to have been very efficient in this respect. In a standard text on the manufacture of iron that was published in 1920, it was reported that the norm then was 26 cwts. of coal,[5] which was no improvement on what had been achieved on Teesside half a century earlier.

Even in the early 1870's, however, much lower figures for coal consumption had been reported by ironmasters using experimental furnaces. In 1872, after studying its use in the United States, John Jones maintained that the adoption

1. John A. Jones, "The Commercial Aspect of Danks's Rotary Puddling Furnace", Journal of the Iron and Steel Institute, (1872), No.1, p.281.

2. Eg. see Jeremiah Head, "Fox, Head and Company's Patent Economical Puddling Furnaces", Journal of the Iron and Steel Institute, (1872), p.228. Also see the discussion following this paper.

3. Jeans. "On the Consumption and Economy of Fuel in the Iron and Steel Manufacture", op.cit., p.145.

4. [Head's comments] Ibid., p.167.

5. Thomas Turner, The Metallurgy of Iron, 6th ed., London, 1920, p.383.

of Danks's rotary furnace in Cleveland would reduce coal consumption to 15 cwts. per ton of puddled iron made.[1] This was by no means an over-optimistic forecast, but there were technical problems associated with Danks's furnace, and others like it, which debarred the general introduction of mechanical puddling.[2] In addition, the supersession of wrought iron by steel effectively suppressed the efforts, which would otherwise surely have been continued, to correct the faults of the new methods. In 1891, Turner was able to declare categorically, as Jeans had foretold a decade earlier, that all rotating furnaces and similar inventions had been abandoned by British ironmasters, and that mechanical appliances in the field of puddling were still exceptional.[3] Lowthian Bell may well have registered this with something not unlike quiet satisfaction; for he, at least, had not agreed with Jeans's dismissal of the reverberatory furnace as 'barbaric'.[4]

Accepting the upper limit of the range given by Head,[5] 27 cwts. of coal may be taken as representative of the amount of fuel needed to make a ton of puddled bars on Teesside. In the absence of any significant technical progress

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1. John A, Jones, op.cit., p.283.

2. The major problem was the difficulty of keeping the machines working for any length of time and the expense of repairs.

3. Thomas Turner, "Economical Puddling and Puddling Cinder" Journal of the Iron and Steel Institute, (1891), No.1 p.123.

4. See his comments on Jeans's article : "On the Consumption and Economy of Fuel in the Iron and Steel Manufacture", op.cit., p.174.

5. The range was 22 to 27 cwts. See Head's comments on ibid., p.167.

in puddling, this figure would have applied throughout the period studied here. The amount of pig iron required was about 22 cwts.[1] The only other material used was 'fettling' for lining the puddling furnace. However, this may be disregarded in a locational context, since it was only rarely a special purchase and the amount used was not large. The normal practice was to make use of whatever was suitable and readily at hand, whether that was haematite, mill-scrap or cinder.[2]

With the product weighing 20 cwts., the fuel 27 cwts., and the pig iron 22 cwts., no single item was dominant in Weber's sense for the puddling section of wrought iron production. Nor would it have been if the fuel requirement in the earlier part of the period had been rather larger than suggested here. Hence, the optimum location should have be been at some intermediate point, rather than either the market or the source of one of the materials. In the Teesside region at least, however, the market was in fact generally coincident with the source of pig iron. The combined physical weight of the product and the pig iron was obviously far greater than that of the coal, without allowing for the even larger economic weight of the first two items which resulted from the higher transport charges they bore as manufactured goods. Consequently, the point where transport costs could be minimized was the point where the market and

1. This figure is given by Bell in <u>Principles of the Manufacture of Iron and Steel</u>, <u>op.cit.</u>, p.365. John A. Jones, (<u>op.cit.</u>, p.281) suggested 21½ cwts.

the pig iron source were coincident. That point was also the optimum location in a broader sense too, since consideration of differential labour and agglomeration economies would merely serve to emphasise its advantages.[1]

Because of the spatial coincidence of market and blast furnace and the relatively high cost of transporting manufactured goods, the optimum location for those Teesside works making rails from pig iron was the same as that for those making only puddled bars. At the end of the period under review, according to Jeans, 40 cwts. of coal were used in converting the necessary amount of pig iron into a ton of iron rails, if none was required for raising steam.[2] In the less efficient works, a further 6 cwts. were needed for heating the boilers. The combined weight of the product and the pig iron was only about 42 cwts. However, the higher transport rates for processed iron raised their economic weight by as much as 60 per cent generally.[3] Even for the relatively inefficient works, which required a quantity of fuel just for heating the boilers, the optimum location was clearly at the point that was both market and pig iron source. Moreover, this would also have been the

1. It was not felt necessary to enlarge on the discussion of labour and agglomeration economies contained in the earlier section on pig iron production.

2. Jeans, "On the Consumption and Economy of Fuel in the Iron and Steel Manufacture", op.cit., pp.144-45.

3. It has been assumed that the rate for wrought iron was the same as that for pig, though it was probably higher, and the economic weight has been taken from Table 8.2.

case in the 1850's, when perhaps 3 tons of coal were required.[1]

The same conclusion concerning the optimum location applies to the works which made rails but not its own puddled bars, since only about 15 cwts. of coal were required for that purpose. Some wrought iron products, however, were much more extravagant consumers of fuel. In 1882, Jeans declared that approximately 60 cwts. of coal were used by the average British works in manufacturing a ton of such items as plates, angles and sheets from pig iron.[2] Head regarded this figure as too high, however, and maintained that 50 cwts. was nearer the mark, in Cleveland at least.[3] Whichever estimate is accepted, and Head's had more support from other ironmasters,[4] the economic weight of the product plus the pig iron was still higher than that of the coal. Again, therefore, the market cum pig iron source was the optimum location. This may not have been true in the 1850's, however, when fuel consumption must have been higher.

Finally, consideration should be given to the case of the integrated works making pig iron and converting it into wrought iron products. It is convenient to begin with the situation in the 1850's, before technical progress had br-

1. See above, p.367.

2. Jeans, "On the Consumption and Economy of Fuel in the Iron and Steel Manufacture", op.cit., p.147.

3. [Head's comments] Ibid., p.167.

4. [Discussion following] Ibid., pp.165-79.

ought the spectacular reductions in fuel consumption achieved by the smelting industry. If it is assumed that the final product was plates, angles or sheets, and therefore more demanding of fuel than rails, then the following economic weights should be compared :

	Cwts.
Coke for making 22 cwts. of pig iron.	44.00
Limestone "	15.40
Ironstone. "	73.37
Coal for calcination.	3.30
Coal for puddling and finishing (approximate)	60.00
Product (approximate)	30.00

Collectively, the fuel constituted the greatest single weight but it was not dominant, though the figure given for the amount of coal used in puddling and finishing is possibly too low. Even so, if the location problem is again regarded as a linear one, the combined attraction of the limestone and the fuel meant that the point of least transport cost was on the coalfield. Moreover, the savings in transport cost resulting from a coalfield location were probably sufficiently large to override the labour and agglomeration economies that would have resulted from a market location.[1] These observations are equally valid for the works making iron rails, since the weights listed above were applicable in that field too. Thus, there is the curious paradox that the optimum location for the fully integrated works was on the coalfield, whereas that for a works engaged in only one

1. Assuming a basic rate of 1d. per ton-mile and a distance to be travelled of 20 to 30 miles, the saving in transport costs would have been 14s. to 20s. on each ton of the product.

aspect - any one aspect - of wrought iron production was at the market.

The situation changed quite dramatically between the 1850's and 1881. The fuel consumption in smelting was halved during that period, and the amount of coal used in making a ton of rails or the heavier wrought iron goods from pig iron was cut to 40 cwts. and 50 cwts. respectively. The main technical breakthroughs were made during the 1860's. By the end of that decade, it is safe to say, the optimum location for any type of integrated works on Teesside had become the market. This was not because the market had become locationally dominant, but because it had come to occupy the median point between the orefield and the coalfield, in a situation where neither the product nor one material was greater in economic weight than the other elements in the location figure combined.

The Distribution of the
Industry on Teesside.

Before the middle of the nineteenth century the wrought iron industry seems to have had a more substantial presence than smelting in North East England.[1] As even the smallest of communities had its own blacksmith, it could also be argued that wrought iron working was more sidespread, but the traditional smith was a draftsman rather than a genuine manufacturer. Prior to 1850, the larger wrought iron works in the North East were concentrated on Tyneside, at Gateshead,

1. See Bell, "The Manufacture of Iron in Connection with the Northumberland and Durham Coal-Field", op.cit., pp.149-55.

Lemington, Walker and neighbouring places. This reflected the size of the area's population, Tyneside's importance as a commercial and industrial centre, and the fact that much of the iron used by the industry was imported through the port of Tyne.

Puddling was not practised in the North East before 1823, when the firm of Losh, Wilson and Bell built some reverberatory furnaces at Walker Ironworks.[1] Subsequently, imports of Scottish pig iron began to grow as wrought iron production expanded, but the North East continued to rely heavily on bar iron from the Midlands and Wales. The first puddling furnaces in the Teesside region were built by Bolckow and Vaughan at the firm's Middlesbrough works in 1840.[2]

Official statistics relating to the wrought iron industry were not collected until much later than those for smelting, and there were none published for the output of puddled iron until 1881. Estimates therefore play a larger role than is desirable. Bell thought that in 1850 there were probably about 300 puddling furnaces in the North East as a whole, and that they had a total capacity of 150,000 tons of iron per year.[3]

Expansion of the industry's capacity, especially on Teesside, followed the growth of pig iron production in the

1. Ibid., p.150.

2. Gott, op.cit., p.25.

3. Bell, "On the Manufacture of Iron in Connection with the Northumberland and Durham Coal-Field", op.cit., p.150.

1850's. In 1861, by which time Hunt's Mineral Statistics had begun including a list of mills and forges in the North East,[1.] there were 197 puddling furnaces and 35 rolling mills in the Teesside region.[2.] Bell indicated that the furnaces then in use had a weekly capacity of 10 tons each,[3.] which would have given Teesside an annual capacity of approximately 100,000 tons of puddled iron.

During the first few years of its existence on Teesside, the wrought iron industry was a less important market for the region's smelting industry than it became later. It was estimated in an earlier section that Teesside's output of pig iron in 1861 was about 334,000 tons.[4.] Nearly 94,000 tons of pig iron were exported in that year from the ports of Middlesbrough, Stockton and the Hartlepools.[5.] Even if the wrought iron industry was operating at full capacity, and 25 cwts. is taken as the amount of pig iron used in making a ton of finished goods,[6.] it still could not have consumed more than 125,000 tons of pig iron, or 37 per cent of the regional output. The remainder was sent elsewhere or used locally for castings. At that time, moreover, the wrought iron industry does not seem to have relied much on export markets; only 6,665 tons of bar and bundle iron

1. This practice was started in 1860, but similar lists for other districts had been begun earlier.
2. Hunt, op.cit., All data relating to numbers and locations of works have been taken from this annual report, unless otherwise indicated.
3. Bell, "On the Manufacture of Iron in Connection with the Northumberland and Durham Coal-Field", op.cit.p.151
4. See section on smelting.
5. Hunt, op.cit., (1862)
6. This amount was suggested as a working figure by Bell, The Iron Trade of the United Kingdom, op.cit., pp.25-42.

and 3,583 tons of iron rails were exported from the region's ports in 1861.[1]

The works with facilities for wrought iron production in 1861 are listed in Table 8.4 . All but Darlington Ironworks were integrated, in the sense that they had blast furnaces as well as finishing departments. With the exception of Bolckow and Vaughan's Middlesbrough works, which was older, they had all been built in the 1850's. Further, with the exception of the Darlington, works, they were all located in Middlesbrough or the area to the east, on the south bank of the Tees, which is at variance with the theoretical conclusion that the coalfield was the optimum location for the integrated works.

It seems likely that this discrepancy occurred for a number of reasons. In the first place, the main base of the iron industry on Teesside was smelting; initially, at least, puddling was a secondary interest. The integrated works was in fact normally a smelting plant to which finishing departments had been added, but only four of the region's fourteen smelting works in 1861 also had puddling facilities. When these were being sited, their owners were probably more concerned with the locational requirements of a smelting plant than those of a fully integrated works, and the optimum location for smelting was the market rather than the coalfield.

1. Hunt, op.cit., (1862)

It is also possible that the ironmasters were confident of being able to reduce fuel consumption, in both or one of the smelting and later stages of production, and that they were partly looking to the future in choosing the Middlesbrough area as the location for integrated works. Of more immediate relevance, it was also the case that firms with integrated works in that area would have incurred no higher transport costs than those which had only finishing works there, and it was the optimum location for the latter and for pig-iron makers. However, the Teesside wrought iron makers were not so much in competition with themselves as with firms in other districts, over which they held an advantage because of the low cost of pig iron in the region. Collectively, therefore, they had a degree of immunity from normal cost pressures.

Table 8.4[1]

Wrought Iron Works in the Teesside Region in 1861

Works	Location	Proprietor	Puddling Furnaces	Rolling Mills.
Darlington.	Albert Hill, Darlington.	Darlington Iron Co.	43	19
Cleveland.	South Bank-Grangetown.	Bolckow and Vaughan.	38	-
Middlesbrough.	Middlesbrough.	Bolckow and Vaughan.	70	6
Tees.	Cargo Fleet.	Gilkes, Wilson Pease and Co.	5	6
Tees Side.	Middlesbrough.	Hopkins and Co.	41	4

1. There were some omissions in Hunt's list of works for 1861, and Table 8.4 is therefore an amalgamation of the lists for 1860 and 1861.

Darlington Ironworks, which was built in 1858 as an exclusively wrought iron establishment, was soundly located. Indeed, as a finishing works it was in a better position than the others in the Teesside region at the time. From its inception, the works was assured of an adequate supply of pig iron from the adjacent blast furnaces of the South Durham Iron Company. The pig iron source and the immediate market were, however, separate; the latter was at Stockton, or some other place with shipping facilities on the lower Tees, since the Darlington works was mainly concerned with making rails for export. That being the case, and bearing in mind that neither the product nor any one material was dominant, the optimum location - the median point - was the source of the pig iron. Moreover, the Darlington Ironworks was in a stronger position than a finishing works in the vicinity of Middlesbrough would have been, because the coal was the heaviest item to be carried and the nearer the median point was to the coalfield, the lower the total transport costs.

The wrought iron industry flourished during the subsequent decade, its record of expansion marred only by the temporary recessions so characteristic of the market for iron goods in general, and for rails in particular. There was, for example, a reduction in the home demand for railway iron in 1866.[1] There are no reliable production statistics for this period, but there is little doubt that the

1. See Burns, op.cit., p.18.

rail trade was of overwhelming importance. Indeed, some Teesside forms - including the Darlington Iron Company, which produced about 70,000 tons of rails annually[1] - made very little else. In the late 1860's, the overseas demand for rails swelled, with the initiation of large construction programmes for railways in North America, India and many parts of Europe.[2] Approximately one-half of the North East's output of puddled iron went into rail production in 1872.[3] For Teesside alone, the proportion was probably much higher; for industries, such as shipbuilding, which provided alternate uses for wrought iron were less strongly represented there than on Tyneside and Wearside.

There were about 1,178 puddling furnaces in the Teesside region in 1871 (Table 8.5), and they were owned by 22 companies, which together had 24 separate works. Although there were furnaces capable of yielding 30 tons of puddled iron per week,[4] Jeans gave some information in 1879 which suggested that the average weekly output was still only 10 tons.[5] If the latter figure is accepted, then the region must have had an annual capacity of about 612,000 tons of

1. Jeans, Jubilee Memorial of the Railway System, op.cit. p.283.

2. Burns, op.cit., chap.2.

3. Bell, Principles of the Manufacture of Iron and Steel, op.cit., p.459.

4. John A. Jones, op.cit., pp.278-92.

5. J.S. Jeans, "Notes on the Progress of the Iron and Steel Industries of the United Kingdom in 1879", Journal of the Iron and Steel Indstitute, (1879), No.2, p.544.

puddled iron in 1871. There had thus been a six-fold increase in capacity since 1861. Clapham estimated that the United Kingdom's annual output of puddled iron reached a peak of perhaps three million tons in the early 1870's.[1] Teesside probably contributed one-sixth of that amount.

The great wave of expansion in the 1860's did not alter the basic pattern of the distribution of puddling capacity within the region. This is as would be expected, since the fuel economies obtained in that period had strengthened the attractions of the median point, which was generally the location where market and pig iron source coincided. In 1871, the puddling furnaces were distributed amongst the various regional centres as follows :

Darlington	321
Hartlepools	161
Stockton.	181
Thornaby	115
Middlesbrough	380
South Bank	20
	1,178

In an article published in 1938,[2] which has been much quoted, Gleave stated that in 1871 there were 456 puddling furnaces in Middlesbrough and 384 in Stockton, though he did not refer to the source of his informatioh. The present examination of the available material suggests that Gleave's figures are incorrect. This may be because he used Hunt's

1. Quoted and accepted by Mitchell, op.cit., p.127.

2. J.T. Gleave, "The Tees-Side Iron and Steel Industry", Geographical Journal, Vol.91 (1938), p.456.

Table 8.5[1].

Wrought Iron Works in the Teesside Region in 1871.

Works	Location	Proprietor	Puddling Furnaces	Rolling Mills
Whessoe	Darlington	Thomas Vaughan & Co.	36	-
Darlington.	Darlington	Darlington Iron Co.	100	6
Springfield.	"	" " "	92	2
Skerne.	"	Pease, Hutchinson and Co.	34	2
Rise Carr.	"	Fry, I'Anson and Co.	33	4
Drinkfield.	"	Drinkfield Iron Co.	26	3
West Hartlepool.	West Hartlepool.	T. Richardson and Sons.	109	2
Hartlepool.	"	Hartlepool Malleable Iron Co.	32	2
Stranton.	"	Sanderson Iron and Steel Co.	20	-
Yorkshire.	Stockton.	South Yorkshire Iron Co.	9	2
Rail Mill.	"	Stockton Rail Mill Co.	70	1
Stockton.	"	Stockton Malleable Iron Co.	58	5
West Stockton.	"	West Stockton Iron Co.	23	3
Westbourne.	"	John Holdsworth and Co.	21	2
North Yorkshire.	Thornaby.	North Yorkshire Iron Co.	76	1
Thornaby.	"	W.Whitwell and Co.	39	3
Britannia.	Middlesbrough.	B. Samuelson & Co.	120	1
Newport.	"	Fox, Head and Co.	54	2
Middlesbrough.	"	Bolckow, Vaughan and Co.	70	1
Cleveland.	South Bank.	" "	-	3
Tees Side.	Middlesbrough.	Hopkins, Gilkes and Co.	100	5
Imperial.	South Bank.	Jackson, Gill & Co.	20	-
West Marsh.	Middlesbrough.	West Marsh Iron Co.	20	1
Ayrton.	"	Jones Brothers & Co.	16	1

1. The list in Table 8.5 has been compiled from a number of sources. Hunt's Mineral Statistics does not have a full list of the works in operation, nor, on the other hand, does the Journal of the Iron and Steel Institute's annual report, which also omits numbers of rolling mills. These two publications for 1871 have therefore been amalgamated, and the remaining gaps have been filled with data from: Anon., "Cleveland Finished Iron Trade", Colliery Guardian, 17 Dec., 1880, p.971; Jeans, Pioneers of the Cleveland Iron Trade, op.cit. passim., and Notes on Northern Industries, London, 1877, passim.

Mineral Statistics, in which a common error is the misplacing of works, a fault which can only be corrected by extensive cross-checking.

As was pointed out earlier, by 1871, at the latest, coal had ceased to dominate the location question for all branches of the wrought iron industry. It has also been demonstrated that when neither the product nor any one material is dominant, and when the places concerned are joined by a railway, the optimum location in terms of transport costs is provided by the median point. For the Teesside wrought iron industry in 1871, this point generally occurred in the towns which had blast furnaces to supply pig iron and an immediate market in the form of shipping facilities, since most of the produce was destined for places outside the region. Stockton, Thornaby and Middlesbrough, and the area to the east of the last of these towns, were such locations.

Although without shipping facilities, Darlington was another sound location. It had blast furnaces and it lay between the coalfield and the market, and thus qualified as a median point. Indeed, in some respect, though not in others, Darlington was superior to alternative locations. For a firm purchasing pig iron in order to make puddled bars and then either rails or plates, angles or sheets for export, total transport costs would have been lower at Darlington than at Stockton or Middlesbrough. This was because the weight of the coal required (40 cwts. or 50 cwts., depending on the product) exceeded the economic weight of the product.

(30 cwts.) by a large margin, and a location nearer the coalfield meant a lower ton-mileage. Nevertheless, there had to be more works of this type in the Stockton and Middlesbrough districts than at Darlington so long as most of the region's smelting plants were concentrated in the first two areas. To have located at Darlington and drawn pig iron supplies from blast furnaces at Stockton, for example, would have meant incurring unnecessary transport costs; it was preferable to locate the works at Stockton.

For a firm purchasing pig iron to make only puddled bars, or puddled iron to make either rails or plates, angles or sheets, for export, total transport costs would have been higher at Darlington than at Stockton or Middlesbrough. This was because the weight of the coal required (27 cwts. for puddled bars, 13 cwts. for rails, and 23 cwts. for plates, angles or sheets) was exceeded by the economic weight of the product (about 30 cwts. in each case) and Darlington was further from the market, so that the overall ton-mileage was higher. To supply a purely local market with any of the products so far considered, however, any place which made iron - pig or puddled, as was required - was as sound a location as any other.

Finally, the case of the integrated works should be examined. For this type of enterprise, the optimum location by 1871 was the market, since that was the median point between the coalfield and the orefield. As it must be assumed that most such works were primarily concerned with export-oriented production, it was preferable for them to be located alongside navigable water, to minimize the distance to be travelled overland. A works located at Darlington would have incurred higher transport costs than one in lower Teesside; while the fuel (66.62 cwts. for rails and 76.62 cwts. for heavier products) and the limestone (13.2 cwts.) would have had less far to travel in the former case, the ironstone (73.37 cwts.) and the product (30 cwts.) required carrying over the distance thereby saved. By the same token, it can be shown that Stockton was a better location than any of the places to the east. A firm located at Middlesbrough, for example, would have had less far to haul the iron ore than one at Stockton, but further to haul the limestone and fuel, which together were heavier.

A number of new finishing works had been built in Darlington by 1871. The Darlington Iron Company had added to its already large capacity by constructing the Springfield works on an adjacent site to that of its original establishment.[1] Both works were principally occupied with making rails from pig iron supplied by the South Durham Iron Company's blast furnaces.[2] The other new firms and works in the town were more concerned with producing plates and a variety of heavy forgings,[3] for which they puddled their own iron. In accordance with the theoretical observations made above,

1. Jeans, Jubilee Memorial of the Railway System., op.cit. p.283.

2. Loc.cit., and idem., Pioneers of the Cleveland Iron Trade, op.cit., pp.193-95.

3. Idem., Jubilee Memorial of the Railway System, op.cit. pp.283-86.

it would seem that all of the Darlington works were well located; they were engaged in fields where to locate at Darlington meant that transport costs were minimized, regardless of whether the product was intended for a local or an external market.

Many of the rail-making firms had works in the Stockton-Thornaby and Middlesbrough areas, and they also produced their own puddled iron. They would have had higher transport costs to bear than their counterparts in Darlington, but their pig iron supplies came from neighbouring smelting plants and they were located at the market, which meant that their locations were basically sound. So long as Darlington did not produce sufficient pig iron for all, some wrought iron firms were obliged to adopt second-best locations. This resembles the situation postulated in the theoretical introduction to the present chapter, where it was pointed out that if firms belonging to a material-oriented industry could not obtain sufficient supplies of that material from one source, then they would have to make use of another, even though transport costs became higher as a result.

It is interesting to note that between 1861 and 1871 one integrated works, Whitwell's Thornaby Ironworks, was built in the Stockton-Thornaby area, which was described above as the optimum location for such a plant. Most of the others of this type were in the vicinity of Middlesbrough, and were essentially smelting works to which puddling furnaces and rolling mills had been added. The most important new feature in the distribution pattern for 1871 was the appearance of three works in the Hartlepools area. The largest of these was the integrated West Hartlepool works of Thomas Richardson, which had only recently been taken over from Pile, Spence and Company, a shipbuilding firm forced into liquidation in 1867.[1.] Following his acquisition of the works, Richardson immediately initiated a programme of expansion, building blast furnaces and increasing the number of puddling furnaces from 30 to more than 100. Originally, the works had been concerned with the manufacture of shipbuilding materials for Pile-Spence's yard. Under Richardson, ships' plates and angles continued to be made, but the emphasis was switched to rail production.[2.]

Locationally, West Hartlepool was a sound choice for the wrought iron industry. For the integrated works, it had the attraction of good facilities for importing iron ore and for shipping its produce, as well as rail connections with the coalfield and a growing local engineering sector. Together the ore and the product outweighed the fuel required. Provided that pig iron was made available from the local blast furnaces, West Hartlepool was just as advantageous as Middlesbrough and Stockton for the non-integrated works.

1. See Wood, op.cit., pp.72-74. By 1874, expansion had been such that employment at the works had risen from 500 to 2,500 people.

2. Ibid., p.73. By 1874, the capacity of the works was 1,000 tons of rails per week and 250 tons of plates.

The British wrought iron industry is believed to have reached its peak in 1872 or 1873.[1] This was also true of most regional branches of the industry, though not apparently of that on Teesside. Nevertheless, prices and rates of expansion were certainly at a peak then. The price of Cleveland iron rails was comparatively stable through the 1860's at about £7 per ton, but it rose to a record level of £11.4s. per ton in the early months of 1873,[2] due to the initiation of large-scale construction programmes overseas. Cleveland bars commanded a similarly inflated market price.[3] A downturn in trade, which lengthened into depression, occurred in the second half of 1873. From this, the wrought iron industry never fully recovered, though Teesside fared better than most other districts.

The problem was not so much that the industry was permanently crippled by the depression itself, though a number of firms were forced into liquidation by it, but that mounting obsolescence finally caught up with it during this period. Since 1856, when Bessemer had introduced his converter, wrought iron had had a potential rival in mild steel. Iron had been saved - or, rather, granted a temporary reprieve - by a combination of factors : technical problems in the steel industry,[4] a shortage of ores suitable for the Bessemer process - which had helped to keep steel prices high -, unfam-

1. Mitchell, op.cit., p.127.

2. Carr and Taplin, op.cit., p.29.

3. Bell, The Iron Trade of the United Kingdom, op.cit., p.29.

4. See Flinn, "Scandinavian Iron Ore Mining and the British Steel Industry," op.cit., p.31.

iliarity with and suspicion of the new product, and a seemingly inexhaustible demand for ferrous metals of all descriptions. Nevertheless, steel production had steadily grown, and even before the crisis of the mid-1870's there were warning signals to disturb the equanimity of the more discerning ironmasters.

Whereas iron rails maintained a constant price of about £7 per ton, the price of Bessemer rails dropped from £17.10s. per ton in 1864 to £10 in 1870.[1] By the latter date, steel makers had overcome many of the technical problems associated with the Bessemer process, and they were beginning to alleviate the pressure on domestic sources of phosphorous-free ore by exploiting foreign deposits, most notably those in Spain.[2] In 1870, while contemplating the future prospects of iron rail makers like himself, Edward Williams said that he believed they would be able to hold their own, despite the admittedly greater durability of the steel product, provided that the price of steel rails remained above £9 per ton.[3] The euphoria of the next year or two temporarily banished worries over the competition from steel, but Williams's hopes were not to be kept alive for much longer.

The price of steel rails continued to fall, probably aided by the depression, and in 1880 it stood at £6.8s. per

1. Bell, The Iron Trade of the United Kingdom, op.cit., p.20.

2. Flinn, "Scandinavian Iron Ore Mining and the British Steel Industry", op.cit., p.20.

3. Edward Williams, "On the Manufacture of Rails," Journal of the Iron and Steel Institute, (1869-70), No.1, p.169.

ton.[1] Wrought iron rails were then selling at £5.10s.,[2] but this price may well have been unrealistic; for many firms had been producing rails at a loss in preference to having their works stand idle, which was even more costly.[3] In any case, steel had a competitive advantage at such low prices, and it was probably only inertia on the part of rail buyers which kept the iron makers in production at all. The liquidation of many firms in South Wales and other districts may also have helped the survivors.

The loss of the rail trade and the depression together had a catastrophic effect on the wrought iron industry. Table 8.6 is a copy of a statement prepared by Edward Williams concerning production in the Middlesbrough district,[4] an area he did not define but which certainly included the whole of Teesside, and perhaps some places to the north as well. In this area, the production of iron rails fell from 350,000 tons in 1872 to little more than 7,000 tons in 1882. The proportion of the total wrought iron output accounted for by rails thus dropped from 49 to 1 per cent.

In 1879, in his capacity as Secretary to the Iron and Steel Institute, Jeans reported that only 19 of the 43 wrought iron works in the North East as a whole were still in

1. Burnham and Hoskins, _op.cit._, p.166.

2. _Ibid._, p.160.

3. Burns, _op.cit._, p.28.

4. Published in Bell, _Principles of the Manufacture of Iron and Steel_, _op.cit._, p.459.

Table 8.6

Statement by Edward Williams Concerning Wrought Iron Production in the Middlesbrough District.[1]

Year	Total ('000 tons)	Percentage of Total: Rails	Plates	Angles	Bars
1872	702	49	29	10	12
1873	707	53	27	7	13
1874	671	45	31	9	15
1875	646	44	31	7	18
1876	484	26	41	12	21
1877	455	9	54	17	20
1878	485	5	55	21	19
1879	333	2	60	17	21
1880	584	5	63	18	14
1881	667	3	67	18	12
1882	726	1	68	21	10

production.[2] Of the rest, 21 belonged to companies which had gone into liquidation since 1873. The number of puddling furnaces at work had declined from 2,158 to 830. Many of the remainder were standing idle, but some had been dismantled to make way for new steel plants. Generally, as might be expected, the firms engaged solely in wrought iron production were the ones which had been affected most severely.

Fortunately for the firms which had not quite abandoned all hope, 1879 marked the nadir of the industry's fortunes, at least in the North East, and Jeans was able to inform the Institute that there were signs of a faint stir in market activity. This quickened and became a recovery, but it was one which scarcely touched other parts of the country. The rail trade was extinct, and best forgotten,

1. *Loc. cit.*

2. Jeans, "Notes on the Progress of the Iron and Steel Industries of the United Kingdom in 1879", *op.cit.* pp.544-45.

so far as the iron makers were concerned, but the demand for shipbuilding materials, a field in which steel still had only a tenuous fpothold, was beginning to grow quickly.[1] The significance of this for Teesside can be seen from Table 8.6. In 1882, largely as a result of the growth of iron shipbuilding, production of wrought iron was actually higher than it had ever been before.

Table 8.7 comprises a list of wrought iron works extant on Teesside in 1881. There were 31 in all, representing an increase of 7 over the number for 1871, but only 11 were in production. The newcomers had all been built, or construction of them started, before the onset of the depression in 1873. There were 335 fewer puddling furnaces working in 1881 than there had been in 1871, but the number had been much larger a year or two earlier. The recovery of 1880 had been surprisingly strong, but it was soon to be reversed, with steel replacing iron in shipbuilding as well as rail making.[2]

Many of the firms that failed or suspended production in the 1870's were quite old and well-established concerns. Hopkins, Gilkes and Company and Thomas Vaughan and Company, both with fine reputations, were amongst those to be liquidated. The Britannia and the West Hartlepool works changed ownership as a result of bankruptcy, or its imminence. For Dorman and Long, on the other hand, this was a period of

1. Burns, op.cit., p.28.

2. Bell foresaw this. See his Principles of the Manufacture of Iron and Steel, op.cit., p.460.

expansion; the company purchased the Britannia and West Marsh works, and began the long chain of take-overs and mergers which was to culminate in its massive stature of the modern era. In another vein, Bolckow and Vaughan placed its faith in steel at a comparatively early date, and by 1881 the firm had dismantled all its puddling furnaces except those at Witton Park. The Darlington Iron Company, with nearly 200 puddling furnaces at its two works, was rather less adept at re-orientation; in 1881 it was still producing puddled iron, but three-quarters of its capacity was standing idle.

Industrial decline may be a lengthy process which amounts to the slow dissolution of the original structure, with the less efficient and adaptable firms succumbing earliest to the forces of change. In the case of the wrought iron industry, however, decline was quite precipitate, and the events of the mid-1870's left the industry in a much-reduced condition. This was less true of Teesside than most districts, since the ironmasters there were able to obtain a measure of relief by switching resources from rail production to the making of shipbuilding materials.

The firms on Teesside that suffered the most were those which were highly specialised and heavily committed to the rail trade. Theirs was always a risky, though presumably very profitable, business in so much as it depended largely on foreign markets and railway construction was often a highly speculative venture. The combination of depression, which was more severe in overseas than home markets, and

Table 8.7

Wrought-Iron Works in the Teesside Region in 1881.

Works	Location	Proprietor	Puddling Furnaces	Rolling Mills
Whessoe.+	Darlington.	Thomas Vaughan and Co.	-	-
Darlington.	"	Darlington Iron Co.Ltd.	45	6
Springfield.+	"	"	-	-
Skerne.	"	Skerne Ironworks Co.	70	5
Rise Carr.	"	Fry, I'Anson and Co.	32	3
Hartlepool.	West Hartlepool.	Hartlepool Rolling Mills Co.	34	2
West Hartlepool.	"	West Hartlepool Iron Co. Ltd.	100	2
Stranton.+	"	Robert H. Charlton.	-	-
Carr House.+	"	Dunlop, Meredith and Co. Ltd.	-	-
Stockton.	Stockton.	Stockton Malleable Iron Co. Ltd.)	) 101	10
Rail Mill.	"	" ")		
West Stockton.	"	West Stockton Iron Works Co.	57	5
Stockton.	"	Richmond Iron Works Co.	22	3
Bowesfield.	"	Bowesfield Iron Co.Ltd.	40	2
Yorkshire.+	"	South Yorkshire Iron Co. Ltd.	-	-
Westbpurne.	"	John Holdsworth and Co.	22	2
Richmond.	"	R. Jaques and Co.	24	3
Carlton.+	Carlton.	Carlton Iron Co. Ltd.	-	-
Thornaby.	Thornaby.	W.Whitwell and Co.	33	4
North Yorkshire.+	"	North Yorkshire Iron Co. Ltd.	-	-
Erimus.+	"	Erimus Iron Works Co. Ltd.	-	-
Middlesbrough.	Middlesbrough.	Bolckow, Vaughan and Co. Ltd.	-	1
Tees Side.+	"	Tees Side Iron and Engine Works Ltd.	-	-
Newport.	"	Fox, Head and Co.	46	5
West Marsh.	"	Dorman, Long and Co.	20	2
Star.+	"	Star Rolling Mills Co.	-	-
Britannia.	"	Dorman, Long and Co.	120	1
Ayrton.	"	Jones Brothers and Co. Ltd.	29	2
Cleveland.	South Bank.	Bolckow, Vaughan and Co. Ltd.	-	6
Imperial.	"	Jackson, Gill and Co. Ltd.	38	3
Eston Grange.+	Grangetown.	Eston Grange Iron Co.	-	-

+ Signifies that the works were not in operation. Numbers of furnaces and mills for other works refer to those in use.

competition from steel proved too great a burden for many of the iron rail makers to bear. Conversely, the less specialised firms escaped the worst effects of the period. Those which were also engaged in smelting simply stopped or reduced their production of wrought iron and continued making pig iron, the market for which was affected only temporarily and slightly. Other firms took the opportunity to transfer to steel making, a switch which might have been more difficult to effect if delayed further.

A comparison of the lists of works with puddling furnaces in 1871 and 1881 indicates that during the expansionary phase of the early 1870's, development was concentrated in the Middlesbrough and Stockton areas. Most of the new works were concerned only with puddling and the subsequent stages of production. They would, therefore, have been better located at Darlington if sufficient pig iron had been obtainable there. As the smelting industry remained concentrated in the towns of lower Teesside, this was not possible, however, and their locations were sound in those circumstances. There is no evidence that the difficulties experienced by the wrought iron industry in the mid-1870's had a spatial bias; firms were affected more in accordance with their reliance on the rail trade than their relative locations within the region.

Summary.

The wrought iron industry on Teesside provides an example of a regional industry hurried into being by the process of economic development and summarily checked, when still expanding rapidly, by a growing obsolescence which was itself a result of that process. The industry developed rapidly after 1850, under the influence of a favourable cost structure - once smelting was established in the region - and a growing demand for its products. By 1871, Teesside produced about one-sixth of the nation's output of wrought iron.

Expansion continued virtually unabated until about 1873. Then, demand started to fall, especially for rails, with the onset of a depression. In addition, and more seriously in the longer term, a threat to the industry's future began to emerge in the form of competition from steel. The price differential between wrought iron and mild steel had become very small, and seemed likely to continue declining. With little difference in price between the two materials, the greater durability of steel gave it a marked advantage for purposes such as rail making, and rails were the traditional staple of the wrought iron industry. As a result, the making of iron rails was practically abandoned during the depression. In 1880 there was an upsurge in the demand for iron for shipbuilding purposes which gave the Teesside ironmasters some relief, but the respite was to be short-lived, as steel soon became pre-eminent in that field too.

The locational requirements of the wrought iron industry are difficult to assess, because of the variety of products and the varying levels of integration on the part of individual firms. It was necessary to examine the different types of works separately, in order to take account of these variations. One point to emerge from the theoretical discussion was that neither the product nor one material was dominant for any type of works during the period studied. Another was that the optimum locations for the various types of works, excepting the integrated ironworks, did not change between 1851 and 1881.

As in smelting, substantial fuel economies were obtained by the wrought iron industry, but not in puddling. The puddling furnace and process changed very little, if at all. Fuel economies were won in the mill rather than the forge, and they generally resulted from the adoption of techniques for harnessing part of the waste heat given off by furnaces. Innovations of this nature reduced the attraction of the coalfield for the various stages of production, without, however, bringing about a fundamental transformation of their locational orientations.

For the different categories of wrought iron works distinguished in this study, the optimum location was in each case an intermediate point between the market and the sources of the various materials if the problem is construed in terms of the normal two-dimensional location figure. However, it was found more meaningful to view the problem as a one-dimensional one, and to use the principle of the median point, which was discussed at some length earlier in the present chapter. The most significant change noted was that the optimum location for the integrated works shifted from the coalfield in the 1850's to the market in the 1870's. For non-integrated works, throughout the period, the median point and the optimum location were generally at the point where the market and the pig iron source coincided.

However, the position was really more complex than this suggests. For a particular type of works, there was an optimum location for each firm and another for that branch of the industry as a whole. This was because both the market and the pig iron source were multiple. Thus, for the type of firm which purchased pig iron and made iron rails, the best location in the region for its works was at Darlington, where overall transport costs could be minimized. However, there were comparatively few blast furnaces at Darlington, which was not the best location for a smelting plant, and hence sufficient pig iron was made there to support only a small number of wrought iron works. Some rail makers, perforce, were obliged to obtain their supplies of pig iron from blast furnaces at Middlesbrough or Stockton. For these firms, Middlesbrough or Stockton was consequently the optimum location, even though total transport costs were higher than they would have been had it been possible to obtain pig iron at, and locate at, Darlington. A further point is that if blast furnaces had been built at a place still nearer to the coalfield, then that place would have been an even better location for the rail makers than Darlington.

For other types of works, Stockton or Middlesbrough was preferable as a location to Darlington. However, a particular firm which purchased its supplies of iron from Darlington may still have found that town to be its own optimum location. This distinction between the industry - or type of production - and the individual firm is important. If the supply of a certain material is limited at the optimum location for a given industry, then some firms, if the demand for their produce is sufficient, will seek alternative locations, despite the likelihood of them incurring higher costs by doing so.

In practice, the various sections of the Teesside wrought iron industry generally had locations that were sound in terms of transport costs. Individual firms, in most cases, adopted locations which were optimum for themselves, considering where their materials came from and their products went to, if not always for the branch of the industry they represented. The only notable exceptions were provided by integrated works in the early part of the period. For them, the optimum location in the 1850's was the coalfield, but some were present in lower Teesside. The most probable explanation is that they were built not as integrated works but as smelting plants, and that the finishing departments were relatively unimportant or added as an afterthought. For smelting plants then, as for them and for integrated works in the 1870's, the towns of lower Teesside were the best locations.

Miscellaneous Iron Manufactures:
Castings and Forgings.

The large ironworks generally had facilities for making castings and forgings but there were many small establishments which produced one or both of these items only, and made neither pig nor puddled iron. It is with the latter that the present section is mainly concerned. Forgings were used chiefly in industry and construction, but castings included a wide range of industrial and domestic goods. After the development of the puddling process for manufacturing wrought iron, and hence throughout the nineteenth century, cast iron was generally reserved for use in fields where moulding was necessary or where the finished product was required to have great strength under compression. Wrought iron was used when the desired shape could be obtained by hammering or rolling or when tensile strength was required in the product.

Very little fuel was used in the foundry. When the plant was attached to blast furnaces, the pig iron could be transferred in a molten state to the moulds. When the foundry was independent, pig iron was reheated in cupolas, a process requiring an average of 4 cwts. of coal per ton of castings.[1] Fuel consumption was therefore a locational factor of minor importance.[2] As there was little wastage of iron during founding, the weights of the

1. Jeans, "On the Consumption and Economy of Fuel in the Iron and Steel Manufacture," op.cit., p.155.

2. Also see Isard, "Some Locational Factors in the Iron and Steel Industry Since the Early Nineteenth Century," op.cit., p.207.

pig iron and the product were virtually the same, and, so, neither the product nor one material was dominant. In such circumstances, the optimum location would normally be assumed to be an intermediate point. On Teesside, however, the market for castings - whether local industrial centre or port - was coincident spatially with the source of pig iron, since smelting plants were located in the places where the demand for castings must have been greatest. Theoretically, therefore, foundries should have been confined to those places by the combined weight of the product and the pig iron. Consideration of differential labour and agglomeratioh economies does not require any alteration in the assumption that the point where transport costs were lowest would have been the optimum location. Labour and agglomeration economies, like transport economies, would have been greatest in urban places.

The production of forgings took place in a rather different locational context. On Teesside, the demand was mainly for the heavier items, such as various materials for the shipbuilding and other heavy engineering trades. In 1882, Jeans estimated that the average fuel consumption in making such goods from pig iron was 7 tons of coal per ton of forgings.[1] This precludes all other considerations and means that the optimum location for the independent forge must have been the coalfield. Thirty years earlier, the attractions of the coalfield must have been greater still.

1. Jeans, "On the Consumption and Economy of Fuel in the Iron and Steel Manufacture", op.cit., p.156.

In Table 8.8 are listed those businesses which appeared under the heading of 'Engineer and Iron Founder' in two local trade directories for 1851.[1] There are certain disadvantages in resorting to the use of directories for this purpose, but there is no alternative source with quite as much information relating to iron founding. One disadvantage is that directory entries do not indicate how large a particular firm or works was. The directories used here also omitted the smaller places in North Yorkshire, but the evidence for Durham suggests that this is not important, since it was only the larger settlements which had foundries.

Darlington appears to have had a disproportionately large number of foundries, but supplementary evidence indicates that they were all small concerns, little removed from the smithy in scale. Jeans described how in 1854 a Carlisle firm attempted to purchase land in Darlington for a forge from John Pease, a member of the family which had contributed so much to the industrialization of Teesside. Another member of the Pease family was then establishing a company to build blast furnaces in the town, but the Carlisle firm's application was rejected,

> ... on the ground that there was a feeling in Darlington against having the atmosphere vitiated by manufactures , and he [John Pease] would not be the first to introduce such a nuisance into his native town.[2]

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1. Hagar and Company, Directory of the County of Durham ...., Nottingham, 1851; and Robert Ward, Ward's North of England Directory, Newcastle, 1851.

2. Jeans, Jubilee Memorial of the Railway System, op.cit. p.280.

Apart from illuminating John Pease's independence of spirit, and independence of the rest of his family, this episode indicates that there was then nothing so substantial as an ironworks in Darlington.

Like others in the region, the Darlington foundries probably still relied on imported bar iron in 1851. Their market would have been very localized, and based on the demand for tools, household goods and parts for agricultural machinery. The foundries at Stockton seem to have been larger in scale and to have depended more on the industrial demand for castings. The Portrack Lane works had been established as early as 1806, and in the 1860's it gave employment to 150 people.[1.] The West Row foundry was even older, dating from the mid-eighteenth century, and it employed 70 people in the 1860's.[2.] The various works at Stockton probably owed their size mainly to the local shipbuilding industry; for even before the advent of iron hulls and marine engines there were many parts of a ship which could usefully be made of iron.

Shipbuilding and boat construction must also have been important to the Hartlepools foundries. The Middleton Iron Works, however, was concerned more specifically with engine building, for which castings were vital, and it was the largest of the works involved with founding in the vicinity of the Hartlepools. Established in 1839, the Middleton works

1. Heavisides, op.cit., p.151.

2. Ibid., p.153.

Table 8.8

Engineers and Iron Founders in 1851.[1]

Location	Firm	Address.
Darlington.	W. Davison.	7, Prospect Place.
"	A. Kitching.	Market Place and Railway Foundry.
"	W. and J. Wray.	Tubwell Row and Bridge Row.
"	Executors of W. Lister.	Hope Town.
"	J. Naggs.	Chapel St.
"	J. Finkell.	Tubwell Row.
"	J. Forrest.	Queen St.
Stockton.	G. Brown and Brothers.	Portrack Lane Ironworks, Portrack Lane,
"	M. Cadle.	41, High St.
"	Fossick and Hackworth.	Stockton Iron Foundry, Norton Road.
"	J. Mainwaring.	Eagle Foundry, Skinner St.
"	R. Roger.	West Row Foundry.
West Hartlepool.	S. Bastow.	
	R. Malthouse.	
	T. Richardson and Sons.	Middleton.
Hartlepool.	A. Liddell.	Northgate St. and Commercial St.
	R. Malthouse.	High St.
Middlesbrough.	Barningham Brothers.	Commercial St.
"	Bolckow and Vaughan.	Vulcan St.
"	Gilkes, Wilson and Co.	Tees Engine Works, Lower Commercial St.
"	R. Malthouse.	Stockton St. and Turton St.
"	R. Hedley.	Cleveland Iron Works, Lower Commercial St.
Haverton Hill.	S. Robinson.	Haverton Hill Iron Works.
Seaton Carew.	S. Barston.	Carr House.
Castle Eden.	T. Richardson and Sons.	

1. For sources of information see text.

had been bought in 1847 by Thomas Richardson, who already had a similar business at Castle Eden and whose son was in later years to extend the family interests into various other industrial fields.[1] Under Richardson's management, 200 locomotive, stationary, pumping and marine engines had been built at the Middleton works by 1851.[2]

The largest foundries in the region at this time may well have been located at Middlesbrough, but, if so, they were not specialised works. Bolckow and Vaughan, who had begun building marine engines in the 1840's, had a foundry at their Vulcan Street ironworks, where they used pig iron from their blast furnaces at Witton Park. William Barningham, who was later to establish the Darlington and Springfield wrought iron works, was then engaged at Middlesbrough in manufacturing railway switches and crossings.[3] Gilkes and Wilson, later to build blast furnaces and a puddling plant, were also occupied in railway engineering, but their interests were in locomotive engines and rolling stock.[4] The remaining Middlesbrough ironfounders were probably more specialised as such, but little is known of them.

1. Robert Wood, "The Middleton Works", in Articles on Local History, Vol.1 , typescript, Hartlepools Public Reference Library, 1964, pp.27-29.

2. Loc.cit.

3. Jeans, Pioneers of the Cleveland Iron Trade, op.cit. p.189.

4. Ibid., pp.120-21.

So far as it is possible to judge, the foundries on Teesside in 1851 were distributed in a manner which was likely to minimize transport costs. Most were located in towns that were ports, as well as markets for castings, and hence were the region's sources of iron at a time when it had to be imported. There was also a number of small establishments at Darlington, which was not a port, but this is not surprising. As an important service centre, Darlington was the focus of the demand for small ironware emanating from the surrounding area. As neither the product nor any one material was locationally dominant, and because Darlington was a median point on the line between the coalfield and the ports through which pig iron was imported, it was more efficient to manufacture castings for the local market at Darlington than anywhere else.

It is, however, rather unrealistic to consider founding in isolation. Much of the work was undertaken in foundries which formed part of more general engineering or iron making establishments, and even many of the small and more specialised firms probably produced forgings as well. Indeed, it is doubtful if there were any works which made only castings or forgings, and certainly there were no specialist forges listed in the directories for 1851. The latter point may be taken as evidence that the principles of location theory were adhered to, and that forge works were confined to the coalfield, as it was suggested earlier they should have been. In their locational requirements, the forges on Teesside, that were part of more general works yielded precedence to the requirements of the works as a whole.

Two other types of iron working represented in the region in 1851 merit notice : chain and cable making and nail manufacturing. As can be seen from Tables 8.9 and 8.10, both were confined to the main towns. The firms engaged in those trades were small, and they presumably relied entirely on local demand. A market location was probably best for them when the market lay between the coalfield and the ports which provided the iron, as in the case of Darlington, or when the market centre was also a port, as in the cases of the other large towns.

The complex structures of the iron making and engineering industries, and the limited data available, means that it is not possible to discuss separately either the production of castings or that of forgings in much detail for later years. Both certainly expanded on a massive scale during the subsequent three decades, but the bulk of the output of castings and forgings must have come from general engineering and metallurgical works rather than specialised establishments. Nevertheless, for the sake of obtaining some measure of comparison with the position in 1851, a list of 'Engineers and Iron Founders' has been prepared for the region in 1879 (Table 8.11). It excludes those firms and works mainly concerned with pig iron or wrought iron making, or both, the view being taken that their locational requirements and choices can have been little influenced by those of their

Table 8.9

Chain and Cable Makers in 1851.[1]

Location	Firm	Address
Darlington.	J. Coull.	Tubwell Row.
Hartlepool.	Bruce and Son.	High St.
"	R. Malthouse.	"
"	T. Robson.	"
West Hartlepool.	Bruce and Son.	
"	R. Malthouse.	
"	P. Simm .	Middleton.
Middlesbrough.	R. Malthouse.	Stockton St. and Turton St.
"	J. Pearson and Son.	Dock Works, Lower Commercial St.
"	R. Richardson.	Vulcan St.

Table 8.10

Nail Manufacturers in 1851.[2]

Location.	Firm.	Address.
Darlington.	J. Coull.	Tubwell.Row.
"	T. Cuthbertson.	59 Bond Gate.
"	T. Dobson.	Church St.
"	W. Hobson.	Northumberland Place.
"	J. Groves.	12, Tubwell Row.
"	W. Tolson.	Northgate.
Stockton.	W. Burnham.	44, Brunswick St.
"	J. Mainwaring.	Eagle Foundry, Skinner St,
Hartlepool.	T. Holmes.	Minerva Place.
"	T. Robson.	Union Place and Victoria Docks.
"	G. Wilson.	High St.
Middlesbrough.	J. Telford.	Commercial St.

1. Sources of data : Ward, op.cit.; and Hagar, op.cit.

2. Loc.cit.

founding or forging departments. Even so, the establishments included were not specialist foundries. Forgings as well as castings were probably generally made, and in many cases both may have been subordinate to the overall production of machinery or iron structures.

Perhaps the most striking feature of Table 8.11 is that most of the works were located in the five main towns. Very few were outside them and, of those, only four were not in their immediate vicinity. The four works in the last group were respectively located at Coxhoe, Liverton, Lofthouse and Guisborough, all of which were mining centres, and they probably depended on the local mining industries for custom. There would have been a need for repair and maintenance facilities for mine machinery and railway rolling stock in those areas.

So far as works in the main towns are concerned, Stockton and Darlington were the principal centres. Numbers alone may be an inadequate guide, but there is supporting evidence for this view. Darlington was perhaps the most distinctive of the towns, in terms of industrial structure. It was heavily committed to railway engineering, as a result of its place on the main north-south line in eastern England and the historical role of its citizens in railway development. The engineering and founding firms in Darlington were accordingly deeply involved with manufacturing railway equipment and with the provision of repair facilities for rolling stock and locomotives. For example, the Darlington Forge

Table 8.11

Engineers and Iron Founders in 1879.[1]

Location.	Firm.	Address.
Stockton.	Ashmore and While.	Hope Iron Works.
"	G. Brown and Brothers.	Portrack Lane Iron Works.
"	G. Clough and Co.	Vulcan Iron Works.
"	J. Pickering.	Globe Works.
"	R. Roger.	West Row.
"	Stockton Forge Co.	North End.
"	H. Wilson and Co.	Phoenix Works.
"	Johnson and Reay.	Moor Iron Works.
"	Smith and Thomson.	Millfield Iron Works.
"	Blair and Co.	Norton Road.
"	N. Downing.	6, Richmond St.
"	J. Mainwaring and Co.	Eagle Foundry, Skinner St.
West Hartlepool.	J. White.	Whitby St.
"	G. Bower.	Milton Ironworks.
"	North of England Waggon Co.	Stranton.
"	T. Richardson and Sons.	Middleton.
Hartlepool.	G. Clarke, T. Nelson and Co.	Millbank Forgeworks.
"	M. Golightly.	Corporation Rd.
Darlington.	Cleveland Bridge and Engineering Co.	Bank Top.
"	Darlington Forge Co.	Albert Hill.
"	Darlington Railway Waggon Co.	" "
"	G. Denham.	Low Mill Works, Backhouse St.
"	R. Teasdale.	19, Pease St. and Thomas St.
"	Ord and Maddison.	3, Northgate.
"	W. Liddell.	Vulcan Foundry, Freeman's Place.
"	Charles Ianson and Co.	Whessoe St.
"	Kellett and Macfeggan.	Union Foundry.
"	J. Shewell and Co.	Albert Hill.
"	Bouch and Dale.	North Road Locomotive Engine Works.

/Cont...

Table 8.11 (Contd.)

Location.	Firm.	Address.
Middlesbrough.	John Archer and Co.	Bottle House Foundry Docks.
"	Macdonald and Co.	Atlas Foundry.
"	James Mellanby.	West Marsh.
"	Richardson and Coverdale.	Acklam Foundry.
"	J.M. Thompson and Co.	Dock Hill Engine Works.
North Ormesby.	Cochrane and Co.	Victoria Foundry.
South Stockton.	Allan and Son.	
	Head, Wrightson and Co.	Teesdale Iron Works.
Coxhoe.	G. Blair and Co.	
Liverton.	Ryde and Goldsworthy.	
Guisborough.	Cleveland Iron Works.	
Lofthouse.	Robinson Brothers.	

1. Sources of data :

E.R. Kelly, The Post Office Directory of Durham and Northumberland, London, 1879, and The Post Office Directory of the North and East Ridings of Yorkshire, with the City of York, London, 1879.

Company, which employed 400 people, specialised in making wrought iron wheels for railway waggons and engines, though it also produced other items.[1] The Darlington Railway Wagon Company was obviously also concerned with railway engineering.

The other Teesside towns were less specialised than Darlington. Middlesbrough had only a few small works, and they had fairly wide interests. Stockton leaned towards pipe and tube production and the manufacture of bridge sections. The Hartlepools, on the other hand, were more concerned with producing mechanical items and structural materials for the local shipbuilding industry. For firms in the 'Engineers and Iron Founders' category, therefore, there was no significant locational shift between 1851 and 1879. Rather, there was a greater concentration at the original locations, which were the main towns. As these were initially service centres and later iron making centres as well, they were ideal locations for the production of castings, and probably for general engineering too. Throughout the period, however, they were poor locations for the manufacture of heavy forgings, and there were no specialised forge works on Teesside.

Steel Production.

Teesside's success as an iron producing district was in itself partly responsible for the tardy development of steel making in the region. While ironmasters in many other areas

1. Jeans, Jubilee Memorial of the Railway System, op.cit. pp.280-81.

were examining and experimenting with processes for manufacturing steel long before the crisis of the mid-1870's, in some cases spurred on by the depletion of local reserves of iron ore and coal and by mounting costs, those on Teesside tended to assume that their future was assured by a combination of ample natural resources, low costs and the world's immense appetite for iron goods of all descriptions. There were also the matters of industrial skill and flair to be taken into account, but Teessiders, by birth ahd by adoption seemed to believe that the region had something of a monopoly of those too. William Barrett must have found that few members of his audience disagreed with the substance of his address to a meeting of the Cleveland Institution of Engineers in 1869 :

> We have here [in Cleveland] the most modern and efficient blast furnace plant. We use the minimum quantity of fuel to make a ton of iron; and though our advantages of position are great, still no small part of this success stands to the credit of engineering skill ....
>
> . . . .
>
> In iron manufacturing, ..., many improvements have been made by Cleveland engineers; and I feel confidence in stating that in the specialties for which the district is suited, a better manufactured iron ore can now be produced for a given price than would be obtainable in any other locality. Besides this, our rolling mills possess superiority, in being better laid out, in containing heavier, larger, and more capable machinery, in making more use of labour saving, and fuel saving, contrivances than their competitors elsewhere, enabling them to supply with ease weights, lengths, widths, and thicknesses which would somewhat perplex the men and machinery of older mills.[1]

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1. William Barrett, "President's Address to the Fifth Annual General Meeting of the Cleveland Institution of Engineers", <u>Proceedings of the Cleveland Institution of Engineers</u>, (1869), p.13.

Prior to 1870, there was no sense of alarm amongst the Teesside ironmasters over the prospect of competition from steel, and the warning implicit in Edward Williams's survey of the future of the iron rail trade in 1869 was doubtless soon put out of mind during the boom conditions which ushered in the new decade.[1] There was still a substantial price difference between wrought iron and mild steel, and the latter, while a useful metal - admittedly superior to iron in some respects -, was still unacceptable in many fields. Perhaps more important, and certainly of more immediate significance, pig iron made from Cleveland ore could not be used in the acid Bessemer and open-hearth processes, which were then the only methods known of producing steel in large quantities. To have transferred resources to either of those processes would have meant using imported ore and losing the advantages resulting from the local presence of ironstone. It would also have meant surrendering much of the capital already sunk in wrought iron works, at a time when the demand for wrought iron was high. There was consequently little incentive for Teesside ironmasters to wswitch to steel production, and the pressures on them to do so were not yet compelling.

Even so, more sustained efforts could usefully have been made to find a means of making steel from Cleveland pig before the crisis arose which was to destroy the wrought iron industry. In retrospect, it seems strange that the

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1. For his discourse, see Williams, op.cit., pp.156-71.

solution, which was a simple one, was not found earlier than 1879. The main obstacle was perhaps the common feeling amongst the ironmasters that the problem was intractable. Nevertheless, with the advantage of hindsight again, it is clear that the ingenuity, time and money expended on efforts to improve the puddling process would have been better employed in this field.

There were intermittent experiments over a number of years, but the most notable of the early attempts to manufacture steel from Cleveland pig iron was made in 1869 by Bernhard Samuelson.[1] Disregarding suggestions to the contrary, Samuelson was satisfied that the open-hearth furnace could be used for that purpose, and he accordingly leased the North Yorkshire Ironworks at South Stockton and adapted it to produce steel rails, plates and angles. It soon became clear, however, that the phosphorous problem had not been eliminated by ignoring it, and the venture was quickly abandoned, having cost Samuelson £30,000.[2]

Steel was not made in the Teesside region for almost another decade after this episode. In 1875, tired of waiting for the wrought iron market to recover, Bolckow and Vaughan began to lay the foundations for a Bessemer steel plant which would use imported ore.[3] This, the Cleveland Steelworks, was located in the vicinity of Grangetown - Eston

1. See Jeans, Pioneers of the Cleveland Iron Trade, op.cit. pp.224-29.

2. Ibid., p.228.

3. Burns, op.cit., p.23.

Junction, as it was then known -, and it opened in 1877. By the following year, 1000 tons of steel rails were being made there weekly.[1] A few other firms decided to follow the lead given by Bolckow and Vaughan, and were encouraged to do so by the discovery in 1879 that the fitting of a lining of basic material to the converter permitted the making of steel, by the Bessemer process, from phosphoric pig. Table 8.12 lists the steel plants built by 1881.

Table 8.12

Steel Plants on Teesside in 1881.[2]

Location	Works	Firm	Facilities
Grangetown.	Cleveland Steelworks.	Bolckow, Vaughan and Co.	8 Bessemer converters of various capacities.
Middlesbrough.	North Eastern Steelworks.+	North Eastern Steel Co.	4 10-ton Bessemer converters.
"	Erimus Steel Works.		2 6-ton Bessemer converters.
Darlington.	Darlington Iron Works.	Darlington Iron Co.	2 6-ton Bessemer converters.
Middlesbrough.		Butler Brothers.	1 open-hearth furnace.

+ Under construction.

The early steel industry on Teesside was thus geared towards the Bessemer process, which was highly significant in a locational context. The Bessemer process gave rise to substantial fuel economies and contributed to the further undermining of the attractions of the coalfield. It was possible for molten pig iron to be run directly to the converter from the blast furnace, and once it was there, no

1. Charles Wilson, "Company Histories : 1, Dorman Long", Steel Review, Vol.6 (1957), p.16.

2. Data from Hunt, op.cit.

additional fuel was needed to make steel ingots. This contrasted very favourably with the wasteful procedure of converting pig into wrought iron by means of puddling. Theoretically, at least, it was possible to produce finished steel, as rails or in other forms, without consuming any fuel other than that used in smelting.[1] In practice, however, the industry was still fairly remote from realising that possibility.

Modes of operation varied considerably between firms and works, and this must be taken into account in assessing the industry's locational optimum. Bolckow-Vaughan's Cleveland Steelworks was a good model of one type of works. It was built as an integrated plant, with blast furnaces, converters, reheating furnaces and rolling mills.[2] It was also one of the first in the country to incorporate the system, favoured on the Continent,[3] of charging the converter with molten pig iron brought directly from the blast furnace.[4]

At the time when the Cleveland Steelworks was planned, only the acid processes for making steel were available. Provision was therefore made for drawing supplies of haematite from Spain. The Spanish ore was richer in iron than that from Cleveland, and 40 cwts. of it sufficed to make a ton of steel.[5] Because a smaller quantity of ore was re-

1. See Burnham and Hoskins, op.cit., p.187.

2. See Jeans, Notes on Northern Industries, op.cit., pp.143-49.

3. Burns, op.cit., pp.49-50.

4. Jeans, Notes on Northern Industries, op.cit., p.143.

5. Bell, Principles of the Manufacture of Iron and Steel, op.cit., p.114.

quired, less fuel was needed. For furnaces of the size built by Bolckow and Vaughan, about 19 cwts. of coke per ton of pig made were used normally with Spanish ore,[1.] though lower figures were not uncommon.[2.] A further, but small, fuel saving resulted from the fact that it was unnecessary to calcine haematite before charging it to the blast furnace. In addition to the fuel used during smelting, 13 cwts. of coal, according to Jeans,[3.] were consumed in converting steel ingots into rails, which were the main product.

Thus, the approximate quantities of materials needed to make a ton of steel rails in an integrated works using the acid Bessemer process were : 32 cwts. of coke and coal, 40 cwts. of haematite and 5 cwts. of limestone.[4.] Since the ore was imported and the product exported, the market and the source of the iron ore were effectively coincident, so far as the region was concerned. Together, the ore and the product weighed more than the other materials. Hence, the optimum location for works in this category was a point alongside navigable water which had docking facilities. It was also necessary for that point to be as close to the coalfield as possible, since it would have been inefficient to have

1. I.e. furnaces 72 feet high - see Jeans, Notes on Northern Industries, op.cit., p.144.

2. Bell (Principles of the Manufacture of Iron and Steel, op.cit., p.114) gave 17.6 cwts. as the figure pertaining to one of the Clarence furnaces. However, Jeans ("On the Consumption and Economy of Fuel in the Iron and Steel Manufacture", op.cit., p.133) suggests that 19 cwts. was more typical.

3. Jeans, ibid., p.153. This figure applied to works with converters close to blast furnaces.

4. Figure for limestone consumption from Bell, Principles of Iron and Steel Manufacture, op.cit., p.114.

moved the coal and the limestone any further than could not be avoided.

In the abstract, Stockton or Thornaby, which were as far upstream as vessels of any size could reach on the Tees, would seem to have fulfilled these conditions best. Grangetown may therefore have been inferior as a location for the Cleveland Steelworks. It is possible, however, that there was some form of scale economies - perhaps administrative - Bolckow and Vaughan could obtain by building their new plant adjacent to some of their existing works, in which case Grangetown may have been preferable to places further upstream for that firm.

The position was changed slightly by the adoption of the Thomas-Gilchrist basic process for making steel. By 1881, at least three of the converters at the Cleveland Steelworks had been equipped to produce basic steel,[1] and these were used along with the others until Bolckow and Vaughan abandoned the Bessemer converter in favour of the open-hearth furnace in 1911.[2] In making basic Bessemer steel, Cleveland ironstone was used, and this meant that slightly more fuel, for smelting and calcining, and a lot more ore were required. As a result, the market - as the median point between the coalfield and the orefield - was the optimum location. To minimize transport costs, however, the best market in the

1. Anon., Thomas and Gilchrist : Bolckow and Vaughan, 1879-1929, Middlesbrough, 1929, pp.26-27.

2. Loc.cit.

region was the one nearest to the source of the ore, the ore being heavier than the fuel and the limestone together. In these terms, Middlesbrough and the area to the east were preferable as locations to Stockton or Thornaby. As an integrated works producing basic Bessemer steel, therefore, the Cleveland Steelworks was admirably located.

There was a rivalry between the various steel processes at this time. The open-hearth furnace, which could also be used for making acid or basic steel after 1879, was much slower to be adopted than the Bessemer converter. As Burns has suggested, one probable reason was that "at first its economic value was not clear, since production costs were above Bessemer costs."[1] During the 1870's, the cost of making rails by the Bessemer process fell substantially, with the result that the existing open-hearth producers were virtually all eliminated.[2] The open-hearth furnace did have some advantages, such as its suitability for making steel from scrap and the greater control it allowed over the conversion process, but it was not until much later that they were accepted as sufficient to justify the abandonment of the Bessemer converter.[3] Certainly, there was little interest in the open-hearth furnace on Teesside in 1881.

1. Burns, op.cit., p.51.

2. Birch, op.cit., p.375.

3. Open-hearth steel production did not exceed the Bessemer output until 1894 (ibid., p.377), and Bolckow and Vaughan did not decide to use only open-hearth furnaces until 1911.

So far as the Bessemer converter was concerned, the basic process was relatively slow to be accepted because it was more costly than the acid process.[1] The main reason for this was that the basic lining used in the converter had a short life, and the frequency with which it had to be repaired and replaced involved considerable material and labour costs, as well as interrupting production. There was also the small extra cost of adding basic materials to the charge to be taken into account. On the other hand, it was possible to use pig iron made from local and hence cheaper ore, which represented a saving, but this was more valuable to Continental firms than to British manufacturers who had coastal locations for their works.[2]

Ironically, while the discovery of the basic process meant that Cleveland ore could be used for steel making, it is doubtful if there was any advantage in it for Teesside producers.[3] They were obtaining supplies of Spanish haematite for a few shillings per ton, the extra cost of transporting the ore being compensated by a higher iron content. In 1884, Lowthian Bell stated that it was his belief that it would ultimately prove possible to make basic steel from Cleveland ore as cheaply as acid steel was being made from Spanish ore.[4] This is a clear indication that the invention of the basic process had not proved so beneficial as might have been expected.

1. Burns, op.cit., p.76.
2. Carr and Taplin, op.cit., p.156.
3. Burns, op.cit., p.173.
4. Bell, Principles of the Manufacture of Iron and Steel, op.cit., pp.4-5.

In addition to the matter of cost, there was also a problem of quality associated with the basic process. Prejudice helped to limit the demand for basic steel for a considerable period, but it does not seem to have been entirely unjustified.[1] The basic steel produced in the Bessemer converter, in particular, varied considerably in quality. In part, this was due to the lack of experience in dealing with the minor impurities of the pig iron,[2] but it was also due to the rather crude nature of the Bessemer process itself. Iron was turned into steel very quickly in the converter, and there was little opportunity to regulate the process. This was a shortcoming which eventually led to the supersession of the Bessemer converter by the open-hearth furnace.

For these various reasons, Bolckow and Vaughan continued making both acid and basic steel for many years after 1879. On the other hand, the North-Eastern Steel Company made nothing but basic Bessemer steel from the outset, and it showed satisfactory profits as a result of doing so.[3] This company began constructing its works at Middlesbrough in 1881 and rolled its first steel rails, the staple product, in 1884.[4] It did not, however, have any blast furnaces prior to 1896, and the location of the North-Eastern Steelworks must therefore be assessed separately from that of Bolckow-Vaughan's Cleveland Steelworks.

1. Burns, op.cit., pp.174-81.
2. Cleveland basic steel suffered from an excess of sulphur and phosphorous at first. See ibid., p.176.
3. Ibid., p.171.
4. Loc.cit.

According to Jeans, heating pig iron in cupolas, instead of running it in a molten state from the blast furnace to the converter, raised the average coal consumption in making a ton of steel rails to 16 cwts.,[1] excluding the fuel used in smelting. The fuel required still weighed less, however, than the pig iron or the product. Hence, the optimum location for a works that made steel rails but not its own pig iron was either the market or the pig iron source, depending on which of these was the median point, or the place where the two were coincident. The best location in the region was probably Stockton or Thormaby, both of which had blast furnaces and shipping facilities and were nearer the coalfield than were places to the east. However, Middlesbrough was a sound location for a firm obtaining its pig iron from blast furnaces in that town, as the North-Eastern Steel Company must have done.

The Bessemer plant at Darlington, belonging to the Darlington Iron Company, had perhaps the poorest location of the steel works on Teesside. It did not have its own blast furnaces, though pig iron may have been drawn in a molten state from the nearby South Durham Ironworks. The introduction of Gjers's 'soaking pits' in 1882 must have lowered costs somewhat, since it obviated the need to reheat ingots prior to their being rolled.[2] Nevertheless, costs cannot have been other than high. The main product of the Darlington works

1. Jeans, "On the Consumption and Economy of Fuel in the Iron and Steel Manufacture", op.cit., p.152.

2. Birch, op.cit., p.365.

was rails, and they had to be shipped from the ports on the lower Tees. Whereas a firm with its works at Middlesbrough had to carry only 16 cwts. of coal between Darlington and Middlesbrough, the Darlington Iron Company had to carry the economic weight of the product, which must have been 30 cwts., over that distance. The time was fast approaching when Teesside firms would find it difficult to compete in foreign markets if they continued to bear such unnecessary costs.

The Shipbuilding Industry.

National Development.

As in the cases of so many other industries, shipbuilding in the United Kingdom underwent a dramatic transformation in the third quarter of the nineteenth century. One indication is provided by various statistical series. For example, the national mercantile marine rose from 3,662,000 to 6,692,000 tons between 1851 and 1881. This expansion occurred despite a reduction in the total number of registered vessels from 26,043 to 24,830,[1.] revealing that the size of the average British ship virtually doubled in that period. The output of British yards grew at an increasing rate, and was consistently far higher than in the first half of the century. Most of the output helped to swell the home merchant fleet but a substantial, and rising, proportion was exported. From mid-century to the later 1880's. the shipbuilding industry steadily increased its share of the national

1. Statistical data from Mitchell, op.cit., p.218.

income.[1] It was, therefore, a time of general expansion, with home and foreign markets growing, and the tonnage and value of the output rising.

These overall quantitative trends were intimately related to qualitative changes taking place in the industry, changes involving the adoption of new materials and sources of power which were quite as revolutionary as contemporary innovations in the iron industries. In 1851 the British merchant navy was essentially a fleet of wooden sailing ships. It consisted of 3,476,000 tons of sail-shipping and only 187,000 tons of steam-shipping.[2] There are no figures for the reppective tonnages of iron and wooden vessels at that time, but of the ships being built in 1851, 134,000 tons were of wood and 16,000 tons of iron.[3] By 1881, the situation was very different. The two major streams of technical change affecting the shipbuilding industry in the intervening period were the transitions from sail to steam power and from wood to iron hulls. The two, however, were not so complementary as might be supposed; there were wood and there were iron sailing and steam ships, as well as a great many hybrids. The iron steam-ship did not come into its own until comparatively late, and was in any case soon threatened with supersession by the steel steam-ship.

1. See Deane and Cole, op.cit., pp.234-36.

2. Mitchell, op.cit., p.218.

3. Loc.cit.

From its lowly position in 1851, iron rose to account for 30 per cent of the tonnage being built in 1860,[1] and 50 per cent soon afterwards.[2] By 1881, seven times as much new tonnage was being made of iron as of wood.[3] In that same year, the total amount of shipping registered in the United Kingdom consisted of 3,688,000 tons of sailing vessels and 3,004,000 tons of steam vessels, and the tonnage of steam ships under construction was four times as large as that of sailing ships. By 1883, more of the tonnage registered in this country was driven by steam than sail.

In terms of numbers of vessels, the transition from sail to steam was less impressive. Between 1851 and 1881, the number of registered steam ships rose from 1,227 to 5,505, but the number of sailing ships only fell from 24,816 to 19,325. Although steam was close to parity with sail in terms of tonnage by the end of the period, steam ships were much less numerous, as they continued to be until into the twentieth century. However, it is probable that for some years before 1881 the steam fleet had been doing more work.[4]

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1. G.B. Hunter and E.W. De Rusett, "Sixty Years of Merchant Shipping on the North East Coast", Transactions of the North East Coast Institution of Engineers and Shipbuilders, Vol.26 (1909), p.95.

2. K. Maywald, "The Construction Costs and the Value of the British Merchant Fleet, 1850-1938", Scottish Journal of Political Economy, Vol. 9 (1956), p.46.

3. Mitchell, op.cit., p.218. Subsequent references to tonnages and numbers are also to this source, unless stated otherwise.

4. J.H. Clapham, An Economic History of Modern Britain : Free Trade and Steel, 1850-1886, Cambridge, 1963, p.72.

The rivalry between sail and steam extended over a long period, despite the apparent advantages held by the latter. Experimental work on steam-driven marine engines began in the eighteenth century,[1] but it met with little success until William Symington built the first operational steam boat, a tug, in 1802.[2] Subsequently, the pace of development quickened.[3] By 1822, 151 steamers had been launched in the United Kingdom - 48 of them on the Clyde - and twice as many in the United States.[4] Steam boats had thus lost some of their novelty, and by 1834 there was a hundred of them working as tugs on the Tyne.[5]

Even so, the early steamers had a limited value. For a long period they were confined to rivers and coastal waters by the unreliability of their engines, their slow speed and their large fuel requirements.[6] With time, however, improvements were made and the range of the steamer was extended. During the 1820's steam boats worked in the Channel and along the shores of the North and Irish Seas, in the 1830's they penetrated the Mediterranean as far as Malta

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1. Leslie Jones, <u>Shipbuilding in Britain</u>, Cardiff, 1957, pp.17-18.

2. George Blake, <u>Lloyds' Register of Shipping, 1760-1960</u>, London, 1960, p.36.

3. Jones, <u>op.cit.</u>, pp.17-18.

4. <u>Loc.cit.</u>

5. N.A. Elliott, "Tyneside : A Study in the Development of an Industrial Seaport", unpublished Ph.D. thesis, University of Durham 1955, p.298.

6. Blake, <u>op.cit.</u>, p.38.

and Egypt and even crossed the Atlantic, and by 1840 they were used on regular services to most European seaboard countries and to the United States.[1.]

Despite such progress, however, steam boats built prior to 1850 were typically small, wooden, driven by paddle wheels and unsuitable for carrying bulk cargoes. In 1847, the average size was still only 125.5 tons, and the total British steam tonnage of 116,000 was little more than the sailing tonnage under construction.[2.] The 924 steamers in the British register in that year were mainly river boats, tugs or carriers of mail, passengers and lightweight cargoes. At mid-century, the oceans and open seas were still the fastness of the sailing ship.[3.]

Iron, too, was slow to be accepted and exploited by shipowners and shipbuilders, though the antecedents of the iron ship, in the form of barges, also lay in the eighteenth century.[4.] The Liverpool-built Ironside, launched in 1830, is generally believed to have been the first iron sailing ship.[5.] Before it took to the water, however, a number of

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1. G.S. Graham, "The Ascendancy of the Sailing Ship,1850-1885", Economic History Review, Vol.9 (1956), p.74.

2. J.H. Clapham, An Economic History of Modern Britain : The Early Railway Age, 1820-1850, Cambridge, 1959,p.438.

3. See ibid., p.439.

4. David Dougan, The History of North East Shipbuilding, London, 1968, p.37.

5. Clapham, Free Trade and Steel, 1850-1886, op.cit., p.63.

iron steam-boats had been made on the Clyde and on the Mersey.[1] The first iron ship produced in the North East was a small steamer launched at South Shields in 1839.[2] It was followed by others in the 1840's, as yards for building iron vessels proliferated along the Tyne. Iron ships were still comparatively rare at that time, however, and even in 1847 Lloyd's had no regular system for classifying them.[3] Clapham has estimated that no more than 150 iron ships had been built by 1847.[4]

In 1851, most of the 16,000 tons of iron shipping under construction consisted of steam boats, and they represented more than half the steam-powered vessels then being built.[5] However, most of the new shipping on the stocks, in terms of tonnage and numbers, still comprised wooden sailing ships.[6] Moreover, the great days of sail were still to come, though iron was to take the place of wood at an increasing rate, as it became cheaper and as the shipbuilding industry acquired the new skills necessary to cope with it.[7] On the Tyne and in Scotland, many of the early iron vessels were made not by shipbuilders but by engineers and boilermakers.[8] The use of

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1. Blake, op.cit., p.40.
2. Dougan, op.cit., p.38.
3. Clapham, The Early Railway Age, op.cit., p.440.
4. Loc.cit.
5. Mitchell, op.cit., p.223.
6. Loc.cit.
7. Blake, op.cit., pp.40-42.
8. Hunter and Rusett, op.cit., p.96.

iron was encouraged by the appointment in 1853 of a special Lloyd's sub-committee to tour the various iron shipyards, with a view to drawing up a set of specifications to be met in the construction of iron ships.[1]

By the mid-1850's, iron had superseded wood only for steam-driven passenger and experimental war ships.[2] In the form of the screw collier, however, iron and steam had come together to challenge the sailing ship's monopoly of the bulk-carrying trade. The first of these highly successful craft was launched at Jarrow, on Tyneside, in 1852.[3] It was designed specifically for the purpose of carrying coal to London, in the hope that it would allow the North East coal industry to retain its traditional primacy in the London market in the face of competition from the Midlands, which had recently gained access by rail to the South East. The first of the new line, the John Bowes, cost £10,000 to build, as against £1,000 for a sailing vessel of similar capacity, and was regarded as a risky venture. On its first voyage, however, it completed in five days work that would have taken a sailing collier two months to accomplish.

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1. Blake, op.cit., p.42.
2. Graham, op.cit., p.76.
3. It was built by Charles Mark Palmer. See his article : "On the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear and Tees", Report of the 33rd, Meeting of the British Association, 1863, pp.694-701.

The extra construction costs and the cost of the fuel were outweighed by the ability of the iron screw collier to forge ahead through seas and winds that would have seriously delayed a sailing ship. Within three years Palmer, the conceiver of the idea, had built 26 vessels similar to the John Bowes.[1] Their success gave a much-needed fillip to shipbuilding on Tyneside, and elsewhere, encouraging the use of iron for hulls and stimulating research into means of improving marine engines.[2] The iron screw steamer steadily expanded in numbers after the original proving voyages. Over distances of up to 500 miles, it could carry merchandise at about one-third of the cost incurred by the paddle steamer, and two-thirds of that of the sailing ship.[3] Over longer distances, especially when the winds were steady and there was no question of driving into high seas, the large wooden sailing ship was still faster and cheaper than any other form of transport,[4] even though its capacity was smaller than that of an iron ship of similar dimensions.

On the great oceanic routes the traditional sailing ship did, however, meet with growing competition during the 1850's. This was from sailing ships made of iron or built to a composite design. In 1851 a mere 2,000 tons of iron sailing ships were under construction in the United Kingdom,[5]

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1. Dougan, op.cit., p.44.
2. See Westcott Abell, The Shipwright's Trade, Cambridge, 1948, pp.157-61.
3. Graham, op.cit., p.76.
4. Loc.cit.
5. Mitchell, op.cit.

but the tonnage rose steadily. In 1875, the peak year, there were 199,000 tons on the stocks.[1] The tonnage of wooden sailing vessels being built contracted equally steadily from 125,000 tons in 1851 to 17,000 tons in 1881.[2]

One of the main advantages of using iron was that it became possible to overcome the traditional problem of a shortage of home-grown timber, a problem which had long plagued the Royal Navy and had forced mercantile interests to use relatively expensive foreign wood or have their ships built in foreign yards.[3] In particular, iron could be used as a substitute for the large structural timbers, which were the most difficult to obtain.[4] This gave rise to the composite design, in which wood was laid on an iron frame. Many of the tea clippers built in the 1850's were in fact composite ships.[5]

There were other advantages too. As Palmer pointed out, an iron ship weighed 35 per cent less than a vessel of the same size made of wood,[6] largely because the hull did not

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1. Loc.cit.
2. Loc.cit.
3. Clapham (Free Trade and Steel, op.cit., p.65) says that a large proportion of the additions made to the British mercantile fleet in the twenty years after Waterloo was purchased from Canadian and American yards for this reason.
4. Ibid., p.67.
5. Ibid., p.68; and Blake, op.cit., p.46
6. Palmer, op.cit., p.695.

need to be so thick. Size for size, therefore, the iron ship had more cargo space. It was also stronger, and could be driven harder into a head-sea. Palmer argued that :

> The additional strength obtainable, ..., allows iron ships to be built much longer and with finer lines, thus ensuring higher sailing or steaming qualities, with greater carrying power, and therefore, greater commercial results.[1]

Perhaps the main disadvantage, apart from a shortage of skilled men for working iron and the shipbuilding industry's reluctance to reduce its traditional commitment to wood,[2] was that iron hulls were very susceptible to fouling.[3] This made the iron sailing ships slower than their wooden counterparts, which had copper-sheathed undersides. Over long routes, such as the clipper track from China, this difference could be of critical importance, especially where speed brought its own rewards. On the China run, iron-hulled sailing ships could take six months instead of the three months required by the clippers. In addition, the expense of cleaning iron hulls could itself be considerable.[4] Until at least 1870, therefore, the wooden sailing ship and the lighter and more spacious composite vessel retained their dominance on the long-distance routes.[5]

1. *Loc.cit.*

2. Graham, *op.cit.*, p.75.

3. *Ibid.*, p.76.

4. Graham (*loc.cit.*) mentions that the P. & O. Steamship Company spent about £70,000 per year on cleaning the hulls of their ships.

5. *Loc.cit.*

Indeed, it was not until the 1850's that British wooden sailing ships attained their finest expression. It was only then, for example, that they began to rival the American clippers for speed.[1] At the same time, there was a lowering of material costs which enabled British yards to compete with those on the eastern seaboard of North America. This affected not the better quality timber but many of the ancillary materials - such as iron, copper, hemp and sail cloth - which together accounted for a large part of construction costs.[2] More use also began to be made of softwoods, other than for the clippers which relied on expensive hardwoods for the strength to withstand long periods of fast sailing.[3] It has been estimated that a ship built of softwood cost £17 or £18 per ton in 1850, whereas the Blackwall frigates, which were built of teak on oak frames and were elaborately equipped for the China run, cost £22 to £25 per ton.[4] In contrast, an iron ship then cost £25 to £30 per ton.[5]

Nevertheless, iron came to be generally accepted for steam ships between 1855 and 1865, according to Clapham. In that same period the iron sailing ship became common on all routes where speed was not of critical importance, as a result of the decline in the cost of iron relative to that of wood and the growing appreciation of the greater carrying

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1. Ibid., p.79.
2. Ibid., p.80.
3. Loc.cit.
4. Loc.cit.
5. Loc.cit.

capacity of iron vessels.[1] The sailing fleet reached its maximum size in 1865, when there were 4,936,776 tons of sail shipping employing 158,000 men.[2] Thereafter, the tonnage began to fall, particularly that of wooden ships, despite the constantly improving sailing performances which resulted from a growing knowledge of the world's wind patterns and ocean currents.

The development of the more efficient compound engine in the 1860's gave the steam ship a commercial stimulus, and its competitive stature was further enhanced by the growing network of bunkering facilities.[3] The compound engine reduced fuel consumption by 60 per cent, and thereby increased the range of the steam ship as well as lowering its operating costs.[4] By 1870, it had become profitable to use steam ships in trading with China. The opening of the Suez Canal was of further assistance, in that it reduced the distances between coaling stations for ships travelling to the Indian Ocean. These factors together led to a slump in the building of sailing ships. However, sail later recovered by concentrating on the long-distance traffic in cheap, bulky commodities. Many sailing ships were relegated to carrying coal to the more distant parts of the world, often supplying the bunkers established for steam ships.

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1. Maywald (op.cit., p.50) shows that the slight fall in monetary costs was much greater in real terms.

2. Clapham, Free Trade and Steel, op.cit., p.67.

3. Graham, op.cit., p.83.

4. See ibid., pp.82-88 for details of the improvements in marine engines and the ascendancy of steam.

This, they could do very cheaply, and often very profitably, especially when the coal served as ballast on the outward run for ships whose main business was the carrying of grain from America or wool and wheat from Australia.

The sailing ships were not finally eclipsed until the price of steel fell sufficiently to render it as cheap as iron, and hence acceptable to shipbuilders and owners concerned with keeping construction costs as low as possible. This came about in the early 1880's, and by then steel was recognised to be superior to iron for hulls. More important, steel could withstand greater pressures than iron, which made higher pressures in ships' boilers feasible. In turn, this opened the way to the invention of the triple-expansion engine, which - with its high pressure and much greater efficiency - finally made the steam ship supreme over even the longest of trade routes.

The Industry on Teesside.

Shipbuilding on Teesside has a long pedigree. Yarm was once an important centre for the industry, though it played only a minor role in the nineteenth century. There were undoubtedly breaks in the early record, but there is evidence that shipbuilding has been practised in the region continuously since the mid-eighteenth century. At that time, according to Heavisides,[1] there was a yard at Stockton belonging to the Headlam family. It subsequently had a chequered history. From the Headlams it passed, in succession, to

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1. Heavisides, op.cit., p.55.

Michael Humphrey, a Mr. Stephenson, Thomas Haw, a Mr. Mellanby, and then Pearse, Lockwood and Company. Under Thomas Haw's ownership, from 1772 to about 1800, some 61 ships were built at that yard, the largest being one of 750 tons.

Thomas Haw's son followed his father into shipbuilding and worked in premises adjacent to the original family yard, after the latter had been sold.[1] Later, he moved to another yard in Stockton, in Cottage Row. Mellanby's son also went into shipbuilding, and he worked in his father's yard for many years, before leaving it to Henry Markham and moving to a site near Stockton bridge.[2] There was thus a family tradition in the industry, and there was also continuity in the use of particular sites.

In the late 1770's, Mark Pye was constructing frigates for the Admiralty at Stockton, and by 1783 there were three yards in the town fully employed on Admiralty work.[3] Another yard was similarly engaged at Portrack, between Stockton and Middlesbrough. This flurry of activity was largely a result of the new constructioh programme for warships occasioned by the American War of Independence. Between 1782 and 1790, Mark Pye and Thomas Haw, between them, built 24 vessels for the Royal Navy. Demand was sustained during the Napoleonic Wars that followed, and in the years from 1790 to 1805 Haw, alone, built a further 40 ships. Subsequently, the demand eased and in the period from 1805 to 1817 Haw's output fell to 16 ships.

1. Ibid., p.56.

2. Loc.cit.

3. See Dougan, op.cit., pp.25-26.

Stockton was undoubtedly the major shipbuilding centre on Teesside at that time, but the small town and port of Yarm still retained some of its traditional skills. In 1812 a shipping company was formed at Yarm for the purpose of developing a service to and from London.[1] The company was soon reduced to bankruptcy but during its short life it commissioned four ships, two of which were actually built in Yarm. The yard where they were constructed was situated on the north bank of the Tees, near Yarm bridge, and it subsequently produced a number of other vessels. It was in Yarm, too, that John Pile, who was to become an important figure in the industrial life of West Hartlepool, served his apprenticeship and began building ships on his own account.[2]

The channel ofmthe Tees was notoriously shallow and tortuous immediately below Yarm, but that was probably not a major handicap at the time, since ships were still very small on the whole. The largest vessel launched at Stockton by Pye or Haw was a mere 97 feet in length,[3] but even that was considered to be of an impressive size in the early nineteenth century. Even at Sunderland, no ship had been built to a length in excess of 100 feet,[4] and it was there that many of the East Indiamen - the largest ships afloat - were made. Excluding East Indiamen, there were only 20 ships in 1810, out of a total of 24,000 in the British mercantile marine, which exceeded 600 tons in burthen, and there was

1. Heavisides, op.cit., p.56.

2. Loc.cit.

3. Dougan, op.cit., p.26.

4. Hunter and Rusett, op.cit., p.95.

not one which reached 1,000 tons. Yet, a vessel of 1,200 tons was only about 130 feet long.[1] In 1810 the common trader had a burthen of 200 to 300 tons, and one of 400 tons was large.[2]

It is a fitting reflection on the small size of most vessels of the day that in 1817 the brothers Simpson were able to build a large sloop at their premises in Portrack Lane near Stockton. When complete, the ship was placed on rollers and taken to the Tees via the centre of Stockton, a journey which lasted two days.[3] Stockton's status as a shipbuilding centre was enhanced in 1823 by the establishment of the Steam Vessel Company in the town.[4] A year later, this firm lauched the Tees's first steam-powered ship, an innovation which came later than on the Tyne and the Clyde but earlier than on the Wear.[5] Even so, Teesside was something of a backwater for the shipbuilding industry, and outside Stockton and Yarm the industry was not represented in the region for another decade.

In 1833, J. Laing launched Middlesbrough's first ship from his yard near the site of the modern Transporter bridge.[6]

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1. Abell, op.cit., p.100.
2. Loc.cit.
3. Heavisides, op.cit., p.58.
4. Dougan, op.cit., p.30.
5. Loc.cit.
6. Lillie, op.cit., p.65.

This was followed by the construction of other vessels in the town by a number of small firms, none of which survived for more than a few years and some of which produced only one ship.[1] At the time, Teesside was a location of indifferent attractions for the industry; the engineering trades were still undeveloped locally, and though the various ports were conveniently situated for importing timber from the Scandinavian and Baltic countries, the same could be said of most places on the east cost of Britain.

It should also be recognised, however, that the short-lived nature of Middlesbrough's early shipyards was not unusual. Prior to the development of iron hulls and steam engines, shipbuilding was essentially a craftsman's industry, consisting of small units. The yards themselves required little capital investment, since they needed very little fixed equipment, and businesses were established and disestablished according to fluctuations in economic activity and the level of demand for new ships.[2] Demand was running high in the 1830's, due to expansion in the coal trade and a consequent need for additional colliers,[3] but it fell in the following decade, and that was probably the reason for the disappearance of a number of Middlesbrough firms. Without advance orders, and payments, the small business would have been unable to find sufficient capital to keep working; for the cost of even a 300-ton vessesl was about £5,000 in 1849.[4]

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1. Ibid., p.65 and pp.104-105.
2. Jones, op.cit., p.24.
3. Loc.cit.
4. Ibid., p.10. The cost was £15 per ton in 1849.

In the Hartlepools, the first shipyard to be opened in the modern era was that of Richardson and Parkin in 1835.[1.] It was located in the old town, and provides another illustrative comment on the contemporary nature of the industry; Richardson and Parkin had their premises in the High Street, and their first three ships were built there in sections, and then carried to the waterfront for assembly and launching. The crowded state of the peninsula and their need for more working space persuaded the partners to transfer their operations to Middleton in 1838. There, the Hartlepool Dock and Railway Company had built slipways as an enticement.[2.] In 1839 John Denton also established a yard at Middleton, and he built 32 of the 44 ships launched there prior to 1851.[3.]

So far as the building of wooden sailing ships is concerned, there was a number of locations in the Teesside region which would have been almost equally attractive. The bulk of the timber used was imported, and the cost associated with this material would have been the same whether it was unloaded at Hartlepool or Stockton, or some place between, providing that there were sites available with docking facilities and adequate storage space. However, Stockton may well have had advantages due to characteristics not shared by other places. It was the largest port and one of the two largest towns in the region, and would therefore have been

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1. See Wood, West Hartlepool, op.cit., p.57.

2. Loc.cit. and idem., "Shipbuilding"in Articles on Local History, op.cit., p.35.

3. J. Procter, supplement to Cuthbert Sharpe, A History of Hartlepool, 2nd. ed., Hartlepool, 1851, p.57.

better equipped to supply shipbuilders with many of the ancillary materials needed, such as iron and brass fittings, sail cloth, paint and other items. Again, as a port of some stature and tradition, Stockton would have been more likely to have the specialist craftsmen required by shipyards, if only for occasional work. These points in Stockton's favour may be loosely translated into labour and agglomeration economies; in terms of transport costs, there can have been little difference between many potential locations for the shipbuilding industry on Teesside.

In 1851, according to local directories,[1] there were two shipbuilding firms with businesses in Stockton, and one of these, William Turnbull and Company, had a second yard across the river at South Stockton. Turnbull and Robert Craggs, the former's partner, had begun their business in 1832 on Stockton Quayside.[2] Francis Coates had the other yard, which was also on the Quayside, and he undertook repairs and the provision of ancillary equipment and materials as well as building. No doubt, Stockton's role as a port created a need for such services, since there must have been many visiting ships requiring repairs and replacements for damage and losses sustained at sea. Both Coates and Turnbull made wooden sailing ships, and the former, at least, also built boats.

1. Unless otherwise stated, information on shipbuilding firms comes from the directories : Ward, op.cit.; and Hagar, op.cit., both for 1851.

2. Information from : Letter from the Borough Librarian of Stockton to Mr. J.F. Hall-Craggs, dated 7.11.1960, in File No. 0627 ; River Tees, Stockton Public Library.

Four shipbuilding firms were active in the Hartlepools in 1851 : John Winspeare, Luke Blumer and Son, John P. Denton and Company, and William Turnbull and Company. All had their premises at Middleton, which was to become part of West Hartlepool. Denton's firm was the oldest of the group, having been established in 1839,[1.] and it was also the most productive. By 1851, Denton had already launched 32 ships, and he was to build a further 24 between then and 1863.[2.] Thomas Richardson, a partner in the first shipbuilding firm to be established in Hartlepool, had built 5 vessels with Richard Parkin and another 2 with his son by 1850.[3.] His death in that year put an end to the Richardson family's direct involvement in shipbuilding, as his son subsequently concentrated on iron making and marine engineering.

Luke Blumer had founded his yard at Middleton as recently as 1849 and had completed only two ships by 1851.[4.] He built seven more between that date and 1866, when the business was abandoned. John Winspeare, too, operated on a comparatively small scale; by 1851 he had finished three ships.[5.] Contemporary accounts omit any mention of William Turnbull's activities in West Hartlepool,[6.] which suggests that either his business in that town was newly established or his interests lay in some field other than shipbuilding, despite his

1. Wood, <u>West Hartlepool</u>, <u>op.cit</u>., p.57.

2. <u>Loc.cit</u>.; and Procter, <u>op.cit</u>., p.57.

3. Procter, <u>op.cit</u>., p.57.

4. <u>Loc.cit</u>.; and Wood, <u>West Hartlepool</u>, <u>op.cit</u>., p.57.

5. Procter, <u>op.cit</u>., p.57.

6. Procter claimed to list all the ships launched in the Hartlepools, but made no mention of any built by Turnbull up to the time of writing (1851).

designation in the local directories.

Middlesbrough had four shipbuilding firms in 1851 : George Armstrong, Robert Coverdale, J.G. Holmes and Sons, and William Scrafton and Company. All of them had yards in Commercial Street or Lower Commercial Street, a continuation of the former, and were therefore located either on the river bank or very close to it. Holmes's was the oldest shipbuilding business in Middlesbrough; he had reserved for himself one of the original building lots offered for sale by the Middlesbrough owners, and had founded his business there in 1834.[1.] By mid-century, Holmes was one of the town's principal citizens, and in 1853 he was duly elected to its first Borough Council. Little is known of the other Middlesbrough shipbuilders of the time.

In terms of the number of firms present in each place, Stockton would seem to have been less important as a shipbuilding centre than either Middlesbrough or the Hartlepools in 1851. However, it is probable that there was little difference between the various towns in terms of their respective outputs, though these are not known. It is clear, nevertheless, that Stockton was not in the commanding position in which, it was suggested earlier, it should have been. Middlesbrough and the Hartlepools appear to have had attractions of their own sufficient to counter Stockton's more general advantages as a location for the industry. In large

1. Lillie, op.cit., p.65.

part , these probably stemmed from the shift of the coal trade downriver from Stockton to Middlesbrough and the Hartlepools. Inevitably, that must have resulted in the emergence of greater opportunities in the fields of ship repairing and the making and supplying of auxiliary equipment and materials in the towns between Stockton and the sea, and most shipbuilders of the period were partially engaged in those fields. Table 8.13 indicates that in some respects Middlesbrough and the Hartlepools had higher concentrations of trades and professions connected with shipping and maritime trade than Stockton. These factors would have encouraged the development of shipbuilding in those places, despite the greater size and more sophisticated economy of Stockton.

Table 8.13

Ancillary Trades and Professions, 1851.[1]

	Middlesbrough.	Hartlepool.	West Hartlepool.	Stockton.
Boat Builder.	1	5		2
Ship Surveyor.	1			
Block and Mast Maker.	2	4	1	3
Ship Chandler.	5	16	7	3
Ship Owner.	17	(42)		10
Steam Boat Owner.	15	(5)		
Master Mariner.	65	(78)		30
Ship Smith.	5	3	4	3
Anchor Maker.		1		
Coal Fitter.	11	22	11	8
Consul.	2	13		11
Shipping Company.				4
Sail Cloth Maker.				5
Marine Store Dealer.		8		7
Sail Maker.	4	5	3	6
Nautical Instrument Maker.		2	1	
Ship Broker.	6	23	9	4
Ship Wright.		2	2	

1. Data from Hagar, op.cit., and Ward, op.cit.

Under pressures emanating from technical progress in the national industry, and from local economic development, the Teesside shipbuilding industry began to change relatively quickly during the 1850's. The traditional craftsmen, and the non-specialists who occasionally contracted to build one or two vessels, lost ground to newer and larger firms which were prepared, and able, to build in iron or a mixture of iron and wood, on the composite pattern. This adjustment was encouraged by the growing acceptance of steam-powered ships and the rise of marine engineering. The regional development of the shipbuilding industry was related quite fundamentally to the emergence of various metallurgical industries on Teesside.

At Stockton, Francis Coates was still in business as a shipbuilder and ship repairer in 1857,[1.] but his firm was one of those which had disappeared by the end of the period under review.[2.] William Turnbull died in 1858, but the company in which he had been the senior partner was continued under the title of R. Craggs and Sons.[3.] In 1861, however, the Craggs transferred the headquarters of their shipbuilding business to Middlesbrough and closed the Stockton yard.[4.]

There were also some new developments in Stockton during this period. In 1853, Pearse, Lockwood and Company took over

1. William Fordyce, The History and Antiquities of the County Palatine of Durham, Vol.2, Newcastle, 1857, p.180.

2. Unless otherwise stated, Kelly's directories, which were referred to earlier, have been used to obtain information relating to the end of the period.

3. Letter from Borough Librarian of Stockton, op.cit.

4. Loc.cit.

the yard which had been occupied by Thomas Haw some fifty years earlier and established a new shipbuilding business there.[1] This firm concentrated on building iron ships, and by 1865 it had launched 42,588 tons of shipping, most of which consisted of iron steamers.[2] At the end of the period, in 1881, Pearse-Lockwood and Samuel Welch were the only shipbuilders in Stockton. The latter firm built iron steamers ranging from tugs to passenger and cargo vessels.[3]

The first iron ship to be made on the Tees was launched by the Stockton Iron Shipbuilding Company from its yard at South Stockton, in 1854.[4] Despite its technical proficiency this was a company which soon ran into commercial difficulty.[5] As a result, it was absorbed by Richardson, Duck and Company before 1857.[6] The latter firm quickly developed into a major force in the local economy. By 1865 it had launched 55,493 tons of shipping, including 50 screw steamers, and was said to be the largest shipbuilding concern on the Tees.[7]

Middlesbrough's first iron ship, the De Brus, was built by Rake, Kimber and Company and launched in 1858.[8] This

1. Leonard Ropner, "An Account of the North Shore Shipyard", typescript dated 25 March, 1930, in File No. 0627 in Stockton Public Library.

2. Loc.cit.; and Heavisides, op.cit., p.59. The ships built consisted of 34 steamers, 20 sailers and 10 barges.

3. Kelly, op.cit.

4. Dougan, op.cit., p.47.

5. Heavisides, op.cit., p.59.

6. By which time, Richardson and Duck were established - Fordyce, op.cit., p.180.

7. Heavisides, op.cit., p.59.

8. Dougan, op.cit., p.47.

was an experimental project, in that it represented yet another attempt by Joseph Pease to broaden the industrial base of Middlesbrough. Rake and Kimber were loaned capital for their enterprise by the Middlesbrough Owners, who also let them have the site of their yard for a nominal or small sum.[1.] However, the experiment was not a success. In addition to the De Brus, Rake and Kimber built only three other ships, two of them under sub-contract from Richardson and Duck, before a shortage of orders forced the firm to close its yard in 1858.[2.]

During 1859, however, Richardson and Duck themselves took over and re-opened Rake and Kimber's yard, which was situated where the Transporter bridge now stands, and placed Raylton Dixon in charge of it.[3.] Dixon went into partnership with Thomas Backhouse in 1862 and obtained ownership of the yard on his own account.[4.] This new firm also purchased adjacent premises from two other shipbuilders - Candlish Fox and David Jays - and the whole complex became known as the Cleveland Dockyard.[5.] After Backhouse's retirement in 1873, Dixon continued in business with his brother. The firm was notably successful, perhaps justifying Pease's faith in the prospects for shipbuilding in the town, and launched 450 ships in the first 35 years of its existence.[6.] By 1881, it had already launched 189 vessels, and the Cleveland Dockyard

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1. Lillie, op.cit., p.104.
2. Dougan, op.cit., pp.47-48.
3. Loc.cit.
4. Lillie, op.cit., p.299.
5. Loc.cit.
6. Loc.cit.

- which covered 10 acres of land and employed 1,550 men - was one of the largest shipbuilding establishments in the North of England.[1]

As was mentioned earlier, Robert Craggs and Sons moved their shipbuilding business to Middlesbrough in 1861. There, the firm purchased a site and equipped it for both construction and repair work. In 1866, it also leased an adjacent yard from Leach and Coates.[2] Craggs concentrated on building iron steamers, and it was at about this time that the older firms which made only wooden ships disappeared. By 1881 there were three shipbuilders in Middlesbrough : Robert Craggs and Sons, Dixon Brothers, and William Harkess. The last of these had begun production in 1853. Its yard was on one side of Cragg's, which, in turn, was adjacent to the Dixon's yard.[3]

In the Hartlepools, John Denton's was for a long time the most important shipbuilding business. His fifty-sixth ship was launched in 1863,[4] the year after he took William Gray as his partner. As a partnership, the firm built another thirty-one ships before Denton's death in 1871. Subsequently, Gray acquired the whole business, which later still was absorbed by a large modern combine. During 1868 Denton

1. H. Gilzean Reid, Middlesbrough and its Jubilee, Middlesbrough, 1881, p.109.

2. Lillie, op.cit., pp.296-97.

3. Loc.cit.

4. See Wood, West Hartlepool, op.cit., for information on West Hartlepool's shipbuilders.

and Gray took over a small yard, adjacent to their own, which had belonged to Luke Blumer, one of the shipbuilders operating in 1851. Soon afterwards, in 1869, Denton and Gray decided to abandon their own yard and transfer to a more spacious one at West Hartlepool, which had formerly been occupied by Pile, Spence and Company.

Pile-Spence had been the first firm of shipbuilders to open a yard at West Hartlepool, as opposed to Middleton which was more part of the old town, and they had done so in 1854, at the instigation of Ralph Ward Jackson. West Hartlepool was as much Jackson's creation as Middlesbrough was Joseph Pease's, and in the matter of attracting new industries and businesses to his progeny, Jackson was quite as zealous as Pease. One of his gambits, a successful one as it transpired, was to build a modern graving docks at West Hartlepool in order to lure shipbuilders from the crowded and poorly equipped old town of Hartlepool. John Pile was one of those to succumb to the bait. He established his business there, and launched his first vessel, a tea-clipper, in 1854. Pile's second ship, an iron steamer, was completed in the following year. Joseph Spence joined the firm as a partner in 1859, and it prospered until the financial collapse of a London bank in 1866 brought about its own bankruptcy. By then, Pile and Spence had already built 78 ships, and their modern yard was taken over by Denton and Gray as soon as it became empty.

By the close of the period under review, there were three shipbuilding concerns in the Hartlepools. One of these, William Gray and Company, was the direct descendant of John Denton's firm, which had been working in 1851. Another was Irvine and Company, which was established in West Hartlepool by 1864. The third was Edward Withy and Company, a firm that had been formed in 1869 and had occupied the Middleton yard vacated by Denton and Gray.

Although there was little difference between the number of shipbuilding firms in the region in 1851 and the number in 1881, there is no doubt that both the industry's capacity and its actual output had risen substantially during the intervening years. Output statistics and estimates are available to substantiate this view. Palmer estimated that the output of iron ships on Teesside in 1862 was 9,660 tons.[1] This compared with 32,175 tons on Tyneside and 15,608 tons on the Wear. There are no figures for the output of wooden ships, but even in 1862 it was certainly much lower than that for iron ships. The average yard on the Tees produced no more than two 300-tonners in a normal year, and if a figure of 5,000 tons is given as the output of wooden ships in 1862, it is too high rather than too low. In 1883, in contrast, Teesside yards launched 136,000 tons of new shipping,[2] all of it built of iron. The Hartlepools were responsible for

1. Charles M. Palmer, "On the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear and Tees", in A History of the Trade and Manufactures of the Tyne, Wear and Tees, ed. W.G. Armstrong, Newcastle, 1863, p.126.

2. T. Wrightson, "Engineering Trades and Shipbuilding", in Notes on the Industries of Cleveland and South Durham Prepared for the Use of the Iron and Steel Institute ...., Middlesbrough, 1883, p.13.

60,000 tons, and the remainder came in equal proportions from Middlesbrough and from Stockton and South Stockton together.

Locationally, therefore, there was little change in the industry during the period studied, despite the technical transformation it underwent. At the end of the period, as at the beginning, the major ports were the locations adopted. In 1851 this was because wood - then the main material - had to be imported, because the major ports were also the principal towns and manufacturing centres - and hence had pools of skilled labour and made many of the ancillary materials and equipment needed -, and because there were opportunities there in the related field of ship repairing. For these reasons, Stockton, Middlesbrough and Hartlepool were the most convenient locations available and the places were production was likely to be cheapest, and the shipbuilding industry was confined to them.

The advantages possessed by the main ports were increased by the shift from wood to iron and that from sail to steam, since those places were also iron making and engineering centres. It is not possible to determine just how important transport costs were to the shipbuilding industry, but there certainly must have been a strong incentive to minimize them. Approximately two-thirds of the tonnage of an iron ship was accounted for by the actual weight of the iron.[1] Iron was therefore the dominant material used, and

1. Palmer, op.cit., p.126.

the cost-penalties of adopting a location where iron was not made must have been considerable. This, incidentally, was probably the reason why Pile-Spence at West Hartlepool, Richardson-Duck at South Stockton and Palmer at Jarrow built blast furnaces, puddling furnaces and other iron-working facilities on sites adjacent to their respective shipyards.

Summary.

The series of empirical studies presented in this chapter illustrates the relevance of many of the principles outlined in the theoretical introduction, and provides examples of many of the situations discussed thereiin hypothetical terms. In particular, the close correlation between optimum and actual industrial patterns leaves little doubt that the minimization of transport costs was treated generally as a matter of great importance. The writings of contemporary ironmasters such as Lowthian Bell confirm this interpretation. It is not surprising that this should have been the case; for the iron and steel industries, involved as they were, and are, with heavy and bulky products and even heavier and bulkier materials, have always been regarded as classic subjects for study along the lines suggested by Weber. Whatever the natural advantages held by Teesside ironmasters, they were not so great that they could not have been frittered away through unnecessarily high transport costs incurred as a result of the adoption of poor locations.

One of the more interesting general conclusions arrived at through these studies is that for many industries the location problem is essentially linear rather than areal in form.[1] This is because "seldom, if ever, can men or resources move with equal ease in every direction throughout an area; instead they ordinarily follow well-defined transportation routes".[2] This observation is particularly appropriate in the cases of materials such as coal and iron ore and products such as pig iron, which travel overland most economically by rail. In nineteenth-century Teesside, at least, individual companies had neither the resources nor the interest to seek Parliamentary approval for, or to build, their own railways, other than short private lines. Instead, they were obliged to make the best use they could of a railway network which, on the whole, had been constructed without their special requirements in mind. Hence, the point of minimum transport costs for the industries studied in this chapter was generally on the existing railway system. In most cases, in fact, it was either the market alone or the market in combination with the source of a material, such as pig iron, one or the other of these being the median point on the transportation line.

1. This conclusion was reached independently of a very similar one arrived at by Martin Beckmann in his Location Theory, New York, 1968, pp.21-22.

2. James A. Quinn, "The Hypothesis of Median Location", American Sociological Review, Vol.8 (1943), p.149.

Another matter of general significance is that because there were alternative markets and material sources, instead of just one of each, it was often the case on Teesside that the optimum location for a particular firm was not necessarily that for the industry as a whole. Thus, while one firm might have had a sound location in so far as its own market and material sources were concerned, it might still have incurred higher transport costs than another in the same type of business. This would have affected its competitive status in external rather than internal markets. The situation often arose because the supply of a certain material, say pig iron, at a given point within the region was insufficient to support all the firms requiring it, with the result that some had to turn to alternative sources.

For the industries which underwent expansion on Teesside between 1851 and 1881, internal and external factors, affecting both the supply and the demand conditions, made important contributions to their success. Economic development in Britain and overseas raised the levels of demand for iron and steel products, by finding new applications for them and by enabling society at large to afford more of them. Teesside benefited disproportionately, because it was a new industrial district with natural resources sufficient to ensure it comparatively low costs in many fields. Technical innovations, to which the region made important contributions, within the various industries helped to lower costs, and cost reductions stimulated demand still more. In a locational context, the most significant innovations were those which resulted in large fuel economies, and thereby reduced the attraction of the coalfield.

The wrought iron industry, which experienced contrary fortunes, was rather exceptional. In twenty years, from the early 1850's to the early 1870's, it grew from insignificance to occupy a commanding position in the Teesside economy. Subsequently, however, much as traditonal handicraft-type industries are adversely affected by the development of modern manufacturing, it was displaced by the steel industry. To some extent, perhaps, this occurred because the ironmasters failed to mechanize puddling, and hence to lower the cost of wrought iron substantially, but more fundamentally it was because wrought iron became obsolete. Steel was technically superior and cost no more to produce. The continued decline of steel costs after 1881 sealed the fate of the wrought iron industry, but before that date many of the major firms had begun dismantling their puddling furnaces and building steel plants to replace them.

CHAPTER NINE

LOCATION AND THE TERTIARY SECTOR

The Theoretical Framework.

Central Place Theory.

The study of locational change in the tertiary sector of the œconomy is perhaps best approached through the medium of central place theory. In its classical form, as presented by Christaller, this theory was intended to provide a deductive explanation of the number, size and distribution of towns.[1] It was also to be a theory of the location of urban trades and institutions, to complement the work of von Thünen and Weber for the agricultural and industrial sectors;[2] and it is this aspect of it which is of relevance in the present context.

The nature and limitations of central place theory are sufficiently well known to require no more than a brief summary here.[3] Most human settlements, in Christaller's view, exist primarily to supply their surrounding areas with goods and services. These goods and services - which, on grounds of efficiency in a competitive economy, are best offered for sale at points central to their respective markets - are termed 'central goods', and the places offering them 'central

1. See Walter Christaller, Central Places in Southern Germany, trans. Carlisle W. Baskin, Englewood Cliffs, New Jersey, 1966, Introduction.

2. Ibid., p.7.

3. Some of the more important publications in this field which have been drawn upon are : Christaller, op.cit., 230 pp.; Brian J.L. Berry, Geography of Market Centers and Retail Distribution, Englewood Cliffs, New Jersey, 1967, 146 pp.; Brian J.L. Berry and Allan Pred, Central Place Studies : A Bibliography of Theory and Applications, Philadelphia, 1965, 152 + 50 pp.; Edwin von Böventer, "Towards a United Theory of Spatial Economic Structure", Papers and Proceedings of the Regional Science Association, Vol.10 (1963), pp.162-87.

places'. Ideally, a central place is located at the centre of the area it supplies with central goods.

The more central goods a place supplies, the greater is its 'centrality' and the higher its 'order' in the settlement system. Higher-order places therefore offer many goods for sale, and lower-order places relatively few. Goods are also arranged systematically. Those which have large threshold values - the threshold being the minimum amount of purchasing power necessary to ensure that a certain good is offered for sale - are found only in higher-order centres, which command larger market areas, and they are known as higher-order goods. Low-order goods, in contrast, have small thresholds and they are consequently found in central places both large and small. Low-order centres are more numerous than their high-order counterparts. Also, they are more closely spaced and they have smaller trade areas. More generally, a series of variables can be correlated with the rankings of central places. Thus :

> Higher order places offer more goods, have more establishments and business types, larger populations, tributary areas and tributary populations,do greater volumes of business, and are more widely spaced than lower order places.[1].

In the Christaller scheme, certain restrictive conditions are assumed - including the concept of a homogeneous plain, consumer rationality, and an even distribution of the rural population -, and an ideal central place system is

1. Berry, and Pred, op.cit., p.3.

envisaged which has a hierarchic structure and a hexagonal spatial distribution of centres. The various orders in the hierarchy consist of discrete groups of central places which are founded on discrete groups of central functions. Places at a given level of the hierarchy are alike in terms of the variables which were earlier said to be correlated with rank, and they are uniformly spaced. Each, moreover, is located at the centre of a hexagonal-shaped trade area. Further, each place of a given order serves lower-order centres, in respect of functions which the latter are too small to perform, and, in turn, is served by some higher-order place - unless there is no place of a higher order.

Various criticisms have been made of this model. One, which would be generally accepted when comparisons with the real world are made, is that central place theory does not take account of non-tertiary functions when considering urban origins. Since mining and manufacturing projects have obviously played a crucial role in urban development in many areas, it is argued that central place theory cannot be such a comprehensive explanation of urban locations as Christaller would appear to have believed. Dacey has remarked that

> because mining, transportation, manufacturing, and similar activities are excluded, central place systems are probably restricted to predominantly agricultural regions where the economic support of cities and towns is largely the provision of goods and services to the rural population.[1].

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1. Michael F. Dacey, "A Probability Model for Central Place Locations", <u>Annals of the Association of American Geographers</u>, Vol.56 (1966), p.561.

No doubt, this is the main reason why so many empirical studies of central place systems have been made in areas that are essentially rural and agricultural in character. Nevertheless, while non-tertiary activities may tend to distort central place systems, they should not obliterate them. Indeed, Davies has reported recently on the identification of just such a system in the indubitably industrial area of the South Wales coalfield.[1] While central place activities may not be the prime cause of urban development in a given area, they will certainly come into existence and form a system, albeit a modified one. In recent years, however, central place theory has come to be thought more appropriate as a theory of the location of tertiary activities rather than as a theory of settlement location.[2] As such, it has been applied to major urban-industrial areas, notably Chicago, where shopping centres constitute the urban equivalent of the rural central place.[3]

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1. Wayne K.D. Davies, "Centrality and the Central Place Hierarchy", Urban Studies, Vol.4 (1967), pp.61-79.

2. Berry and Pred, op.cit., p.6; amd Allan Pred, Behavior and Location : Foundations for a Geographic and Dynamic Location Theory, Part 1, Lund Studies in Geography, Series B, No.27, Lund, 1967, p.98.

3. Eg. : Barry J. Garner, The Internal Structure of Retail Nucleations, Studies in Geography, Northwestern University, No.12 (1966), 208 pp.; James W. Simmons, Toronto's Changing Retail Complex : A Study in Growth and Blight, University of Chicago, Department of Geography, Research Paper No.104, 1966, 126 pp.; James W. Simmons, The Changing Pattern of Retail Location, University of Chicago, Department of Geography, Research Paper No.92, 1964, 200 pp.; Brian J.L. Berry, Commercial Structure and Commercial Blight, University of Chicago, Department of Geography, Research Paper No.85, 1963, 235 pp.

A second major criticism of the classical model is that the hexagonal arrangement of service centres, which it postulates, is not to be found in the real world. Since the hexagonal pattern is a result of the highly restrictive axioms of the theory, however, it is readily acceptable that it will not arise in a pure form in reality. Nevertheless, there is evidence that it is often approximated, and a number of studies have been made of the ways in which basically hexagonal networks can be distorted by random and other types of disturbance.[1.]

To a considerable extent, however, this subject has become irrelevant to modern studies. Particularly with the application of central place theory to large urban areas, empirical work has been concentrated on the identification and description of central place hierarchies rather than the geometric properties of the various systems. The hexagonal lattice has consequently been largely confined to pure theory and to exploratory geometric studies. Indeed, Berry and Garrison modified the theory in such a manner that they were able to demonstrate that a hierarchy of central places can arise without the centres being arranged in a hexagonal pattern.

Regardless of the distribution of population and purchasing power in an area, the application of the twin concepts

1. For example, see : Peter Haggett, Locational Analysis in Human Geography, London, 1965, pp.88-92; and Barry J. Garner, "Models of Urban Geography and Settlement Location", chap.9 in Models in Geography, ed. Richard J. Chorley and Peter Haggett, London, 1967, pp. 309-312.

of range and threshold permits the derivation of a central place hierarchy.[1] In this modern and less restricted form, central place theory provides a broad intellectual framework for the analysis of the location patterns of tertiary activities, within both urban and rural areas. To the extent that settlements are dependent on their central place activities, the theory also provides one explanation of their distribution. In summary, central places are organised in a hierarchic fashion, such that places of a given order supply all the types of goods supplied by lower-order places plus some which are offered only in places of that and higher orders. The higher the order, the fewer central places does it contain. Variables such as population size, trade area size, volume of business, and the distance between centres of equal stature, all depend for their value on the position of a central place in the hierarchy.

The Central Place Model and Economic Growth.

As Christaller was aware, his central place model is a product of partial static equilibrium theory,[2] and as such it is bound to have only a tenuous relationship with the reality of systems under continuous change.[3] At best,

1. Brian J.L. Berry and William L. Garrison, "Recent Developments of Central Place Theory", Papers and Proceedings of the Regional Science Association, Vol.4 (1958) pp.107-120.

2. See Christaller, op.cit., part G.

3. Location theories in general are of a partial-equilibrium and static type. For a discussion of some of the problems this entails see Böventer, op.cit., pp.163-87.

> ... at any point in time, the geographic distribution of retail and service business in central places approximates an equilibrium adjustment to the geographic distribution of consumers.[1]

Under normal conditions change is to be expected, and during periods of vigorous economic growth - particularly during industrialization - it is both endemic and characteristic. Production processes, the organisation of distribution, levels of demand and supply, and even consumer taste are all subject to rapid alteration, with important consequences for the spatial organisation of the service industries.

Christaller attempted to introduce a dynamic element to his model by examining the likely effects of fluctuations in various individual components.[2] A difficulty associated with this approach to the problem is that the ramifications resulting from variations in selected elements, if followed beyond their immediate consequences, tend to become unmanagably complex. In a balanced system, one disturbance can affect all the elements of equilibrium. Nevertheless, in the absence of even a simple dynamic model, this approach has been adopted in the present study. For convenience, the agents of change are considered first from the standpoint of demand and then from that of supply. The basic model used in the following discussion is the one developed by Berry and Garrison, which is simpler than Christaller's.

1. Berry, Geography of Market Centers and Retail Distribution, op.cit., p.4.

2. See Christaller, op.cit., part C.

Change Associated with Demand.

It is expedient to begin with the hypothesis of a significant upward shift in the level of real per capita income, which is indicative of economic growth. This amounts to an increase in total purchasing power and aggregate demand. Precisely how it will affect individual service industries is essentially an empirical problem, the solution of which depends upon the level of economic development, the composition of the tertiary sector and the overall pattern of demand in a given situation. In short, a rise in total purchasing power will have different consequences for different industries.

In general, however, it is probable that the demand for most commodities will rise to some extent, and that this will lead to a corresponding increase in the volume of business transacted for most industries. Since existing establishments are assumed to be operating at optimum scales initially - under a system of perfect competition -, and if supply conditions are held constant, the additional volume of business will require the creation of new service outlets. There will consequently be an increase in the numbers of shops and offices supplying the goods and services in question.[1]

This process of expansion may be examined in terms of

1. In line with current usage, the following definitions have been adopted in this study : a business establishment is a shop or office, a central function is a service industry supplying a particular good or service, and a functional unit is that part of a business establishment performing a single function. Thus, one shop may comprise more than one functional unit.

threshold levels, the threshold being "...the minimum amount of purchasing power necessary to support the supply of a central good from a central place."[1]. If demand is initially sufficient to sustain one shop retailing a particular type of good, then a doubling of demand will bring a second shop into existence. The threshold may also be expressed, and in empirical studies usually is, as the minimum number of people necessary to support one service outlet of a certain type. A rise in the per capita income has the effect of reducing threshold levels in this sense, since it lowers the number of people required to sustain a particular type of service outlet. This, of course, means that additional outlets can be established. An increase in per capita income also permits the entry of functions or industries previously debarred from a region because the level of demand was insufficient to support even one outlet.

Population expansion tends to have the same effect upon a central place system as a rise in per capita income. It leads to a growth in total demand, and, given that existing establishments are of an optimum size, more shops and offices are therefore required. Industrialization typically involves both economic and demographic growth, and the overall effect of it is consequently greater than if only one or the other type of expansion occurred alone.

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1. Berry and Garrison, "Recent Developments of Central Place Theory", <u>op.cit.</u>, p.111.

As hinted earlier, however, the impact of these changes varies in strength between industries. To a large extent, this is because the elasticity of demand is not the same for different commodities, with the result that economic growth tends to alter the overall pattern of demand. While demand rises absolutely for most goods and services, with an increase in the level of per capita income, it also rises more for some than for others. Consequently, some industries benefit more than others from economic growth. Similarly, demographic growth differentiates between industries.

With rising standards of living, there is a universal tendency for people to adjust their patterns of expenditure. 'Necessities', with their low demand elasticities, decline in relative importance, while 'luxuries', and other goods with a more elastic demand, become more prominent in household budgets. On the one hand, this is reflected in the pattern of food outlays; people spend only a little more on staple items, such as those in the high-starch group, but considerably more on relatively expensive foodstuffs, such as meat, fruit and dairy produce. On the other hand, food outlays as a whole tend to decline in relative significance, while expenditure on durables, consumer services and non-essential commodities grows.

Consumer taste, however, is not static, and in a developing economy increasing affluence combines with growing sophistication on the part of the consumer to alter the structure of demand preferences. In nineteenth-century

Britain, for example, there was a shift in demand away from crude and semi-finished consumer goods towards better-quality and fully-finished products. This shift was very marked in the textile trades, where tailors, milliners, dressmakers and other specialists benefited at the expense of drapers, who simply sold rolls of cloth.[1] Less predictably, there are often movements in the pattern of demand which owe more to the vagaries of fashion than a more rational preference for goods of a higher quality or more convenient form.

Factors such as these, combined with the more basic variations in demand elasticity, tend to result in industrialization bringing about radical changes in the structure of demand as well as an overall increase in its volume. The net effect is that the demand for some commodities rises more than that for others, and for others still it remains stable or actually declines. In turn, there are differences in the rates of increase or decrease in the numbers of service outlets supplying the various goods.

While population expansion does not necessarily lead to changes in the pattern of demand, it will tend to do so if it involves substantial immigration, as is generally the case during industrialization. The extent to which immigrants, with their different tastes and preferences, influence the pattern of demand depends upon many factors, including their numbers and the degree of dissimilarity between their

1. See James B. Jefferys, Retail Trading in Britain, 1850-1950, Cambridge, 1954, chap.13.

own cultural background and that of their hosts. Time may also be an important consideration; large-scale immigration over a short period is likely to influence the pattern of demand more than an inflow of similar size spread over a longer period. This is because assimilation may prove more difficult in the former than the latter case, with the result that the immigrants are more likely to retain their traditional modes of living. Yet another factor is the degree of cohesion of the alien culture, or cultures, particularly when it is thrust into a strange environment, since this will affect the extent to which assimilation is possible.[1]

New functions to the region, permitted entry by the growth of purchasing power - a result of economic and demographic growth -, will be located in the higher order central places. Some may have such high thresholds that they can appear only in the highest-ranking centre, since that is the one place where they are assured of sufficient support. The location of additional units of a type of business already present in the region will depend upon the spatial distribution of the extra purchasing power. If population and economic growth had occurred at the same rate throughout the region, then the numbers of the different types of shops and offices would increase at a uniform rate in the various

1. An interesting view of the significance of cultural plurality for a central place system is provided by Robert A. Murdie's study of Mennonites in a part of Ontario. See his article "Cultural Differences in Consumer Travel", Economic Geography, Vol.41 (1965), pp.211-33.

central places. In reality, however, it is most unlikely that the different parts of a region would be affected to the same extent.

Within a region undergoing industrialization, both economic and population growth tend to be spatially unequal. They are greatest in existing or new urban-industrial areas and smallest in rural areas. Per capita income levels rise relatively slowly in rural districts, and there are doubts as to whether they ever, even in the long run, catch up with those in urban areas. Similarly, largely through migration, population expansion is greater in the latter than the former areas. This is partly because of the higher living standards in urban-industrial centres and partly because the mechanization of farming, which usually accompanies industrialization and is a process that releases labour from agriculture, encourages rural depopulation.

For these reasons, it is more meaningful in the present context to assume that economic and population growth will be concentrated in and near large urban centres, though rural districts which have mineral resources will also receive a significant share. The typical service function or industry, faced with a rising demand for its product, will open additional outlets in those growth areas. Some of the new outlets will be located in centres which previously supplied the goods in question. Others, however, will be located in new central places or in centres which previously did not supply those goods, because they could not meet the threshold requirements of the industries concerned. Expansion thus involves the multiplication of service outlets, and the diminution of their respective trade areas, since a smaller area can supply sufficient purchasina power to support one outlet.

By raising the total purchasing power of an area, economic and demographic growth may lead to the creation of new service centres in places which had previously been unable to satisfy the threshold requirements of even the lowest-order functions. The location of new functions and additional business establishments in an existing central place amount to its being upgraded; the centre acquires a greater range of functions and a larger number of businesses than it had initially, and consequently assumes a higher rank. In contrast, the increased ubiquity of an industry, resulting from a rise in the demand for its product, is tantamount to its being downgraded, since fewer people and a smaller area are required to support one outlet for it.

In rural districts change is likely to take other forms as - a result of alterations in demand conditions. Although rural per capita incomes will tend to rise, if slowly, it is probable that rural depopulation will outweigh this development, with the net result of a decline in aggregate purchasing power and demand. That beihg the case, central places at all levels of the hierarchy in rural areas will lose businesses and functions. Some lower-order centres may disappear entirely, and surviving centres will require larger trade areas if they are to have sufficient support to allow them to continue functioning at their original levels. All central functions will be represented by fewer numbers of outlets in fewer places than initially, and some may disappear from rural areas. In the latter case, consumers will be obliged to travel greater distances, perhaps as far as major urban centres, to purchase goods once obtainable locally.

The projected pattern of development thus has two major components : one urban, one rural - one expanding, one contracting. It should be stressed, however, that it applies to a well-settled region undergoing industrial revolution. At least in the short run, a rather different model is required for newly-settled areas. In the latter, the sparseness, even absence, of the initial rural population plus the ongoing process of agricultural development is likely to result in the expansion of both the urban and the rural component of the model.

Changes Associated
with Supply Conditions.

Changes in the tertiary sector of the economy, affecting the means of producing and distributing goods, both contribute to and result from economic growth. They may themselves be the culmination of forces at work within as well as without the tertiary sector, but their main significance in the present context is in the extent to which they contribute to a lowering of costs. The following discussion concentrates largely upon changes emanating from within the tertiary sector. Although less dramatic, and perhaps under-valued, in comparison with the more obvious forms of economic development, such as the construction of railways and factories, there is little doubt that progress in the service industries has a vital contribution to make to industrialization. More generally, it is a commonplace that economic growth is normally associated with, or involves, the expansion of tertiary employment.

In nineteenth-century Britain, at least, many of the improvements made in service industries were encouraged or forced by progress in the manufacturing sphere. The spread of the factory system, the growth of large-scale production and of specialised manufacturing, and many other developments all helped to bring about a revision of the retailer's role in a large number of trades. He became more specialised himself, not so much with regard to the range of goods he handled, though that too in some cases, but in the work he undertook. Large-scale factory production ensured greater standardization, and the retailer could therefore be more sure of the nature and quality of the goods he ordered. This released him from the labour of sorting, grading, testing and valuing each consignment of the merchandise forwarded. These activities were undertaken in the factory or the wholesaler's warehouse instead of the shop, which was a more efficient arrangement.

Similarly, the retailer relinquished many other tasks which were more properly the province of the manufacturer, as more and more processes were found to be amenable to mechanization. The shoe-making trade provides a good example of the manner in which retailing increasingly became separated from manufacturing. Although there were a few specialised and large-scale producers in the Midlands in the middle of the nineteenth century, essentially "... the footwear trade in the United Kingdom ... was a handicraft trade".[1] The shoe dealer was also the shoemaker. During the second half of the century, however, the making and the selling of boots and shoes grew further apart from one another - the one undertaken in the factory and the other in the shop.[2]

This trend, towards a greater division between the making and the selling of goods, was apparent in virtually all the retail trades after about 1850. It touched even the foodstuffs trades. Grocers had always been "... part manufacturers as well as retailers",[3] blending tea and grinding and mixing spices as well as selling them, for example, but they steadily became less involved with processing and packaging. Similarly, though largely due to the growth of meat imports towards the end of the century, the traditional butcher became overshadowed by the meat retailer. The latter had little or no hand in the selection, slaughter and dres-

1. Jefferys, op.cit., p.353.

2. Ibid., chap.14.

3. Ibid., p.127, and chap.5 as a whole.

sing of animals, but simply sold meat as another shop-keeper sold shoes.[1]

Increasing specialisation in the retail trades took these and many other forms. In combination with advances in other sectors of the economy, it meant that greater efficiency was achieved and that the retailer contributed to the decline in the real prices of many consumer goods. Not all pressures for change emanated from the manufacturers, however; there were many cases of retailers insisting that their suppliers should improve their own methods of production. There were even retailing organisations, dissatisfied with existing arrangements, which themselves forayed into the realms of manufacturing and wholesaling.[2] The cooperative movement was somewhat exceptional, in that it amounted to the customers doing their own foraying, but there were more orthodox retailers who emulated the cooperatives and took to manufacturing some of the commodities they sold.

In addition to these types of change, there were others arising from conditions within the various service industries. Many of these were directly comparable with improvements in manufacturing, such as technical and managerial innovations, the accumulation and exploitation of additional capital resources, the growth of larger business units, and the realisation of scale economies previously unattainable.

1. <u>Ibid</u>., chap.6.

2. <u>Ibid</u>., p.10.

Jefferys has commented :

> On the one hand the distributive trades were compelled to adapt themselves to the shifts and changes in the economic and social structure of the country. On the other hand the distributive trades possessed their own dynamic ....".[1]

One source of improvement was the greater significance attached to the role of the wholesaler, and the greater use made of his services. The wholesaler did much to make the distributive system more efficient, and was indeed vital to it once the distance between maker and seller began to increase, as production became more centralized with the growth of large-scale manufacturing. Another important factor was the emergence of large retailing firms, including the cooperative societies, department stores and multiple-store organisations. Between 1875 and 1914 these types of firm raised their share of the national retail trade from 2 - 3 per cent. to 17-21 per cent.[2] Multiple retailing - that is, retailing by firms with more than one shop - became especially important.[3] The firms engaged in it were able to obtain notable scale economics through such practices as bulk-buying, administrative centralization and specialization, and standardization in selling.[4] Similar advantages were obtained by other types of large retailing organisation.

1. Ibid., p.6.

2. Ibid., p.29.

3. Ibid., passim; and Peter Mathias, Retailing Revolution : A History of Multiple Retailing in the Food Trades Based upon the Allied Suppliers Group of Companies, London, 1967, 425 pp.

4. Jefferys, op.cit., p.27.

These developments in nineteenth-century Britain provide a general guide to the types of change experienced by the tertiary sector during industrialization. The most significant conclusion to be drawn from them, in relation to central place theory, is that they lead to lower real costs and prices, which is equivalent to an increase in purchasing power or demand. Hence, they tend to have the same effects as population expansion or a rise in per capita income.

Improvements in supply conditions that lead to a lowering of real costs and prices effectively reduce threshold levels - in the sense that fewer people are necessary to support a business of a certain type -, and thereby permit the entry of more functions and business establishments. Variations must be expected between industries, however, with those that have made the most progress experiencing the highest rates of expansion. Those industries confronted with a lowering of their thresholds will become more ubiquitous, obtaining representation in a greater number of central places. If their thresholds decline by an amount above the average, then they will also occupy a lower rank in the hierarchy. Conversely, functions not affected by cost reductions will be no more ubiquitous than they were originally, while any which experience cost increases will become less so. Both may ascend in rank.

Although it is likely to be less significant than in the case of changing demand conditions, a discrepancy between the rural and urban components of the central place system may well arise. Innovation and change in general are very much the prerogative of urban places, and tend to lag behind in rural areas. In the short run, at least, it seems realistic to accept that cost reductions of the types outlined above will not be so large in rural as urban areas. Thresholds will consequently not decline so much, and the resulting changes will be less evident.

A complicating factor which has not been considered so far is the possibility of differential scale economies within the same industry. This is ignored, or, rather, debarred, by central place theory as such, but it should be incorporated in the type of dynamic model being constructed here. Effectively, differential scale economies may mean that two, or more, thresholds exist for one industry - perhaps one for the shop owned by the small firm, and one for the retail outlet of a large multiple or similar organisation. The establishment of large-scale outlets would also have the effect of offsetting the need for more business units which, it has been suggested, arises from population and, or, economic growth.

Towards a Synthesis.

Although there are advantages, notably that of simplicity, in examining separately the effects of changes in the conditions of demand and supply on a central place system, this approach overlooks the manner in which the two affect each other and are inter-related. However, this shortcoming is not of great importance, since the object of the present analysis is to obtain a broad understanding of the processes involved. To reiterate, the model developed here is one of a well-settled region, with one or more urban-industrial centres set in a rural-agricultural matrix, which experiences economic and demographic growth as a result of industrialization.

Reductions in real unit costs, resulting from progress inside and outside the tertiary sector, have the same type of effect on the central place system as increases in real per capita income and population. All three contribute to the raising of purchasing power and the level of aggregate demand in a given area, and thus they encourage expansion in the service sector. However, due to changes in the pattern of demand - as a result of greater affluence, the vagaries of fashion, differential demand elasticities, and alterations in the composition of the population - and to variations in the rate of innovation, individual tertiary industries are affected to a differing extent.

As threshold values become lower generally, most industries will obtain additional outlets and thus become more ubiquitous. Some industries will gain representation in the region for the first time. The proliferation of new service outlets may be checked in individual industries by a tendency to create larger establishments in order to benefit from scale economies. At the opposite end of the spectrum, there may be industries subject to decline rather than expansion, as a result of changes in public taste or in technical or organisational matters.

The model predicts a significant difference between rural and urban areas. Since population and economic growth tend to be greatest in the larger towns and cities, it is there, and in the immediate vicinity, that the central place system is likely to expand the most. New functions and additional outlets for those already established will be obtained by the larger central places and urban shopping centres. The increasingly prosperous and dense population of the urban-industrial areas will also require, or permit, the establishment of new service centres in them. Trade areas will thus shrink in size.

In rural districts, however, despite some rise in incomes, depopulation - with a movement to the towns and the factories - will result in the contraction of the central place system. At each level of the settlement hierarchy, some central places will lose businesses and functions - and consequently be relegated to a lower rank -, while a number of small places may cease to be service centres. The trade areas of surviving central places will become larger, in reflection of the decline in rural population density and the smaller number of centres at each level of the hierarchy. Consumers will therefore be required, in many cases, to travel further.

The empirical evidence available from central place studies in many parts of the world suggests that this model is well founded. The processes of change outlined above appear to operate even when economic growth is less rapid than during the industrialization phase. In North America, the scene of many such studies, the rural component of central place systems has been in decline throughout the twentieth century. This has been especially noticeable at lower levels of the hierarchy, where large numbers of hamlets, villages and small towns have been downgraded, and many have ceased to function as service centres. Surviving rural central places have consequently come to serve larger areas and more distant consumers.[1]

On the other hand, it would seem that expansion in urban-industrial areas is a somewhat more complex process than has been suggested here. For example, transportation improvements affect more than the cost structures of various service industries. The advent of the private motor car, coupled with rising living standards, has encouraged the wayward consumer in his defiance of what Warntz has termed the 'tyranny of space'. Transportation costs and the inconvenience and time-costs of travelling have been so reduced that the consumer is much less inclined to shop at the nearest central place than once was the case.[2] This has resulted in large numbers of consumers ignoring the additional costs involved and choosing to shop in towns and central

1. See, for example, Berry's review of the evidence in his Geography of Market Centers and Retail Distribution, op.cit., pp.114-18.

2. Berry, Geography of Market Centers and Retail Distribution, op.cit., p.115; and J. Rutherford, M.I. Logan and G.J. Missen, New Viewpoints in Economic Geography, Sydney, 1966, p.375.

business districts rather than more local central places and shopping centres.[1] In many cases, moreover, the additional costs can be defrayed in part, at least, by combining shopping excusions or by shopping in large stores, where scale economies make lower prices possible. Within the modern era, therefore, cheaper and more convenient modes of transport have contributed to the decline of the rural element of the central place system and the growth of the urban element. It is doubtful, however, if this can be said of the nineteenth century. Then, transport costs were of much greater significance, and the incentive to minimize travel that much stronger. The model which has been developed here should consequently be more appropriate for conditions in the nineteenth century.

Aspects of the Teesside Central Place System.

The Scope of the Enquiry.

Local trade directories were used to obtain the basic information required concerning the service industries on Teesside.[2] The accuracy of directories is uncertain, a matter which was discussed in Chapter 2, but there is no

1. Eg. W.A.V. Clark, "Consumer Travel Patterns and the Concept of Range", Annals of the Association of American Geographers, Vol.58 (1968), pp.386-96.

2. The directories used are : Robert Ward (ed.), Ward's North of England Directory, Newcastle, 1851; Hagar and Co. (ed.), Directory of the County of Durham ...., Nottingham, 1851; E.R. Kelly (ed.), The Post Office Directory of Durham and Northumberland, London, 1879; E.R. Kelly (ed.), The Post Office Directory of the North and East Ridings of Yorkshire, London 1879.

real alternatige to them for this purpose. It is generally believed, however, that directories published after 1850 are fairly reliable. In the present study it was felt necessary to cross-check the data for 1851, the earlier of the two dates chosen, by using two directories. Regrettably, this was possible for only half the r egion. The two local directories found for 1851 - Ward's and Hagar's - did not include places, other than Middlesbrough, in North Yorkshire. Rather than use data from directories published ih the early 1840's or late 1850's, which was the only alternative, it was decided that the villages of North Yorkshire should be omitted from the first half of the study.

This problem did not arise in connection with the second half of the study, since the much more accurate and comprehensive Post Office directories were by then available for the Teesside area. However, 1879 rather than 1881 had to be adopted as the terminal date for the study. This was because the Post Office directories were published at intervals of several years, and editions for both North Yorkshire and Durham were released in 1879. Thus, there is a complete coverage of the Teesside region for 1879, but only a partial coverage for 1851.

Another operational problem encountered was the question of which activities should be included in the study. It is difficult to avoid concluding from the literature on the subject that there is some confusion, in practice if not in theory, over the range of functions catered for by central place theory. At least, the functions selected for inclusion in empirical studies vary considerably. Christaller left little doubt, however, as to the principles which should be used to resolve this difficulty. He included 'central' and excluded 'dispersed' and 'indifferent' goods and functions.[1] By the term central good was meant a commodity which is necessarily offered for sale, and perhaps also made, at a point central to the market for it. The necessity for such a location is an economic one; it is occasioned by the profit maximization motive.

Indifferent and dispersed goods, on the other hand, are those for which a central location, on the part of the supplier, is either unnecessary or positively deleterious. Mail-order firms and travelling salesmen are examples of business establishments supplying these types of goods. In modern economies, however, Christaller argued, non-central goods are of marginal significance. The twin processes of urbanization and centralization, which have accompanied economic development, have placed a premium on centrality as the ordering principle.

In practice, somewhat narrower interpretations of the term central good have generally been adopted than Christaller would have wished. In empirical studies, the main emphasis has been placed on the retail component of central place systems, to the exclusion of many wholesaling and

1. Christaller, op.cit., pp.19-21.

other tertiary functions, as well as central manufacturing industries. Partially, at least, this is undoubtedly because many central place studies, especially in North America, have been concerned with rural areas, where functions and centres alike tend to belong to low orders and few activities other than retailing are represented.

Another partial explanation of this overt concentration on retailing is that in practice it is difficult, if not impossible, to classify many of the higher-order functions in complex urban economies as either central or non-central. Many, indeed, may be considered to belong to both categories. It is therefore simpler to omit them. However, the exclusion of activities other than retail functions is much more undesirable in the case of urban than rural studies. Large towns and cities provide the only locations for many tertiary industries, notably those concerned with finance, and they consequently have a range of functions not to be found in rural districts.

Davies has suggested that it may well be the case that large central places can only be differentiated functionally by taking these higher-order actitivities into account.[1] The suggestion was made because there is empirical evidence that new retail functions are added at a declining rate as the size of a settlement increases.[2] The logical inference to

1. Wayne K.D. Davies, "Some Considerations of Scale in Central Place Analysis", Tijdshrift voor Economische en Sociale Geografie, Vol.56 (1965), p.221.

2. See Haggett, op.cit., p.116.

be drawn from this evidence is that above a certain level, central places will have identical functional complements even though their population sizes differ substantially. Intuitively, this may seem unlikely, but to prove the inference incorrect it is necessary to include activities other than retailing in the analysis.

If such functions are to be included, however, some yardstick is essential for separating central and non-central activities. It must also be recognised that a solution to this problem is unlikely to be universally appropriate; what is a central function in one socio-economic context may not be so in another. In the present case, functions have been included if they appear to have been non-basic, or predominantly so, to the region as a whole.[1] That is, those industries which were intended primarily to serve the regional population have been classified as central functions, whether they were concerned with retailing, wholesaling or manufacturing.

The Central Place System in 1851.

The Relationship Between Population and Central Functions.

It is a commonplace that the larger a town is, the more types of shops it will have and goods it will stock. This relationship between population size and the number of central functions is a fundamental concern of central place

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1. This approach was also adopted by James B. Kenyon in his "On the Relationship Between Central Function and Size of Place", Annals of the Association of American Geographers, Vol.57 (1967), pp.736-50.

theory, since it is one of the factors underlying the concept of a hierarchy of central places. A number of empirical studies have consequently been undertaken to investigate the precise form of this relationship, with many of them being modelled upon the pioneer work of Berry and Garrison in Snohomish County in the north-west corner of the United States.[1.]

Amongst others, Thomas in Iowa,[2.] Stafford in Illinois,[3.] King in Canterbury, New Zealand,[4.] and Gunawardena in Ceylon[5.] have all confirmed Berry and Garrison's conclusion that there is a strong and positive relationship between population size and the size of the functional complement of settlements. There is also a general consensus that the relationship is curvilinear in form; more specifically, it is log-linear. This means that although central places add extra functions as they increase in size, they do so at a decreasing rate.[6.] It has been suggested, accordingly, that

1. Brian J.L. Berry and William L. Garrison, "The Functional Bases of the Central Place Hierarchy", Economic Geography, Vol.34 (1958), pp.145-54; and "A Note on Central Place Theory and the Range of a Good", Economic Geography, Vol.34 (1958), pp.304-311.

2. Edwin N. Thomas, "Some Comments on the Functional Bases for Small Iowa Towns", Iowa Business Digest, (1960).

3. Howard A. Stafford, "The Functional Bases of Small Towns", Economic Geography, Vol.39 (1963), pp.165-75.

4. Leslie J. King, "The Functional Role of Small Towns in Canterbury", Proceedings of the Third New Zealand Geography Conference, Palmerston North, New Zealand, 1961, pp.139-49.

5. K.A. Gunawardena, "Service Centres in Southern Ceylon", unpublished Ph.D. thesis, University of Cambridge, 1964 : reported by Haggett, op.cit., pp.115-16.

6. Haggett, op.cit., p.116.

there is a limit to the functional complexity of central places.[1] All the studies mentioned so far, however, have been concerned with small rural settlements, and consequently with relatively low-order functions. It may be, as was suggested earlier, that a different picture would emerge if non-retail activities were included.

Data for places within that part of the Teesside region in Durham were collected from local directories for the year 1851. In all - following the amalgamation of like activities and the separate listing of different ones performed by the same firm -, some 163 central functions and 95 central places were identified. Population figures were available for parishes but not for small towns and villages. To overcome this problem, the central places in each parish were combined, and the parish totals for functions and population were used in the analysis. Since most parishes had only one central place, the adjustments this procedure required were not great; the 95 original central places were reduced to 81 parishes.

There may be some doubts as to the propriety of using population totals for parishes instead of the actual central places, but it was felt that this expedient was defensible on grounds other than sheer necessity. The size of the functional complex of a village, or any other grade of settlement reflects not just the size of its own population but

1. Stafford, op.cit., p.170.

also that of its service area. As most parishes in the Teesside region had one, and only one, service centre, there is strong reason to believe that the trade area of most centres approximated the area of the parish in which they were situated. Hence, the number of functions performed by a centre would generally have been related to the size of the population of the parish of which it was a part. For large towns this would not have been true, but they were few and their presence should not detract significantly from the validity of this argument. On balance, the use pf population figures for parishes seems no less justified than using figures for central places, since the latter procedure is based on the implicit, and by no means self-evident proposition that central place-tributary area population ratios are constant throughout a region.

Table 9.1 contains lists of the central places and parishes examined, and a summary of thedata for 1851. Analysis revealed that there is a close and positive relationship between population size and number of functions for the parishes studied, the simple correlation coefficient being +0.95. Examination of several non-linear transformations revealed that none fitted so well as the linear regression model, which, unusually, was therefore deemed more appropriate than any of the common curvilinear models. In other words, there is a relationship between the two variables such that the rate of increase in the number of functions as population size becomes larger is constant. Figure 9.1

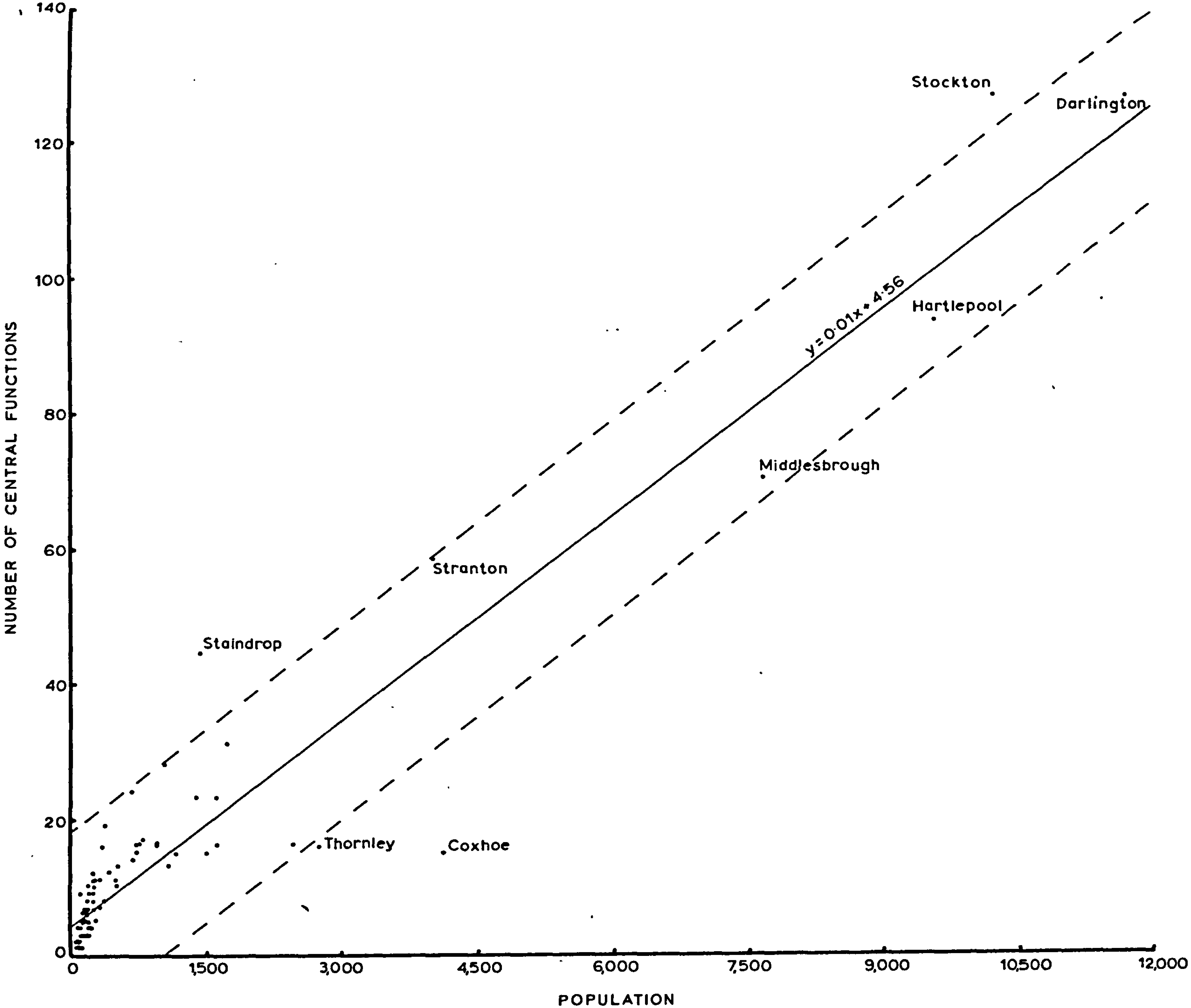

Figure 9.1 Population and Central Functions, 1851

Table 9.1

Parishes and Central Places in 1851.

Parish	Central Place	Number of Establishm-ents.	Number of Central Functi-ons.	Number of Funct-ional Units.	Popu-lat-ion.
	Easington.	33	14	38	
	Thorp.	2	2	2	
Easington.		35	16	40	91[illegible]
	New Shotton.	14	7	14	
	Shotton.	11	9	11	
Shotton.		25	16	25	1,607
	Thornley.	1	1	1	
	New Thornley.	52	15	65	
Thornley.		53	16	66	2,740
	Wingate.	1	1	1	
	Wingate Grange.	25	14	32	
	Wheatley Hill Lane.	3	1	3	
Wingate.		29	16	36	2,456
Castle Eden.	Castle Eden.	20	11	22	[illegible]
	Monk Hesleden.	8	5	10	
	East Hetton.	15	10	20	
Monk Hesleden.		23	15	30	1,495
Kelloe.	Kelloe.	8	7	9	149
Hutton Henry.	Hutton Henry.	17	13	19	1,067
Sheraton.	Sheraton.	6	6	7	147
	Cornforth.	30	14	33	
	Blackgate.	29	14	33	
Cornforth.		59	28	66	1,040
Coxhoe.	Coxhoe.	30	15	42	4,101
Garmondsway Moor.	Garmondsway Moor.	1	1	1	129
	Trimdon.	17	10	19	
	Trimdon Grange.	9	6	11	
	New Trimdon.	13	7	16	
Trimdon.		39	23	46	1,598
Hart.	Hart.	13	11	16	297
Bishop Middleham	Bishop Middleham.	28	12	31	446
Fishburn.	Fishburn.	12	11	14	261
Butterwick and Oldacres.	Butterwick.	1	1	1	64
Embleton.	Embleton.	1	1	1	113
Elwick.	Elwick.	12	7	14	250
Hartlepool.	Hartlepool.	620	93	641	9,503
Mainsforth.	Mainsforth.	1	2	2	59
Sedgefield.	Sedgefield.	81	23	85	1,362
Elwick Hall.	Elwick Hall.	3	4	4	187
Dalton Piercy.	Dalton Piercy.	2	1	2	91
	Stranton.	29	14	34	
	West Hartlepool.	164	44	171	
Stranton.		193	58	205	4,008

/Cont..

Table 9.1 (Contd.)

Parish	Central Place	Number of Establishments.	Number of Central Functions.	Number of Functional Units.	Population.
Bradbury.	Bradbury.	8	7	9	171
Seaton Carew.	Seaton Carew.	24	15	31	728
Mordon.	Mordon.	5	5	6	163
Grindon.	Thorp Thewles.	11	10	13	267
Wolviston.	Wolviston.	38	16	40	75[illegible]
Newton Bewley.	Newton Bewley.	3	3	3	121
Greatham.	Greatham.	31	10	35	651
Cockfield.	Cockfield.	18	10	18	647
Redworth.	Redworth.	10	6	11	322
Middridge and Grange.	Middridge Grange.	1	1	1	54
Great Aycliffe.	Great Aycliffe.	43	17	49	812
Preston le Skerne.	Preston le Skerne.	4	4	4	139
Cowpen.	Cowpen Bewley.	5	4	5	217
Wackerfield.	Wackerfield.	5	4	5	[illegible]
Bolam.	Bolam.	5	4	[illegible]	125
Houghton le Side.	Houghton le Side.	5	5	6	146
Heighington.	Heighington.	25	14	29	685
Brafferton.	Brafferton.	10	9	12	206
Great Stainton.	Great Stainton.	1	1	1	117
Bishopton.	Bishopton.	35	19	39	365
Redmarshall.	Redmarshall.	2	2	2	76
Carlton.	Carlton.	4	5	5	186
Norton.	Norton.	63	31	72	1,725
	Billingham.	17	11	18	
	Haverton.	5	3	4	
	Port Clarence.	2	2	2	
Billingham.		24	16	24	723
Staindrop.	Staindrop.	97	44	117	1,429
Ingleton.	Ingleton.	19	11	19	305
Killerby.	Killerby.	4	5	5	93
Summerhouse.	Summerhouse.	9	8	11	177
Denton.	Denton.	8	9	9	121
Walworth.	Walworth.	2	3	3	142
Coatham Mundeville.	Coatham Mundeville.	5	6	[illegible]	149
Little Stainton.	Little Stainton.	5	5	6	82
Gainford.	Gainford.	51	24	59	669
Whessoe.	Harrowgate.	4	4	4	110
Barmpton.	Barmpton.	2	2	2	135
Elton.	Elton.	3	4	4	84
East Hartburn.	East Hartburn.	10	10	13	174

Table 9.1 (contd.)

Parish	Central Place.	Number of Establishments.	Number of Central Functions.	Number of Functional Units.	Population.
Stockton.	Stockton.	1,018	126	1,062	10,172
Middlesbrough.	Middlesbrough.	388	70	403	7,631
Piercebridge.	Piercebridge.	11	8	12	225
	High Coniscliffe.	7	6	8	
	Carlbury.	5	6	6	
High Coniscliffe.		12	12	14	248
Cockerton.	Cockerton.	19	13	22	537
Haughton le Skerne.	Haughton le Skerne.	17	10	19	474
Great Burdon.	Great Burdon.	4	4	4	96
Morton Palms	Morton Palms.	2	2	2	68
Sadberge.	Sadberge.	16	8	16	371
Low Coniscliffe.	Low Coniscliffe.	5	3	5	203
Long Newton.	Long Newton.	8	7	8	325
	Middleton St. George	7	7	8	
	Middleton One Row.	13	9	14	
Middleton St. George.		20	16	22	332
Egglescliffe.	Egglescliffe.	16	10	17	493
Blackwell.	Blackwell.	9	5	9	272
Hurworth.	Hurworth.	41	15	51	1,154
Neasham.	Neasham.	15	9	20	295
Low Dinsdale.	Low Dinsdale.	3	3	3	157
Aislaby.	Aislaby.	1	1	1	141
Darlington.	Darlington.	952	126	1,031	11,582

shows the 81 parishes plotted on a scatter diagram, together with the regression line of Y on X (functions on population) and lines representing the standard error of estimate at the 95 per cent confidence level.

The great majority of parishes had fewer than 20 central functions and less than 1,100 people in 1851. Between them and Stockton and Darlington, which contained the two most important towns in the region, there were very few parishes with centres of intermediate size. Stockton, Darlington, Stranton, Hartlepool, Middlesbrough and Staindrop were the only parishes to have central places of more than a very modest stature.

More interesting, perhaps, is the linear relationship revealed between the two variables considered. This would seem to be abnormal in view of reports from other studies, which indicate that a log-linear relationship is the norm. In an attempt to explain this discrepancy, the first possibility examined was that it was due to errors in the data used. On reflection, however, this seemed an improbable explanation. In the first place, a system of cross-checking - which involved the comparison of entries in one directory with those in another - was employed when compiling the data, so that the significance of the error factor must have been greatly reduced. Second, inaccuracies in the data would mainly have been in the form of omissions, and would have affected the large towns rather than the small centres, since the latter had few functions to list. Omissions would have tended to 'bend' the regression line downwards in its upper regions - because they led to an understatement of the numbers of functions present in the large towns -, and would therefore have exaggerated, not reduced, any semblance of a curvilinear relationship.

A second possibility is that the normal curvilinear relationship may be more appropriate for central place systems in a modern rather than a nineteenth-century economic context. However, there is no obvious reason why this should be the case. Indeed, a contrary argument seems more plausible. The sophistication and greater efficiency of modern economies, plus the strong tendency towards centralization, suggests that today the regression line in Figure 9.1 should exhibit an upward curve, such that cities gain disproportionate numbers of additional functions as they increase in size. The modern decline of small service centres ought to encourage the emergence of such a situation.

It should also be pointed out that the use of population data for parishes rather than central places could not have converted a log-linear into a linear relationship. The exclusion of the dispersed population from the parish totals, if that were possible, would merely result in a general shift to the left along the X axis of Figure 9.1.

The most probable explanation is that a linear relationship between population size and number of functions was found in the present study because a more catholic definition of 'central function' was used than has generally been the case. It is conceivable that the inclusion of certain wholesaling and manufacturing activities would tend to favour a linear rather than a log-linear relationship. This is because these are activities that are more evident in large towns than villages and hamlets. Hence, their inclusion would counter the tendency, already remarked on, of central places to add retail functions at a declining rate as they grow in size. This conclusion substantiates the suggestion made by Davies which was discussed a little earlier.

Returning to Figure 9.1, it can be seen that although most of the 81 parishes lie within the zone delimited by the standard error lines, a few are located outside it and may be regarded as anomalies. Two of these parishes, Stockton and Staindrop, have a 'surplus' of functions; that is, they have more central functions than would be expected of places of their respective sizes. Stockton, for example, had the same number of activities as the parish of Darlington, though it had 1,410 fewer people than the latter. This suggests that the town of Stockton served a larger trade-area population than did that of Darlington. It is possible that Stockton drew some custom from the still relatively new town of Middlesbrough, but it cannot have done so to a large extent; for Middlesbrough had no fewer functions than the size of its population warranted.

Staindrop, the other parish with a functional surplus, is perhaps a more surprising anomaly. The parish contained one service centre, a small town of the same name, and was located on the western edge of the region. As it had such a large functional complex, the town of Staindrop clearly must have served a relatively large trade-area population. This was undoubtedly largely due to its isolation from the main Teesside towns. Staindrop was some twelve miles to the west of Darlington, and there was no railway in its vicinity until the line from Darlington to Barnard Castle was completed in 1856. The town was therefore more sheltered than most of the smaller central places in the region from competition from the larger centres. That Staindrop and not some alternative settlement in the area should have been so important may well have been due to the Duke of Cleveland having his residence at Raby Castle, on the outskirts of the town, which would have assured it of some local prominence.

Two parishes, Thornley and Coxhoe, appear from Figure 9.1 to have been deficient in central functions. Coxhoe, with a population in excess of 4,000, is particularly striking. Both of these were coal mining parishes, and in both the mining industry had recently undergone expansion. The imbalance of population and functions may therefor . have resulted from the tertiary sector's inability to keep pace with the growth of mining and population, in which case it would have been a temporary phenomenon. Such a situation must have been common in Durham, and other mining areas, as new shafts were often sunk in open country, well away from established settlements, and the mining companies themselves were obliged to provide shopping facilites and other amenities.

Although they have not been entered in either Figure 9.1 or Table 9.1, there were a number of parishes without any central functions of an economic character. Together, they accounted for about 20 per cent. of all the parishes in that part of the region within Durham, and they have been listed in Table 9.2. Half of them did have nucleated settlements, but these were diminutive hamlets consisting of farmers' and farm workers' cottages and perhaps a church. Their small population size is an important factor in explaining the absence of central functions in these parishes. Approximately half of them had fewer than 50 inhabitants, and all but five had less than 100. While there were some parishes with service centres which had fewer than 100 people, there were none with less than 50. Clearly, therefore, most of the parishes in Table 9.2 had too few people to justify the establishment of service centres within them. There were, however, five obvious exceptions - parishes with substantial populations - and their lack of central places must be attributed to some other factor. In three cases, at least, it is probable that the proximity of very large service centres is the explanation, since that would have made it difficult and unnecessary to establish low-order centres. Thus, Throston was adjacent to Stranton and the Hartlepools, Raby to Staindrop and Preston to Stockton.

Table 9.2

Parishes Without Service Centres in 1851.[1]

Parish	Population.	Hamlet
Nesbitt.	11	
Thorpe Bulmer.	31	
Thrislington.	45	
Throston.	240	Throston.
Brierton.	33	Brierton.
Claxton.	49	
Foxton and Shotton.	58	
School Aycliffe.	31	School Aycliffe.
Stillington.	70	Stillington.
Whitton.	50	Whitton.
Hilton.	101	
Langton.	95	
Morton Tinmouth.	28	
Headlam.	129	
Archdeacon Newton.	62	Archdeacon Newton.
East and West Newbiggin.	37	
Preston upon Tees.	113	Preston upon Tees.
Sockburn.	43	
Raby with Keverstone.	313	
Newsham.	67	Newsham.
Elstob.	38	Elstob.

Population and the Number of Establishments.

For theoretical reasons there should also be a close and positive relationship between population size and the number of establishments, an establishment being a service outlet, such as a shop or office. This was found to be the case for the Teesside central places, or parishes, examined for 1851. The correlation coefficient was +0.94. The relationship between the two variables was also found to be linear in form, as is indicated in Figure 9.2 . These findings match the results obtained from other empirical studies

1. Hagar (op.cit.) mentions whether or not a parish had a nucleated settlement.

of central place systems.[1] As population increases, therefore, there is a constant proportional rise in the number of business establishments.

It can be seen from the scatter diagram in Figure 9.2 that the distribution of parishes is much the same as that obtained by comparing population and functions. Again there is a heavy concentration of parishes in the lower reaches of the scale, with most of them having fewer than 50 shops and offices. Only Darlington, Stockton, Hartlepool, Middlesbrough and Stranton had more than 100 establishments. It is interesting to note that in terms of numbers of establishments, rather than functions, Staindrop was not outstanding, and belonged with the large villages rather than the main towns. Thus, while the population served by the town of Staindrop was sufficiently large to support a comparatively large range of functions, it was sufficient to sustain only the expected number of establishments. This indicates that shops, and other service outlets, were less specialised in Staindrop than was generally the case.

There are several anomalies in the basic pattern. One of these is Stockton, the only parish with a 'surplus' of business establishments. Indeed, in terms of establishments, Stoctkon was outstanding in the region, surpassing even Darlington, which had a larger population. Again, it may be

1. Eg. see : Stafford, op.cit.; King, op.cit.; H. Gardiner Barnum, Market Centers and Hinterlands in Baden-Württenberg, University of Chicago, Department of Geography Research Papers, No.103 (1966), pp.18-21; and Brian J.L. Berry, H. Gardiner Barnum and Robert J. Tennant, "Retail Location and Consumer Behavior", Papers of the Regional Science Association, Vol.9 (1962), pp.69-70.

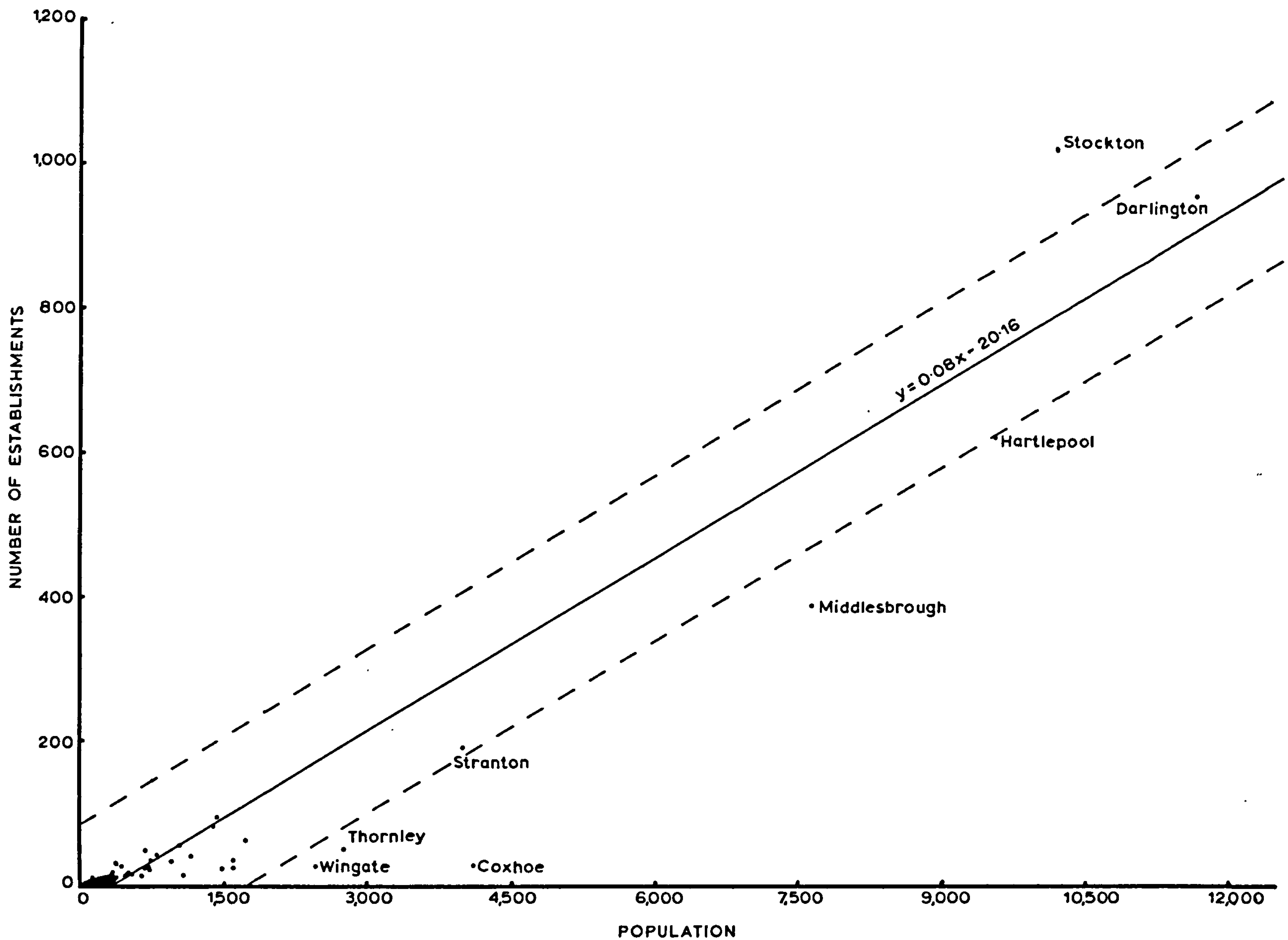

Figure 9.2 Population and Establishments, 1851

inferred that the trade-area population was exceptionally large in relation to the parish population in the case of Stockton, and that the town of Stockton relied more heavily on the population of its trade area than did other service centres. The fact that Middlesbrough had fewer establishments than the size of its population would have permitted suggests that Stockton may well have drawn custom from the town of Middlesbrough, which was comparatively new and perhaps under-equipped as a commercial centre.

The remaining anomalies in Figure 9.2 are Coxhoe, Thornley and Wingate, all of which had fewer business establishments than was normal for parishes of their population sizes. Like the other two, Wingate was a coal mining parish, and it seems probable that in all three the service industries had yet to respond to the recent expansion of mining and of the population, as was suggested earlier.

Population and Functional Units.

Whereas a business establishment may supply a variety of goods, a functional unit supplies only one type. Functional units are therefore more numerous than establishments, since one of the latter may incorporate several of the former. A close and positive relationship is to be expected between population size and the number of functional units. In the present study a correlation coefficient of +0.94 was found to exist between the two variables, and the relationship was also found to be linear. These results compare closely

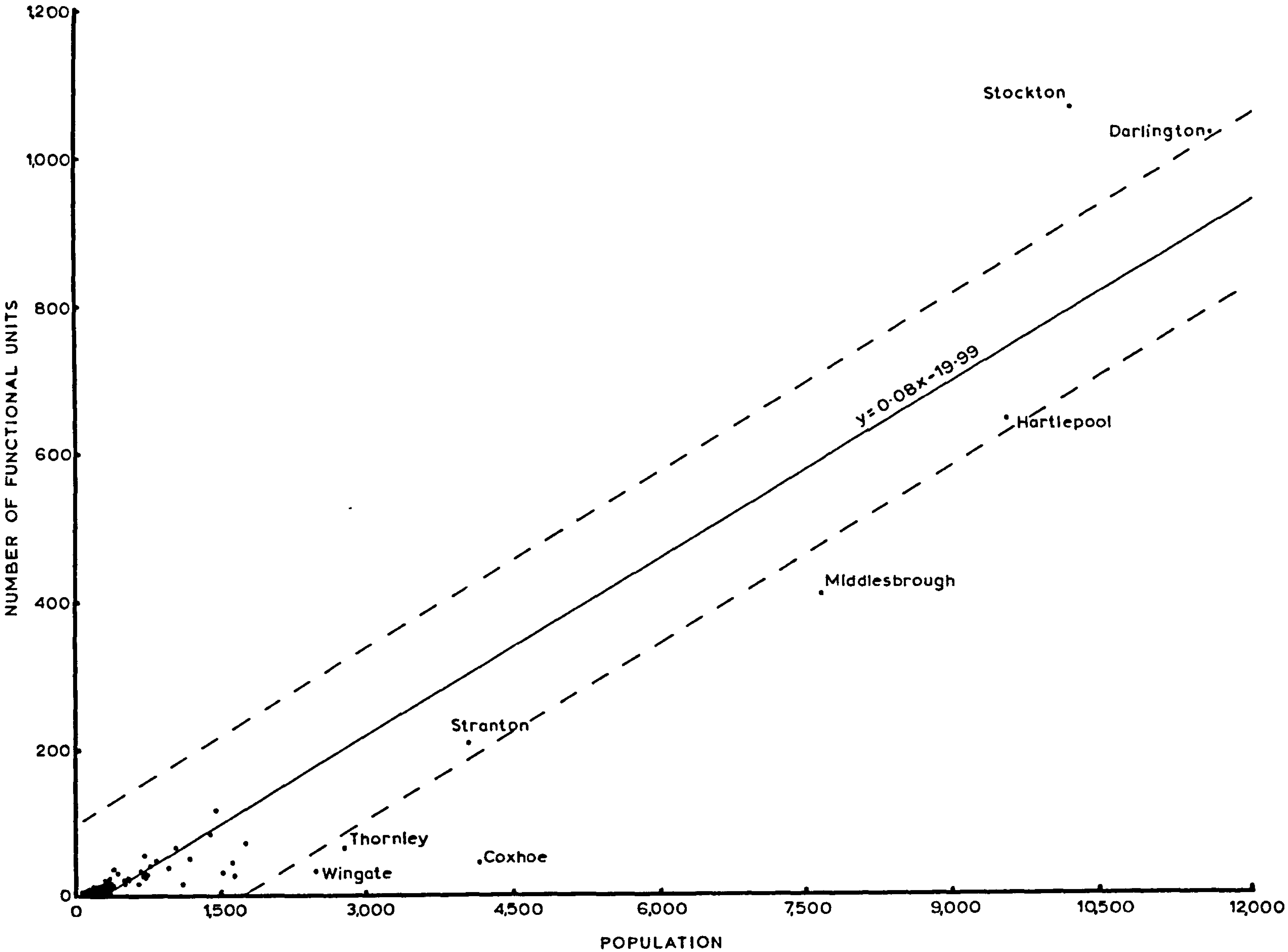

Figure 9.3 Population and Functional Units, 1851

with those obtained in other studies.[1]

The anomalies noted in Figure 9.2 are joined in Figure 9.3 by Darlington, which, like Stockton, had a surplus of functional units. Since these were the only parishes to have a surplus, it seems quite possible that their anomalous position is due to the inclusion of non-retail activities in the analysis. Stockton and Darlington would be most affected by this, as they contained most of the region's central functions in the wholesale and manufacturing categories. If retail functions alone had been included, then both parishes would probably have had 'normal' quotas of functional units for places of their respective sizes. Middlesbrough, Coxhoe, Wingate and Thornley all had deficits of functional units, presumably for the same reasons that they had deficits of establishments.

A Hierarchy of Central Places.

It was decided to examine the data compiled for Teesside - or, rather, for part of the region - in 1851 with a view to determining whether or not a hierarchy of central places could be said to have existed at that date. The question of whether or not such hierarchies do exist in reality is a rather vexed one. Certainly they have been proclaimed in many parts of the world,[2] but the methods used to identify them have not been totally convincing, and

1. Eg. see : King, op.cit.; Stafford, op.cit., pp.170-71; and Berry, Barnum and Tennant, op.cit., pp.69-70.

2. See Berry and Pred, op.cit.

doubts must remain.[1]

The concept of a hierarchy is a fundamental part of central place theory, both in the Christaller original and the Berry-Garrison modified forms. Basically, it is a result of the 'fixed-k' assumption embodied in those models.[2] The term k refers to the number of central places of a given order served by each central place of the order immediately above them. Generally, according to Christaller, k has a value of 3, though in special circumstances it may be higher. This value is fixed in the sense that it applies at all levels of the hierarchy, except the highest, in a particular system.

A consequence of the fixed-k assumption is that if k = 3, then there will be one centre of the highest order and 3,9,27 ... 3^{n-1} centres at successively lower orders in the hierarchy. Thus, the numbers of central places in successive orders are arranged in a regular geometrical progression. Further, the distribution of centres of different sizes is stepped or discontinuous.[3] Each tier of the hierarchy consists of places with identical population sizes and functional complexes, and places of a given order perform all those functions performed in lower-order centres plus a group of functions found only in places of their own and higher orders.

1. Haggett, op.cit., pp.124-25.

2. Ibid., pp.118-25; and William Bunge, Theoretical Geography, 2nd ed., Lund, 1966, pp.134-40.

3. Loc.cit.; and B.J. Garner, "Models of Urban Geography and Settlement Location", in Models in Geography, op.cit., pp.322-26.

Central functions may be thought of as being ranked, according to their respective threshold levels, and grouped into classes, on the basis of the order of central places in which they first appear. For example, only second-order, and higher, places have second-order functions. If each lowest-order central place serves 300 people, then functions with thresholds ranging from 1 to 300 people will be found in places of that order and of higher orders. Functions with thresholds of more than 300 people will not be located in central places of the lowest order. In this sense, then, the hierarchy of central places is founded upon groups of central functions.

Before discussing the difficulties entailed in seeking to verify the hierarchic model, mention should be made of an alternative scheme. Lösch favoured the concept of a variable -k factor,[1] which leads to a more complex theoretical system. In particular, his model yields an almost continuous array of central places, rather than a hierarchy, and places in it which are of the same size do not necessarily have the same types of functions; nor do larger centres necessarily have all the functions possessed by smaller places.[2] It can be argued that Lösch's model is more realistic than Christaller's though this would be denied by some, but even so it has had little empirical application. One probable reason is that it

1. August Lösch, The Economics of Location, trans. W.H. Woglom and W.F. Stolper, New Haven, 1954.

2. Haggett, op.cit., pp.122-24.

would be difficult to test in practice. Another is that it has less appeal than the simpler and more elegant Christaller model.[1] Finally, Böventer has suggested that Lösch's scheme is more relevant to market-oriented secondary production than to the service industries.[2]

The main operational problem associated with the Christaller model is the difficulty of proving conclusively the existence of a settlement hierarchy. In some studies the hierarchy has been assumed almost as an axiom, in others overtly subjective criteria have been used to identify it, and in most the evidence and methods employed to investigate it are not invulnerable to criticism.[3] Perhaps the major difficulty is that in the real world central places of the same size cannot be expected to have identical functional complexes, nor can those with the same functional status be expected to have populations of equal size. There is a need, therefore, for the application of tests capable of determining whether or not there is a fundamental hierarchic structure, such that deviations can be regarded as the results of minor or random imperfections. In most cases, however, the tests adopted can be criticised as inadequate in some respect. For the moment, though, controversy appears

1. Bunge, op.cit., pp.134-40; and M.J. Beckmann, "City Hierarchies and the Distribution of City Size", Economic Development and Cultural Change, Vol.6 (1958), pp.243-48.

2. Böventer, op.cit.

3. See Wayne K.D, Davies, "The Ranking of Service Centres : A Critical Review" Transactions of the Institute of British Geographers, No.40 (1966), pp.51-65.

to have been stilled by the perhaps welcome but certainly ambivalent judgement that it is possible for a continuum and a hierarchy of central places to co-exist,[1] and that the scale of the enquiry will determine whether one or the other is identified. Thus :

> If a small relatively homogeneous subregion is studied, the existence of a hierarchy of urban centres is more apparent.... If, on the other hand, much larger areas are studied, the heterogeneity is greater and inter- and intra-area differences combine to create a continuum.[2]

In the present case, comparatively simple techniques have been used to examine the question of whether or not a hierarchy existed. The general approach is essentially that employed by Berry and Garrison in their early Snohomish study. Briefly, an attempt was made to identify groups of central places and groups of central functions, and then to establish whether or not the two sets of groups were related.

At this stage of the analysis it was possible to dispense with the parish aggregations and return to using the central places themselves, since population figures were not required. The 95 central places listed in Table 9.1 were ranked, in descending order, according to the number of central functions they possessed. Table 9.3 presents the array thus obtained. The next step required the testing of this array to establish whether or not there was a tendency to-

1. Berry, Barnum and Tennant, <u>op.cit.</u>, pp.102-103.

2. Brian J.L. Berry and H. Gardiner Barnum, "Aggregate Relations and Elemental Components of Central Place Systems", <u>Journal of Regional Science</u>, Vol.4 (1962)p.35.

wards grouping amongst its members. As Johnston has argued recently,[1.] this would seem to be an essential preliminary if classification is to have more than a convenience value. Taxonomic procedures themselves simply reduce a given number of objects into a smaller number of classes, or vice-versa, on the basis of some specified criterion or criteria; they do not guarantee that these classes have any intrinsic value.

The family of nearest-neighbour techniques provides a number of preliminary tests. It consists of a group of measures designed to establish whether a distribution of points is random or tends towards uniformity or clustering.[2.] The common characteristic of these measures is that they compare the mean distance between each point and its nearest neighbour with the theoretical mean distance which would obtain if the distribution were random. Perfect coincidence of the actual and theoretical mean values indicates that the distribution is indeed random. Otherwise, it tends to be clustered or uniform, and the departure from the norm can be tested for significance.

Interest in nearest-neighbour analysis stems from the work of Clark and Evans in the field of plant ecology. Their

1. R.J. Johnston, "Grouping and Regionalizing : Some Methodological and Technical Observations", paper prepared for the I.G.U. Quantitative Commission Meetings at Ann Arbor and London, August, 1969, pp.13-14.

2. These techniques are reviewed in : Leslie J. King, Statistical Analysis in Geography, Englewood Cliffs, New Jersey, 1969, chap.5; and P. Greig-Smith, Quantitative Plant Ecology, 2nd.ed., London, 1964, chap.3.

Table 9.3

Settlements Ranked According to Numbers of Functions in 1851.

	Central Place	No. of Functions.
Group A.	Darlington.	126
	Stockton.	126
Group B.	Hartlepool.	93
	Middlesbrough.	70
Group C.	West Hartlepool.	44
	Staindrop.	44
Group D.	Norton.	31
	Gainford.	24
	Sedgefield.	23
	Di[illegible]nton.	19
	Great Aycliffe.	17
	New Thornley.	15
	Wolviston.	15
	Coxhoe.	15
	Seaton Carew.	15
	Hurworth.	15
	Cornforth.	14
	Blackgate.	14
	Stranton.	14
	Easington.	14
	Wingate Grange.	14
	Heighington.	14
	Hutton Henry.	13
	Cockerton.	13
	Bishop Middleham.	12
	Billingham.	11
	Castle Eden.	11
	Hart.	11
	Fishburn.	11
	Ingleton.	11
	Trimdon.	10
	East Hetton.	10
	Thorpe Thewles.	10
	Greatham.	10
	Cockfield.	10
	Haughton le Skerne.	10
	Egglescliffe.	10
	East Hartburn.	9
	Shotton.	9
	Middleton one Row.	9
	Brafferton.	9
	Neasham.	9
	Denton.	9
	Summerhouse.	8
	Piercebridge.	8
	Sadberge.	8
	New Trimdon.	7

Central Place.	No. of Functions
Kelloe.	7
New Shotton.	7
Middleton St. George.	7
Elwick.	7
Bradbury.	7
Long Newton.	7
Trimdon Grange.	6
High Coniscliffe.	6
Carlbury.	6
Redworth.	6
Coatham Mundeville.	6
Sheraton.	5
Monk Hesleden.	5
Mordon.	5
Houghton le Side.	5
Carlton.	5
Killerby.	5
Little Stainton.	5
Blackwell.	5
Elwick Hall.	4
Preston le Skerne.	4
Cowpen Bewley.	4
Wackerfield.	4
Bolam.	4
Harrowgate.	4
Elton.	4
Great Burdon.	4
Haverton.	3
Newton Bewley.	3
Walworth.	3
Low Coniscliffe.	3
Low Dinsdale.	3
Port Clarence.	2
Mainsforth.	2
Redmarshall.	2
Morton Palms.	2
Thornley.	1
Wingate.	1
Wheatley Hill Lane.	1
Thorp.	1
Barmpton.	1
Garmondsway Moor.	1
Butterwick.	1
Embleton.	1
Dalton Piercy.	1
Middridge Grange.	1
Great Stainton.	1
Aislaby.	1

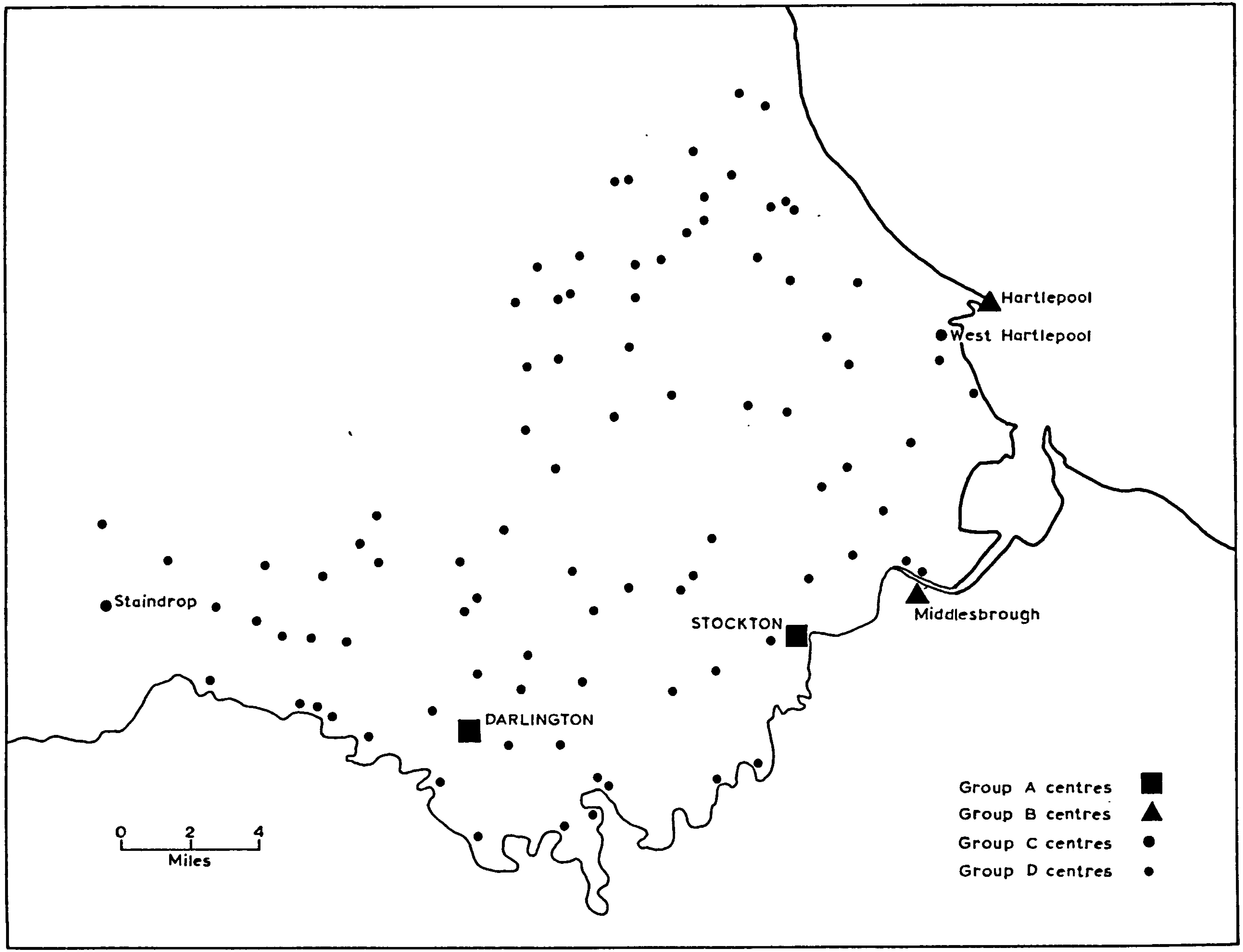

Figure 9.4 Central Places, 1851

original contribution was a technique for use with two-dimensional distributions, such as plant communities.[1] Subsequently, they produced a simplified version of that technique which could be applied to distributions in n-dimensional space.[2] This simplified method was used by Dacey to examine the spacing of river towns along the Mississippi,[3] a problem in one dimension. Basically, it consists of comparing the number of reflexive pairs - that is, pairs of points each member of which is the nearest neighbour of the other - in a distribution with the number that would be present if the distribution were random.

This reflexive-pairs measure was applied to the array in Table 9.3, with the result that the distribution was declared to be almost perfectly uniform. It was felt, however, that the result might have been distorted by a peculiar feature of the array : its inclusion of a number of groups consisting of points of exactly equal value. For example, several central places had just one central function, several more had two functions, and in general there was more than one central place with any given number of functions. A review of the relevant literature revealed no discussion of this type of situation, but it clearly deserves consideration.

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1. P.J. Clarke and F.C. Evans, "Distance to Nearest Neighbour as a Measure of Spatial Relationships in Populations", Ecology, Vol.35 (1954), pp.445-53.

2. Idem., "On Some Aspects of Spatial Pattern in Biological Populations", Science, Vol.121 (1955), pp.397-98; and P.J. Clarke, "Grouping in Spatial Distributions", Science, Vol.123 (1956), pp.373-74.

3. M.F. Dacey, "The Spacing of River Towns", Annals of the Association of American Geographers, Vol.50 (1960), pp.59-61. Subsequently, Dacey published a large number of papers concerning nearest-neighbour methods, most of which are listed by Peter R. Gould in his "Methodological Developments since the Fifties", Progress in Geography, Vol.1 (1969), pp.31-32.

One of its consequences is that the proportion of points with reflexive partners is inevitably very large. For this reason, it was decided to check the result obtained by using a less crude technique.[1]

In an unpublished paper Cowie has provided the mathematical expression for a one-dimensional version of the original Clark-Evans method.[2] This was used to examine the array of central places in Table 9.3. The initial result suggested that the distribution did not differ significantly from random, and was quite different from the result obtained by using the reflexive-pairs method. As Cowie points out, however, nearest-neighbour techniques "... produce very sensitive statistics."[3] In particular, they are essentially concerned with comparing mean values, but, as they do not embody a measure of the scatter of points around those means, results can be grossly distorted by the presence of anomalous individuals.[4] Table 9.3 seemed to require fresh scrutiny on this ground.

In the arrary of central places, Hartlepool and Middlesbrough are sufficiently isolated to cause some distortion

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1. That it is fairly crude is evident from a sequel to Dacey's paper on river towns : P.W. Porter, "Earnest and the Orephagians : A Fable for the Instruction of Young Geographers", Annals of the Association of American Geographers, Vol.50 (1960), pp.297-99.

2. Stewart R. Cowie, "The Cumulative Frequency Nearest Neigbour Method for the Identification of Spatial Patterns", unpublished paper, University of Bristol, Department of Geography, Seminar Paper Series A, No.10 (n.d.), 16 pp.

3. Ibid., p.2.

4. Ibid., pp.8-9.

of the result. They form a reciprocal pair as first-order neighbours, but the distance between them is 23 units, which is very large in the circumstances. Together, they contribute 46 units to the sum total of nearest-neighbour distances, which is only 60 units. Hartlepool and Middlesbrough were excluded from the distribution and the analysis repeated, this time with the result that a significant tendency towards clustering was found. As it seemed to represent the fundamental character of the array, this result was accepted, and regarded as sufficient justification for dividing the array into groups.

The central places were grouped in accordance with two criteria : Clark's dictum that each member of a group should be closer to some other member of that group than to any member of another,[1] and the additional requirement, which is often implicit, that no group should have just one member[2]. In practice, the three largest steps in the distribution, which were much greater than any others, were deemed substantial breaks and used to identify four groups of central places. The groups were:

A) Stockton and Darlington, with 126 functions;
B) Middlesbrough and Hartlepool, with 70-93 functions;
C) West Hartlepool and Staindrop, with 44 functions;
D) all other places, with 1-31 functions.

1. Clark, "Grouping in Spatial Distributions", op.cit., p.373.

2. This specification avoids the situation in which an arbitrary decision has to be made as to whether an individual is sufficiently far from its nearest neighbour to warrant its being regarded as a group in its own right.

Berry and Garrison,[1] - in an early study -, King,[2] and Davies[3] have all used virtually the same method of defining groups of central places. King, however, noted that it leaves something to be desired, since it does not provide an objective guide to the number of groups that should be recognised.[4] In the present case four groups were identified, but the number could have been enlarged - quite objectively - by accepting smaller breaks in the distribution as significant. At an extreme, if an array consisted only of points belonging to reflexive pairs, then the criteria adopted here could yield N/2 groups, where N is the number of points.

This problem of determing how many groups should be recognised appears to be intractable, and it is neither removed nor circumvented by the use of more sophisticated taxonomic procedures.[5] These may classify individuals according to complex criteria, and they may even provide a guide to the relative efficiency of different solutions, but at some stage the controller of the experiment must enter the

1. Berry and Garrison, "The Functional Bases of the Central Place Hierarchy", op.cit.

2. King, "The Functional Role of Small Towns in Canterbury", op.cit.

3. Davies, "Centrality and the Central Place Hierarchy", op.cit.

4. King, "The Functional Role of Small Towns in Canterbury", op.cit., p.148.

5. See Johnston, op.cit., pp.13-14.

proceedings and exercise his essentially subjective influence.[1] This may be in order to assess the significance of breaks in the distribution under examination, or it may be simply to select the grouping procedure to be used.

Tarrant has recently advocated the adoption of a technique which provides a measure of the loss of accuracy incurred at each stage in the process of assigning individuals to a group.[2] This has the advantage of providing information upon which an assessment can be made. Since grouping consists of generalizing a given body of data, however, the investigator is still left with the fundamental problem of deciding what level of accuracy - loss is acceptable. The factor-analytic methods used by Berry and his associates, though more complex, seem to have the same limitations, and are certainly open to criticism.[3] It may be concluded that different techniques yield different solutions, and that the 'natural group' remains as elusive for the taxonomist as is the 'natural region' for the geographer.[4]

In the present study the central functions were treated in much the same manner as the central places but first it was necessary to devise a means of ranking them. Usually,

1. Loc.cit.; and R.J. Johnston, "Choice in Classification : The Subjectivity of Objective Methods", Annals of the Association of American Geographers, Vol.58 (1968), pp.575-89.

2. J.R. Tarrant, "A Note Concerning the Definition of Groups of Settlements for a Central Place Hierarchy", Economic Geography, Vol.44 (1968), pp.144-51.

3. See Haggett, op.cit., p.125; and Davies, "The Ranking of Service Centres : A Critical Review", op.cit.

4. See the discussion of natural groups in : Robert K. Sokal and Peter H.A. Sneath, Principles of Numerical Taxonomy, San Francisco, 1963, pp.11-20.

where a subjective approach has not been adopted,[1] threshold values have been calculated and employed for this purpose.[2] In practice, however, thresholds are difficult to measure, and the methods which have been used to do so are vulnerable to criticism. The threshold for a particular function may be defined as the minimum amount of purchasing power necessary to support one unit of it. Provided that purchasing power is distributed evenly within a population, the threshold may also be expressed in terms of numbers of people. Thus, the total population of a central place and its complementary region divided by the number of outlets for a particular good should give the threshold population for the function supplying that good.

While census authorities provide population figures for even small central places in many parts of the world, they obviously cannot do so for such an indistinct unit as the complementary region. In empirical studies, this has led to the use of the populations of central places alone in determining threshold levels. For example, Berry and Garrison plotted the numbers of establishments against the populations of central places, for each function in turn, and then fitted

1. Eg. as in Barry J. Garner, The Internal Structure of Retail Nucleations, Northwestern University, Studies in Geography, No.12, Evanston, 1966, p.65.

2. Eg. King, "The Functional Role of Small Towns in Canterbury," op.cit.; and Barnum, op.cit.

regression lines to determine what size a place needed to be if it were to support just one establishment of each type.[1] The values thus obtained were regarded as the threshold populations for the various functions.

This is a rather tedious procedure, and in the present case it would require repeating 163 times in order to account for all the functions involved. More significantly, the method does not yield genuine thresholds, since it does not entail consideration of the populations of trade areas.[2] In addition, there are differences between rural and urban patterns of demand and levels of purchasing power, and the[illegible] may also mean that the inclusion of trade-area populations in the analysis would affect the threshold values sufficiently to alter the ranking of functions. Further, Davies has argued that it is a mistake to use population figures at all, since they depend partially upon employment in the primary and secondary sectors as well as the service industries.[3]

In the present study, these disadvantages are surpassed in importance by the additional problem that population data are generally available only for parishes, and not for central places. There are grounds, some of which were outlined ear-

1. See Berry and Garrison, "The Functional Bases of the Central Place Hierarchy", op.cit., and "Central Place Theory and the Range of a Good", op.cit.

2. Bunge, op.cit., pp.149-50; Haggett, op.cit., p.117; and King, "The Functional Role of Small Towns in Canterbury", op.cit., p.148.

3. Davies, "The Ranking of Service Centres : A Critical Review", op.cit., p.59.

lier, for believing that the mid-nineteenth century parish approximated quite closely to the village trade area in many rural districts. However, these are not overwhelmingly strong, and in any case they would not apply to towns large enough to serve an area more extensive than the parish. Hence, the Berry-Garrison method of deriving threshold values and ranking functions was rejected as inappropriate.

Some alternative index for ranking the central functions was therefore required, and the one chosen was the number of functional units per function. A central function's rating on such a scale is clearly related to its threshold : the higher the threshold, the smaller the number of outlets, and vice-versa. For a particular function, the number of functional units is in fact the quotient of the total population divided by the threshold population. This index consequently provides an acceptable alternative to ranking functions on the basis of their respective thresholds. Garner has furnished empirical support for this view. For several sets of data, he found significant correlations between arrays of functions ranked according to three related criteria : threshold, number of places in which each function occurs, and number of establishments per function.[1] Either of the last two measures could therefore be used instead of the threshold for ranking purposes.

1. Garner, The Internal Structure of Retail Nucleations, op.cit., Appendix D.

Table 9.4 lists the functions present in the Teesside region in 1851 ranked on the basis of the numbers of functional units. This array was tested for evidence of clustering, using Cowie's version of the original Clark-Evans nearest-neighbour technique. Again, however, the initial result was not satisfactory; it suggested a slight tendency towards uniformity, but it could have been disproportionately influenced by the presence of an isolated individual point. A second analysis was therefore undertaken from which 'Boot and Shoe Makers and Dealers' was omitted, since it alone accounted for one-third of the sum total of nearest-neighbour distances. With this adjustment made, the distribution showed significant signs of clustering. This secohd result was accepted as a truer indication of the basic character of the array, but it is clear that the operation limitations of nearest-neighbour methods can be formidable.

Using precisely the same procedure as that employed in connection with the central places, the central functions were then each assigned to one of four groups. These were as follows :

1) functions with values of 376 to 512;
2) " " " " 189 to 252;
3) " " " " 75 to 130;
4) " " " " 1 to 51.

With the separate identification of groups of places and functions complete, it remained to demonstrate that the two sets of groups were related to each other, and that there was a

Table 9.4

Central Functions Ranked According to their Numbers of Functional Units, 1851

Rank	Function	No. of Functional Units.
Group 1		
1	Grocer.	512
2	Hotel/Public House /Inn.	481
3	Boot and Shoe Maker/Dealer.	376
Group 2		
4	Butcher.	252
5	Tailor.	240
6	Joiner and Carpenter.	189
Group 3		
7	Black, White and Shoe Smith.	130
8	Corn Miller.	125
9	Draper.	122
10	Insurance Agent.	109
11	Hqtter and Milliner.	104
12	Beer House/Beer Retailer.	103
13	Builder.	99
14	Cartwright.	87
15	Cabinet Maker.	83
16	Mason.	75
Group 4		
17.5	Brewer.	51
"	Straw Bonnet Maker	51
19	Druggist and Chemist.	50
21	Fruiterer and Greengrocer.	49
"	Baker.	49
"	Provision Merchant	49
23	Boarding/Lodging House.	42
24.5	Glass, China and Earthenware Dealer.	41
"	Glazier.	41
27	Flour Dealer.	40
"	Surgeon.	40
"	Cow Keeper.	40
29	Solicitor.	38
30	Tea Dealer.	37
31	Hair Dresser.	36
33.5	Confectioner.	35
"	Bricklayer.	35
"	Dress Maker.	35
"	Painter.	35
36	Commission Agent.	34
38	Leather Worker/ Dealer.	32
"	Timber Merchant.	32
"	Plumber.	32
40	Bookseller and Stationer.	31
41	Gas Fitter,	30
42.5	Gilder.	29
"	Outfitter, Clothier, Clothes Dealer.	29
45	Wine and Spirit Merchant.	28
"	Saddle and Harness Maker.	28
"	Clock and Watch Maker.	28
47.5	Hosier and Haberdasher.	27
"	Printer.	27
49	Ironmonger and Hardware Dealer.	25
50	Furniture Broker.	24
51.5	Tinner and Brazier.	23
"	Auctioneer and Appraiser.	23
53	Cooper.	19
54	Ale and Porter Merchant.	17
56	Corn and Flour Merchant.	16
"	Temperance Hotel & Boarding House.	16
"	Rope and Twine Maker.	16
58	Land Agent and Surveyor.	15
60.5	Carter.	13
"	Coal Dealer.	13
"	Bookbinder.	13
"	Bank.	13
63	Machine Wright and Millwright.	12

Table 9.4 (Contd.)

Rank	Function	No. of Functional Units.	Rank	Function	No. of Functional Units.
65	Eating House.	11	112	Pig Jobber.	3
"	Paper Hanger.	11	"	Mattress Maker.	3
"	Toy Dealer.	11	"	Bird & Animal Preserver.	3
67.5	Tobacco Pipe Maker.	10	"	Portrait Painter.	3
"	Veterinary Surgeon.	10	"	Clog & Pattern Maker.	3
69	Upholsterer.	9	"	Engraver .	3
75.5	Fishmonger.	8	"	Glass Maker.	3
"	Poulterer and Game Dealer.	8	"	Smallware Dealer.	3
"	Turner.	8	122.5	Brush Maker.	2
"	Glover.	8	"	Cork Cutter.	2
"	Cab Proprietor.	8	"	Share Broker.	2
"	Chimney Sweeper.	8	"	Flax Manufacturer and Dresser.	2
"	Civil Engineer.	8	"	Glue Maker.	2
"	Livery Stables.	8	"	Hay and Straw Dealer.	2
"	News Agent.	8	"	Organ Builder.	2
"	Registry for Servants	8	"	Tobacco Manufacturer.	2
"	Maltster.	8	"	Lath Render.	2
"	Cattle Dealer.	8	"	Oil & Colour Merchant.	2
83	Plasterer.	7	"	Stove, Grate and Fender Maker.	2
"	Lemonade, Ginger Beer & Soda Water Maker	7	"	Potato Merchant.	2
"	Stay & Corset Maker.	7	146.5	Perfumer.	1
86	Coach Maker.	6	"	Worsted Dealer.	1
"	Dyer.	6	"	Spade and Shovel Maker.	1
"	Saw Mill.	6	"	Horse Dealer.	1
92.5	Hop Merchant.	5	"	Looking Glass and Picture Frame Maker.	1
"	Basket Maker.	5	"	Oatmeal Maker.	1
"	Carver.	5	"	Sacking Maker.	1
"	Accountant.	5	"	Slater.	1
"	Architect.	5	"	Baths Keeper.	1
"	Worsted Spinner.	5	"	Barometer Maker.	1
"	Canvas Maker.	5	"	Pianoforte Tuner.	1
"	Cutler.	5	"	Paint Maker.	1
"	Nurseryman and Seedsman.	5	"	Slate Merchant.	1
"	Tallow Chandler.	5	"	Paper Merchant.	1
102.5	Berlin Wool Repository.	4	"	Herbalist.	1
"	Linen Maker.	4	"	Florist.	1
"	Pawnbroker.	4	"	Clock Case Maker.	1
"	Jeweller.	4	"	Carpet Maker.	1
"	Ham & Bacon Dealer.	4	"	Cheesemonger.	1
"	Chair Maker.	4	"	German Yeast Importer.	1
"	Physician.	4			
"	Dentist.	4			
"	Gun Maker.	4			
"	Music & Musical Instrument Dealer	4			

Table 9.4 (Contd.)

Rank	Function	No. of Funct-ional Units.
146.5	Clothes Cleaner.	1
"	Feather Merchant.	1
"	Mat Maker.	1
"	Oil Cloth Maker.	1
"	Carpet Dealer.	1
"	Flax Merchant.	1
"	Flock Merchant.	1
"	Furrier.	1
"	Woolstapler.	1
"	Laceman.	1
"	Blacking Maker.	1
"	Cordial Maker.	1
"	French Polisher.	1
"	Glass Cutter.	1
"	Builders' Materials Supplier.	1
"	Rag and Bone Merchant.	1

hierachy of central places. Following the pattern set by a number of earlier studies,[1.] this problem was approached through the use of variance analysis.

The technique of variance analysis may be used to compare a number of sets of data when the object is to determine whether or not they are related to each other, or are samples drawn from the same statistical population. In the present context, the samples, or sets of data, are represented by the sixteen cells of the matrix displayed in Table 9.5. For each cell in the matrix, which was formed by juxtaposing the groups of places and the groups of functions, the average number of functional units per function per place was calculated. Thus, it can be said that the average Class-A central place had 78.33 functional units for the average Class-1 central function, whereas the average central place in Class D had only 2.05 functional units of that type.

Table 9.5

The Average Number of Functional Units per Function per Central Place in 1851.

Classes of Central Functions.	Classes of Central Places			
	A	B	C	D
1	78.33	42.17	12.33	2.05
2	35.50	22.00	7.00	1.05
3	18.15	9.55	3.10	0.45
4	3.55	1.56	0.37	0.01

Using variance analysis, it was found that the differences between the cells in Table 9.5 were significantly grea-

1. Eg. : Berry and Garrison, "The Functional Bases of the Central Place Hierarchy", op.cit.; King, "The Functional Role of Small Towns in Canterbury", op.cit.; and Robert C. Mayfield, "A Central-Place Hierarchy in Northern India", in Economic and Cultural Topics, Part 1 of Quantitative Geography, ed. W.L. Garrison and D.F. Marble, Northwestern University, Studies in Geography, No.13, 1967, pp.120-66

ter than the differences within them. Hence, it may be concluded that the samples were not from the same statistical population. This corroborates the validity of the groupings of central places and central functions, demonstrates that the two sets of groups were associated with one another, and may be accepted as substantiation of the hypothesis that there was a hierarchy of central places in the Teesside region in 1851. As in most empirical studies, there may be some remaining vestiges of uncertainty, but these should be considered in the light of the truism that relationships are bound to be more poorly defined in the real world than in a theoretical model. Places of the same population size cannot be expected to have precisely the same range of functions, and the distinctions between levels of the settlement hierarchy will tend to be blurred, and perhaps recognisable only in statistical terms. Nevertheless, Tables 9.5 and 9.6 indicate that there were significant differences in the Teesside region between places belonging to various levels of the hierarchy.

Table 9.6

Summary of the Analysis of Variance

Source of Variation	Sum of Squares	Degrees of Freedom.	Mean Square	F
Between Groups.	27,854.1	15	1,857	108+
Within Groups.	10,932.8	636	17.18	

+ Significant at the 99.9 per cent confidence level.

The Central Place System
in GreaterDetail.

In 1851 the highest order in the Teesside settlement hierarchy consisted of two central places : Darlington and Stockton. Darlington was the larger of the two in terms of population size, having some 1,400 people more than Stockton, but they had exactly the same number of central functions. Stockton, however, had rather more business establishments and functional units, and on this basis may be considered to have been marginally more important as a service centre. In terms of functions, functional units and establishments, Stockton had a modest surplus, over and above the numbers to be expected of a town of such a size. Darlington had a surplus only of functional units. This difference may be interpreted as evidence that Stockton's hinterland population was unusually large, in relation to its own population, whereas Darlington was very close to the norm in this respect.

The B-tier in the hierarchy also consisted of two towns : Hartlepool and Middlesbrough. The former was an ancient borough, port and market town, but it was in a rather dilapidated state in the early nineteenth century and was only saved from further decay by the growth of the coal trade. In 1801, the population of Hartlepool numbered 1,000 people, and the town's once vital harbour was seeded with corn.[1] From being the major port of the County Palatine of Durham,

1. Robert Wood, West Hartlepool, West Hartlepool, 1967, p.1 and p.12.

as well as a redoubtable military fortress,[1] Hartlepool had degenerated into a small fishing community. Its recovery awaited the development of railways and coal mining in south Durham. The first load of coal intended for shipment from Hartlepool arrived there by rail in 1835.[2] Within a short time after that date, new dock facilities had been built, new industries established, and Hartlepool had found a commercial vigour unknown in the town since the days of the Prince Bishops. By 1851, it was a substantial settlement, port and industrial town. With ninety-three central functions, Hartlepool was also the third most important service centre on Teesside.

Middlesbrough also owed its position in 1851 to the growth of the coal trade. The town had been founded some twenty years earlier as a virtual out-port for Stockton, but it had subsequently developed into a commercial centre of considerable stature in the region. From the scatter diagrams presented in an earlier section (Figures 9.1 , 9.2 and 9.3), it can be seen that of the two Class-B central places, only Middlesbrough was in any way anomalous. Like Hartlepool, however, it did have a normal quota of functions and this is somewhat surprising, since new industrial towns tend to be deficient as commercial centres. Older towns, especially if they are large and located nearby, overshadow new settlements and prevent them from developing a functio-

1. Joseph Hetherington, "A Physical and Economic Geography of Northern Tees-Side," unpublished Ph.D. thesis, University of Durham, 1958, Vol.1, pp.201-203.

2. *Ibid.*, p.204.

nal range commensurate with their size.

In 1851, however, Middlesbrough had a normal functional complex for a central place of its size on Teesside, which implies that it had been able to appropriate a hinterland population of normal proportions. As was noted earlier, the town did have slightly fewer establishments and functional units than might have been expected, but this does not seem very significant; it could have reflected a measure of under-development in the tertiary sector, but it could also have resulted from differences in the scale of service outlets between old and new central places. Middlesbrough was essentially a normal service centre.

On reconsideration, this seems less surprising than it did at first. In studies dealing with past situations, there is a common tendency to foreshorten the time-scale, a tendency which is more marked the more distant a period is from the present. By 1851, Middlesbrough was no longer a new and booming town; most of its growth had occurred in the 1830's. During the 1840's Hartlepool became the main centre of the coal-shipping trade on the Tees, and Middlesbrough experienced little expansion. Indeed, there were many at the time who had doubts about the latter's future. By mid-century, therefore, Middlesbrough's service industries had had a decade of comparative quiescence in which to correct any initial imbalance there might have been in the town's commercial structure.

A further possible explanation of Middlesbrough's apparent normality, as a service centre, in 1851 is to be found in the spatial properties of the regional central place system. To anticipate, it seems plausible to suggest that Hotelling's solution to a classic location problem is relevant.[1] Hotelling was concerned with finding the equilibrium positions for two retailers serving a linear market, and used the analogy of two ice-cream venders on a beach. The equilibrium state is in fact attained when the vendors are located side-by-side in the centre of the beach, and each controls exactly one-half of the market. In any other situation, one vendor can always increase his share of the market by moving towards his competitor.

For a substantial part of the south-eastern quarter of the Teesside region, Middlesbrough was the nearest large central place. Because of the spatial constraints imposed by the North Yorks Moors and Cleveland Hills, the coastline and the Tees itself, the nearest alternative centre of similar or higher status was Stockton, to the west of Middlesbrough. The latter town must therefore have been able to tap a larger hinterland than would have been the case had it been located further downstream, or had there been other large central places to the east or south east. In either of those situations, the area sheltered from the influence of other B-level, or higher, centres would have been smaller. The spatial character of the regional central place system therefore pr-

1. H. Hotelling, "Stability in Competition", Economic Journal, Vol.41 (1929), pp.52-53.

obably helped Middlesbrough to carve out a hinterland by affording the town a degree of immunity from the forces of spatial competition.

The third level in the regional hierarchy, consisting of C-Class central places, contained West Hartlepool and Staindrop, each with forty-four functions. It is at this level that the larger villages in that part of the region within North Yorkshire, such as Guisborough and Stokesley, would probably have appeared if data had been available for them. Despite their functional parity, West Hartlepool and Staindrop were quite different towns in most respects. The former had been in existence for a mere four years, though it was already a substantial settlement, and owed its origin to the coal trade. Administratively, it was not a town at all, being neither a borough nor even an Improvement District; it was ruled officially by the parish council of Stranton, and unofficially by the railway company which had built it.[1] In other respects, West Hartlepool was more an industrial annexe of the ancient borough of Hartlepool than a town in its own right.

Staindrop differed not only from West Hartlepool but also from the other towns discussed so far. Essentially, it was a traditional country market town set in the midst of a purely agricultural rural area, and the base of its economy was provided by its activities as a service centre. As it was some distance away from mineral workings, railways, major

1. See Wood, op.cit., passim.

roads and manufacturing centres, Staindrop was as yet little affected by industrial expansion alongside the lower reaches of the Tees. An interesting distinction between the two Class-C centres is that while they had an equal number of central functions, Staindrop's population was probably only half the size of that of West Hartlepool. The latter's larger population was reflected in its greater numbers of functional units and establishments rather than its range of functions.

From these observations, it is possible to conclude that, as would be expected, West Hartlepool served only a very small hinterland population. Its service industries were mainly concerned with supplying the town's own population. Staindrop, on the other hand, clearly relied heavily on the population of its hinterland, since it had a functional complex as large as West Hartlepool's. The surplus of functions apparent in Figure 9. indicates further that Staindrop drew support from parishes other than its own. Raby, which did not have a central place, was certainly one of these. Staindrop thus resembles the rural central places of exaggerated importance which have been found in other areas by King, Stafford and others.[1.]

An empirical conclusion worth drawing at this point is that the observations made so far tend to cast doubt on

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1. King, "The Functional Role of Small Towns in Canterbury", op.cit., p.143; and Stafford, op.cit., pp.173-4.

Berry's assertion that

> well-defined population : function ratios characterise a system of central places only where the major economic base of these centres consists of central place functions.[1]

This view has been echoed by King,[2] but the present study has supplied evidence of a very high correlation coefficient between population and functions despite the fact that only one of the six largest towns in the region in 1851 was fundamentally dependent on its central place activities. It seems likely that 'well-defined population : function ratios are more common than Berry would allow.

Most central places in the Teesside region belonged to the lowest level of the hierarchy, which is Class D. The number of functions performed by places in this category ranged from one to thirty-one, which is a comparatively large span and indicates that Class D includes village of some substance as well as small hamlets. Generally, however, the differences between successive places in the ranked array are too small to justify further sub-division, the usual step being only one or two functions. Norton had the relatively large number of seven functions more than its nearest neighbour, Gainford, but it was still a village rather than a town, and was placed in Class D accordingly.

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1. Brian J.L. Berry, "The Impact of Expanding Metropolitan Communities upon the Central Place Hierarchy", <u>Annals of the Association of American Geographers</u>, Vol.50 (1960), p.115.

2. King, "The Functional Role of Small Towns in Canterbury", <u>op.cit</u>., p.148.

Most parishes in the area studied had at least one central place in this category, several parishes also had a higher-order centre, and a number had a substantial D centre plus a small supplementary hamlet. About one-fifth of the parishes were without any service centre at all, but the great majority had one central place and it usually belonged to Class D. This, and the high correlation coefficient between parish populations and numbers of functions, suggests that most of the D centres were supported mainly by the populations of their own parishes.

There are good reasons why this should have been the case. Traditionally, the parish or township was the basic territorial unit for purposes of ecclesiastical and civil administration, and the village was the hub of social organisation at the local scale. Social and political factors therefore favoured the village being the focus of the local economy, as indeed it always had been. Contemporary modes of transportation tended to encourage the preservation of this traditional structure in most areas. Away from the immediate vicinity of the railways and the turnpikes - and these were essentially concerned with non-local traffic -, people still moved about their daily affairs much as they always had done : by foot, horse-back, or some form of slow horse-drawn vehicle. Neither the stage-coach nor the railway was of much relevance, especially in rural districts. As a result, there were quite rigorous restraints, in terms of financial and time costs on consumer travel, and these tended to favour the retention of the village's traditional role as a local service centre.

The hierarchy of central places was based on groups of central functions, which have so far been given little attention. Functions in Group 1 consisted of those with the most functional units, or lowest thresholds, and included the following : grocer; public house/hotel; and boot and shoe maker/dealer. These were the most common of the various types of service business. In the larger central places groceries were retailed by specialist tradesmen, but in the villages and hamlets they were normally sold in combination with other goods, frequently with draperies. The traditional grocer had a much narrower professional interest in foodstuffs than his modern namesake. Specifically, he dealt in the less perishable commodities, such as tea, sugar, spices and preserves, most of which were either imported or made from imported raw materials.[1] The emphasis on dry goods makes the common combination of groceries and draperies seem less unlikely. Although the distinction between them grew less sharp in the second half of the century, in 1850 it was the provision dealer and not the grocer who sold fresh foodstuffs.[2]

The public house cum hotel was also present in large numbers. In addition to its more obvious functions in the

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1. See Jefferys, op.cit., chap.5; and Dorothy Davis, A History of Shopping, London, 1966, chap.12.

2. Loc.cit.

catering and entertainment spheres, the public house was an important institution in that it held a vital place in the transportation system. It was a staging post in what remained of the coaching network, the terminus and point of origin for road carriers, and, in towns, the depot for omnibuses operating on urban passenger services.

The ubiquity of the shoe-maker is perhaps only surprising to the modern observer. The footwear industry remained at the handicraft stage in most parts of the country, and it was made up of large numbers of small-scale producer-retailers.[1] It might be added that boots, in particular, were of great importance, and were probably short-lived, in an age when the footwear market was provided by a walking rather than a riding public.

Two of the three functions in Group 2, butcher and joiner/carpenter, obviously supplied basic goods and services for which there was a large market, and hence required comparatively few people to support them. The presence of the third, tailor, is more surprising, since today it is a relatively high-order retail function found almost entirely in town centres. Again, however, the explanation is to be found in the contemporary organisation of the trade in question. In the mid-nineteenth century, the tailor, like the shoe-maker, was a small-scale producer-retailer.[2] The clothing factory was of little importance - non-existent on

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1. Jefferys, op.cit., chap.14.
2. Ibid., chap.13.

Teesside - and even the sewing machine had still to be introduced.

Although working-class men can have had little to spend on new clothes, those they did buy were purchased from the local tailor. Hand-sewn garments required much time and labour to produce, with the result that a small number of customers could keep a tailor in full employment. His threshold was therefore low, and the evidence from this study indicates that there were very few functions with lower thresholds. The female equivalent of the tailor, the dressmaker, occupies a considerably higher rank in Table 9.4 and must, therefore, have had a higher threshold. This may have been because less money was spent on female clothing, but a more likely explanation is that a higher proportion of female clothes were made in the home.

At the opposite end of the spectrum, in Table 9.4 , are the highest-order functions represented in the region in 1851. They form a motley collection of very specialised activities, most of which were found only in the largest towns, and some of which appeared in only one central place. Their large number meant that Stockton and Darlington each had 126 central functions, whereas most centres had fewer than 30. It should perhaps be stressed that it was the highly specialised nature of the activities in Group 4, and the limited demand for them, rather than the value of their produce, that gave them such high thresholds.

Some consideration should be given to the role of markets and fairs in the regional central place system, a subject which has so far been ignored In the middle of the nineteenth century these institutions were still of great importance in places, despite the growth of fixed-site retailing. The essential difference between markets and fairs is that the former are held very frequently, usually once or twice each week, while the latter - which are larger events - are held only on a few special days in the year.[1.] This distinction is worth retaining, though nineteenth-century writers tended to blur it by referring to livestock markets as fairs even when they were held at weekly intervals.

In 1851, the only places within that part of the region in Durham which still held markets were Stockton, Darlington, Hartlepool, Staindrop, Sedgefield and Middlesbrough (which was actually in North Yorkshire but has been included here).[2.] Five of these were amongst the six towns identified earlier as the most important central places in the region, and West Hartleppol joined them a few years later. Thus, markets were generally held in places which were already major service centres by virtue of their fixed retail and other facilities.

With the exception of that at Middlesbrough, the markets in the area in 1851 were all ancient institutions. Stockton, Sedgefield and Staindrop had been granted franchises to hold

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1. See : Ministry of Agriculture and Fisheries, Report on Markets and Fairs in England and Wales ; Part 1 : General Review, London, 1927, p.7.

2. Hagar, op.cit.

markets in the fourteenth century by the Bishops of Durham.[1] Darlington's market charter was even older.[2] In most cases, however, the markets had discontinuous histories, and had known long periods of disuse. Greatham was one place which no longer exercised its ancient right to hold a market,[3] and it was probably not alone in that respect.

By the mid-nineteenth century, markets varied in character quite considerably, and undertook a wide range of functions. Most, however, had both retail and wholesale components, and all were under some form of legal control.[4] Local growers of vegetables and fruit, and some dairy and poultry farmers, used the markets to sell their produce directly to the consumer. In urban areas, especially, they were joined by retailers offering non-local, even imported, foodstuffs and furnishings and household utensils. The pure retailers usually operated on well-marked circuits, as is still the case today, appearing at a different place on each day of the week. Then, as now, the main advantage of the market system to the retailer was that it gave him access to premises which were simply equipped but cheap. Particularly in relation to working-class demand, this gave him a competitive advantage over those of his rivals who had fixed shops. By moving to a different place each day, it is also probable that he could draw upon a larger market and achieve a higher

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1. Loc.cit.

2. County Borough of Darlington, Official Markets Handbook, London, n.d. [circa 1953] p.16.

3. Hagar, op.cit.

4. Ministry of Agriculture and Fisheries, op.cit.

turnover than would otherwise have been possible, since many goods must have been shopped for only on a weekly basis.

There were wholesalers as well as retailers in the market place. In rural areas, which were essentially food-producing districts, buying agents used the periodic markets to collect local surpluses of livestock, meat, vegetables and grains intended for urban consumption. In urban areas, wholesale dealers used the markets to distribute foodstuffs and other commodities to local retailers.

On Teesside the most important market towns were Stockton and Darlington, both of which held two markets each week. The principal market at Stockton was on Wednesday.[1.] Traditionally, this had been mainly a retail market, serving the more immediate needs of local producers and consumers, though other activities had presumably always taken place as well, especially in the harvest season. In 1811, however, a monthly livestock fair was added.[2.] This proved so successful that it became a fortnightly event in 1830, and a weekly one in 1851.[3.] The Saturday market at Stockton was essentially a supplement, mainly concerned with retailing, which was established early in the nineteenth century. Wardell has attributed its origin directly to the opening of Stockton bridge in 1776, a step which gave Stockton improved

1. William Whellan and Company, History Topography and Directory of the County Palatine of Durham, Preston, 1856, p.571.

2. Loc.cit.

3. Loc.cit.

access to Cleveland.[1] This, however, seems too mechanistic an answer; it appears inadequate in another sense, too, since more than a quarter of a century separated the two events, and such a lag refutes the suggestion that there was an immediate causal connection between them. The establishment of a second weekly market at Stockton was probably no more, and no less, than a result of steady economic growth in the Tees-side area and the commercial development of the town itself as a regional centre.

The physical equipment of Stockton's market was fairly representative of the facilities provided in most of the North East's market towns. The market was held - as the retail section is still - in the High Street which even today remains impressively spacious for a town centre. Most of the stalls were set out in the open around the Town Hall, a building constructed in 1735 and extended in 1768 to provide accommodation for the market administrators.[2] Immediately to the south of the Town Hall, a market cross was erected in 1768, to replace an older model, and beyond that a butchers' shambles was built in the same year. The original shambles was replaced in 1825 by an edifice which presumably represented a functional improvement but was, nevertheless, not to everyone's taste : "It must be confessed ... that the beauty of the High Street, in the centre of which it [the Shambles]

1. J.W, Wardell, The History of Yarm, Yarm, 1957, p.131.

2. E. Mackenzie and M. Ross, An Historical, Topographical and Descriptive View of the County Palatine of Durham, Vol.II, Newcastle, 1834, pp.37-38.

stands is decidedly injured by it".[1]

The Stockton-on-Tees Extension and Improvement Act of 1869 contained several measures affecting the market, including a new schedule of market tolls,[2] and it provides useful clues to the range of commodities sold there as well as other pertinent matters. Thus, it is apparent that provision was made for both wholesale and retail butchers in the shambles. The tolls imposed on dealers in fruit, vegetables, furniture, household equipment and miscellaneous foodstuffs varied according to whether the traders concerned required 'standage', 'stallage', or just space for parking their carts and waggons. Levies were also exacted on sales by auction, which was the normal medium for selling livestock and many categories of other goods.

As a market town, Darlington was certainly the equal, and possibly the superior, of Stockton. Its main market day was Monday, but a supplementary market was held each Friday.[3] A very wide range of activities was catered for, but Darlington was particularly notable as a collection centre for livestock and other farm produce, and in this capacity it served an extensive area.[4] In 1851 the fortnightly cattle market,

1. Loc.cit.

2. 32 and 33 Victoria, pt.10.

3. William Fordyce, The History and Antiquities of the County Palatine of Durham, Vol.1, Newcastle, 1857, p.478.

4. Loc.cit.

which was held on Monday, became a weekly event.[1] This may very well have been intended to counter the similar innovation at Stockton; for there was a civic consciousness of a need to compete with that town. At the public meeting where the decision to introduce this measure was taken, it was also decided to abolish the tolls which had always been levied on market patrons who were not residents of Darlington, since these were believed to be driving large numbers of people in the neighbouring district to shop in Stockton.[2] Darlington market was held in the large Market Square, in the heart of what had been the medieval town.[3] A shambles had been built there in 1815,[4] but in 1851 the remainder of the area was still uncovered. In addition to the weekly markets, Darlington had nine annual fairs for the sale of cattle, sheep, horses and wool, and one for the hiring of servants.[5] Stockton, in contrast, had only three fairs.[6]

Staindrop's market was quite as old as, but of less importance than, the markets at Darlington and Stockton. It had only been revived, after a long period of disuse, in the early part of the nineteenth century, but in 1851 it seems to have been flourishing.[7] Nevertheless, it was a small

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1. Loc.cit.
2. Loc.cit.
3. See Nikolaus Pevsner, The Buildings of England : County Durham, London, 1953, pp.71-76.
4. Fordyce, op.cit., p.477
5. Ibid., p.478.
6. Ibid., p.179.
7. Ibid., p.84; Mackensie and Ross, op.cit., p.192; and Hagar, op.cit.,

market which must have served a very localized area. In this, Staindrop was like Sedgefield, which had a weekly general market, a monthly pig fair and two annual cattle fairs. None of these, however, was well regarded by contemporary writers, and in 1851 the weekly market seems to have been in a particularly poor condition.[1]

Hartlepool had a weekly market and three or four annual fairs, though the latter seem to have been in abeyance for much of the time.[2] The market, which had an Elizabethan charter of origin, had been reconstituted with the revival of the town which had followed the development of coal shipping. It appears to have been another small retail market. An attempt was made in 1851 to attract supplies of corn by abolishing the grain tolls and offering prizes to the largest suppliers. In the first year after these changes, 20,000 bushels of wheat and 6,000 bushels of oats were marketed in Hartlepool,[3] but this initial success was short-lived and the grain trade soon began to decline.[4]

The Act of Parliament which in 1841 gave Middlesbrough an Improvement Commission also sanctioned the establishment of a market in the town.[5] The granting of the latter right had in fact been anticipated by the founding of a weekly

1. Hagar, op.cit.; Mackenzie and Ross, op.cit., p.427; and Fordyce, op.cit., p.332.

2. Fordyce, op.cit., p.267.

3. Loc.cit.

4. Whellan, op.cit., p.508.

5. William Lillie, The History of Middlesbrough, Middlesbrough, 1968, pp.79-82 and 139-41.

market, held on Saturdays, at the end of the previous year. In 1851 the market was still comparatively primitive, though stalls had been built, and a room in the new Town Hall had been acquired for administrative purposes. The choice of Saturday as market day suggests that the town fathers intended the market to cater mainly for Middlesbrough's own population; for Saturday was also market day at Stockton, and they could not have expected to capture much of the older town's clientele.

The markets and fairs thus played an important role in the tertiary sector of the Teesside economy. They provided a machinery for the collection of the region's agricultural surpluses, and they had a retail element which served the needs of the working-class population. The spatial distribution of markets broadly confirms the picture developed earlier of the central place hierarchy; with one exception, they were held only in the region's highest-ranking towns. In this sense, periodic markets seem to have complemented the more permanent commercial facilities of towns rather than to have provided substitutes for them.

The Central Place System in 1879.

The same approach to studying the central place system was used for 1879 as for 1851. As more data were available for 1879, however, it was possible to enlarge the scope of the inquiry to cover the whole region, and not just that part of it in Durham. Otherwise, differences are marginal. Particular care was taken to ensure that the categories of central functions used for 1879 matched those for 1851 as closely as possible.

Population and Central Functions.

Analysis of the relationship between population size and number of central functions, for the 160 parishes included in the study, revealed that the two variables were highly correlated in a positive manner. The simple correlation coefficient is +0.89. As for 1851, the relationship can best be described as linear (Figure 9.5). Nevertheless, the relationship was not so close in 1879 as at the earlier date, and a visual comparison of Figures 9.1 and 9.5 indicates that the parishes were more widely scattered around the norm at the end of the period than at the beginning. This may, however, simply reflect the larger number of parishes used in the second study. The scatter diagram for 1879 appears better balanced, in the sense that there is less polarization between the few large central places and the many small ones, an observation which is considered further at a later stage.

There are twice as many 'anomalies' in Figure 9.5 as in Figure 9.1 , but since twice as many parishes were included for 1879 as far 1851 this is not significant. The two deficit parishes - that is, parishes with fewer functions than would be expected on the basis of their population size - in Figure 9.5 are Linthorpe and Stockton. The first of these is readily explicable. Whereas Linthorpe was in 1851 an ordinary parish with a central village, it was in 1879

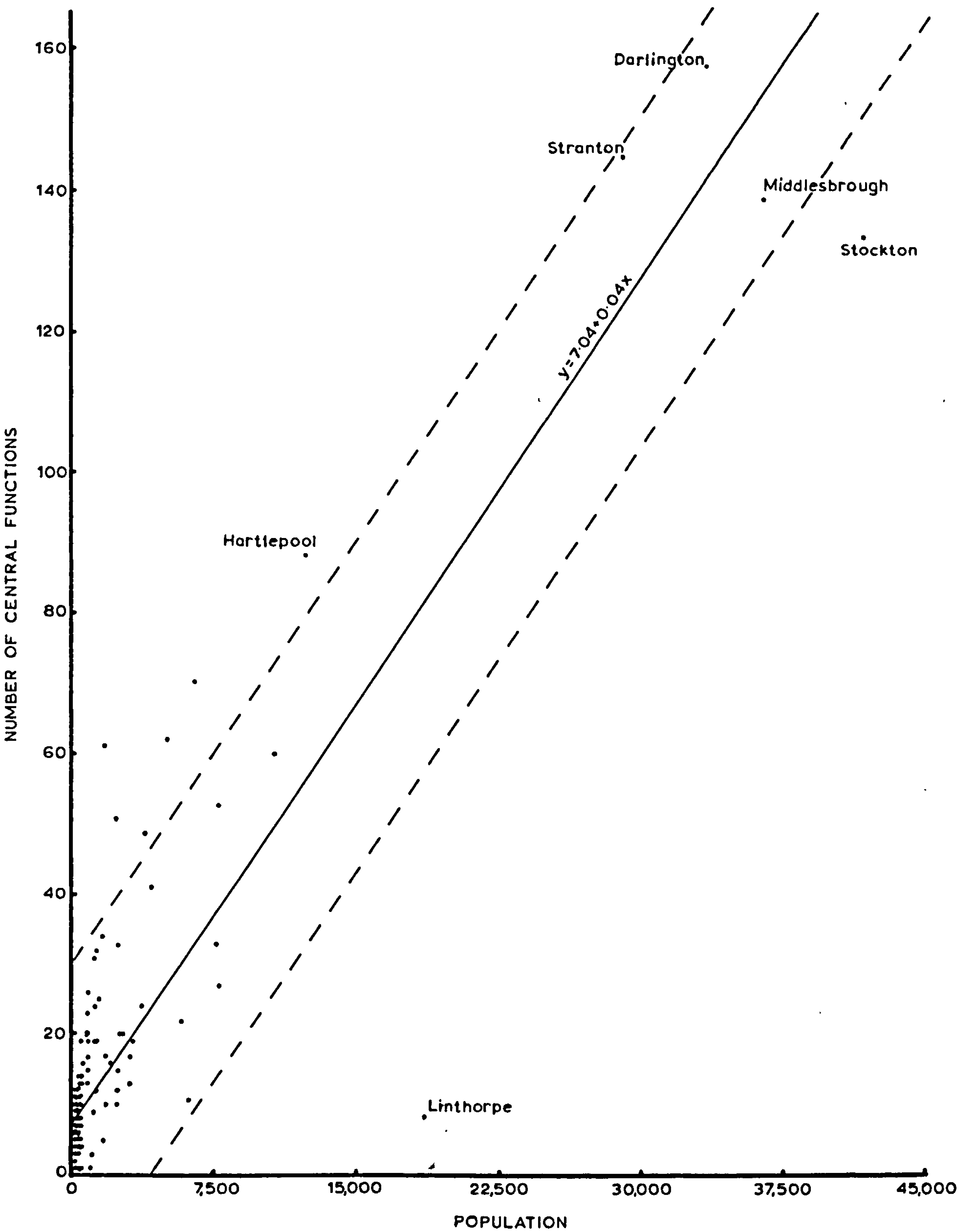

Figure 9.5 Population and Central Functions, 1879

Table 9.7

Parishes and Central Places in 1879

Parish	Central Place	Population.	No. of Establishments.	No. of Central Functions.	No. of Functional Units.
Middlesbrough.	Middlesbrough.	36,631	917	138	987
Stockton.	Stockton.	41,719	927	133	1,017
	West Hartlepool.		735	125	798
	Stranton.		40	19	40
Stranton.		29,143	775	144	838
Darlington.	Darlington.	33,428	1,027	157	1,177
Hartlepool.	Hartlepool.	12,361	410	88	423
Lofthouse.	Lofthouse.	4,318	92	41	104
	Ingleby Greenhow.		7	7	8
	Greenhow.		1	1	1
	Battersby.		2	4	4
Ingleby Greenhow.		391	10	12	13
Kildale.	Kildale.	280	5	5	6
Kirkby.	Kirkby.	244	9	11	11
	Coatnam.		114	38	120
	Kirkleatham.		1	1	1
	Warrenby.		7	6	7
	Yearby.		3	4	4
Kirkleatham.		3,898	125	49	132
Kirklevington.	Kirklevington.	197	2	2	2
Picton.	Picton.	108	1	1	1
Low Worsall.	Low Worsall.	199	5	5	5
	Hinderwell.		17	12	22
	Staithes.		37	17	47
	Runswick.		5	4	6
Hinderwell.		2,467	59	33	75
Roxby.		186	6	6	5
	Ingleby Arncliffe.		13	9	13
	Ingleby Cross.		5	3	5
Ingleby Arncliffe.		306	18	12	18
Guisborough.	Guisborough.	6,616	165	70	198
Hutton Lowcross.	Hutton Lowcross.	233	1	1	1
Commondale.	Commondale.	167	3	2	3
East Harlsey.	East Harlsey.	379	14	10	14
Hilton.	Hilton.	135	9	6	10
	Leven Bridge.		3	3	3
	Middleton upon Leven.		1	1	1
Middleton upon Leven.		87	4	4	4
Faceby.	Faceby.	174	4	5	5
Eppleby.	Eppleby.	417	12	7	12
Barforth.	Barforth.	135	1	1	1
Ovington.	Ovington.	150	9	9	10
Gilling.	Gilling.	872	23	13	25
Liverton.	Liverton.	669	5	5	5
Eryholme.	Eryholme.	185	2	2	2
Eston.	Eston.	6,297	36	11	36

Table 9.7 (contd.)

Parish	Central Place	Population.	No.of Establishments.	No.of Central Functions.	No.of Functional Units
	Normanby.		13	10	14
	South Bank.		40	17	42
Normanby.		7,714	53	27	56
Crathorne.	Crathorne.	247	7	7	8
Croft.	Croft.	537	31	11	32
Dalton.	Dalton.	187	4	3	4
	Danby.		6	5	[illegible]
	Little Fryup.		2	2	2
	Ainthorpe.		4	5	5
	Castleton.		30	19	37
Danby.		1,304	42	31	50
Easby.	Easby.	136	2	2	2
Easington (North Yorkshire)	Easington.	644	6	4	6
Redcar.	Redcar.	2,297	186	51	203
	Great Broughton.		16	11	19
	Little Broughton.		2	2	2
Broughton.		566	18	13	21
Carlton (North Yorkshire.)	Carlton	253	9	8	11
Cleasby.	Cleasby.	178	2	2	2
Stapleton.	Stapleton.	151	4	5	5
Bilsdale Midcable.	Chop Gate.	677	12	7	12
	Brotton.		47	22	51
	Carlin How.		2	2	2
Brotton.		3,753	49	24	53
Skinningrove.	Skinningrove.	1,775	4	5	5
Kilton.	Kilton.	431	1	1	1
Acklam.	Acklam.	164	2	2	2
Appleton on Wiske.	Appleton on Wiske.	331	15	11	17
Great Ayton.	Great Ayton.	1,754	54	34	67
Nunthorpe.	Nunthorpe.	165	2	3	3
Barton.	Barton.	515	19	13	20
Manfield.	Manfield.	276	3	3	3
Cliffe.	Cliffe.	72	1	1	1
	Marske.		23	16	28
	Saltburn.		100	46	119
Marske.		5,113	123	62	147
Marton.	Marton.	1,057	3	3	4
Melsonby.	Melsonby.	532	12	10	13
Middleton Tyas	Middleton Tyas.	540	17	9	17
Newton.	Newton.	116	3	4	4
	Ormesby.		9	8	9
	North Ormesby.		66	25	67
Ormesby.		7,774	75	33	76
Upsall.	Upsall.	137	1	1	1
Osmotherley.	Osmotherley.	920	39	20	40
West Rounton.	West Rounton.	219	10	7	10

Table 9.7 (Contd.)

Parish.	Central Place.	Population.	No. of Establishments.	No. of Central Functions.	No. of Functional Units.
Rudby.	Rudby.	81	2	2	2
Hutton Rudby.	Hutton Rudby.	849	31	15	38
East Rounton.	East Rounton.	166	2	2	2
Seamer.	Seamer.	246	9	6	9
Great Smeaton.	Great Smeaton.	192	7	5	7
Hornby.	Hornby.	258	4	4	4
Girsby.	Girsby.	68	2	2	2
	Stainton.		10	7	10
	Thornton.		2	2	2
Stainton.		337	12	9	12
Ingleby Barwick.	Ingleby Barwick.	132	1	1	1
Maltby.	Maltby.	113	3	3	4
Aldbrough.	Aldbrough.	400	18	10	19
Caldwell.	Caldwell.	175	4	4	4
	Thornaby.		5	4	5
	South Stockton.		189	56	203
Thornaby.		10,795	194	60	208
Upleatham.	Upleatham.	488	4	4	4
	Whorlton.		18	15	22
	Swainby.		1	1	1
Whorlton.		631	19	16	23
Potto.	Potto.	209	5	5	5
	Wilton.		3	3	4
	Lazenby.		10	9	11
Wilton,		1,293	13	12	15
Linthorpe.	Linthorpe.	18,736	9	8	9
Moorsholme.	Great Moorsholme.	392	10	7	11
	Boosbeck.		10	6	10
	Skelton.		58	38	69
	Lingdale.		15	9	17
Skelton.		7,820	83	53	96
Stanghow.	Stanghow.	1,162	1	1	1
Stokesley.	Stokesley.	1,802.	138	61	146
Newby.	Newby.	115	2	2	2
Yarm.	Yarm.	1,485	70	32	72
Aislaby.	Aislaby.	125	2	2	2
Great Aycliffe.	Great Aycliffe.	839	39	23	40
Brafferton.	Brafferton.	171	7	5	7
Preston le Skerne.	Preston le Skerne.	135	1	1	1
	Billingham.		19	11	19
	Haverton Hill.		7	4	7
	Port Clarence.		6	4	6
Billingham.		1,488	32	19	42
Cowpen Bewley.	Cowpen Bewley.	997	1	1	1
Bishop Middleham.	Bishop Middleham.	480	25	13	25
Bishopton.	Bishopton.	350	22	14	23
Castle Eden.	Castle Eden.	880	18	17	20
Cockfield.	Cockfield.	1,205	18	9	18

Table 9.7 (Contd.)

Parish	Central Place.	Population.	No. of Establishments.	No. of Central Functions.	No. of Functional Units.
High Coniscliffe.	High Coniscliffe.	355	12	10	13
Low Coniscliffe.	Low Coniscliffe.	164	3	3	3
Cornforth.	Cornforth.	2,553	43	15	45
Coxhoe.	Coxhoe.	2,455	58	12	58
Blackwell.	Blackwell.	406	4	3	4
Cockerton.	Cockerton.	2,778	41	20	41
Egglescliffe.	Egglescliffe .	655	16	10	16
Easington (Durham)	Easington.	1,200	36	19	40
Elton.	Elton.	113	1	1	1
Gainford.	Gainford.	897	32	19	35
Bolam.	Bolam.	117	3	3	3
Denton.	Denton.	84	2	2	2
Headlam.	Headlam.	107	2	2	2
Houghton le Side.	Houghton le Side.	103	1	1	1
Langton.	Langton.	101	3	3	3
Piercebridge.	Piercebridge.	206	10	8	10
Summerhouse.	Summerhouse.	118	2	2	2
Greatham.	Greatham.	737	21	13	22
Grindon.	Thorpe Thewles.	345	12	8	12
Hart.	Hart.	291	13	9	13
Dalton Piercy.	Dalton Piercy.	82	1	1	1
Elwick.	Elwick.	228	10	7	10
Haughton le Skerne.	Haughton le Skerne;	713	21	14	21
Barmpton.	Barmpton.	108	1	1	1
Coatham Mundeville.	Coatham Mundeville.	127	,3	3	3
Great Burdon.	Great Burdon.	120	4	4	4
Whessoe.	Whessoe.	256	8	5	8
Heighington.	Heighington.	621	44	19	46
Little Stainton.	Little Stainton.	70	3	3	3
Low Dinsdale.	Low Dinsdale.	252	2	2	2
Redworth.	Redworth.	553	11	6	11
Walworth.	Walworth.	182	4	3	4
Hurworth.	Hurworth.	1,519	62	25	67
Neasham.	Neasham.	421	10	8	10
Ingleton.	Ingleton.	246	17	12	17
Hilton (Durham)	Hilton.	106	3	3	3
Killerby.	Killerby.	89	1	1	1
	Middleton St. George.		8	7	8
	Middleton one Row.		16	6	16
	Fighting Cocks.		22	13	23
Middleton St. George.		1,103	46	26	47

Table 9.7 (Contd.)

Parish	Central Place	Population.	No. of Establishments.	No. of Central Functions.	No. of Functional Units.
	Monk Hesleden.		4	4	4
	Castle Eden Colliery		9	6	9
Monk Hesleden.		2,421	13	10	13
Hutton Henry.	Hutton Henry.	1,825	18	10	19
Sheraton with Hulam.	Sheraton with Hulam.	176	5	4	5
Long Newton.	Long Newton.	268	6	4	6
Norton.	Norton.	3,195	49	19	5[illegible]
Redmarshall.	Redmarshall.	91	2	2	2
Carlton (Durham)	Carlton.	209	3	3	3
Sadberge.	Sadberge.	371	19	10	19
Seaton Carew.	Seaton Carew.	1,734	37	17	37
Sedgefield.	Sedgefield.	2,601	45	20	49
Bradbury.	Bradbury.	193	5	4	5
Fishburn.	Fishburn.	317	8	5	8
Mordon.	Mordon.	171	1	1	1
Middridge Grange.	Middridge.	64	10	6	11
	Shotton Colliery.		21	10	24
	Shotton.		6	6	6
Shotton.		2,131	27	16	30
Staindrop.	Staindrop.	1,318	64	24	67
Great Stainton.	Great Stainton.	98	3	3	3
Elstob.	Elstob.	74	1	1	1
Stillington.	Stillington.	50	3	3	3
East Hartburn.	East Hartburn.	360	6	5	6
Preston on Tees.	Preston on Tees.	163	2	2	2
Thornley.	Thornley.	3,132	49	17	52
Trimdon.	Trimdon.	3,057	27	13	27
	Wheatley Hill.		9	4	9
	Wingate.		31	18	33
Wingate.		5,949	40	22	42
Wolviston.	Wolviston.	605	22	14	23
Newton Bewley.	Newton Bewley.	131	2	2	2

a residential suburb of Middlesbrough which was fully integrated into the urban area and reliant on the town centre for service provision. This, however, is only an immediate explanation, and as such it shifts attention to Middlesbrough as a problem centre. If the population and functions of Linthorpe are added to those of Middlesbrough, as they should be, then the town of Middlesbrough can be seen to have had a substantial deficit of central functions.

Middlesbrough, which had a population approaching 56,000 and was the largest town in the region in 1879, had about sixty functions fewer than would be expected for a place of its size. It would seem, therefore, that the pace and amount of expansion since 1851 had brought about a functional imbalance in the tertiary sector. This implies, as was almost certainly the case, that Middlesbrough's own population had grown much faster than that of its hinterland. The position of some of the other large centres in the region tends to confirm this view. With only half the population, West Hartlepool had almost as many central functions as Middlesbrough in 1879, while Darlington had more despite having 20,000 fewer people.

Stockton's deficit is perhaps more surprising at first glance, but it seems to have resulted from the same type of change that had affected Middlesbrough. The population of Stockton had increased four-fold from its 1851 level, and the character of the town had also altered. By 1879, Stockton was essentially an industrial centre, and its role as the supplier of services to the surrounding rural area was less significant. Interestingly, the town had added very few extra central functions to its original range, and by 1879 it had slipped to fourth place amongst the central places of the region.

There were six parishes - Hartlepool, Marske, Guisborough, Stokesley, Redcar and Kirkleatham - with a surplus of functions in 1879. Hartlepool, which consisted entirely of the town of that name, was the most important of them. Although it was the fifth largest settlement in the region, with a population of more than 12,000 and with 88 central functions, the town of Hartlepool had a slightly smaller functional complex than it had had in 1851. Its surplus of functions should therefore be recognised as the result of a change in the slope of the regional regression line since 1851, rather than the result of a change in the town's commercial stature.

The other parishes with surpluses in 1879 were all located in North Yorkshire, and were therefore not included in the analysis for 1851. They all contained large villages or small towns, and it may be inferred that they all served disproportionately large hinterlands. An interesting point is that by 1879 none of the anomalies noted in Figure 9.1 for 1851 remained; the service industries in the parishes of Staindrop, Thornley and Coxhoe had all adjusted in the appropriate directions. In the cases of Thornley and Coxhoe, this tends to substantiate the view expressed earlier that their functional deficits in 1851 were the temporary products of a time lag between expansion in the mining and tertiary sectors.

Of the large towns, only Darlington and West Hartlepool remain to be discussed. Like the others, Darlington had undergone a large expansion in population since 1851, with a three-fold increase. Unlike Stockton and Middlesbrough, however, Darlington's functional complex had grown at a commensurate rate, In 1879, Darlington had a greater range of central functions than any other place in the region, even though it only ranked third in terms of population size. Rather surprisingly, West Hartlepool had also grown in a well-balanced manner as a central place , despite being primarily a heavy industrial centre and having the disadvantage of a location adjacent to that of the established town of old Hartlepool. In 1879 it had a population of approximately 28,000 and a range of 125 central functions.

Finally, it is useful to compare the regression coefficients for 1851 and 1879. In principle, economic growth ought to result in a larger regression coefficient; that is, it should mean that a given number of people can support a larger number of functions. Paradoxically, however, the regression coefficient for Teesside is higher for 1851 than for 1879, and the regression line in Figure 9.1 is consequently steeper than that in Figure 9.5 . The most likely explanation is that this was a temporary situation, and that it resulted from population growth having been so rapid that it had exceeded the rate at which new functions had been added. This, in turn, could be taken as evidence to support the view that above a certain size new functions are added at a declining rate. However, the relationship between population and functions on Teesside in 1879 was still linear rather than log-linear. It therefore seems more probable that the tertiary sector had simply failed to keep pace with population increase.

Population and Establishments.

The simple correlation coefficient between these two variables in 1879 was +0.94, the same as that in 1851. Again, the relationship was also linear in form, as is shown in Figure 9.6 . There is some evidence that the smaller central places had more establishments in 1879 than at the beginning of the period, but the gap between the few large and the many small centres was still very wide. In terms of establishment numbers also, Darlington was the most important central place in the region. If Linthorpe is amalgamated with Middlesbrough, then the latter was on a par with Stockton. West Hartlepool and Hartlepool occupied fourth and fifth places respectively.

Considering Middlesbrough and Linthorpe as one, Middlesbrough was the only parish in the region to have a substantial deficit of establishments. It had three times as many shops, offices and other establishments as in 1851, but the increase in their numbers had lagged behind population

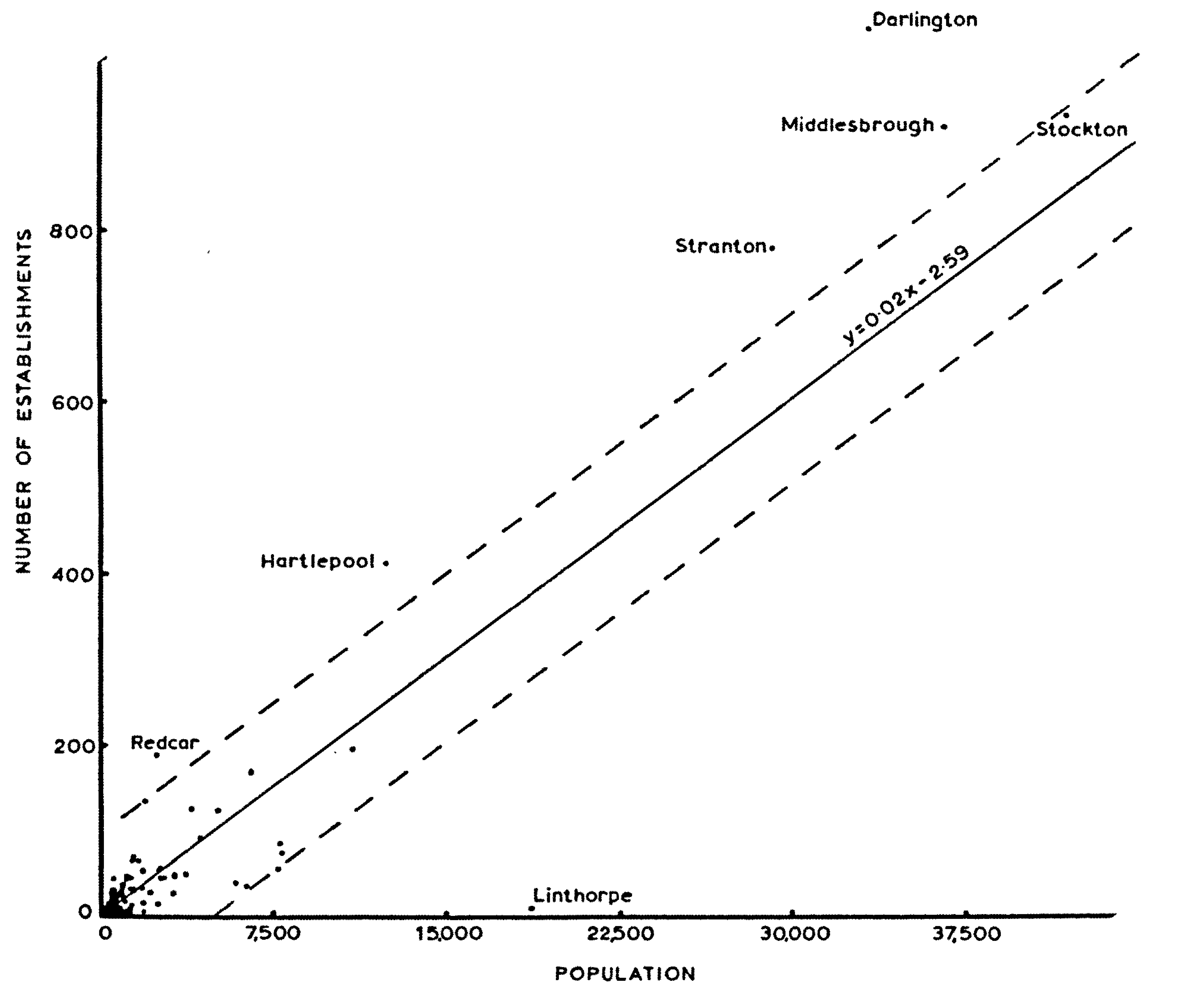

Figure 9.6 Population and Establishments, 1879

growth. The sheer speed of population expansion and the failure of Middlesbrough to capture a hinterland population proportionate in size to its own seem to have been responsible for this.

Three of the other very large towns - Darlington, West Hartlepool and Hartlepool - had surpluses of establishments, which indicates that the ratio of hinterland population to central place population was in their cases rather larger than normal. Compared with 1851, Darlington had added 75 new establishments, though its population had increased three-fold, and West Hartlepool had added 600. On the other hand, Stockton had lost about 90 establishments and Hartlepool had lost well over 200. These various changes indicate that there had been a significant upward shift in the scale of service outlets during the intervening period, so that fewer were needed to serve a population of a given size. Not even in the case of West Hartlepool had there been an increase in numbers of establishments to match population growth.

Population and Functional Units.

The simple correlation coefficient between population and functional units was +0.94. As in 1851, the relationship was linear in form. In detail, the picture is much the same as that for population and establishments, though there are minor differences. Darlington had more functional units than any other place in the region, and it was also the only large centre to have a surplus. Indeed, Stockton and Middlesbrough-

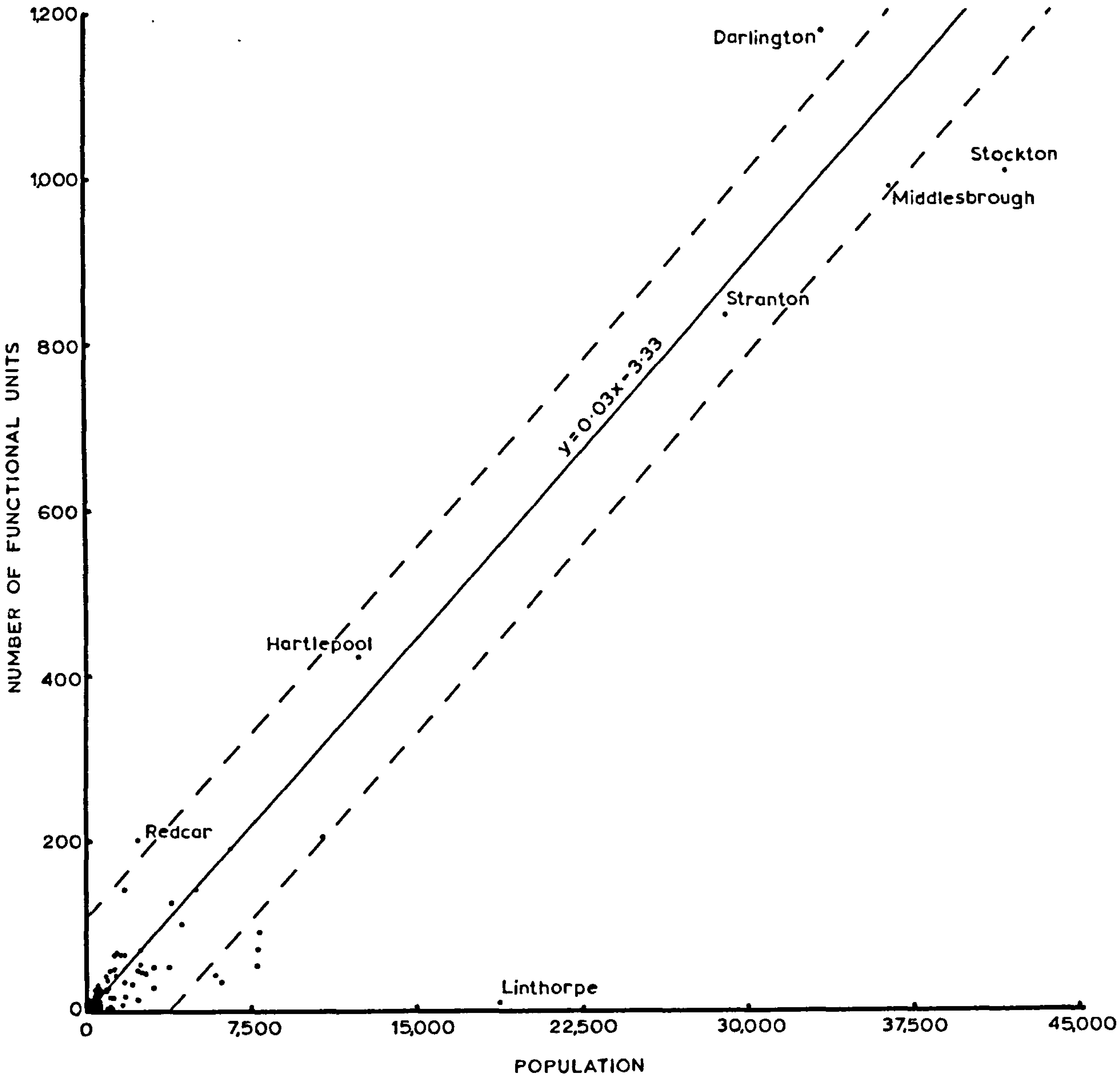

Figure 9.7 Population and Functional Units, 1879

if Linthorpe is amalgamated with it - had deficits. It can be seen from Figures 9.3 and 9.7 , that the main urban parishes had more 'normal' numbers of functional units than they had of establishments, in relation to their respective populations. This indicates that establishments in the larger central places were more specialised than those in smaller centres; otherwise, more of the larger towns would have had surpluses of functional units as well as establishments.

A Hierarchy of Central Places.

As for 1851, an attempt was made to determine whether or not there was a hierarchy of central places in 1879, and the same methods were used as in the earlier study. The 191 central places included in the analysis are ranked in Table 9.8 on the basis of their numbers of central functions.[1] Experiments with the nearest-neighbour techniques discussed earlier were conducted on this array, but the results were inconclusive and were therefore not considered further. They showed that the distribution could be regarded as uniform, random or clustered according to whether it was analysed as a whole or one or both of the two most isolated points were excluded.

The array was subsequently partitioned into groups on the basis of the criteria described earlier. The great majority of the 191 central places were separated from their

1. Linthorpe was treated as a separate place, rather than as a part of Middlesbrough, for this purpose.

Table 9.8

Central Places Ranked According to Numbers of Central Functions in 1879.

Group	Central Place	No.of Funct-ions	Central Place	No.of Funct-ions.
A	Darlington.	157	Ingleton.	12
	Middlesbrough.	138	Coxhoe.	12
	Stockton.	133	Hinderwell.	12
	West Hartlepool.	125	Kirkby.	11
			Eston.	11
B	Hartlepool.	88	Croft.	11
	Guisborough.	70	Great Broughton.	11
	Stokesley.	61	Appleton on Wiske.	11
	South Stockton.	56	Billingham.	11
	Redcar.	51	East Harlsey.	10
	Saltburn.	46	Normanby.	10
	Lofthouse.	41	Melsonby.	10
	Coatham.	38	Aldbrough.	10
	Skelton.	38	High Coniscliffe.	10
	Great Ayton.	34	Egglescliffe.	10
	Yarm.	32	Hutton Henry.	10
			Sadberge.	10
C	North Ormesby.	25	Shotton Colliery.	10
	Hurworth.	25	Ingleby Arncliffe.	9
	Staindrop.	24	Ovington.	9
	Great Aycliife.	23	Middleton Tyas.	9
	Brotton.	22	Lazenby.	9
	Osmotherley.	20	Lingdale.	9
	Cockerton.	20	Cockfield.	9
	Sedgefield.	20	Hart.	9
	Stranton.	19	Carlton.	8
	Castleton.	19	Ormesby.	8
	Easington (Durham)	19	Linthorpe.	8
	Gainford.	19	Piercebridge.	8
	Heighington.	19	Thorpe Thewles.	8
	Norton.	19	Neasham.	8
	Wingate.	18	Ingleby Greenhow.	7
	Staithes.	17	Eppleby.	7
	South Bank.	17	Crathorne.	7
	Castle Eden.	17	Chop Gate.	7
	Seaton Carew.	17	West Rounton.	7
	Thornley.	17	Stainton.	7
	Marske.	16	Great Moorsholme.	7
	Hutton Rudby.	15	Elwick.	7
	Whorlton.	15	Middleton St, George.	7
	Cornforth.	15	Warrenby.	6
	Wolviston.	14	Roxby.	6
	Haughton le Skerne.	14	Hilton.	6
	Bishopton.	14	Seamer.	6
	Gilling.	13	Boosbeck	6
	Barton.	13	Redworth.	6
	Bishop Middleham.	13	Middleton one Row.	6
	Greatham.	13	Castle Eden Colliery.	6
	Fighting Cocks.	13	Middridge.	6
	Trimdon.	13	Shotton.	6

Table 9.8 (Contd.)

Central Place	No. of Functions
Kildale.	5
Low Worsall.	5
Faceby.	5
Liverton.	5
Danby.	5
Airthorpe.	5
Stapleton.	5
Skinningrove.	5
Great Smeaton.	5
Potto.	5
Brafferton.	5
Whessoe.	5
Fishburn.	5
East Hartburn.	5
Battersby.	4
Yearby.	4
Runswick.	4
Easington.	4
Newton.	4
Hornby.	4
Caldwell.	4
Thornaby.	4
Upleatham.	4
Haverton Hill.	4
Port Clarence.	4
Great Burdon.	4
Monk Heslēden.	4
Sheraton with Hulam.	4
Long Newton.	4
Bradbury.	4
Wheatley Hill.	4
Ingleby Cross.	3
Dalton.	3
Nunthorpe.	3
Manfield.	3
Stillington.	3
Great Stainton.	3
Carlton (Durham).	3
Hilton (Durham).	3
Walworth.	3
Little Stainton.	3
Coatham Mundeville.	3
Langton.	3
Bolam.	3
Blackwell.	3
Low Coniscliffe.	3
Wilton.	3
Morton.	3
Leven Bridge.	3
Maltby.	3
Summerhouse.	2
Dinsdale.	2
Newton Bewley.	[illegible]
Denton.	2
Preston on Tees.	2
Redmarshall.	2
Headlam.	2
Aislaby.	2
Newby.	2
Thornton.	2
Girsby.	2
Carlin How.	2
Little Broughton.	2
Cleasby.	2
East Rounton.	2
Little Fryup.	2
Easby.	2
Commondale.	2
Kirk Levington.	2
Eryholme.	2
Acklam.	2
Rudby.	2
Greenhow.	1
Kirkleatham.	1
Picton.	1
Hutton Lowcross.	1
Middleton upon Leven.	1
Barforth.	1
Kilton.	1
Cliffe.	1
Elstob.	1
Mordon.	1
Killerby.	1
Barmpton.	1
Dalton Piercy.	1
Houghton le Side.	1
Elton.	1
Cowpen Bewley.	1
Preston le Skerne.	1
Stanghow.	1
Swainby.	1
Ingleby Barwick.	1
Upsall.	1

Table 9.9

Central Functions Ranked According to Numbers of Functional Units.

Group	Function	No. of Functional Units.	Function	No. of Functional Units.
I	Grocer, Provision & Tea Dealer.	816	Corn & Flour Merchant & Dealer.	48
	Inn/Hotel/Public House.	799	Coffee House/Dining & Refreshment Rooms.	48
II	Butcher.	484	Accountant & Auditor.	46
	Boot & Shoe Maker/Dealer.	426	Furniture Dealer.	46
III	Tailor.	326	Saddler & Harness Maker.	45
	Draper.	284	Hosier.	44
IV	Boarding House.	230	Printer.	41
	Beer Retailer.	224	Fishmonger.	39
	Joiner & Carpenter.	212	Commission Agent.	39
	Blacksmith, Shoe & General Smith.	211	Pawnbroker.	39
	Builder.	177	Jeweller, Silversmith & Goldsmith.	39
	Insurance Agent.	167	Timber Merchant.	38
	Greengrocer & Fruiterer.	158	Baker.	37
V	Painter & Decorator.	113	Cartwright.	37
	Solicitor.	97	Livery Stable and Coach & Cab Proprietor.	36
	Miller.	96	General Dealer.	33
	Surgeon.	95	Fancy Repository.	32
	Ironmonger & Hardwareman.	83	News Agent.	31
	Bookseller & Stationer.	83	Bank.	29
	Confectioner.	80	Surveyor.	28
	Mason.	79	Nurseryman & Seedsman.	28
	Hatter & Milliner.	75	Architect.	26
	Druggist & Chemist.	75	Glazier.	26
	Hair Dresser.	74	Leather Worker & Dealer.	26
	Tobacconist.	71	Brewer.	24
	Land, House & Estate Agent.	70	Cattle Dealer.	23
	Auctioneer & Appraiser.	64	Bricklayer.	22
	Wheelwright.	62	Lemonade, Ginger Beer & Soda Water Maker.	21
	Cabinet Maker.	60	Veterinary Surgeon.	20
	Clothier, Clothes Dealer, Outfitter.	58	Photographer.	20
	Dressmaker.	57	Dyer.	19
	Wine & Spirit Merchant.	56	Saw Mill.	19
	Plumber.	56	Upholsterer.	18
	Cow Keeper.	55	Wholesale Grocer & Provision Dealer.	17
	Watch & Clock Maker/Dealer.	51	Dentist.	17
	Glass, China & Earthenware Dealer.	50	Coal Dealer.	17
			Temperance Hotel.	16
			Carver.	15
			Mercer.	14
			Cooper.	14
			Tin Worker.	14
			Cooperative Society Store.	14
			Finance Company.	13

Table 9.9 (Contd.)

Function	No. of Functional Units.	Function	No. of Functional Units.
Herbalist.	13	London, Birmingham & Sheffield Warehouse.	5
Wholesale Fruit & Vegetable Merchant.	13	Boot & Shoe Retail Store.	5
Physician.	13	Millwright.	5
Tea Dealer.	13	Cutler.	4
Slater.	12	Straw Hat Maker.	4
Slate Merchant.	12	Wholesale Druggist.	4
Building Society.	12	Wholesale Confectioner.	4
Wholesale Tea Merchant.	12	Tool Maker/Dealer.	4
Gilder.	12	Tobacco Manufacturer.	4
Ale & Porter Merchant.	12	Fish Curer.	4
Undertaker.	12	Wholesale Draper.	4
Hay & Straw Dealer.	11	Venetian Blind Maker.	4
Toy Dealer.	11	Consulting Engineer.	4
Game & Poultry Dealer.	11	Picture Frame Maker.	4
Engraver & Lithographer.	10	Clothes Cleaner.	3
Sewing Machine Depot.	10	Organ Builder.	3
Building Materials Supplier.	10	Berlin Wool Repository.	3
Clogger & Patten Maker.	10	Machinist.	3
Musical Instrument Dealer.	10	Clay Pipe Maker.	3
		Taxidermist.	3
Dairy.	9	Corn Factor.	3
Basket Maker.	9	Carter.	3
Gas Fitter.	9	Brush Maker.	3
Coach & Carriage Builder.	9	Whplesale Boot & Shoe Merchant.	3
Chimney Sweeper.	9		
Florist.	8	Baby Linen Warehouse.	3
Tallow Chandler.	8	Music Seller.	3
Second-hand Clothes Dealer.	8	Glass Merchant.	3
		Carpet Dealer.	3
Agricultural Implement Maker.	8	Italian Warehouseman.	3
		Ladies' Outfitter.	3
Registry Office for Servants.	7	Woolstapler.	3
		Jet Ornament Maker/ Dealer.	3
Cheese, Butter & Bacon Dealer.	7		
		Optician.	2
Haberdasher.	7	File Cutter.	2
Stock & Share Broker.	7	Umbrella Maker.	2
Lath Render.	6	Paper Merchant.	2
Yeast Importer & Merchant.	6	French Polisher.	2
Fine Art Dealer.	6	Wholesale Mercer.	2
Wardrobe Dealer.	6	Wholesale Wine & Spirit Merchant.	2
Gum Maker.	6		
Bookbinder.	6	Paint Maker.	2
Civil Engineer.	6	Glass Maker.	2
Laundry.	6	Lime Merchant.	2
Wholesale Stationer.	6	Bill Posting Company.	2
Rope Maker.	6	Mattress Maker.	2
Plasterer.	6	Oil & Colour Merchant.	2
Pig Dealer.	6	Merchant Tailor.	2
Baths.	5	Stone Merchant.	2
Publisher.	5	Coppersmith & Brass Finisher.	2

Table 9.9 (Contd.)

Function.	No. of Functional Units.	Function	No. of Functional Units.
Potato Merchant.	2	Artist.	1
Cork Cutter.	1	Fine Art Pottery.	1
Agricultural Engineer.	1	Feather Purifier.	1
Quantity Surveyor.	1	Contract Caterer.	1
Barrister.	1	Tripe Dresser.	1
Wholesale Tobacconist.	1	Patent Medicine Vendor.	1
Wholesale Drysalter.	1	Locksmith.	1
Packing Maker.	1	Furrier.	1
Wholesale Cheese, Butter & Bacon Factor.	1	Worsted Spinner.	1
Firewood Dealer.	1	Stuff Maker.	1
Oil & Grease Manufacturer.	1	Fishing Rod Dealer.	1
Tallow Merchant.	1	Maker of Horticultural Implements & Buildings.	1
Waterproof Cover Maker.	1	Wholesale News Agent.	1
Wholesale Paint, Varnish & Brush Maker.	1	Mens' Lacer.	1
Lamp Dealer.	1	Pastry Cook.	1
Electric Bell Maker.	1	Plush Maker.	1
Wholesale Italian Warehouseman.	1	Cigar Dealer.	1
Horse & Cattle Food Maker.	1	Wholesale Earthenware Dealer.	1
Hop Merchant.	1	Wood Turner.	1
Pianoforte Tuner.	1	Horse Dealer.	1
Egg Merchant.	1	Perfumer.	1
American Fresh Meat Agent.	1		
Nail Maker.	1		
Chair Maker.	1		
Cement Merchant.	1		
Wholesale Dealer in Stable Requisites.	1		
Wholesale Dealer in Chimney Sweepers Materials.	1		
Glover.	1		
Clay Merchant.	1		
Saw Maker.	1		
Felt Manufacturer.	1		
Second-hand Bookseller.	1		
Analytical & Consulting Chemist.	1		
Furniture Remover.	1		
Blasting Powder & Cartridge Maker.	1		
Domestic Machinery Dealer.	1		

nearest neighbours by no more than one unit. Consequently, they had to be regarded as members of one group even though there was a substantial difference between the lowest and the highest members of it, which respectively had one and twenty-five central functions. Only fifteen central places were clearly not members of this very large group (Group C), and they were assigned to Groups A and B.

The various central functions, 230 in number, were ranked on the basis of their numbers of functional units. Somewhat surprisingly, nearest-neighbour analysis gave the straightforward result that the array of functions in Table 9.9 was significantly clustered, but previous experience did not inspire such confidence in this result. The functions were subsequently allocated to five groups, and these groups were then compared with the groups of central places by means of variance analysis. As in 1851, the result of this exercise was highly significant, and substantiated the hypothesis that there was a hierarchy of central places based on groups of central functions.

Table 9.10

Summary of the Analysis of Variance

Source of Variation	Sum of Squares	Degrees of Freedom.	Mean Square	F
Between Groups.	24,710	14	1,765	480+
Within Groups.	2,480	675	3.68	

+Result significant at the 99.9 per cent confidence level.

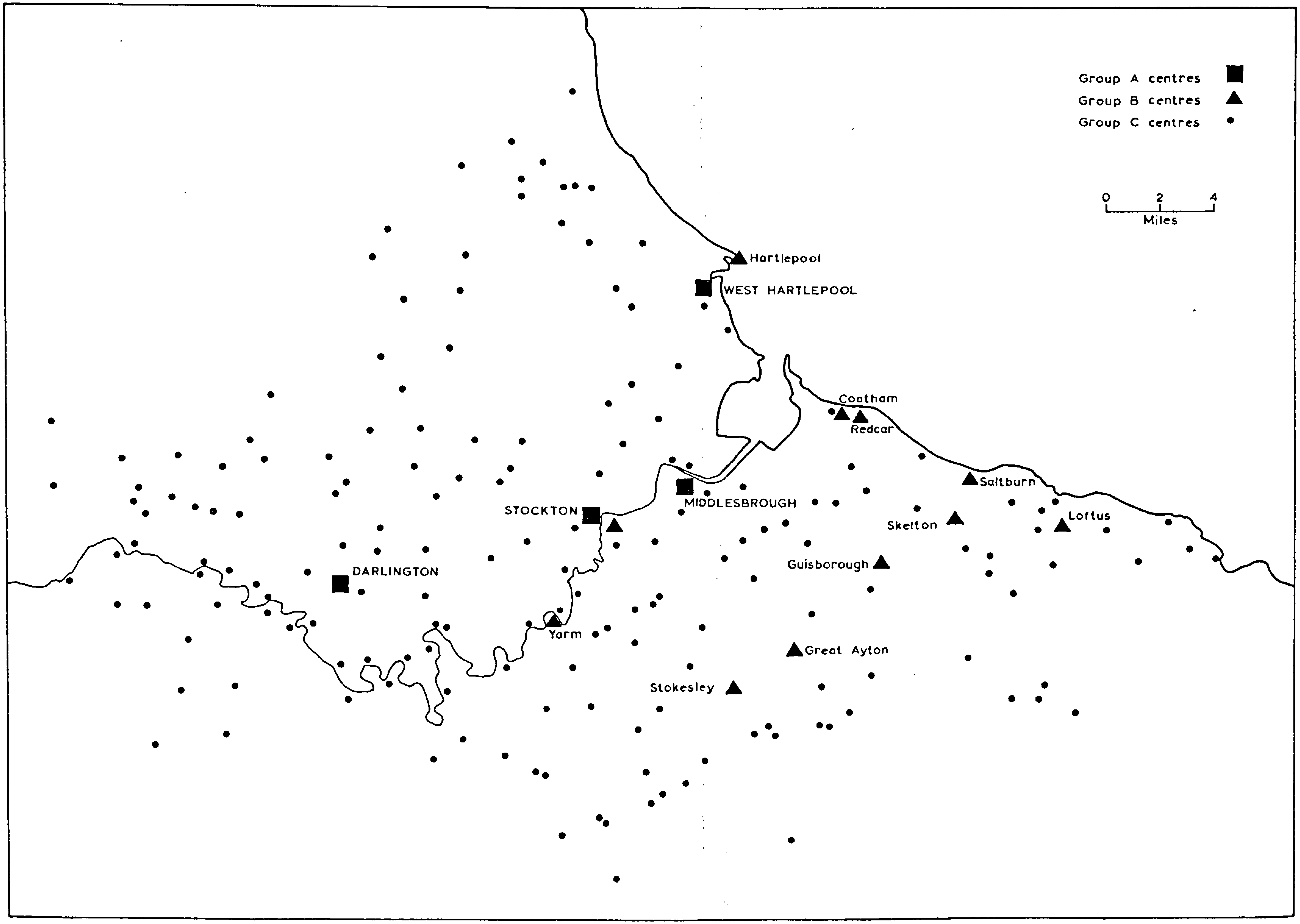

Figure 9.8 Central Places, 1879

Details of the Central Place System.

Four central places - Darlington, Middlesbrough, Stockton and West Hartlepool - constituted the highest order in the regional hierarchy in 1879. Of these, Darlington - with more functions, establishments and functional units than any of the others - was the most important, though it had 6,000 people fewer than Stockton and 21,000 fewer than Middlesbrough. In relation to its size, Darlington had a normal quota of central functions for a settlement on Teesside. To a greater extent than either Stockton or Middlesbrough, and despite industrialization, it had therefore retained its original role as the service centre for an extensive rural area. Although Darlington had a greater functional range than any other central place in the region, very few of the functions represented there were unique to that town alone; most were found in at least one other place. Those which were found nowhere else belonged to a group of highly specialised activities - each of which was represented in only one centre - shared by all the larger towns.

The three other Group-A centres did not differ greatly from one another in terms of functional complexity, but there were large differences between them in terms of population size. With almost 56,000 people, Middlesbrough was the largest settlement in the region, but it lacked the commercial stature to be expected of a town so large and of such importance in the industrial sphere. As was pointed out earlier, Middlesbrough had very few functions more than West Hartlepool despite having twice the latter's population. Its deficiencies appear to have been due to the town's failure to capture a hinterland commensurate in size to its own population - which may have partly resulted from the proximity of Stockton - and to the sluggish response tof the tertiary sector to the new opportunities created by industrial development. In addition, the predominantly working-class social character of Middlesbrough may have had the effect of inhibiting the development of some of the more exotic tertiary trades represented in Darlington and Stockton, both of which probably had a larger as well as a more firmly established middle class.

Stockton apparently experienced little expansion in the tertiary sector between 1851 and 1879, despite the rapid pace of industrial development and population increase during that period. The number of functions changed very little, and in 1879 Stockton had a smaller range of functions than would be expected on the basis of its population size, which indicates that the town's hinterland population had not risen in proportion with its own. The number of establishments had actually declined, suggesting that an increase had occurred in the scale of service outlets.

West Hartlepool was one of the more surprising members of the central place hierarchy in 1879. It is customary to regard West Hartlepool as a typical example of a Victorian new industrial town, built very quickly and having little claim to commercial prominence. Yet it had few service functions less than Middlesbrough, Stockton or Darlington, though it was smaller than any of them, and very much smaller than Middlesbrough. It also had the handicap of a coastal location, and hence its trade area could only be half the size it would have been at an inland location. The most probable explanation of West Hartlepool's impressive development as a service centre is that it had annexed part of old Hartlepool's hinterland.

The B order of the regional hierarchy in 1879 consisted of eleven central places, all but one of which were omitted from the 1851 study because they were located in that part of the region within North Yorkshire. The solitary exception was Hartlepool, which had almost 3,000 more people than in 1851, but approximately the same number of functions and many fewer establishments and functional units. As a central place, therefore, Hartlepool had remained stationary or declined, and this lends support to the explanation given above of West Hartlepool's rapid development. To some extent, this shift of commercial power from the old to the new town was perhaps due to the physical congestion of the peninsula upon which the former stood, but more generally it was a result of the transfer of industrial and demographic primacy to the latter.

The other B-level centres were a mixture of new and old, and of industrial and rural, central places. Skelton, Lofthouse (or Loftus) and Guisborough had all undergone recent expansion as a result of the development of the Cleveland mining industry.[1] The last of these, however, like Stokesley and Great Ayton, had already been a substantial country market town. South Stockton (or Thornaby), as its name implies, was essentially an industrial annexe of Stockton itself, from which it was separated by the Tees. Redcar, Coatham, and Saltburn had originally been small fishing communities, but the general economic development of the area and the construction of a railway along the coast had given them some prominence as resorts after the middle of the century.

Yarm was perhaps the oddest member of Group B, remaining largely unaffected by the changes which transformed much of the rest of the region in this period. Once it had been the major port on the Tees, and the largest settlement in the region east of Darlington, with multifarious interests in shipbuilding and textiles and trading links with the Continent as early as the twelvth century.[1] Even in the seventeenth century, Yarm was still a busy port and a minor industrial centre of some importance locally, but subsequently it lost ground to, and was finally eclipsed by, Stockton. The normal explanation of the town's decline is that in the eighteenth century ships became steadily larger and began to require more draught and freedom to manoeuvre than could be provided by the Tees between Yarm and Stockton, with the result that the initiative passed to the latter port. No doubt this is substantially correct, but there must also have been

1. See Wardell, op.cit.; R.H. Best, "The Urbanization of Tees-Side", Planning Outlook, Vol.5 (1961), pp.15-17; and A.E. Smailes, North England, London, 1960, chap.9.

a collective failure of entrepreneurial nerve, or lack of imagination, on the part of the townspeople of Yarm that they should have allowed it to happen. Stockton's displacement of Yarm was completed in 1769, when Stockton bridge was opened. This permanently barred the river channel to Yarm for ocean-going vessels, but the completion of the bridge was a symbol rather than the cause of Yarm's decline.

The lowest tier of the central place hierarchy in 1879 consisted of places with from one to twenty-five central functions, and it contained the great majority of service centres in the region. Some of these were new industrial communities, with perhaps a small nucleus dating from earlier times, such as those in the vicinity of Middlesbrough : North Ormesby, South Bank, Warrenby, Haverton Hill and Port Clarence, for example. Others were places which had expanded under the influence of the development of mining. Most, however, were still primarily service centres for rural people. All but about thirty of the nearly two-hundred parishes in the region had at least one central place, and all but a handful of those central places belonged to Group C.

Staindrop was a member of the lowest order of central places in 1879, and since 1851 it had lost a considerable number of functions as well as its relatively high status. To some extent this deterioration may have been the result of the construction of a railway from Darlington to Barnard Castle in 1856, which would have removed Staindrop's protective isolation from large centres. Probably even more important, however, was the general decline, noted in Chapter 5, of the population of this western part of the Teesside region between 1851 and 1881.

By 1879, the list of central functions represented on Teesside had lengthened to 230. Virtually all the additions were confined to one or more of the main towns. While some were concenred with specialised branches of retailing - photographers, fine art dealers, fishing rod dealers and others -, many were functions normally thought of as being of a higher order. One group consisted of types of wholesale business which had not been represented in 1851. A crude indication of the greater significance of middlemen is provided by the fact that whereas there are no activities with the prefix 'wholesale' in the list for 1851, there are nineteen in that for 1879. They range from grocer to news agent, from draper to fruit merchant and from tea merchant to drysalter.

Another category of activities new to the region consisted of those concerned with financial and property transactions, such as the commercial loan agency and the house agent. On a rather different plane, the cooperative movement had obtained a foothold in the region by 1879, and had established retail stores in many towns. Signs that the region had accepted other national trends are provided by the appearance in the list for 1879 of wholesale and retail shoe stores, a merchant tailor and an 'American fresh meat agent', the last of these suggesting that supplies of refrigerated foreign meat had begun to arrive.

Despite these and other changes, the rank-order of functions for 1879 resembles that for 1851 quite closely. Although their respective positions were a little different, eight of the ten most ubiquitous functions in 1851 were still amongst the first ten in 1879. The grocery store was the most numerous business type in 1879, as it had been in 1851. It was followed, also as before, by the public house cum hotel. Both of these functions had added some 300 new units, and the gap between them and their nearest rivals, butchers and shoe makers, had increased.

In general, most functions had more outlets at the end than at the beginning of the period studied, but the rate of expansion had varied considerably between trades. Despite the fact that a much larger area was examined for 1879, and that the regional population had trebled since 1851, a surprising n number of functions had fewer outlets at the end than at the beginning of the period. Table 9.11 lists some of these, but only those functions which had more than ten outlets in 1851 have been included. This is to reduce the influence of data errors; where a function had only one or two utlets, it could easily have been overlooked by the directory compilers. On the basis of what is known of the character of the trades concerned, it seems probable that in most cases the decrease in the number of functional units for the functions in Table 9.11 was the result of an increase in the scale of service outlets. It is possible, however, that the decline in the number of straw bonnet makers was more the result of a decline in the demand for straw bonnets.

Table 9.11

Some of the Functions with Fewer Units in 1879 than in 1851.

Function.	Decrease in Number of Units.
Hatter and Milliner.	28
Straw Bonnet Maker.	47
Cartwright.	50
Cabinet Maker.	23
Brewer.	27
Baker.	12
Glazier.	15
Leather Worker.	6
Gilder.	17
Tin Worker.	9
Cooper.	5
Ale and Porter Merchant.	5
Rope Maker.	10
Bookbinder.	4

As in 1851, the distribution of periodic markets in 1879 tends to confirm the impressions already gained, through the analysis of fixed service facilities, of the central place hierarchy. All four of the Class-A centres had markets in 1879, and so did some of the B centres, including Hartlepool, Guisborough and Lofthouse.[1.] Like Sedgefield, however, Staindrop and Yarm had lost theirs. For Yarm, this loss was no more than a culmination of the processes which for more than a century had been steadily undermining the town's economic status and ehhancing that of Stockton.[2.] Sedgefield's market had been poorly supported in 1851, and it is not surprising that it was abandoned a few years later.[3.] The loss of the weekly market at Staindrop endorses the conclusion arrived at a little earlier : that the town had declined as

1.Unless otherwise stated, information relating to local markets has been obtained from the Kelly directories referred to at the beginning of the chapter.

2.Yarm's weekly market was discontinued in 1867 - Wardell, op.cit., p.131.

3.By 1856, according to Whellan, op.cit., p.522.

a service centre since 1851. Though very small, Castleton still had a weekly market in 1879, and that was probably because the village was deep in the moorlands of North Yorkshire and protected by isolation from the rigours of competition with larger places.

At the end of the period, as at the beginning, Darlington was probably still the region's most important market town. The main market day at Darlington was still Monday, and a supplementary market was still held on Friday, both of which were to the convenience of the farming population. The growing size and economic power of the urban proletariat had been recently acknowledged, however, with the inauguration of an additional general market on Saturday, the only day in the week when the working-class townsman was free- at least in the afternoon - from both the factory and the church. The cattle market and the various annual fairs were as important in 1879 as they had ever been, and few changes affecting them had been made since 1851. Since 1862, however, part of the general market - the foodstuffs section - had been held indoors.[1] A special building for that purpose had been erected on a site - formerly occupied by the Town Hall - adjacent to the Central Buildings in the market place.

Apart from the shambles, Stockton still had no covered market facilities, but that does not seem to have been a serious handicap. The Stockton-on-Tees Market Act of 1876

1. Kelly. op.cit.; and County Borough of Darlington, op.cit., p.17.

empowered the Corporation of the town to purchase land adjacent to the parish churchyard, to the east of the High Street, in order to provide separate facilities for the cattle market. The High Street seems to have become too congested for that purpose. The growth of the urban population had also necessitated changes in the retail market. The local and regional production of fresh foodstuffs was no longer sufficient, and supplies were having to be drawn from increasingly distant places. For example, a substantial import trade in fruit and vegetables had developed with Hamburg and the ports of the Netherlands.[1]

As was the case with many of the other facilities provided by the town's founders, Middlesbrough's Market Place had become too small for its primary purpose, and the weekly market was firmly entrenched in the streets converging on it.[2] Making use of its statutory powers, the Middlesbrough Corporation had purchased land on the edge of the Market Place in 1858 in order to establish a butchers' market. This was followed by the opening of a vegetable market in 1861 and a butter and egg market in 1876. In 1875 a cattle market was established, with a hide and skin section from 1880, in what later became Victoria Square, an area flanking the modern Town Hall. This last innovation was not a success, and the cattle market was abandoned in 1881. For all its size, Middlesbrough was unable to alter the traditional spatial org-

1. Henry Heavisides, <u>The Annals of Stockton-on-Tees</u>, Stockton, 1865, p.70.

2. See Lillie, <u>op.cit.</u>, pp.139-40.

anisation of the regional trade in agricultural commpdities, and its market remained a retail establishment which catered largely for the town's oen population.

Hartlepool's market was in much the same category as Middlesbrough's, being essentially an urban retail market. Nevertheless, the physical facilities at Hartlepool were much better than they had been in 1851. In 1865 the foundation stone of a new Borough Hall and Market Building was laid. The complex was opened in the following year, giving the town a covered market and various public offices in Middlegate Street.[1] By 1883, however, the Corporation had become so dissatisfied with the market, which seldom made a profit, that a decision was made to discontinue it.[2]

West Hartlepool, perhaps because of its larger population, fared rather better than its neighbour in this respect. A year after it came into being, in 1854, the West Hartlepool Improvement Commission began to work for the establishment of a public market in the town.[3] Land, one and a half acres in area, to the south of the existing urban development was purchased and set aside as a market place. This was a rather large plot, but it was hoped to form a cattle and a dairy market, to be supplied with imported goods, as well as a nor-

1. Thomas Richmond, The Local Records of Stockton and the Neighbourhood, Stockton, 1868, p.277 and p.295; and Kelly, op.cit.

2. William Page (ed.), The Victoria History of the County of Durham, V.1.3, London, 1928, p.275.

3. See Wood, op.cit., p.49 and p.92,

mal retail market. In the event, only the last part of the scheme could be implemented, mainly because of Stockton's dominance of the trade in agricultural produce, and a section of the Market Place was later used as sites for a fire station and public wash-houses. In 1861 part of the market was given covered accommodation, but this improved conditions without enhancing the status of the market and it was many years before the scheme realised a profit.[1]

Stokesley seems to have lost its weekly market by 1879[2] but the town's annual cattle and hiring fairs - the latter mainly or ostensibly for the purpose of engaging farm and domestic labour - were still important events. Guisborough, originally very similar to Stokesley, had also lost is market for a period but had regained it in 1855,[3] and in 1879 it held two each week.[4] This recovery and expansion were undoubtedly due to population growth in the area as a result of the development of mining. Guisborough also held annual wool fairs which were of some local importance. As an example of a new development in the field, mention should be made of the Tuesday market established in 1875 at North Ormesby,[5] a place which was virtually a suburb of Middlesbrough. The success of the project suggests that town-dwellers were less inclined than country people to travel far to market, though it may

1. Richmond, op.cit., p.251.
2. At least, no mention of it was made by Kelly, op.cit.
3. William Page (ed.), Victoria County History of the North Riding, Vol.2, London, 1920 p.358.
4. Kelly, op.cit.,
5. Lillie, op.cit., p.141.

simply have been the case that there was sufficient demand to support more than one weekly market in the Middlesbrough area at that time.

A Summary of Change, 1851-1879.

It was established in earlier chapters that the population of the Teesside region increased three-fold between 1851 and 1881, and that the intervening period was also one of industrialization and economic growth. Hence, there clearly must have been a very large increase in the total demand for central goods and services. This increase would not, however, have been shared equally by the different parts of the region. Although there was probably a rise in living standards within most areas, the purely agricultural districts must have generally experienced a decline in the level of demand as a result of depopulation, which was concentrated in those districts. One-third of the parishes in the region lost population - by as much as 40 per cent. in some cases - between 1851 and 1881, and the members of that group were all rural parishes basically dependent on farming. In contrast, urban parishes, those adjacent to the large towns and parishes in mining districts generally experienced population expansion, sometimes on a spectacular scale. These were also the areas in which industrialization occurred and in which economic growth was most vigorous. Consequently, they were the areas in which the demand for central goods and services must have grown.

According to the theoretical model outlined at the beginning of the present chapter, an overall but spatially variable growth in demand would have certain predictable effects on a regional central place system. In particular, it was argued, there would be changes in the relative status of existing centres, which would depend on whether they were in areas of expansion or contraction, and there would be the emergence of new and the disappearance of some old central places. It was also shown that economic growth would tend to affect the degree of ubiquity and the relative status of central functions, as well as causing the demise of some functions and the appearance of others for the first time. These generalizations are supported by the pattern of events on Teesside.

Between 1851 and 1879, very few of the villages in that part of the region within Durham added significantly to their range of central functions. Most of those that did do so belonged to the group of coal mining parishes, listed in Chapter 5, which experienced high rates of population increase in that period. Castle Eden and Wingate were amongst them. However, the population expansion in such parishes was not large absolutely, rarely amounting to more than two or three hundred people, and, as a result, the number of central functions added was usually quite small. The settlements concerned therefore remained villages rather than became towns.

The great majority of small central places in south Durham either declined slightly or maintained their original status in this period. None increased substantially in importance. Staindrop provides a good example of a service centre whose status declined considerably as a result of rural depopulation. At the beginning of the period it was one of the more important towns in the region, and on a par with West Hartlepool; in 1879 it was an ordinary small village, having lost half its range of central functions and its weekly market.

The smaller settlements in North Yorkshire cannot be treated systematically, as it was not possible to obtain data for them in 1851. However, it seems clear that expansion affected lower levels of the hierarchy in North Yorkshire than it did in south Durham. South Stockton, Redcar, Saltburn, Lofthouse, Coatham and Skelton were all substantial central places in 1879, though they had been no more than villages at mid-century. Although it was initially an old market town of some standing, Guisborough had also expanded considerably by the end of the period. North Ormesby, South Bank, Eston, Normanby and Warrenby were some of the smaller central places which had developed entirely since 1851, and there was a number of others in the Cleveland mining district.

With the exception of Hartlepool, the large towns all increased their functional range in this period. Hartlepool actually declined somewhat as a service centre. In part, this was due to the physical restraints imposed by the town's peninsula site. Without the re-development of the old centre, expansion could only have proceeded in an inland direction, and it was more logical that it should have gone to West Hartlepool instead. By 1879, West Hartlepool was larger and more important, commercially and industrially, than its neighbour. Darlington and Stockton gained in commercial stature after 1851, but at both beginning and end of the period they were in the highest order of central places. By 1879, they had been joined by Middlesbrough and West Hartlepool.

Compared with 1851, a large number of central functions which were new to the region had appeared by 1879. Many of these were activities that are normally regarded as being of a high order. In this category might be placed the various types of wholesale business. Their emergence provides evidence that the region's tertiary sector was becoming more specialised, as part of its search for greater efficiency and the means to overcome the problems of coping with a vastly increased population.

Other new functions, however, serve as reminders that a service industry can have a high threshold without it necessarily consisting of large business units or being concerned with a highly valuable commodity. Many were composed of small retail establishments selling goods, such as fishing rods, for which there had previously been insufficient demand, because the population had been too small, incomes too low, or interest unaroused. Changes in other sectors of the economy had also made their mark upon the tertiary trades by 1879. Thus, the growth of factory production in the footwear industry, though scarcely begun, had already had the effect of encouraging the establishment of shops concerned only with the selling, and not at all with the making, of shoes.

Of the functions which had been represented on Teesside in 1851, few had more outlets in 1879 than can be accounted for by the fact that a larger area - and hence more central places - was studied at the latter date. Thus, although there were about 300 more grocers and public houses in 1879 than in 1851, the increase is not in proportion to the additional number of central places. This suggests that there had been a significant rise in the scale of individual service outlets in those trades. In many other trades, there were fewer shops and offices in 1879 than at the beginning of the period, even though the region's population had risen from 120,000 to 337,000. It therefore seems clear that establishments were very considerably larger in 1879 than in 1851 throughout much of the tertiary sector.

On a more general note, the existence of a central place hierarchy on Teesside in both 1851 and 1879 has been demonstrated. With one main exception, the findings were in general accord with those to emerge from other empirical investigations. The exception was that at both the beginning and the end of the period, the relationship between population size and number of central functions was linear, whereas it has usually been found to be log-linear. The conclusion drawn here is that the relationship will be log-linear if retail functions alone are considered, but linear if a wider interpretation of central functions is adopted.

CHAPTER TEN

SUMMARY AND CONCLUSIONS

As was stated at the outset, it was intended that this study should serve two main purposes. In the first place, it was hoped that it would help to illuminate the spatial aspects of economic growth at the regional scale. The second objective was the analysis of locational changes induced and required in individual sectors of the economy by economic growth. The degree to which these complementary goals have been realised can now be considered, and the various findings reported in earlier chapters can be drawn together.

Conceptually, Teesside was regarded as a functional economic region, with the main towns constituting the core, and it was defined on the basis of local road carrier traffic. The spatial structure thus delimited consists of places and areas which were bound together, as an economic system, under the hegemony of the towns of Darlington, Stockton, Middlesbrough, Hartlepool and West Hartlepool. These towns, though different in origin, were alike in that they were all fundamentally affected by the revolutionary changes which began in the Teesside area in the middle of the nineteenth century.

In considering the question of economic growth, changes in the population and employment structures were regarded as crucial indices. The population of the region as a whole almost trebled between 1851 and 1881, rising from 121,000 to 337,000. Expansion was greatest in the decade 1861-71, when it reached the rate of 59 per cent. It was possible to distinguish between migration and natural increase for only part of Teesside - the part consisting of the six central registration districts. In this area, which contained 80 per cent of the regional population in 1851 and 92 per cent in 1881, net immigration provided 100,000 extra people and natural increase 113,000 over the full period. Net immigration, like total increase, was at a peak between 1861 and 1871, when it involved more people than in the other two decades together. Population growth as a whole was slowest in the last of the three decades. Immediately, this was due to a decline in the rate of net immigration; indirectly, but more fundamentally, it was caused by a slowing of the pace of economic expansion.

In the registration districts entirely within the region - constituting the area to which the migration data relate -, population expansion added 45,000 people to the adult labour force between 1851 and 1871. Of them, 30,000 found employment in the mining-engineering-construction group of industries. This group raised its share of the working population over the age of twenty years from 22.8 per cent in 1851 to 47.1 per cent in 1871. The tertiary sector also received many new recruits, but not enough to prevent its share of the adult labour force from declining slightly in this period. The number of adult farm workers remained virtually constant, but the proportion of adult workers employed in farming fell from 25.6 to about 10.5 per cent. between 1851 and 1871.

Together, the massive increase in population - which largely resulted from the direct and indirect effects of immigration - and the relative shifts in employment are evidence of economic growth. Alone, population expansion and immigration may simply reflect an increase in a region's employment capacity, particularly if the region in question already has a relatively high standard of living. On Teesside, however, population growth was linked to the creation of new jobs on a large scale in that sector of the economy - consisting mainly of mining and engineering - which had a higher and more rapidly rising level of productivity than any other at the time. Hence, it is justifiable to conclude that the region underwent economic growth.

Economic growth on Teesside was thus achieved primarily not through the transformation of existing industries - though there were improvements in some of them which helped -, but through the development of industries which were new to the region and had higher levels of productivity than the major traditional economic activities. In view of the nature of these new industries, this development may be said to have amounted to industrialization, a process which occurred half a century later than in most other parts of Britain. However, the conclusion that economic growth was the result of a relative transfer of resources between sectors of the Teesside economy is not an entirely satisfactory explanation since it raises the question of why such a transfer should have taken place.

As is commonly the case, the initial stimulus, in the form of an increase in the demand for iron and iron products, came from outside rather than from within the regional economy. The actual turning-point was the discovery of Cleveland's iron ore resources in 1850, an event which made possible the subsequent industrialization of the Teesside region. The discovery was made by ironmasters who were from North East England but who had no iron smelting plants on Teesside at that time. The Cleveland ore deposits were soon realised to be substantial, and capital began to flow into the region to facilitate their exploitation. Within a few months of the Eston discovery, ironstone was being transported north to works in various parts of Durham. With the development of mining in Cleveland, however, Teesside itself became a viable location for iron manufacturing, and blast furnaces and finishing plants soon began to appear within the region. In turn, a variety of iron-using industries quickly developed, and the accompanying population increase made possible, and necessary, expansion in the tertiary sector. Thus, Teesside's initial economic growth was fundamentally based on the utilization of one of the region's mineral resources.

Population growth, net immigration and changes in employment structure were greatest in the existing urban areas, and their immediate vicinity, and in those rural areas which had reserves of either coal or iron ore. One-third of the parishes in the region lost population between 1851 and 1881, and with few exceptions these were parishes which were almost totally dependent economically on agriculture. There were improvements in farming techniques in this period, and there is evidence that the productivity and profitability of agriculture rose. However, there was no significant reduction in the size of the agricultural labour force, which suggests that productivity gains were relatively small. This and the general depopulation in such districts indicates that economic growth can only have been slow in farming areas.

Rural districts with mineral resources, especially those in the Cleveland orefield, experienced population growth and great changes in their employment structure. Theirs, however, were wasting assets and by the end of the period, with the exhaustion of local mineral deposits, many mining parishes were beginning to lose the population they had gained in earlier years. The more permanent population growth occurred in and near the main urban centres, which had virtually all of the region's manufacturing capacity at both beginning and end of the period. It was there, too, that economic growth must have been greatest; for few rural parishes were able to attract new industries other than mining, and the opportunities for growth based on transferring resources to mining were very limited, and must soon have been exhausted.

The evidence from Teesside seems to substantiate many of the concepts which have been formulated to describe and explain the spatial development of economic growth. Thus, in keeping with the forecasts of the disequilibrium models, urban centres were the major growth points and agricultural districts lagged behind. As would be expected from regional multiplier and growth pole studies, the development of a major industry - iron manufacturing - at certain points within the region was followed by the establishment and expansion, at those points, of manufacturing and service industries connected vertically and laterally to it.

On the other hand, many of the spatial models and conceptual structures tend to over-simplify matters by disregarding the possibility of new urban centres emerging and of the initial leading industry being unable to attract other industries to locations adjacent to its own. The spatial progress of economic growth must depend a great deal on the nature and locational requirements of the industries represented in a particular region. There is, for example, no inherent reason why existing urban centres should become the main growth points; this will only occur if they have sufficient locational advantages to attract the industries capable of making gorwth possible. On Teesside, the existing towns provided the best locations for most branches of iron manufacturing, and they consequently obtained a major share of the new industrial capacity which developed in the region. Had the locational requirements of iron manufacturing been different, however, then new settlements might well have emerged as the region's growth centres. Nevertheless, it remains true that established urban centres have a great locational attraction for most industries which are not bound to raw material sources, and for this reason they often do monopolise growth.

It is also the case that the initial growth industry may be more important as a catalyst than as a growth leader, and may have a limited direct effect on the spatial pattern of development. On Teesside the Cleveland mining industry was the original leader but, although it had a direct effect on the tertiary sector in certain rural areas, mining soon took second place to iron manufacturing in its influence on the spatial progress of economic growth. Iron-ore mining was thus unlike coal mining, which had a fundamental influence on industrial locations and hence the spatial aspects of growth in nineteenth-century Britain. Generally, it may be said that a particular industry will help to decide the spatial pattern of economic growth in a region to the extent that it can attract other industries - both those supplying its materials and those consuming its products - to its own location. In the Teesside context, iron manufacturing attracted many connected industries; iron-ore mining did not.

For the study of locational change in individual sectors of the economy, the general approach adopted in this investigation has been to compare the actual spatial patterns with theoretical patterns derived by subjecting orthodox location models to the conditions which prevail during periods of economic growth. This was done for iron-ore mining, agriculture, manufacturing and the service industries. The practical results of this procedure varied in value, but in principle the method provides a useful means of analysing the changes necessitated by economic growth at a disaggregated level.

In relation to mining, a strict equilibrium model of the location pattern is inappropriate, since change is endemic. Production cannot take place at a fixed site and costs and prices must vary constantly, as a result of local differences in the quality of the resource body and continual change in the distance between market and point of production. Consequently, a location model was formulated which gives an idealized picture of the process of development based on the least-cost principle.

According to this model, development will occur first at the point where overall costs - comprising working and transport costs - are lowest. Providing that normal profits can still be earned, mining will subsequently spread outwards from the original, and optimum, location, even though total costs rise as a result. Economic growth, it was argued, would have the effect of at least partially offsetting the trend towards higher costs, since it would involve technical and organisational improvements within the mining industry itself and in other sectors of the economy, such as transportation. Growth would also involve a rise in demand,

and hence in price. Through its influence on supply and demand conditions, economic growth would thus make possible an extension of mining into areas originally too costly to be worked.

The spatial development of the Cleveland mining industry matched this model quite closely. The first mines to be opened were as near as they could have been to the regional market for iron ore. They were also located in the area where the Main Seam - the chief commercial deposit - was at its thickest and best and was nearest to the surface. Both transport and working costs were therefore potentially at a minimum. Subsequent development took the industry into parts of the orefield where both types of costs steadily rose. Transport costs were, however, the most critical consideration; working costs varied spatially, but not sufficiently to dictate the lines of development.

There is some evidence that companies in parts of the orefield where overall costs were lowest - the Eston and Normanby areas, for example - accepted higher labour costs than they needed to have done. In doing so, they were choosing to take advantage of their superior locations to pay a premium to labour, which was in relatively short supply. Ideally, according to land rent theory, this premium ought to have gone to land, but mineral royalties were leased under lohg-term arrangements and rental payments were not flexible. This meant that the first mining companies in the field paid lower royalties than they would otherwise have done, and that they consequently had surplus revenues which could be used as they wished.

Agricultural location theory, based on the von Thünen model, was found to provide a framework of limited value for the study of intra-regional farming patterns. There was some specialisation of agriculture around the main towns, where the land was largely devoted to grass - to provide fodder and grazing for the urban horse and dairy cow population - and, to a lesser extent, market gardening. Otherwise, however, there is no convincing evidence that land use was significantly related to distance from the market. The most important divide within the region was that between upland and lowland farming, with the former mainly concerned with animal husbandry and the latter with a mixed arable-livestock regime.

The immediate reason for the absence of von Thünen's land-use rings, apart from the inner-most zone of grass and horticulture, was that intra-regional cost variations due to distance from the market were of little significance. To some extent this may have been because the Teesside region was comparatively small. In addition, transport costs can have been of little importance for many agridultural commodities; the cost of taking wheat, for example, to market must have represented a very small part of total costs.

More fundamentally, however, the pattern of farming was shaped by the price structure as well as the cost structure.

and the prices of most agricultural products were not decided at the regional level. Teesside was not a self-sufficient 'isolated state' but a region engaged in trade and responsive to conditions in national and international markets. Thus, the inflated prices of wheat and other cereals in the early nineteenth century, which resulted from political circumstances, meant that such crops were the most profitable agricultural products almost wherever they could be grown. Lowland Teesside farmers consequently specialised in cereal production, with a heavy emphasis on wheat, regardless of the distance of their holdings from the regional market.

By mid-century, conditions had changed and genuine mixed farming systems had become the optimum for areas such as lowland Teesside. With freer international trade, the question of comparative advantage - for countries and continents - was of growing importance, and at the regional scale it tended to override the influence of internal transport costs on farming patterns. After 1870, livestock were the most profitable end of mixed farming systems in lowland Britain, and changes in the pattern of land use on Teesside reflected this national trend. Nevertheless, theoretically there should be land-use zoning, based on degrees of intensity of production, even with a monocultural system. The apparent absence of such zoning on Teesside - away from the vicinity of large towns - suggests that differences in transport costs were not very significant, and that there was a degree of immunity from cost pressures.

In contrast, Weber's industrial location model, despite its faults and limitations, provided a sound basis for examining the distribution of the region's major manufacturing industries. This was because transport costs were of considerable importance for most of the industries studied, which produced bulky and heavy goods of comparatively low unit value from materials of the same nature, and because there was a strong incentive to keep costs in general as low as possible in order to retain a competitive position in world markets.

It was found, however, that the Weber model is more useful if a number of simple but important qualifications are taken into account. In the first place, it is preferable in many cases to regard the location problem as a linear rather than an areal problem. In a theoretical sense this is a retrograde step, since it amounts to a departure from the more general framework of the orthodox model, but in practical terms it is realistic. Very few industrial firms are free and able to build direct lines of communication between their markets and the sources of their materials; most have to operate within the context of an existing transport network, rather than an abstract transportation surface, and the location problem is therefore a matter of finding the best location on that network. It is consequently normally a linear problem.

Another point to emerge from the present study is that when there is more than one market and more than one source of materials, it should be recognised that the optimum location for a particular firm may well differ from that for the industry as a whole. The optimum location for the firm depends on where it obtains, and can expect in the future to obtain, its materials from and where it sells, and can expect to sell, its product. The optimum location for the industry depends on an evaluation of all material sources and markets within a region.

Finally, account should be taken of the varying degrees of integration present within a particular sector of the economy. As was found in the case of iron and steel manufacture on Teesside, the locational requirements of a works making one product can differ considerably from those of a works making that product plus another from it. It is therefore more correct to look for the optimum location of a certain type of industrial establishment rather than that of an industry.

Economic growth on Teesside brought many of the changes in the manufacturing sector which could be predicted on theoretical grounds. A combination of rising demand and innovations leading to cost reductions meant that many industries were able to expand. Some, however, were adversely affected by the consequences of general economic development, and, like the wooden shipbuilding industry, they declined. The wrought iron trade provides an example of an industry which was eventually forced to contract, after a period of rapid expansion, not so much by its own failings as by the rise of a new industry with a cheaper and technically superior product. As well as innovations leading to a simple lowering of costs, there were others - notably in the field of fuel economy - which altered the balance of industrial inputs and thereby contributed to the locational reorientation of certain branches of manufacturing.

Many of the changes in the mining, agricultural and manufacturing sectors had a major impact on the tertiary sector. Industrialization drew large numbers of people from the agricultural districts, with the result that many rural central places lost commercial functions and businesses and were consequently downgraded in the settlement hierarchy. Conversely, in urban and mining areas existing central places were upgraded, and new centres established, as a result of the population influx and vigorous economic growth. In the region as a whole, a large number of new central functions was added during the period covered by this study. Most of these were functions which Teesside had been unable to support in 1851, because their thresholds were too high. In addition, however, there were a few functions represented in 1881 which had not existed in 1851. These owed their appearance not so much to the greater size and prosperity of the region's population as to the increased sophistication of the tertiary sector, and hence to the general development of the British economy as a whole.

More generally, it is clear that the locational patterns of economic activities are inter-dependent, and that change in zone will induce and require change in at least some of the others. Thus, while the distribution of service industries on Teesside was subject to the influence of other industrial distributions, because of the latters' role in determining the spatial pattern of population within the region, the tertiary sector also played an active part in shaping the locational characteristics of other industries. For example, the proliferation of service activities in the main towns enhanced the locational attractions of those places for many types of manufacturing, and especially for those able to obtain agglomeration economies. More obviously, the location of ironworks within the region was decisive in determining the spatial distribution of the heavy engineering trade . Again, the growth of the urban population, which resulted from the development of manufacturing and service industries in the main towns, must have affected farming by raising the level of demand for locally produced and consumed commodities such as milk.

The locational characteristics of individual industries have an important bearing on regional economic growth. Non-optimum locations carry the penalty of higher costs, and economic growth may not be possible - and if possible may be needlessly slow - if industries do not adopt the best locations available. To a large extent the spatial development of economic growth is also determined by the locational requirements and characteristics of the industries which stimulate and sustain it. The preeminence of urban centres in modern economies is fundamentally due to the fact that such places are the optimum and the actual locations of those economic activities which have contributed most to modern economic growth.

Through the development of new industries, the expansion and contraction of industries which had already been represented in the region at mid-century, population growth and the general economic development of the area, Teesside changed quite fundamentally between 1851 and 1881. Most notably, the region ceased to be predominantly rural and agricultural and became urban and industrial. It was in this period that Teesside's modern socio-economic character was formed; change and economic expansion continued after 1881, but at much reduced rates. The region's principal settlements were not amongst the great cities of the age, but they were important as heavy industrial centres. As such, they were, and remain, essentially products of British society in the buoyant middle years of Victoria's reign.

APPENDIX I

PARISH AREAS

The civil parish - which was often the township in northern England - has been used as the basic territorial unit in this study, it being the smallest type of area for which population and agricultural land-use data are available. In the course of analysing population change on Tees side, consideration was given to the possibility that adjustments were made to parish boundaries and areas between 1851 and 1881. There appear, in fact, to have been very few such changes, but some of the points to emerge from the investigation are of interest in a more general context.

A possible source of confusion lies in the Census, which gives the areas as well as the populations of parishes. Most of the Teesside parishes would appear, from the Census, to have had the same areas in 1861 as in 1851, and in 1881 as in 1871, but to have had different areas in 1861 and 1871. This was due to changes in the method of arriving at parish areas.

For the 1831 Census, Rickman attempted to obtain the exact acreage of each parish in the country, but was thwarted by the scarcity of reliable plans and maps. Many of the figures adopted were no more than crude estimates. Nevertheless, in the absence of any feasible alternative course of action, Rickman's figures were used again in the Census of 1841. A decade later, in 1851, it was possible to make extensive revisions, as a large number of accurate maps had become available for certain parts of the country through the work of the Tithe Commission and the Ordnance Survey. The 1851 figures were used again, without general amendment, in 1861. For Durham, Yorkshire and four other counties, the parish acreages were revised once more for the 1871 Census, to take account of the Ordnance Survey's progress in mapping. This last change is the source of the discrepancy on Teesside between the parish acreages for 1861 and 1871.

The alterations to parish boundaries which took place on Teesside in this period resulted from the enactment of legislation applying to the country as a whole. An Act of Parliament was passed in 1857, to deal with the problem of administering relief to the poor in extra-parochial places, which created a number of new parishes and enlarged some already in existence. This particular statute did not affect any of the parishes in the Teesside region, but it is of general interest. All those places for which separate returns were published in the Census were declared to be civil parishes. The remainder were amalgamated with neighbouring parishes. In all, some 600 extra-parochial places were affected, and the necessary arrangements had been completed by 1861.[1]

The Divided Parishes Acts of 1876, 1879 and 1882 initiated a more extensive series of changes to parish areas and parish boundaries. These statutes were intended to permit

1. A list of the places affected was published in : Poor Law Board, Eleventh Annual Report, 1858-9, London, 1859, Appendix No.52, pp.290-307.

the consolidation of fragmented parishes, and between 1881 and 1891 more than one-fifth of the parishes in England and Wales - including many in Durham and North Yorkshire - were affected by them.[1] However, comparatively few changes were made before 1881, which marks the end of the period covered in this study. On Teesside, the only parishes affected before 1881 were Great Smeaton and Croft; a small parcel of land, with 72 inhabitants, was transferred from the former to the latter in 1879. This solitary exchange has in effect been reversed in the present study, in order to render the population data for 1881 comparable with those for earlier years. The great majority of the changes involving Teesside parishes were made between 1881 and 1891 and have been ignored.

Otherwise, it has been assumed that parish boundaries in the Teesside region remained constant in the period covered by this study. There may have been some minor modifications to individual boundaries which have not been traced. Even if this were the case, however, it would be unnecessary to alter significantly the conclusions which have been drawn concerning population change in the region as a whole.

1. The changes which had been made up to that date were listed in the Census for 1891.

APPENDIX II

EMPLOYMENT DATA

For the years 1851, 1861 and 1871, occupation statistics were published in the Population Census for registration districts and for what were termed 'principal towns.'[1] Only Middlesbrough, of the Teesside settlements, qualified as a principal town, and then only in 1871. In 1881, the smallest areal units for which employment data were published by the Census authorities were the registration riding - equivalent to the county - and the urban sanitary district with a population in excess of 50,000. Again, Middlesbrough was the only Teesside town to qualify for separate treatment. Because the scale of coverage varied, it was decided in the present study to use only the data for registration districts, which were available for 1851, 1861 and 1871.

The classification system used by the Census authorities in this period was essentially of an industrial nature, as opposed to the occupation-based system adopted between 1881 and 1911, and it changed little between 1851 and 1871[2]. Some of the broad industrial groups are not very suitable for the purposes of modern analysis, but a degree of regrouping is possible. In Chapters 4 and 5, Bellamy's classification - which is based on that used in later Census

1. Figures for males and females over the age of twenty years are given in : Registrar General, Census of Great Britain, 1851: Population Tables, II : Ages, Civil Condition, Occupations and Birth Places of the People, Vol.2, Durham and Yorkshire Divisions; Census of England and Wales, 1871: Population Abstracts, Vol.3 : Ages Civil Condition, Occupations, and Birth Places of the People, Durham and Yorkshire Divisions.

2. See P.G. Hall, The Industries of London Since 1861, London, 1962, pp.13-15. Joyce Bellamy, "Occupations in Kingston upon Hull, 1841-1948", Yorkshire Bulletin of Economic and Social Research, Vol.4 (1952), p.35; Interdepartmental Committee on Social and Economic Research Census Reports of Great Britain, 1801-1931, No.2 of Guides to Official Sources, London, 1951, pp.27-65.

reports - was adopted. This system recognises twenty-three Industrial Orders.[1]

The classification system still contains some ambiguities, but these are unavoidable. For example, manufacturing and service activities overlap in the 'Food, Drink and Tobacco' Order, as in some others. In part this is because the Census drew no distinction between 'dealers' and 'makers' prior to 1891.[2] More fundamentally, however, there are areas where manufacturing and service activities cannot be distinguished satisfactorily, and this was perhaps an even greater problem in the Victorian era than it is today, since more goods were then made and sold in the same premises than is now the case. Nevertheless, these are points of detail, and they do not invalidate the consolidation of Industrial Orders into secondary and tertiary sectors which was undertaken in Chapters 4 and 5.

Following Bellamy's example, the practice was adopted here of consigning people without specific employment to the 'Unoccupied' category. This group includes wives and other adult dependants as well as those who lived, whether in poverty or plenty, without working in the conventional sense. To the extent that the adult relatives of innkeepers, shoemakers and the like did assist in the family business, this procedure involves some under-enumeration of the labour

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1. For the full classification see Bellamy, <u>op.cit.</u>, Appendix 2.

2. <u>Ibid.</u>, p.45.

force. An exception has been made of farmers' adult male relatives, who have been counted as agricultural workers. Retired people posed a special, though minor, problem. They were generally placed in their former occupation groups by the Census authorities, which means that there was some over-enumeration of the labour force. However, a check made in 1881, for a county, revealed that the inclusion of retired people raised the 'occupied' adult population by only 2 per cent.[1]

Although the employment tables for 1851 and 1861 are fully comparable, only broad comparisons can be made between these and the tables for 1871. This is because the data published for registration districts - though not those for registration ridings - were less detailed for 1871 than for the earlier years.[2] In particular, mining and manufacturing activities were grouped together in 1871, and they have therefore had to be treated as a single sector in the present study, which is unfortunate.

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1. See Registrar General, Census of England and Wales, 1881 : Population Abstracts, Vol.4 : General Report, p.28.

2. Information was provided only for Classes and Orders in 1871, whereas in earlier years it had also been provided for Sub-Orders.

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