"The Port System on the South Shore of the Lower St. Lawrence River."

ABSTRACT

"A Geographical Analysis of the System of Ports on the South Shore of the Lower St. Lawrence River."

The study begins by describing four attributes of ports:- size, function, patterns of location, and morphology. Hypotheses concerning relationships between port activity and elements such as hinterland and facilities are tested using correlation analysis. A multiple regression model is presented that explains ninety percent of variation in port activity in the study area. The validity of the high performance of the model is considered. A more general approach is suggested where sets of ports are considered as a system. Systems concepts provide a framework for understanding how ports develop. A morphological model is presented that is based on the premise that the 'state' of a port system is a function of the interrelationships between its elements. Processes are seen to depend upon changes in these relationships, and a dynamic model is described. Finally both regression and systems models are used to predict the future of the port system in the study area.

Submitted for the Ph.D. degree by Brian Slack, Department of Geography.

A GEOGRAPHICAL ANALYSIS OF THE SYSTEM OF PORTS ON THE SOUTH SHORE OF THE LOWER ST. LAWRENCE RIVER

by

Brian Slack, B.A., M.A.

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Department of Geography,
McGill University,
Montreal.

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INTRODUCTION

This study examines the ports on the south shore of the St. Lawrence River between Quebec City and Gaspé. It sets out to explain variations in attributes of port size, to explore the functional structure of the ports in the study area, and to describe spatial patterns of ports there. The whole thrust of the research is to provide a more generalised level of explanation than that which has characterised most earlier work in port geography. In particular, this study lays the foundations for an approach to the investigation of processes of port development.

In the following chapter it is shown that port geography is a neglected part of urban-economic geography. There is a need to provide a framework for port analysis, and this study is seen as a contribution towards the fulfillment of that need. Such a framework is becoming increasingly necessary because ports themselves, and shipping systems as a whole, are changing rapidly due to new technologies, the impact of which will be felt throughout the entire economic system. To help understand and predict the consequences of these changes a deeper knowledge is required of processes of port development.

In approach and content this dissertation makes original contributions to port geography. In a very literal sense the study is a contribution to knowledge because it deals with many ports that have never before been subject to a scientific investigation. However, its real importance is that it makes a comparative inquiry into a regional set of ports of varying size and type. A major criticism of port geography is that it has been limited to studies of individual ports, or highly biassed sample of ports.

The justification of this research is that explanations of patterns of port activity and processes of port evolution can be obtained only from studies where samples include ports of a wide range of size and function.By excluding all but the largest ports from their investigations,geographers have been providing incomplete explanations. Small ports may play a decisive role in influencing the activity and functions of their largest neighbours,and thus are basic to a more complete understanding of port systems.

Geographical research has produced great quantities of detailed information concerning many of the world's ports,but little is known about how ports grow and evolve.The great emphasis on an empirical approach at the expense of theoretical formulations is reflected in the dearth of models in the field.Only a few port geographers have attempted to generalise and seek model explanations.In this study data are presented and processed in ways which suggest underlying order in patterns of port activity,and several models are devised to account for the regularities revealed.

As indicated in the research design (see Fig.1),the study progresses on two levels.At the micro level the analysis is concerned with examining factors that influence the performance of individual ports in the study area.Precise statements are made concerning the relationships between port size and a number of variables.Correlation and regression analyses are used to derive a statistical model explaining variations in port activity on the south shore of the lower St. Lawrence River.

At the macro level the research broadens to explore the processes

RESEARCH DESIGN

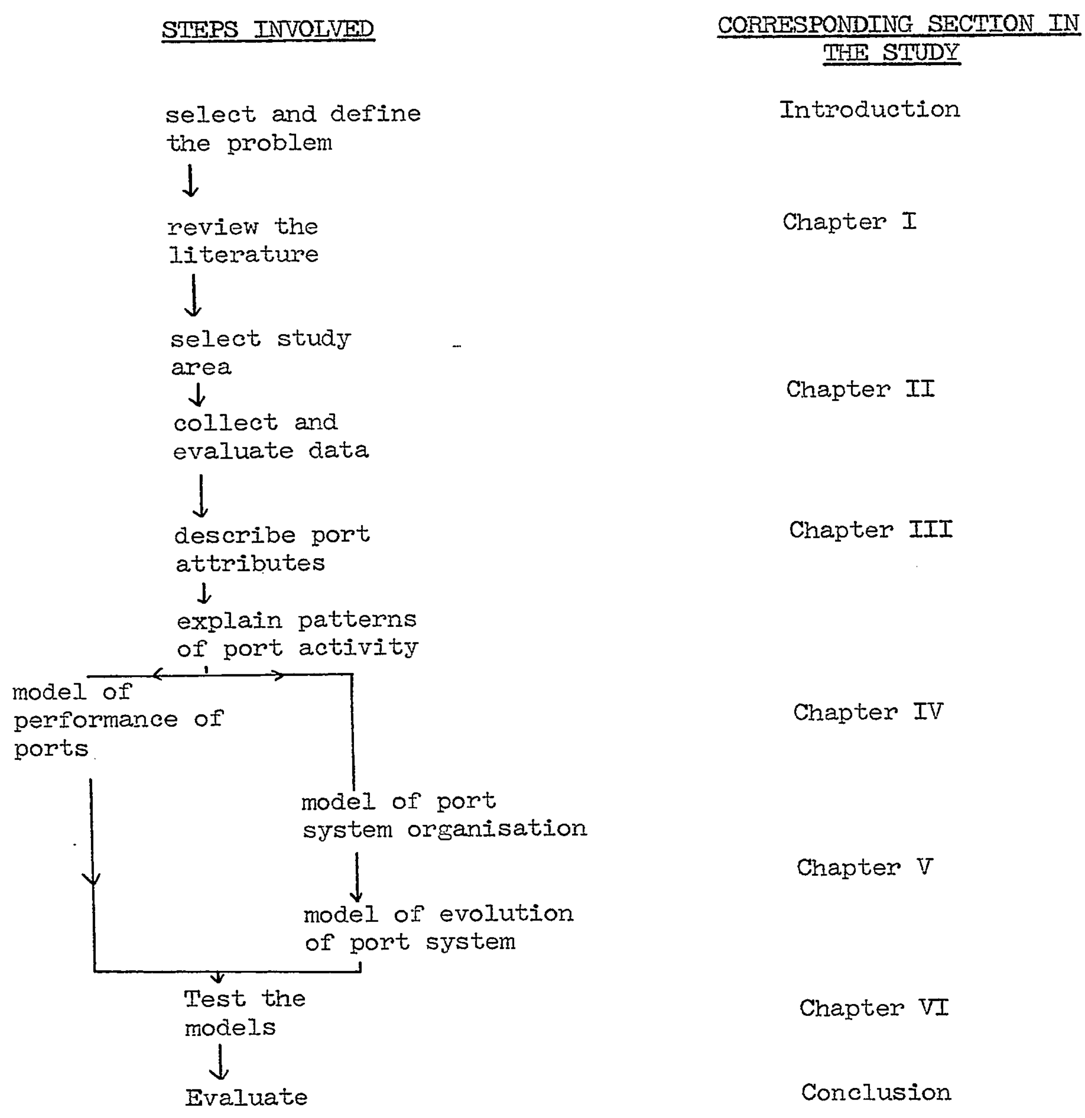

Fig. 1

by which assemblages of ports develop. The ports in the study area are seen as a system, and a systems approach is proposed as offering a suitable analytical framework. The study concentrates upon the interrelationships between the components of a system of ports. A model of organisation and structure is introduced, and is utilised to produce a process model of port development.

The final section of the dissertation applies the findings of the research to suggest a more efficient pattern of water transport in the region. Use is made of both micro and macro level models in the attempt to rationalise the pattern and structure of the ports in the study area. The limitations of the models are examined and recommendations for further research are proposed.

CHAPTER ONE

A CRITICAL REVIEW OF PORT GEOGRAPHY.

A. Introduction.

No study can exist alone. Even the most original can trace links with earlier studies. The purpose of this chapter is to review the literature on port geography. It is hoped that the advances in the field can be isolated, and at the same time some of the large gaps revealed. In tracing the growth and nature of port geography, it is worth comparing the relationship of the specialised study of ports with the much larger field of urban geography. Although Mayer (1966,100) has commented:

> "Many port studies have anticipated subsequent concepts which have become widely accepted principles of urban geography."

the central issue of this chapter is that the reverse is true. Port geography is a relic study left stranded well behind the distant research frontiers of urban geography.

B. The tradition of 'uniqueness'.

It is impossible to isolate the first study of ports. Because of the romance associated with them, as points where the goods, ideas, men, and riches of the seven seas are gathered and dispersed, ports have prompted novelists, artists, laymen, and scholars to contemplate their varied form. In geography the major thrust of port studies has been concerned with the description of individual ports. Most of the large ports of the world have been examined within the case study framework. A bibliography of such studies would be enormous, and serve little purpose for this dissertation. It is interesting to note, however, the number of eminent geographers who have contributed to this type of study: Camu (1959), Daysh (1952), Mayer (1957), Rogers (1958) and Ullman (1943). Even studies that have examined a number of ports in a particular region, have dealt with each one as a quasi-separate entity. Bird's(1963) major work "The Seaports Of Great Britain" is a study of eleven separate ports; and in a similar fashion, Alexandersson and Norstrom's (1963) large work, with the misleading title "World Shipping", describes the most important of the world's ports with hardly any attempt to generalise.

With few exceptions, port geographers have been pre-occupied with the uniqueness of ports. This concern is not limited to geographers; Oram (1965,xi), for example, a former dock superintendent with the Port of London Authority, and presently with the United Nations as a Technical Consultant, has put it more bluntly than any geographer has dared:

> "No two ports are alike. The physical layout is determined by geography, the size and importance by the hinterlands they serve".

This pre-occupation with the uniqueness of ports as objects of geographic analysis has many corollaries with the whole of geography twenty years ago. The shortcomings of the idiographic approach have been scrutinised in many recent studies (Wrigley, 1965). Haggett (1965,2) has claimed:

> "Order and chaos are not part of nature but part of the human mind."

It is no coincidence that the recent vigour of several branches of geography has occurred with the refutation of the concept of the uniqueness of geographic phenomena.

There have been few attempts to go beyond the observation and description of the characteristics of individual ports (see Table 1). Many of them have come about as a result of generalisations in urban geography. As the following review will show, practically all the more general studies have concentrated upon the identification of generic relations. There seems to have been an obsession with classification, most of which has not led to higher levels of explanation. It may be noted that classification represents an early stage in scientific analysis.

C. Location.

It is common for port geographies to begin with a description of the locational attributes, site and situation (Hoyle, 1967). Here the natural conditions, such as shelter, depth of water, tides, as well as the port's position relative to the major shipping lanes are analysed. Very frequently the study will trace how these site conditions are modified as port installations are added. The rationale of this approach is that geography is the study of the relationships between Man and his environment. Thus by examining the physical attributes of the port site and their modification by Man, this concept of geography is being fulfilled. However, as Cole and King (1968,13) demonstrate, such a concept of geography is too simple.

This facet of port study overlaps greatly with early urban geography. Taylor (1949,255-8) for example, produced a port classification system based in part upon stage of development, and also upon what he termed 'geological control'. Ports in his system are a type of coastal settlement whose class depends upon the type of physical feature the harbour occupies.

TOPICS

LEVEL OF GENERALISATION	location	function	facilities	hinterland	foreland
Description	Bird	Slack (1963)	Forward (1967)	Camu (1959)	Weigand (1958)
Measurement	X	Rimmer (1966)	X	Shaffer (1965)	Britton (1965)
Classification	Morgan (1952) Taylor (1949)	Alexandersson (1963) Morgan (1952) Carter (1962)	Weigend (1958)	Shaffer (1965) Ward (1966)	Britton (1965)
General Models	X	Rimmer (1967d)	Bird (1963) Solomon (1963)	X	X

TYPOLOGY OF PORT STUDIES

(Selection of authors referred to in the text)

Fig. 2

It is merely a coincidence that Taylor's examples of 'geological control' over ports were drawn mainly from the study area of this dissertation. Taylor was one of the few researchers concerned with ports at the lower end of the size spectrum.

This example from urban geography was followed by Morgan (1952,26-53) in one of the few general works on ports. Morgan too initially classified ports on the basis of their physical characteristics.

TABLE 1

MORGAN'S SITE CLASSIFICATION

Submerged coast	coral ria fiord embayed volcanoes
emergent coast	off shore bar spit
island protected	
fault harbours	
river ports	river estuary delta

Very few urban geographers (Beaujeu-Garnier and Chabot, 1967) are still concerned with classifying cities according to their site and situation, as this taxonomy is most crude, and has not provided the basis for the formulation of further generalisations and hypotheses. Cities have grown to cover more than one site feature, so that to persist classifying urbanised areas on the basis of one characteristic is fruitless. Montreal, for example, could be considered a river town, an island city, a terrace city, or a plains city all at the same time. Similarly the sites of ports are increasingly man-made and multi-featured as extensions are made.

If attempts to classify ports on the basis of their site conditions has little relevance any more, interest in physical attributes should be continued. Changes in ship design and size are placing increased emphasis on shelter, facilities, and depths of water, as ports are attempting to improve their competitive positions. Individual studies (Corley,1959) have shown how the deepening of a channel has revolutionised the trade of a certain port, but we have little idea of the overall influence of the site upon trade totals and functions. This very important gap in the understanding of ports is a result of port geographers pre-occupation with the unique, and their reluctance to embark upon comparative studies.

D. Facilities.

Related to the analysis of site and situation are the descriptions of port facilities. While many are simple descriptions, some of these studies attempt to show how the installations might influence the trade of the port:

> "The length, depth of water alongside, and quayside equipment of the berths available at a port can have a profound impact on the ability of a port to attract a particular type of traffic and particular types of vessel." (Shaffer,1965,35)

Such statements are frequent but remain imprecise assumptions. There has been little positive research in this area. Alexandersson and Norstrom (1963,118) have raised the question of a measure of the optimum capacity of a port:

> "which is a function of quay length and cargo handling facilities".

But they were immediately negative about this interesting measurement:

> "Even if it were possible to calculate port capacity it would be difficult to find a close correlation between capacity and actual cargo flow".

No attempt was made to calculate this capacity and no correlation was tried. The whole statement contradicts the conventional wisdom as expressed by Shaffer.

The studies of the development of port facilities have certain similarities with urban morphological studies, which attempt to trace the extensions of the built-up area and the gradual modification of the "townscape" (Smailes, 1953). This particular aspect of urban geography has been prevalent amongst European geographers. But whereas urban geographers have been content to describe and classify, there are three examples in port geography which go further. Three descriptive models have been produced to explain the development of port facilities.

Zaremba (1962) has produced five possible patterns of growth for a port city and its harbour facilities. He links the patterns of growth to the site features of the city, and herein lies the weakness of the model. Physical growth of the port is not seen as a function of the need to adapt to new cargo handling technology, to new trade patterns, to changes in port function, or to new trends in shipping, but as a determined product of local site conditions. As will be shown later site conditions provide a set of constraints within which many other elements operate.

Two port geographers, Solomon (1963) and Bird (1963), seem to have produced similar models of the development of port facilities.

Solomon,(1963,160) in a study of the port of Hobart, has suggested that:

> "internal port development may be a systematic evolutionary process".

By following the growth of trade of Hobart, and tracing the coincidental development of facilities, Solomon suggests four stages in the growth of a port. Similarly Bird (1963,27-34) introduced a model for 'Anyport', a hypothetical British port which grows in six stages. As the table indicates the differences between the two models is Bird's inclusion of a stage of dock construction (which is more characteristic of European ports), and his greater elaboration of recent refinements in harbour construction.

Hoyle (1968) has attempted to apply Bird's model to the development of four East African ports. He was able to find some similarities between 'Anyport' and the ports in East Africa, but it is interesting to note that Solomon's model (which Hoyle was not aware of), seems to be the most applicable.

The fact that in three completely different parts of the world, similarities in the evolution of port facilities have been uncovered, suggests that once port geographers begin to seek order, other regularities will be encountered. Bird(1963,417), himself, suggests why ports should reveal certain similarities of form:

> "There is one main reason why major ports should show similar features of layout, arranged in different ways, even if they grew up independently on widely different sites. All ports serve the same world fleet of shipping, or similar cross-sections of it, with the result that they have the same incentives to provide terminals of similar dimensions and capacities".

TABLE 2

STAGES IN THE DEVELOPMENT OF FACILITIES

BIRD	HOYLE	SOLOMON
I PRIMITIVE	I DHOW	I LIGHTERAGE
II MARGINAL QUAY EXTENSION	II PRIMITIVE	II MARGINAL WHARVES
III MARGINAL QUAY ELABORATION	III MARGINAL QUAY EXTENSION	III FINGER PIERS
IV DOCK ELABORATION	IV SIMPLE LINEAL QUAYAGE	IV FINGER PIERS TO MARGINAL WHARVES
V SIMPLE LINEAL QUAYAGE	V SPECIALISED QUAYAGE	
VI SPECIALISED QUAYAGE		

E. Function.

A major concern of port geography has been the analysis of trade patterns. Most studies describe the cargo types and the volume of trade, and try to assess the relative importance of each over a certain period of time. Such studies have led to attempts to determine the function of the port in terms of the types of trade carried on.

Alexandersson and Norstrom(1963) identified two types of ports on the basis of function: general ports, and specific ports. The distinction between them being that general ports handle many types of cargoes, while specific ports ship one commodity only. This is a gross oversimplification, and is another example of a classification of marginal utility. Morgan's (1952,70-79) functional classification based itself on both type of commodity and type of vessel. He identified twelve classes of port: Naval, Fishing, Ferry, Bunkering, Transshipment, Entrepots, Free Ports, Outports, Coastwise, Tramp, Tanker, and Liner.

It is felt that this classification system was produced intuitively. While each group can be justified, the total picture is confusing, not only because many ports tend to be multi-functional, but a port even handling only one type of cargo and accommodating one type of vessel could fall into more than one of Morgan's classes. Thus to refer to the study area, the port of Rimouski receives gasolene from Montreal in large tankers. It is then transshipped to smaller vessels for distribution to other ports in the region. This one function of Rimouski would make it a Transshipment Port, a Coastal Port, and a Tanker port in Morgan's system of functional classification.

A more successful classification has been produced by Carter(1962), which was based upon empirical comparison of a number of features of ports in the United States. Carter selected six attributes: total tonnage, types of commodities, type of traffic (foreign, coastwise, lake, local), balance of trade, variety of commerce, and value of foreign commerce. A number of interesting generalisations were recorded and a six-fold classification of ports was devised. Carter recognised ports associated with petroleum refining, ports associated with the manufacture of steel, ports associated with mining activities, ports which serve as petroleum terminals, ports which transfer bulk products, general cargo ports, and ports which embody two or more of these functions. Although this is probably the best functional classification system available, its limitation is that there is no intrinsic difference between the first five groups, as they include ports which handle bulk commodities. However Carter's work represents one of the few attempts in port geography to compare a system of ports. In contrast, other researchers have selected ports from all over the world as examples to fit their classifications.

Similarities between port functional classification and urban classifications (Murphy,1966) may be drawn. Indeed the port city is one type of urban functional class recognised by many urban geographers. Whereas commodities handled and types of vessels have been used to define port functions, urban functions usually have been based upon employment groupings. In general, urban functional classifications have been more successful because of a greater consistency in choice of differentiating characteristics. Like ports, most urban taxonomies have been concerned with the identification of single functions. However recent approaches to the problem have utilised mutivariate statistical techniques, that allow a wide range of urban attributes to be considered. Perhaps the most outstanding example of this is Moser and Scott's (1961) principal components analysis of 157 cities in England and Wales, where 57 socio-economic characteristics were collapsed into 4 components which then served as a basis for classification. Similar approaches have been followed by Hadden and Borgatta (1965) in a study of American cities, and by King (1966) in a study of Canadian urban dimensions. No such multi-factored and multi-functional studies have been attempted in port geography.

Because port functional classifications are so weak very little is known of the relationships between function and other elements. C. N. Forward (1967) has tried to link recent changes in the function of the port of St. John's, Newfoundland, to the redevelopment of port facilities there. Slack (1963) has attempted to relate facilities to function and neighboring land use in the port of Montreal. Shaffer (1965) has tried to explain the greater functional importance of Durban, as compared with Lourenco Marques, East London, and Port Elizabeth, to its superior handling facilities. There are many other examples, but because all these studies are descriptive and deal with individual cases, no generalisations have been possible.

F. Hinterland.

Concern with trade patterns has led port geographers to examine the origin and destination of the cargoes handled. The delimitation of the hinterlands of ports seems to have been a major research field. In fact, from the literature it would appear that hinterland study is the most important aspect of port geography:

> "The geographical analysis of a seaport or group of seaports is impossible without reference to the concept of hinterland". (Hoyle,1967,76)

Attempts to delimit the hinterlands of particular ports have been numerous, but no well developed procedure has emerged. The complexity of the patterns produced has created problems of accurate delimitation. In very few parts of the world has it been possible to define discrete hinterlands, as there is normally a considerable overlap between them. Shaffer (1965,142) has suggested a three-fold division of hinterlands: a) the immediate environs, clearly dominated by the port city in all aspects of economic life; b) the umland, including, the immediate environs, the region trading almost exclusively with the port; c) the competitive hinterland, that area for whose trade more than one port is competing.

If the hinterland is complex spatially, it is further complicated structurally. As Hoyle (1967,5) has noticed there will be different hinterlands for each of the products:

> "It is more accurate to speak of many individual hinterlands (for example the coffee hinterland of Mombassa, or the sisal hinterland of Tanga) rather than one composite hinterland which in fact may not mean a great deal".

Patton (1961) has shown that the size and shape of the hinterland differs according to whether the product is exported or imported.

Two recent studies have attempted to provide a more analytical framework to hinterland study. Ward (1966) has compared 'hypothetical' hinterlands (points equidistant between ports on the basis of road and rail mileage and cost) with the 'empirical' hinterlands of three Malayan ports, Singapore, Penang, and Port Swettenham. The residuals were then examined and found to be associated with the better quality of transport links and superior port facilities of Singapore. A similar approach was outlined by Rimmer (1967a) in a study of the ports of New Zealand.

This type of approach has been carried one step further by Shaffer (1965,223) who not only identified the natural (equivalent to Ward's hypothetical), and traffic (equivalent to Ward's empirical), but the theoretical hinterlands of the ports of Durban, Lourenco Marques, East London, and Port Elizabeth. The theoretical hinterlands were based upon a gravity model formulation, similar in form to Reilly's law of retail gravitation. He found that the mean deviation between the theoretical and the traffic hinterlands was 50 miles. Unfortunately this interesting line of inquiry was not pursued further by Shaffer and thus the applicability of the gravity model to hinterland delimitation requires much further investigation.

It has been traditional to recognise the hinterland area as a 'field', a territory with fixed boundaries. More recently, however, there has been some criticism of this concept. Robinson (1970) suggests that most hinterland areas are made up of discrete production and consumption points, each linked to the port by commodity flows. This criticism is valid only where a small range of commodities are handled and/or where production points are factories or mines. Many ports handle a wide range of goods, so that superimposition of all production and consumption points frequently reveals a hinterland comparable with a 'field'. Furthermore many commodities handled by ports, agricultural produce, consumer goods for example.

The concern of port geographers with delimiting hinterlands is mirrored in the problems of defining goegraphical regions and urban fields. Unfortunately, advances in the delimitation of hinterlands have not furthered understanding of the relationships between hinterlands and port development. The traditional hinterland study has emphasised differences between ports at the expense of the development of comparisons and generalisations.

G. Foreland

The counterpart of the hinterland is the concept of foreland which was developed by Weigend (1958,185). This refers to:

> "the land areas which lie on the seaward side of the port ..... and with which the port is connected by ocean carriers".

Although this has become an accepted aspect of port study, there have been few detailed analyses of forelands. In a study of the forelands of the port of Melbourne, Britton (1965,109) remarked:

> "From the literature it would appear that forelands and the external relations of ports have been relegated to a secondary place in research, and have not received the same amount of attention that has been given to port hinterlands".

Britton applied several quantitative measures, originally developed in industrial location and industrial structure studies. He employed the location quotient, the index of concentration, and the coefficient of specialisation to reveal trade linkages between the port of Melbourne and other countries. Use of these measures permitted precise description of the forelands of the port.

H. Ports in the Broader Field of Transport Studies.

Although ports are important break of bulk points, they have played a small role in most transportation studies outside of the specific field of port geography. Most recent research in transportation has focussed on networks and flows. Network analysis has employed Graph Theory to provide descriptive measures and assist the investigation of land transport routes (Kansky,1963). Flow studies have sought explanations of size of interactions by employing input-output techniques, (Leontief and Strout,1963) gravity model formulations (Olsson,1965), and linear programming (Cox,1965). A feature of these flow studies has been the concern of measuring interaction between terminal points, and ports as intermediate centres have been ignored. Urban transport has been a particularly active research field, where studies of mixed mode journeys and trip generation have produced abstract statistical models of the journey to work (Wilson, 1968).

Port geography could benefit greatly by employing several of the techniques and concepts of transportation research. The findings of commodity flow studies, in particular, are very relevant. Port geographers have tended to see cargo flows in two separate stages, as movements between hinterland and port, and port with port. It is important to recognise that cargo flows extend beyond destination ports, so that the two ports involved in any commodity movement represent intermediate transfer points only. Several recent port studies (Robinson,1970; Elliott,1969) have recommended that the traditional hinterland-foreland dichotomy should be recognised as a continuum.

Transport studies have also revealed the importance of decision making and corporate organisation in explaining through transport systems. Flows between intermediate points may be determined by corporate decisions that are influenced by the ultimate destination of the commodities. Thus the final destination of goods may determine the selection of both route and transport mode at any particular stage.

Route and mode selection decisions will frequently involve long term investments in carriers and terminal facilities. Such decisions may stabilise patterns of flows for many years, despite subsequent changes in transport technology and the opening up of new route and mode alternatives. Long term effects on commodity flows are characteristic of decisions made by vertically integrated corporations engaged in transfers of bulk commodities such as petroleum.

A very good example of this is provided by the case of crude oil received at Canada's largest refining centre, Montreal. The refining complex in Montreal is dependent entirely upon crude oil imported from the Middle East and Venezuela. Although it is cheaper to ship the crude directly to Montreal by tanker, most of the oil is received by pipeline from Portland, Maine. The decision to build the pipeline was made because of the impossibility (at least until a few years ago) of maintaining supplies of crude through the winter because of ice in the St. Lawrence. The investment by the oil companies in the pipeline was so great that its continuous use is necessary, even through the St. Lawrence shipping season, when the companies could theoretically import oil at cheaper rates by tanker.[1]

It would appear that economists too have been concerned with ports as unique objects. Many of the world's major ports have been subjects of empirical research by economists employed as consultants. More general studies in economics literature have dealt with pricing problems, means of determining freight rates and terminal charges, and with topics such as conferences. (Bennathan and Walters,1969; Goss,1968)

A number of works by economists, however, are much more relevant to port geography. Goss (1967) and Heaver (1968) have produced studies examining the relationships between vessel size and type, and port efficiency. Recently, Johnson and Garnett (1971) have published an excellent survey of the influences of containerisation on ports. These studies are important

[1]Personal communication Imperial Oil Co.

to port geography because explanations of port activity and port evolution hinge upon an understanding of such relationships.

I. Comparisons with Urban Geography.

An attempt has been made in this review to relate the main topics in port geography to the broader field of urban-economic geography. However, the similarities in concepts and subject matter that have been noted are not characteristic of recent research in urban geography. Comparisons between port geography and contemporary urban geography are not possible. Urban geographers are no longer concerned with the descriptions of individual 'sites' and 'situations', but with spatial patterns and regularities. As indicated already, multi-functional classifications and their spatial properties are analysed. Function has been related to size in the analyses of hierarchies. Urban geographers are no longer describing morphologies but are involved in understanding processes of urban growth and internal structure. Some have turned to monte carlo simulation models to provide methods of analysing developing patterns of internal land use and developing systems of cities. Even studies of transport centres have changed, for as Berry (1966 p.408) has noted:

> "The traditional study of the city performing functions at intermediate transport locations has almost vanished (except for port studies). It has been replaced by studies of the relationships of systems of cities and entire transport networks".

Two factors can be isolated as causes of this dynamic change in urban geography. Of paramount importance was the Central Place Theory of Christaller (1966), a general deductive theory of the locational pattern and structure of service centres. It has been important because it sought to explain the relationships between size, spacing and function of cities. It has encouraged urban geographers to leave their descriptive and taxonomic studies, and turn to consider the structure and spatial patterns of whole systems of cities, and, in particular, to identify and measure the relationships between the various attributes of that system.

Simply because of the stimulus it has provided, without commenting on its intrinsic qualities, Christaller's contribution to urban geography must be acknowledged as being without precedence. Central Place Theory has given urban geography a frame of reference. Individual studies can test and enlarge upon a particular aspect of the theory in different study areas. Port geographers are operating in a conceptual vacuum by comparison. Clearly they need such a catalyst.

The "quantitative revolution" (Burton,1963) has complimented Central Place Theory. The application of statistical analysis to urban geography has been important in four ways: i) it has permitted improved descriptions and measurement of urban attributes; ii) it has enabled hypotheses to be tested objectively; iii) it has allowed geographers to weigh the multivariate relationships between geographic phenomena, which could only be alluded to in earlier studies; iv) it has provided analytical techniques which have thrown new light on problems and opened up new avenues of research.

J. Conclusions.

It has been shown that port geography has not developed very far. With a few notable exceptions, even the most recent studies are still concerned with the description of individual ports. Attempts to generalise have been mainly in the field of classification, with taxonomies of site, facilities, function, and hinterland. As Ackerman (1958) has indicated, however, the identification of generic relations represents a very early step in geographic analysis. In only two areas of port geography have there been higher levels of generalisation. The genetic models of port facilities produced by Bird (1963) and Solomon (1963), and Rimmer's (1967d) attempt to produce a model of port development (which will be reviewed in detail in Chapter V) are the only general models that are available.

The implications are clear. The only way for port analysis to develop further is to follow the conceptual and methodological changes of the rest of urban geography. Relationships between various attributes of ports must be investigated, and there is a real need to promote model building. In one way, geographers must lower their sights if they are to accomplish these goals. Most studies have focussed upon the largest ports in the world, which are complex in their locational and functional attributes. The major conceptual advances in urban geography have come from studies of relatively simple areas: southern Germany (Christaller,1966), Iowa (Losch, 1954), Washington State (Berry and Garrison,1958), and Middle Sweden (Hagerstrand,1952).

The advantage of selecting such regions is that it is possible to hold constant many variables, thereby facilitating recognition of essential patterns and processes.

It is hoped that the dissertation can build upon these conclusions. The study goes on to select a comparatively simple set of ports in eastern Canada, and endeavours to investigate various measures of port size, function, location, and morphology. It then examines the relationships between these attributes and variables such as hinterland, facilities, and foreland. From the analysis of these relationships it is hoped to develop a model of port evolution.

CHAPTER TWO

DATA COLLECTION

A. Introduction.

This chapter outlines the reasons for the selection of the study area, and describes the sources of data. Some of the basic problems encountered in data collection are reviewed to provide a perspective on the reliability of the information processed in the thesis.

B. Selection of the Study Area.

As the problem formulated in this dissertation is the identification of patterns and processes of considerable complexity, and because the review of the literature exposed some of the problems of dealing with large ports, it was considered necessary to select a simple area. Simple in terms of its economic structure, with relatively low levels of economic development and urbanisation, so that relationships between hinterlands and port activity could be explored, and simple physically, so that no great breaks of coastline would occur to add complexity to the analysis of patterns of location. Furthermore, it was held to be advantageous for the region to be relatively accessible to Montreal, so that frequent visits could be made to the ports as the needs arose to observe, measure, and interview.

At first all the ports in Quebec were considered, but with over fifty ports serving the province, it was apparent that there were far too many complex ports to be handled with the limited resources at hand. It was decided, therefore, to select some sub-set of the total set of ports in Quebec. The ports on the St. Lawrence River above Quebec City were too varied and large for the type of analysis envisaged. The ports on the Quebec North Shore seemed appropriate because they included a manageable range of sizes and types, and were developing very rapidly. However, the irregular nature of the coastline, especially the Saguenay River, diminished the attractiveness of that area. The section which appeared to meet the specifications most fully were the ports on the south shore of the lower St. Lawrence River (see Fig.3). Accessible to Montreal, serving an area which is simple economically, and located on a coastline remarkable for its uniformity and lack of breaks, the ports in this region were selected for analysis. The fact that the ports are small was considered to be an important advantage in examining the types of problems posed in this dissertation.

C. Data Collection.

It became apparent within a short time of having selected the study area that there would be problems in gathering data and in finding background studies of the ports. The smallness of most of the ports in the study area has resulted in their neglect both by other researchers and by the data gathering agencies. In terms of recent background information only three studies of the south shore of the lower St.Lawrence region have alluded to port development. Pépin's (1962) excellent survey of the region included a brief sketch of the problems of the ports. Camu's (1960) monograph is surprisingly restrictive, as he examined three ports only, Rivière du Loup, Matane, and Rimouski. In a similar way the

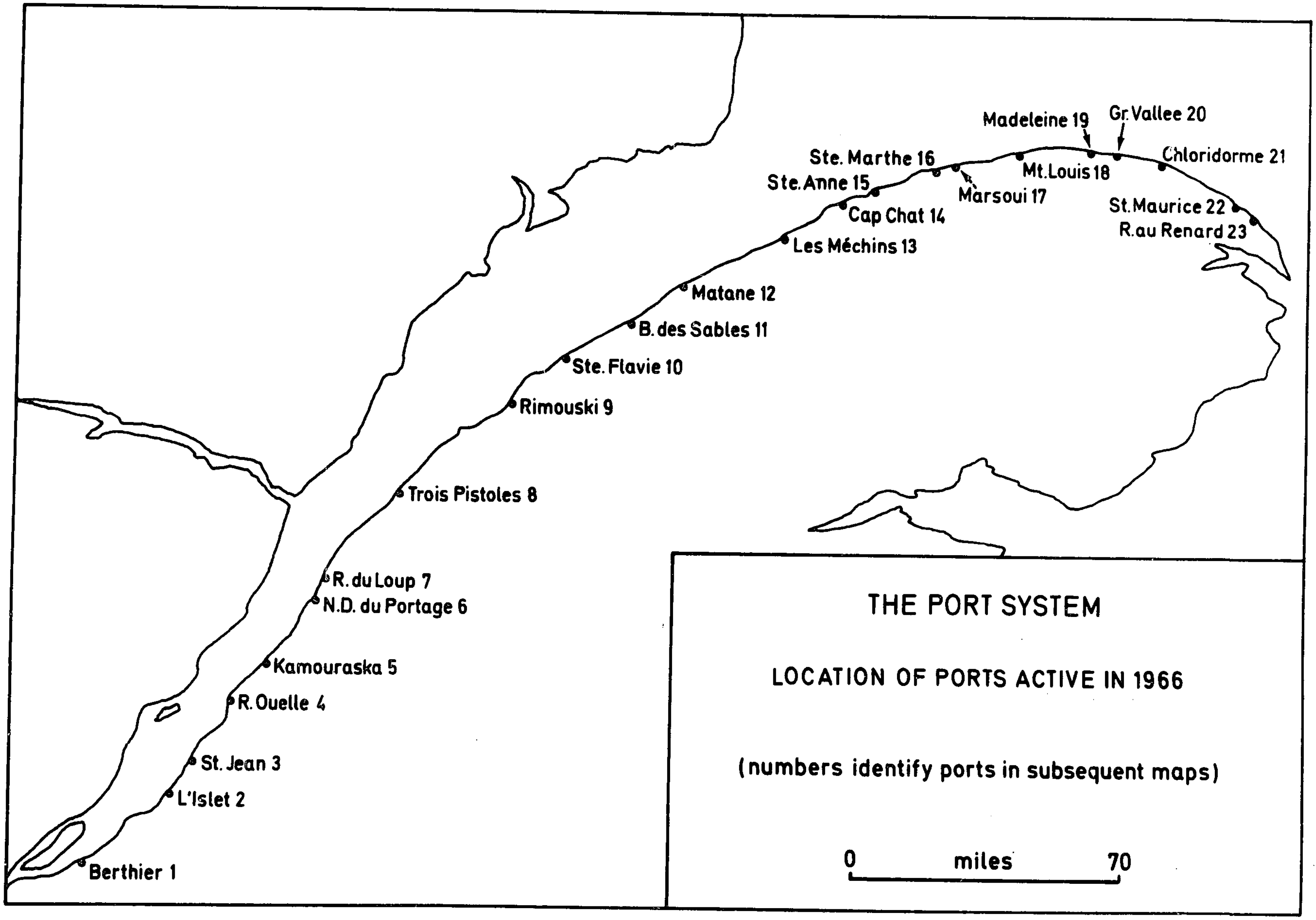
THE PORT SYSTEM
LOCATION OF PORTS ACTIVE IN 1966
(numbers identify ports in subsequent maps)
0 miles 70
Berthier 1
L'Islet 2
St. Jean 3
R. Ouelle 4
Kamouraska 5
N.D. du Portage 6
R. du Loup 7
Trois Pistoles 8
Rimouski 9
Ste. Flavie 10
B. des Sables 11
Matane 12
Les Méchins 13
Cap Chat 14
Ste. Anne 15
Ste. Marthe 16
Marsoui 17
Mt. Louis 18
Madeleine 19
Gr. Vallee 20
Chloridorme 21
St. Maurice 22
R. au Renard 23

Fig. 3

B.E.A.Q.(1965) massive investigation into the social and economic problems of the Gaspé peninsula merely described the facilities and trade of these same ports. Because of the restricted coverage of these studies, their usefulness to this research has been minor.

Similar problems were encountered in obtaining data. From the review of the literature it was apparent that two sets of data would have to be assembled:- the first dealing with measures of the characteristics of the ports themselves (attributes), the second representing factors that might explain the patterns presented by the attributes (independent variables). In the case of measures of attributes, the Dominion Bureau of Statistics is the major source in Canada. Volumes II and III of the annual Shipping Reports list measures of port activity in Canadian ports. While these reports give a wide coverage, the activities of half the ports in the study area are omitted in most years.

Fortunately D.B.S. made available their primary source of data - the reports submitted by ships captains or shipping agents. Each time a ship calls at a Canadian port the law requires that details of the dimensions of the ship, and of the types and tonnages of cargoes loaded or unloaded, with ports of origin or destination be submitted to D.B.S. The Water Transport section of D.B.S. keeps the forms, each one representing the movement of one ship in one port, for a period of three years, after which they are destroyed because of problems of finding storage space.

For the three year period, 1965-7 therefore, very detailed data were obtained on all the ports in the study area. Tonnages and types of cargo, plus details on the movement of every ship in the ports were catalogued. D.B.S. could not furnish such a complete set of data for the years prior to 1965 and the published Shipping Reports exclude approximately half the ports. Faced with the absence of data that could allow a study through time, alternate sources were sought. Questionnaires sent to various government departments revealed that a very useful source of data was located in the House of Commons. Each year the wharfage revenues generated in Canadian ports are tabled in the House, and are kept in the Sessional Papers Office. These totals represent the amounts of money collected by wharfingers or harbour masters in each port in Canada. These lists were consulted and information on port activity in the study area for the period 1951-66 was obtained.

Field work was undertaken in the late summer of 1968 and during 1969. One of the aims of the field work was to gain a general impression of the operation of each port. All of the types of vessel using the ports were observed and cargo handling methods recorded. Some of the basic problems of the ports became apparent, and certain hypotheses tested in Chapter IV were formulated during this period. Although the field work permitted the general form of port facilities to be noted, accurate measurements of the dimensions of the harbours and facilities had to be derived from published sources. The St. Lawrence Pilot of 1966 was found to be an extremely useful source of this information, besides providing details of currents and tides.

Fieldwork was also directed at delimiting the boundaries of the hinterlands of the ports. This task was accomplished in a variety of ways. Wharfingers and harbour masters in each port were contacted and asked to indicate the municipalities providing the port with trade. In addition, formal questionnaires[2] were mailed to the shipping agents engaged in the transfers of pulpwood. Thus lists of municipalities providing cargoes for each of the ports in the study area were obtained. The boundaries of the hinterlands were drawn from these lists.

Delimitation of hinterland boundaries proved to be a comparatively uncomplicated task, but it must be realised that this aspect of data collection represents one of the areas where errors are most likely to be encountered.[3]

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[2]See Appendix B for a sample questionnaire.

[3]Refer to Table 3. The table summarises the major sets of data used, and provides a subjective evaluation of data reliability.

TABLE 3

DATA SOURCES AND RELIABILITY

	VARIABLE	MEASUREMENT SCALE	SOURCE	RELIABILITY	COMMENTS
PORT ATTRIBUTES	cargo tonnage	ratio	D.B.S.	high	
	cargo type		D.B.S.	moderate	lack of precision in class-type definitions e.g. general cargo
	vessel tonnages	ratio	D.B.S.	high	
	vessel numbers	ratio	D.B.S.	high	
	wharfage	ratio	House of Commons	high	
HINTERLAND	population totals	ratio	Census	high	
	agricultural activity	ratio	Census	high	allowing for errors delimiting hinterland boundaries
	manufacturing	ratio	Scott's	moderate	
FACILITIES	extent	ratio	St.Lawrence Pilot	high	
	quality	ratio	D.P.W.	high	
VESSELS	numbers	ratio	D.B.S. and	high	
	tonnages	ratio			
	types	ratio	L'Association des Propriétaires de Navires du St. Laurent Inc.	moderate	lists only the vessels of members
FORELANDS	number of ports trading with each port in the study area	ratio	D.B.S.	high	

Most of the other sets of data are based on primary or secondary sources of considerable reliability. However, it is claimed that errors in delimiting hinterland boundaries have been minimised if only because of the simplicity of the trade patterns of most of the ports.

The Department of Public Works is very evident in the ports in the study area. It is called upon to maintain existing wharves and construct new facilities. In the regional office in Quebec City the files of the department were made available, and from them emerged the picture of the extent of government financial support for the ports in terms of harbour construction, maintenance, and dredging.

The Census of Canada provided data on the economy of the hinterland region. Variables representing population totals and agricultural activity were obtained from this source. However, the lack of coverage of industrial activity at the scale required in either the D.B.S. Census of Manufacturing or the Census of Canada resulted in the use of the less reliable and complete Scott's Industrial Directory of Quebec (1966). Other non-traditional sources of data, including yearly totals of numbers and types of ships, were derived from publications such as the annual reports of L'Association des Propriétaires de Navires du St.Laurent Inc.

D. Conclusion.

The search for data and background information cast a net over a wide spectrum of sources. With one or two notable exceptions it is claimed that these sources have produced data of considerable reliability. This study has benefitted in particular from the very complete set of shipping data obtained from primary D.B.S. sources. The investigation now goes on to examine the patterns presented by the data.

CHAPTER THREE

MEASUREMENT AND THE SEARCH FOR ORDER

A. Introduction.

This chapter describes four important attributes of a system of ports. Size, function, location, and morphology have been selected because they assume distinct geographical dimensions. As very little attention has been given to the problems of measuring these attributes, an important aspect of this section is the evaluation of a number of measures on practical and theoretical grounds.

The central theme of this chapter is the search for order. If this study is to escape from the tradition of uniqueness, basic regularities of these attributes must be identified. Without such regularities being uncovered, general explanations will be impossible.

B. Size.

The question of selecting suitable criteria for measuring port activity and comparing sizes has perplexed many port geographers. (Bird, 1963,21; Alexandersson and Norstrom, 1963,118). Although the problem of measurement is widespread in other spheres of economic geography, here the difficulties have never been fully resolved, despite the fact that tonnage of cargo appears to be the one measure that has achieved most widespread usage.

Port geographers are confronted with a large number of possible criteria to measure port size. As mentioned already, tonnage of cargo is the most widely used measure, but number of vessels, net registered tonnage of ships, value of commodities, and number of commodities have been suggested also. In the following section the relative advantages of each will be examined from a practical and a theoretical point of view.

1. Number of vessels.

As a port may be defined as the point where commodities are transferred to and from vessels, the size of a port could be determined by the extent of vessel traffic. It may be recognised that large ports attract and accommodate more ships than small ports. Moreover, from a practical standpoint this measure is attractive because data on shipping totals are readily available.

Despite its apparent advantages, a measure of port size based on vessel totals is limited in its usefulness. In some ports the total number of ships is grossly inflated because of a ferry service. A regular and frequent ferry service will destroy the validity of comparisons based on this measure where some ports lack a ferry. The solution most frequently employed is to exclude ferry services from totals, a procedure that was followed in this study.

A more severe limitation is that variations in vessel size are increasing as a result of the growth in the number of super tankers. Thus a simple count of ship numbers may inflate the importance of some small ports which exclusively accommodate a large number of small vessels of limited carrying capacity, whereas another port served by fewer but much larger ships may handle more trade.

2. Tonnage of vessels.

Morgan (1952,16) has suggested that the use of net registered tonnage of vessels is an appropriate measure of port size. Net registered tonnage refers to the cargo carrying capacity of a vessel, with the net ton being equivalent to 100 cubic feet. Morgan's argument was that it applies to all classes of traffic - tanker, freighter, passenger liner, and barge. Furthermore it is a measure that is easily obtained from published data sources.

However, Morgan overlooks the twin practical limitations that net registered tonnage totals can be exaggerated by ferries, in the manner described above, and in no way indicates actual trade. The same vessel calling at two ports may unload or load much larger quantities of cargo at one, yet both ports would appear to be equal on the basis of net registered tonnage totals.

3. Tonnage of commodities.

This value is the most easily obtained and the most widely used measure of port activity. Alexandersson and Norstrom (1963,118) state:

> "The size of a port is measured by tonnage of cargo just as naturally as the size of a city is measured by the number of its inhabitants".

Most of those geographers who have examined the problem of measurement agree that this is the most useful measure of port size.

Despite its widespread acceptance, this measure presents one major conceptual difficulty. Cargo tonnages represent the summation of tonnages of a large number of different types of goods. It is as if in agricultural geography comparisons of livestock farms could be made by use of animal totals (which is the larger farm, one with 100 steers or one with 100 chickens and 5 geese?). The same predicament is faced here. It is impossible to compare cargo tonnages when they represent totals of different types of commodities. It would appear that very few port geographers have appreciated this. In practice it is represented by the difficulty of comparing ports which handle large quantities of bulk commodities that can be shipped by relatively few large vessels, with other ports handling a wide range of general cargoes carried by freighters. A good example of this problem is the case of Sept Iles, the major iron ore port on the Quebec North Shore, which by cargo tonnage is equal in importance to Montreal, but by any other criterion is far inferior to, the port of Montreal.

4. Value of shipments.

Conceptually this is the most satisfactory of all the measures. Generally speaking high value commodities generate more income and employment in the port city than low value bulk cargoes.[4] Comparisons based on value of shipments are likely to be meaningful therefore. Unfortunately, this measure is not always available. In Canada this measure is not published at all. Consequently, this study substitutes 'wharfage', the charges levied by the Federal government at each port, and which depend upon the size and type of shipment. Wharfage rates are much higher for high-value goods than bulky raw materials.

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4 An exception would be where the handling of bulk commodities leads to the establishment of processing industries in the port city such as flour mills and oil refineries.

5. Number of commodities.

Evidence from other studies appears to indicate that large ports handle a wide range of commodities. It could be hypothesised therefore, that the bigger the port the more diverse its trade. Number of commodities (regardless of tonnage) appears to be an attractive measure.

In the research a practical limitation of this measure was uncovered. The Dominion Bureau of Statistics gathers data from shipping agents or ships captains who are obliged to submit details of the ship and the cargo transferred at each port of call. Both the type and the tonnage of the cargoes loaded and unloaded are supposed to be itemised. Many respond giving as much detail as possible, but a number of the reports unfortunately do not specify commodities beyond the broad class of "general cargo". For some ports therefore, a true picture of the range of cargoes handled is not available which means that a clear indication of the nature of the trade is obscured, and the reliability of this measure may be questioned.

Only Rimmer (1966) has attempted to assess the performance of a number of measures. Using data from New Zealand he intercorrelated five values. A similar procedure was followed for the ports in the study area, see Table 4. Both matrices are remarkably similar. It would appear that all measures are effective, especially wharfage, tonnage of cargoes, and tonnage of vessels. The question remains how representative are both study areas? In neither are there the large bulk ports that could have introduced complications.

TABLE 4

COMPARISON OF CORRELATION MATRICES OF PORT ATTRIBUTES IN THE GASPE AND NEW ZEALAND.

1. South shore of the lower St. Lawrence.

	(a)	(b)	(c)	(d)	(e)
(a)number of commodities	1				
(b)tonnage of cargo	.73	1			
(c)tonnage of vessels	.85	.91	1		
(d)number of vessels	.60	.89	.81	1	
(e)wharfage	.76	.87	.88	.82	1

correlations > .53 are significant at the 99.5 % confidence level.

n = 23

2. New Zealand.

	(a)	(b)	(c)	(d)	(e)
(a)number of commodities	1				
(b) tonnage of cargo	.80	1			
(c)tonnage of vessels	.77	.93	1		
(d)number of vessels	.80	.94	.82	1	
(e)maximum draught	.70	.64	.73	.68	1

n = 26

Source: Rimmer (1966,83).

With the evidence that wharfage is as good a measure as any other in the study area, it has been selected as the prime measure of port size. It was chosen because it does not present the conceptual difficulties of cargo tonnages, and because it was the only attribute of port size that could be obtained for all the ports in the study area for a twenty year period. A complete coverage of the other measures was found to be unobtainable for the years prior to 1965.

In examining the system of ports it is apparent that there is considerable variation in the size of individual ports. Rimouski is clearly the largest port, generating a wharfage total of $97,087 in 1966, while at the other end of the size spectrum, St. Maurice de l'Echourie produced a mere $116. As Fig.4 shows, the frequency distribution is positively skewed, indicating a large number of small ports with relatively few large ones.

The nature of this frequency distribution suggests certain analogies with urban size distributions, where small centres greatly outnumber large cities. Urban geographers have attempted to fit this size distribution to the so-called rank size rule:

$$Pn=P1(n)^{-1} \qquad (1)$$

Berry (1961) has suggested that the rank size rule be viewed as a lognormal distribution(1), and in a study of 4,187 cities drawn from a sample of thirty-eight countries identified three groups of city - size distributions. Thirteen countries had a log-normal (rank size) distribution; fifteen were characterised by primate distributions, where the highest ranked cities were much larger than those ranked lower; the remaining countries possessed intermediate distributions.

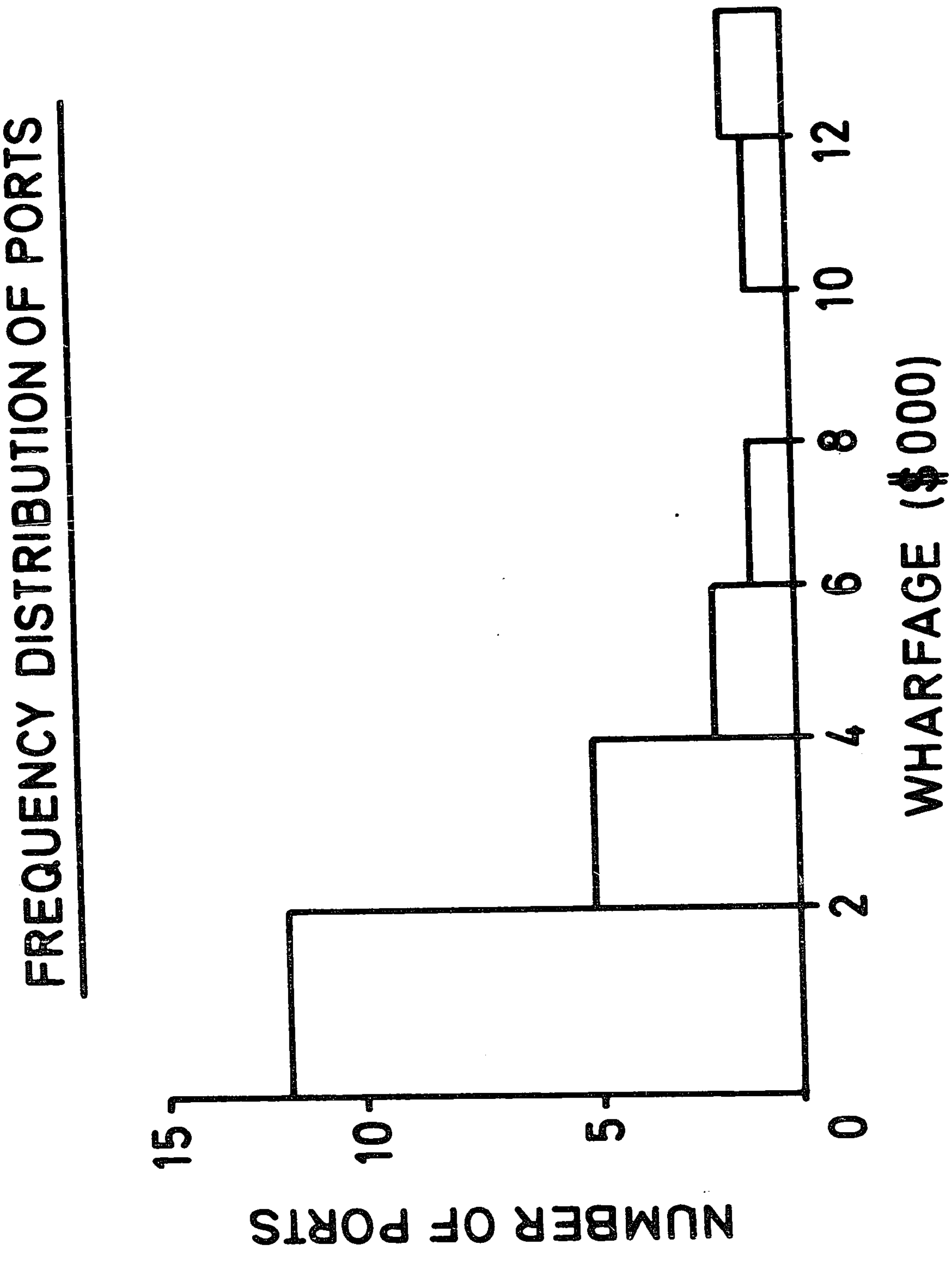

FREQUENCY DISTRIBUTION OF PORTS
NUMBER OF PORTS
0
5
10
15
WHARFAGE ($000)
2
4
6
8
10
12

Fig. 4

The size-distribution of the ports in the study area presented in Fig.5 substitutes wharfage for population. Although the number of observations in the sample is much smaller than Berry's, and interpretation becomes quite tentative therefore, it may be observed that the rank distribution is markedly primate. Rimouski is the leading port by far, but a slight trend towards assertion of a log normal distribution can be seen in the middle range of ports. Berry claims that primate urban patterns occur in countries that are either small, have a short history of urbanisation, or are economically simple. It is interesting to speculate on the applicability of Berry's hypotheses of urban primate patterns to the strongly primate port structure in the study area. The south shore of the lower St. Lawrence is undoubtedly an underdeveloped part of Canada, whose economic structure is dominated by a few primary industries. Furthermore, like many of the countries with a primate urban pattern such as Portugal and Austria whose principal cities serve areas larger than their local city hierarchies, Rimouski serves an area much larger than the south shore region. The ports in the study area represent a sub-system of the much larger system of ports on the entire St. Lawrence River, with Rimouski as the main link.

The implications of the port-size rank distribution will be examined in greater detail in Chapter V. There an attempt will be made to relate the form of the distribution to the steady state of an open system.

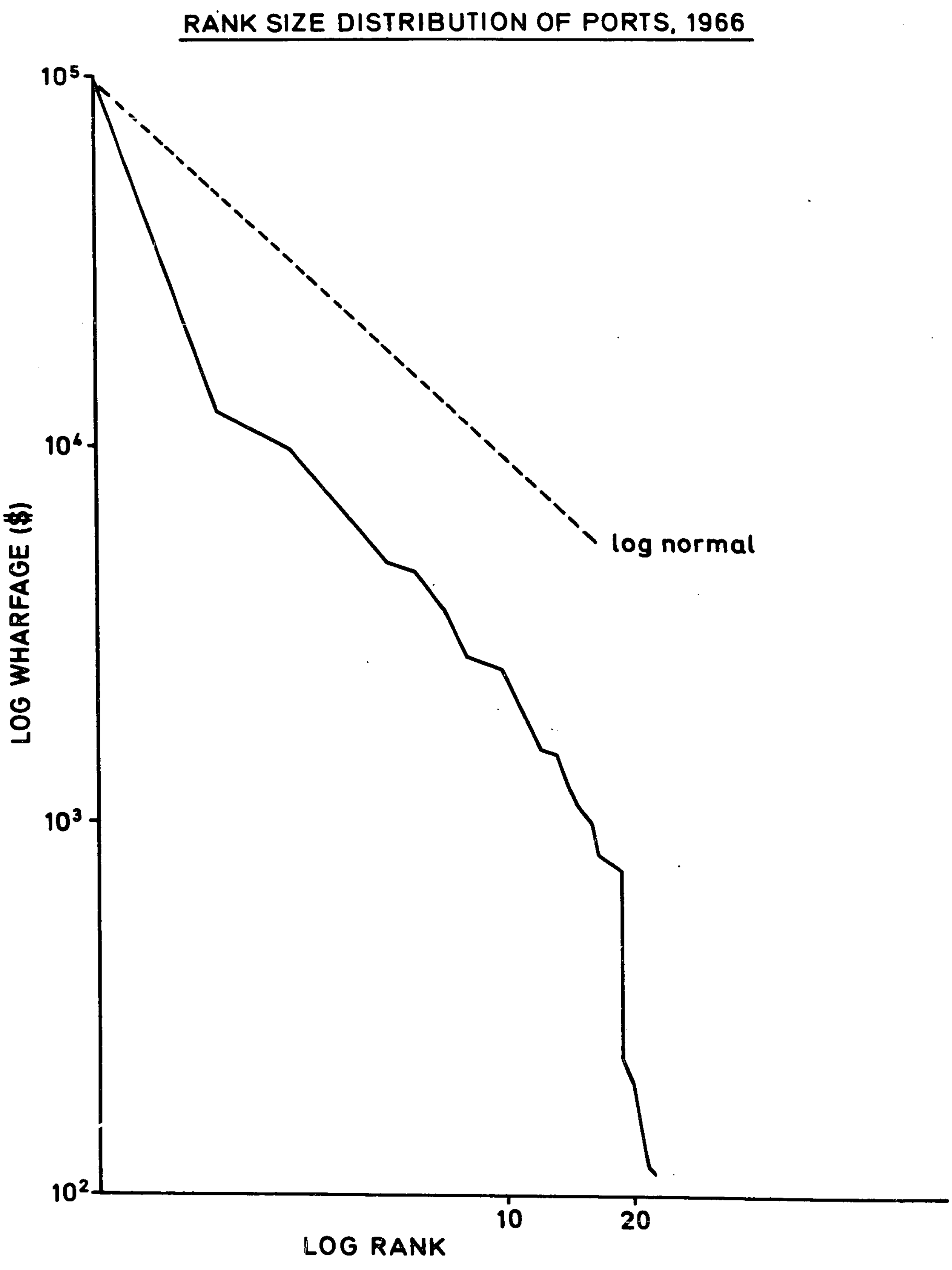

RANK SIZE DISTRIBUTION OF PORTS, 1966
10^5
10^4
10^3
10^2
LOG WHARFAGE ($)
log normal
10
20
LOG RANK

Fig. 5

C. Function.

Functionalism has been used quite extensively in geography as a form of explanation (Harvey,1969). In port studies, analyses of function have nearly always been used to define class types in taxonomic studies. It has been demonstrated that functional classification systems have had little explanatory power as they represent an early stage in the search for processes of port development.

Three related reasons for the lack of success of port functional studies are presented here. In most instances classification has been an end in itself, with no concern for designing taxonomies that might serve as bases for further generalisations. Secondly, all classifications concerned with port functions have depended upon type of cargo as the differentiating characteristic. Yet knowledge that port x is an ore port reveals very little, and there are great variations and differences between ore ports. Finally, port functions have not been related to size or importance. There have been no attempts to measure port importance as in the central place hierarchy.

Despite the lack of success of port functional studies, it is felt that analyses of function are very important to the task of deriving deeper understanding of the organisation and development of port systems. Function must be related to size, however, since it is essential to determine relative values of different functions. Since it has been found difficult to relate cargo type to any ranking of importance - is iron ore a "higher order" commodity than coal or rods and bars? - an alternate functional explanation must be sought.

It is argued here that as the basic function of a port is to serve its hinterland, functional importance may be measured on the basis of the relative size of port trade areas. The lowest ordered port will serve only the area for which it is the nearest port. This region may be called the local hinterland, although other researchers have referred to this as the natural hinterland (Shaffer,1965,17). It is to be expected that the ports whose only function is to serve their local hinterlands will possess limited facilities and handle a narrow range of commodities only. Many of the smallest ports in the world, handling limited tonnages of cargo, would fall into this functional class.

Ports which handle cargo originating from or destined for areas that are closer to another port, may be viewed as performing an additional function. Because they serve an area which has been called the competitive or regional hinterland (in addition to their local umlands), it is likely that these ports will possess good facilities, be centres of the regional land transport network, and thereby handle a wider range of commodities than ports of the lower order. Examples of this group are ports in the English Channel such as Calais and Shoreham(Brookfield,1955), and such Great Lakes ports as Hamilton.

An even more specialised port is one which is engaged in transfers of commodities from one vessel to others. These are transshipment ports and usually occur where cargoes brought in by large vessels are transferred to smaller ships for distribution to other smaller ports in the functional hierarchy. Such ports are those possessing a central location, superior handling facilities, and deep water access. Baie Comeau and Sept Iles, two ports on the north shore of the St. Lawrence River, are good examples of this class.

Finally there are those metropolitan ports whose hinterlands include large portions of the nation or even continent. These are the leading ports of the entire system, usually dominating trade and vessel traffic totals and possessing the greatest range of port facilities. Excellent examples are provided by New York, Rotterdam, and Montreal.

This proposal produces a functional hierarchy that is assumed to be perfectly divisible:

TABLE 5

PROPOSED FUNCTIONAL HIERARCHY OF PORTS.

	local hinterland	competitive hinterland (regional)	transfers (interregional)	national hinterland
4th order	X			
3rd order	X	X		
2nd order	X	X	X	
1st order	X	X	X	X

While various relationships between the functional level of a port and tonnage of cargoes, facilities, and types of vessel have been used as illustrations, they remain hypotheses and will be tested in Chapter IV. This functional hierarchy is useful not only as a system of classification but also as a means of deriving further generalisations and the building of models of port systems. A major limitation of this functional hierarchy is that it requires detailed knowledge of the movements of cargoes so that the various hinterlands may be determined. Delimitation of port hinterlands is not an easy task.

Although this functional classification is presented as an original contribution, it appears to have been anticipated in part by Rimmer(1967a). In a study of the import hinterlands of New Zealand ports he identified three orders of ports. The most important, including Auckland, supply their immediate or 'regional' umlands as well as a larger 'extra-regional' territory with goods of a wide range, including bulk cargoes. The intermediate group of ports serve their regional hinterlands with a full range of goods, but supply their extra-regional trade areas with general cargo only. Finally, the lowest order ports import bulk commodities solely for their regional hinterlands.

In applying the functional classification to the ports in the study area it was evident that the commodity common to nearly all ports is pulpwood. Marsoui, which ships timber from the local saw mill, is the only port on the south shore of the lower St. Lawrence that does not handle this commodity. Large quantities of pulpwood are shipped by the ports to the major pulp and paper centres of Quebec City, Port Alfred, and Trois Rivières. Most of the pulpwood is derived from farmers woodlots, purchased by local entrepreneurs who truck the cords to the nearest port. Pulpwood is a bulky low value commodity that is expensive to transport. In a questionnaire sent to the twenty-seven pulpwood merchants in the study area, they were asked to indicate their reasons for using particular ports. In every case the response indicated that proximity to the pulpwood producing areas was the main factor.

While the local hinterlands are based upon pulpwood, several ports handle other commodities drawn from the local area. Quantities of general cargo, usually building materials, are unloaded from ships of Agence Maritime Inc. who operate a regular service between Montreal and Quebec and the ports in the eastern part of the region. It is interesting to note that this coastal trade includes only those ports east of Matane, the railhead, east of which even road transport is difficult because of the terrain. West of Matane this type of trade is not found as rail and road systems are too competitive.

All twenty-three ports, therefore, handle goods obtained from or destined for the local hinterland, but for eighteen this represents their sole function. The five other ports, Rivière du Loup, Rimouski, Matane, Ste. Anne des Monts, and Mont Louis all handle gasolene and fuel oil. These five ports serve as distribution points not only for their own local hinterlands, but also for a much larger area. In addition, Rimouski handles timber exports from Price, a major sawmill centre (for which Ste. Flavie is the closest port); and Mont Louis ships copper ingots from the smelter at Murdochville on a seasonal basis (in springtime when the usual route to the port of Gaspé is closed to trucks because of the thaw). An extreme case of commodities originating outside the primary hinterland is provided by Rimouski's shipments of explosives manufactured by C.I.L. Ltd. near Montreal.

Rimouski is the only 2nd order port in the system. For in addition to its 3rd and 4th order functions, it serves as a large transshipment port for petroleum. The largest vessels encountered in the system bring petroleum from Canadian refining centres or Aruba to Rimouski where the fuel oil or gasolene is transshipped to smaller coastal tankers for distribution to other petroleum ports in the region and on the north shore of the St. Lawrence River.

Thus in the study area a functional hierarchy is observed. In it there are eighteen ports of the 4th order, four of the 3rd order, and only one 2nd order port.

D. Location.

Studies of port locations have usually stressed individual site features. There have been no specific references to the patterns of location. Rimmer's (1967d) model of port development implied a regular spacing of ports, but empirical studies have not substantiated or refuted this assumption. It is important to recognise that size, function, and number of ports are attributes closely related to patterns of location. The functional hierarchy presented in the previous section is basically a spatial one.

In this section a brief description of the spatial properties of the ports in the study region will be presented. The functional system outlined above will be employed to examine the spatial patterns of the twenty three ports.

As would be expected, considering the nature of the size distribution of ports, smaller ports are more closely spaced than the large centres. The mean distance separating all ports (all ports perform 4th order functions) is 18.4 miles. The average distance between the ports performing 3rd order functions is 44.0 miles. Rimouski, the only 2nd order port, is 183 miles from its nearest neighbour of the same functional class, Quebec City.

In trying to describe the patterns of location of the ports it is important to realise that the 23 ports in operation in 1966 represent a fraction of the wharves and jetties in the region. Forty-seven separate harbour installations exist, most of them constructed at one time or another by the federal government. Many of the twenty-four not used for trade are employed by fishermen who fish on a part time basis, some are used occasionally by pleasure craft, and an increasing number are falling into bad state of repair. Most have been used for trade at some time in the past. For example, the number of active ports fell from thirty to twenty-three between 1951 and 1966. If the total number of port installations is taken, the mean distance separating the forty-seven harbours is 9.3 miles.

A procedure for measuring the spatial patterns of ports is that of nearest neighbour analysis. Following a method developed by Clark and Evans (1954) and introduced to geography by Dacey (1960), linear spacing patterns may be determined by obtaining reflexive pairs of nearest neighbours. Clark and Evans showed that when points are spaced randomly along a line, the proportion of points having nth order reflexive points is $(\frac{2}{3})^n$, i.e. the expected proportion of first nearest neighbour points would be .667. If the actual spacing produces a proportion of reflexive nearest neighbours in excess of .667, then that pattern is more regular than random; and conversely if the proportion is less than .667, the pattern is more clustered than random.[5]

TABLE 6

NEAREST NEIGHBOUR ANALYSIS OF PORT SPATIAL PATTERNS.

	number	expected value	actual value	pattern
all harbours (active and inactive)	47	.667	.597	more clustered than random
4th order ports	23	.667	.782	more uniform than random
3rd order ports	5	.667	.800	uniform

Table 6 shows the results of first nearest neighbour analysis of the ports in the study area. It is apparent that the pattern presented by all harbours is slightly more clustered than random, but that as soon as functions of ports are measured, the spatial patterns become more regular as the functional level increases. This would seem to confirm the work of Semple and Golledge (1970) who have described how entropy (randomness) in settlement patterns on the Prairies is reduced as the urban system develops.[6]

[5]Dacey (1969) showed that the original Clarke and Evans (1954) formulation, $(\frac{2}{3})n$, is incorrect, but that .667 is an accurate measure of randomness for first order reflexive nearest neighbours.

[6]This conclusion is not borne out by the results of a recent study of settlement patterns in the Gaspé peninsula by Massam and Semple(1970). They obtained 1st, 2nd, 3rd, 4th and 5th order reflexive pairs at ten year intervals. It was revealed that patterns of location were random, and although there were slight shifts no distinct trends were apparent between 1940 and 1970.

Encouraging though the results may appear, they must be treated with extreme caution. The technique employed is not a robust one. As Porter (1960) showed rather humorously, linear nearest neighbour analysis can produce misleading results under certain conditions. Another limitation is that the size of the sample is small, and only first nearest neighbour patterns could be ascertained. This fact also precluded the use of other methods of determining the randomness of patterns along a line, such as the one developed by Barton and David (1956). Their technique, introduced to geography by King (1969), is accurate only where $n > 25$. Thus while the results of the analysis would seem to indicate that an increase in importance of ports has significant spatial as well as functional implications, they must be viewed as being quite tentative.

E. Morphology.

The fourth attribute relates to the layout of the facilities of ports, and their relationships with local site features. While we may agree with Oram that no two ports are exactly alike, it has been demonstrated already by Bird, Hoyle, and Solomon that port morphologies are similar.

Port locations in the study area seem to have been influenced by river confluences. The point where a tributary joins the St.Lawrence afforded many advantages for its selection as a settlement site and harbour location. Natural protection for vessels could be provided there, fresh water would be available, and the valley could provide a possible route to the interior. Seventeen of the twenty-three active ports developed facilities where a tributary joins the St.Lawrence. The earliest facilities that developed were lateral quays, usually made of timber, which could accommodate small coastal vessels (see Plate I).

As trade developed the river site usually proved to be restrictive, as there was little room to expand, and the shallowness of the water prevented larger vessels from gaining access. Consequently there was a move to build finger piers at bay heads into deeper water (see the example of Grande Vallée). Where natural shelter could not be provided at such deeper water locations, a measure of artificial shelter was usually provided by the addition of an ell end to the wharf (see St. Anne des Monts).

With even further expansion of trade and because of the growing size of vessels there is an impetus to expand facilities and establish new extensions in deep water. The search for such locations may result in the latest facilities being constructed several miles from the existing port. Such points affording deep water are usually more exposed and there is usually a need to provide extensive shelter provisions. The best examples are provided by Rivière du Loup and Matane where the Department of Public Works have recently built large new harbours. Only Rimouski possessed such facilities (Pointe au Père) prior to 1967, (see Plate 3).

The sequence of port morphology development is summarised in Fig.6, and it is clear that there is considerable agreement with Bird's (1957) 'Anyport'. Development of facilities is seen as a function of trade expansion and changes in vessel requirements. Thus the form of port facilities is an attribute of the port system that would appear to be of use in formulating models of port development.

Plate I : STE ANNE DES MONTS

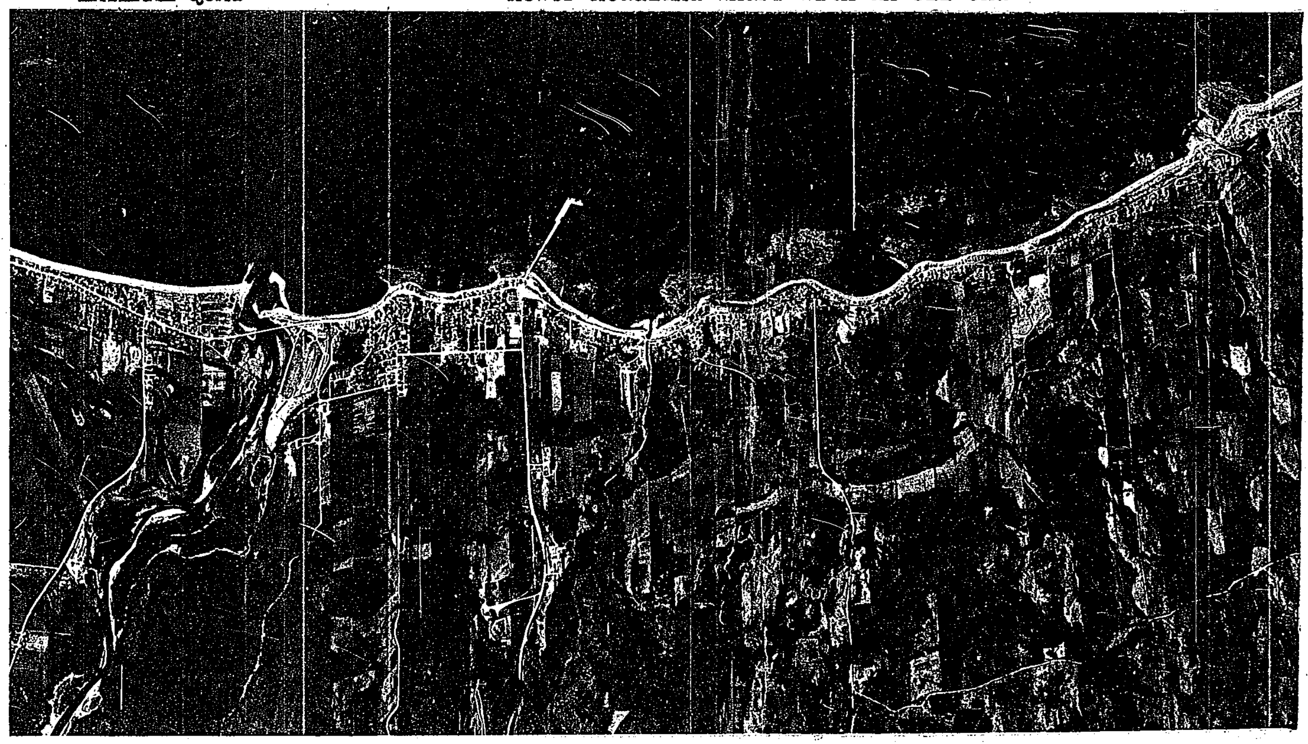


Plate 1 : STE ANNE DES MONTS

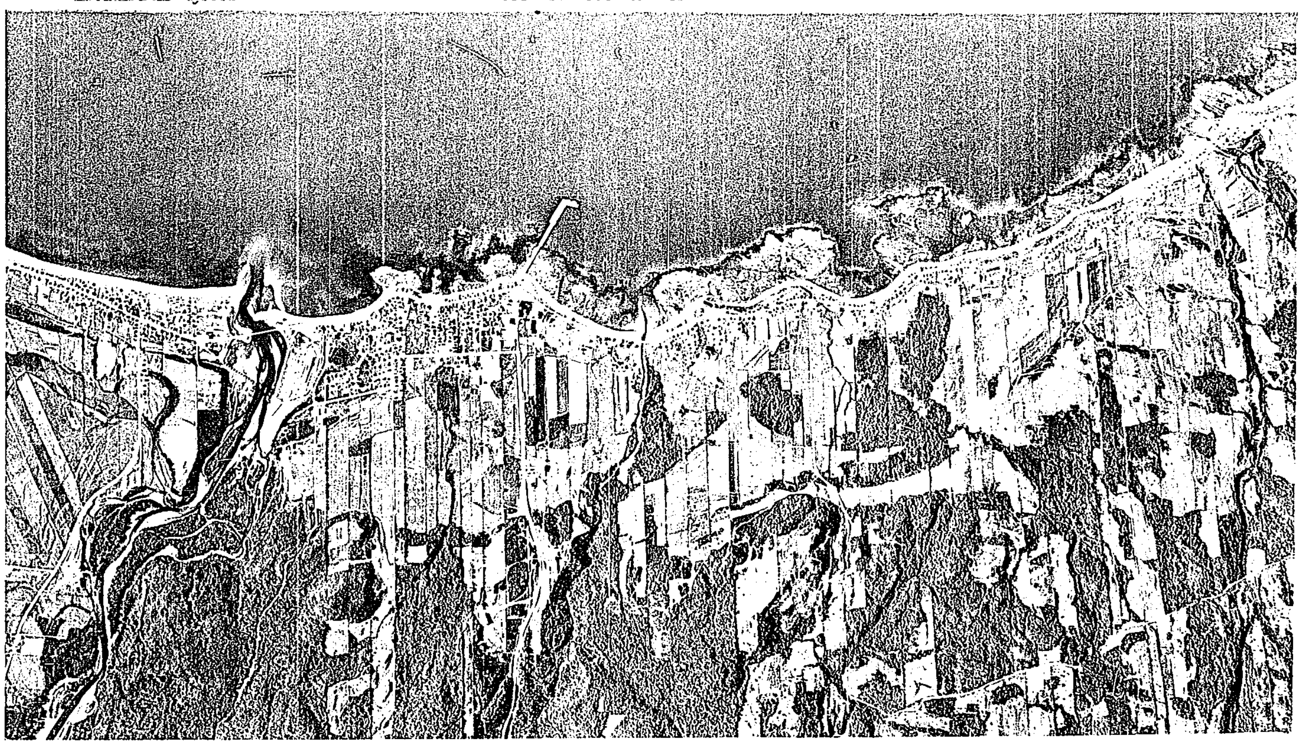


Plate 2 : GRANDE VALLEE

HEADLAND WHARF river quays

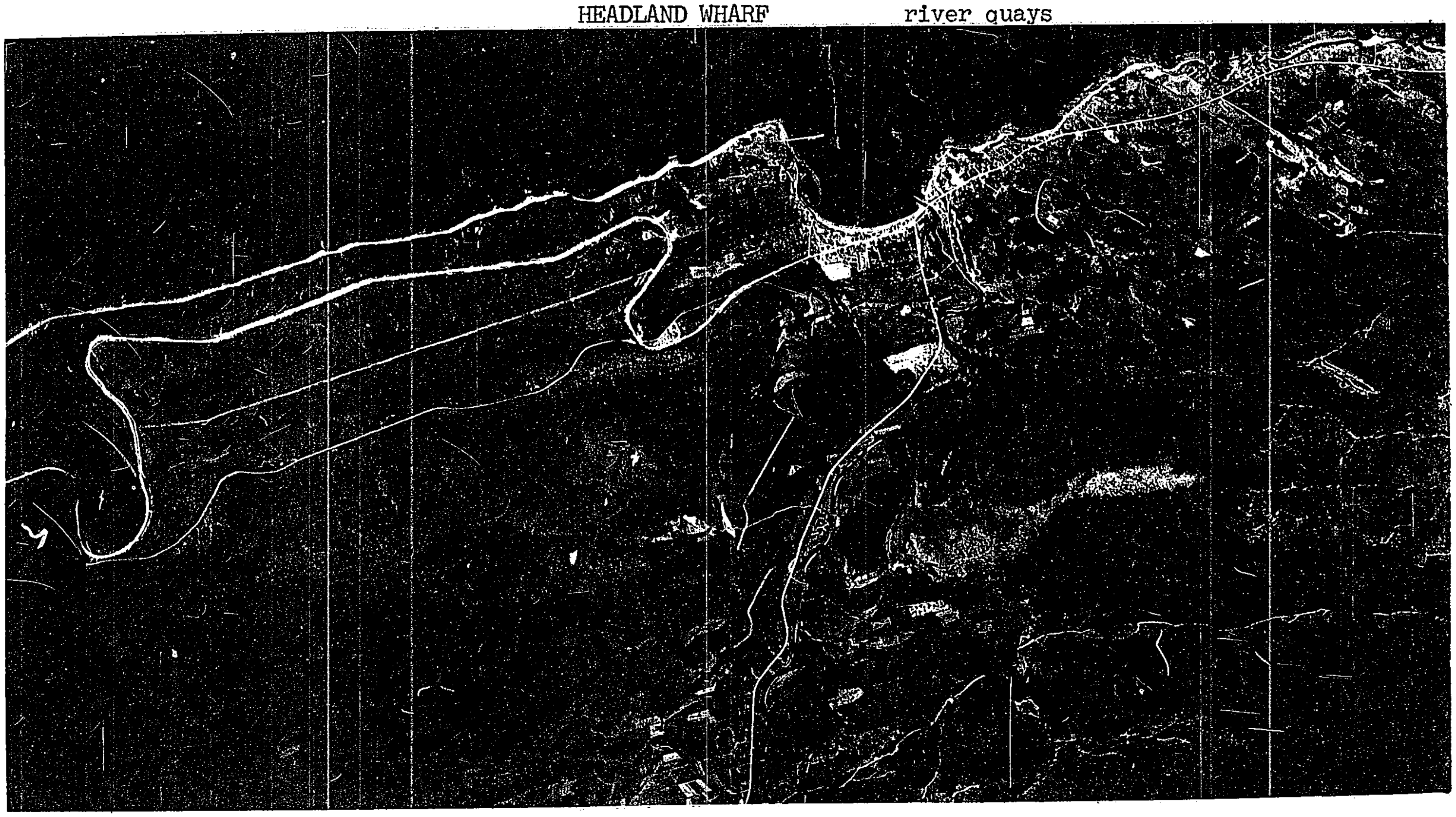


Plate 2 : GRANDE VALLEE

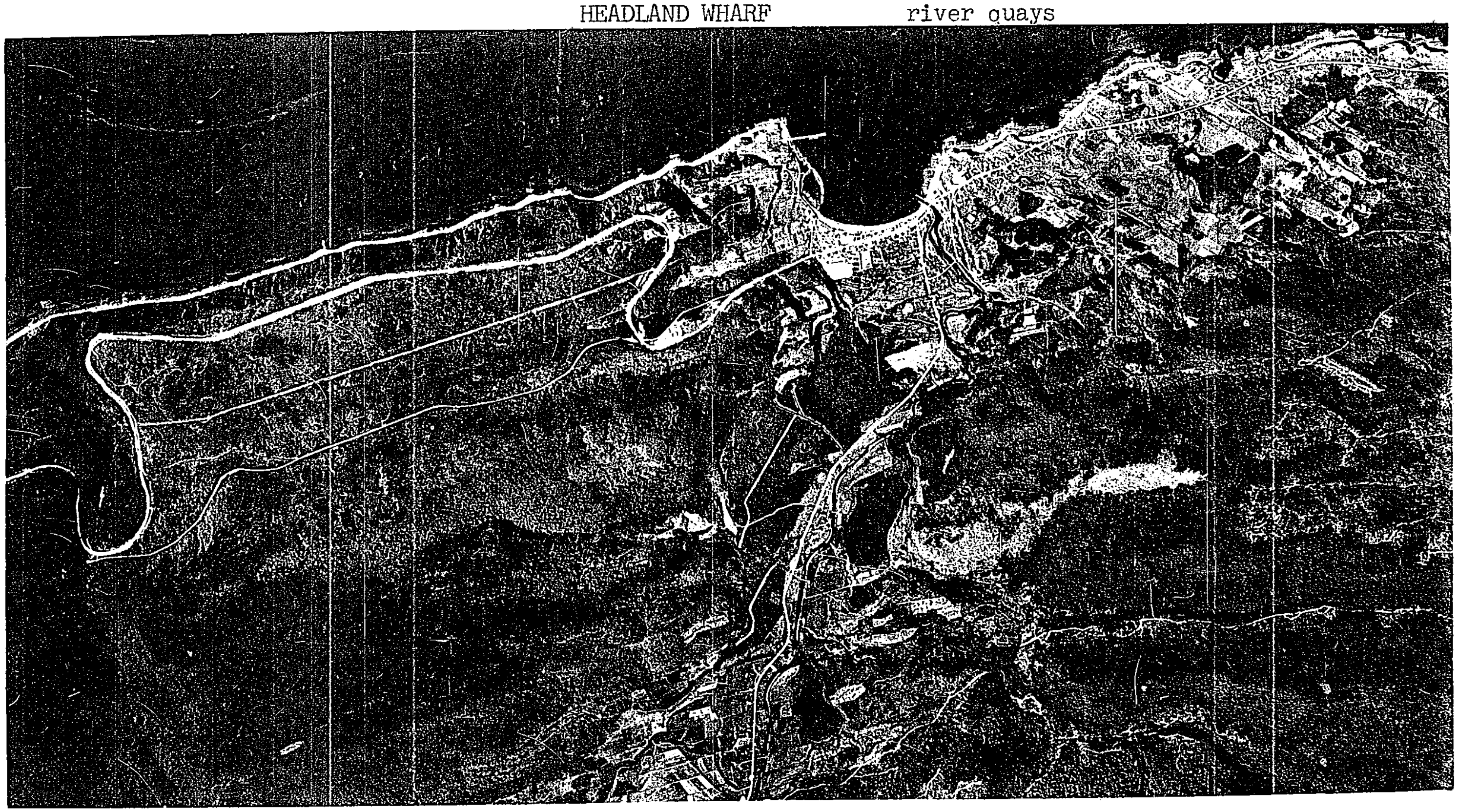


Plate 3 : RIMOUSKI

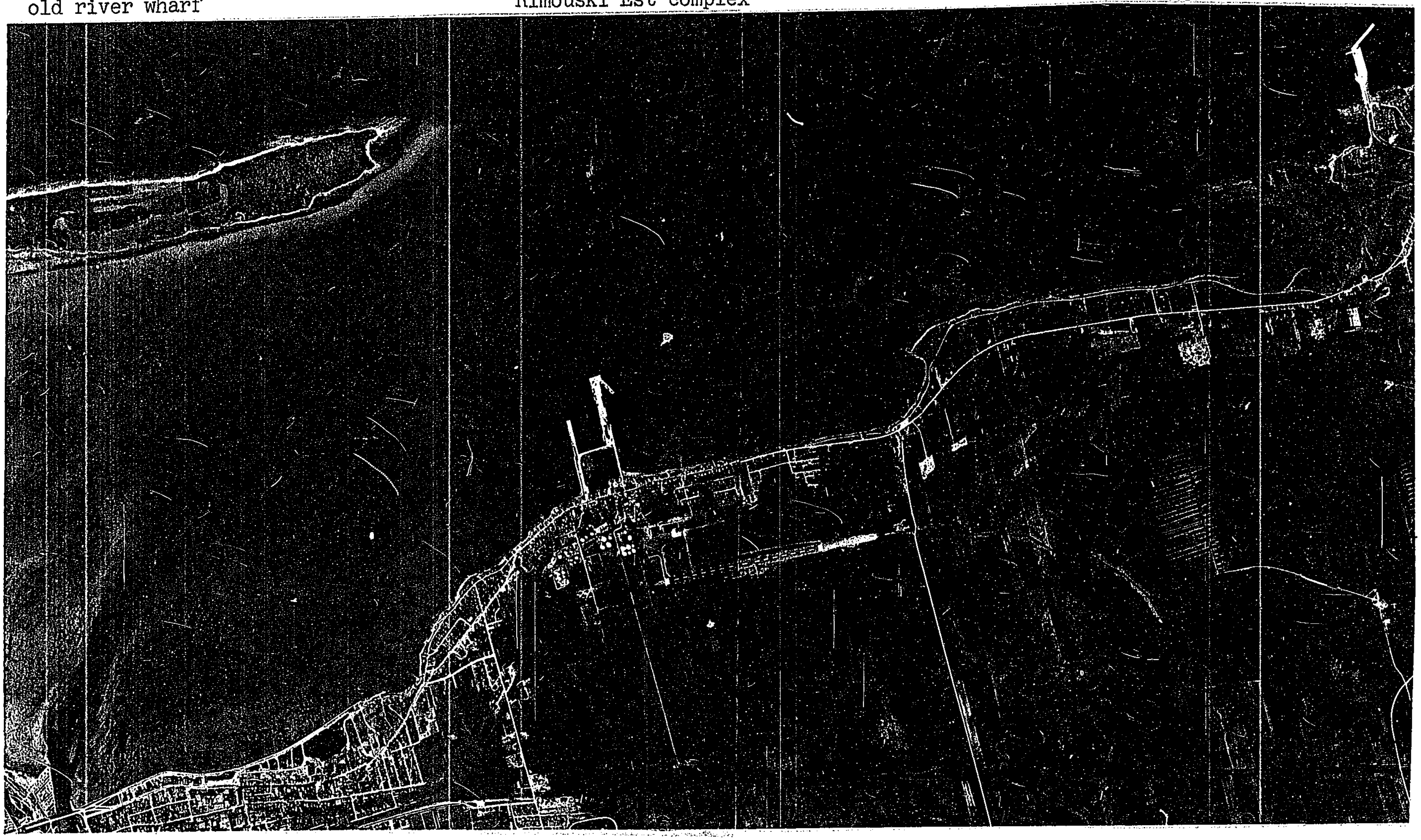
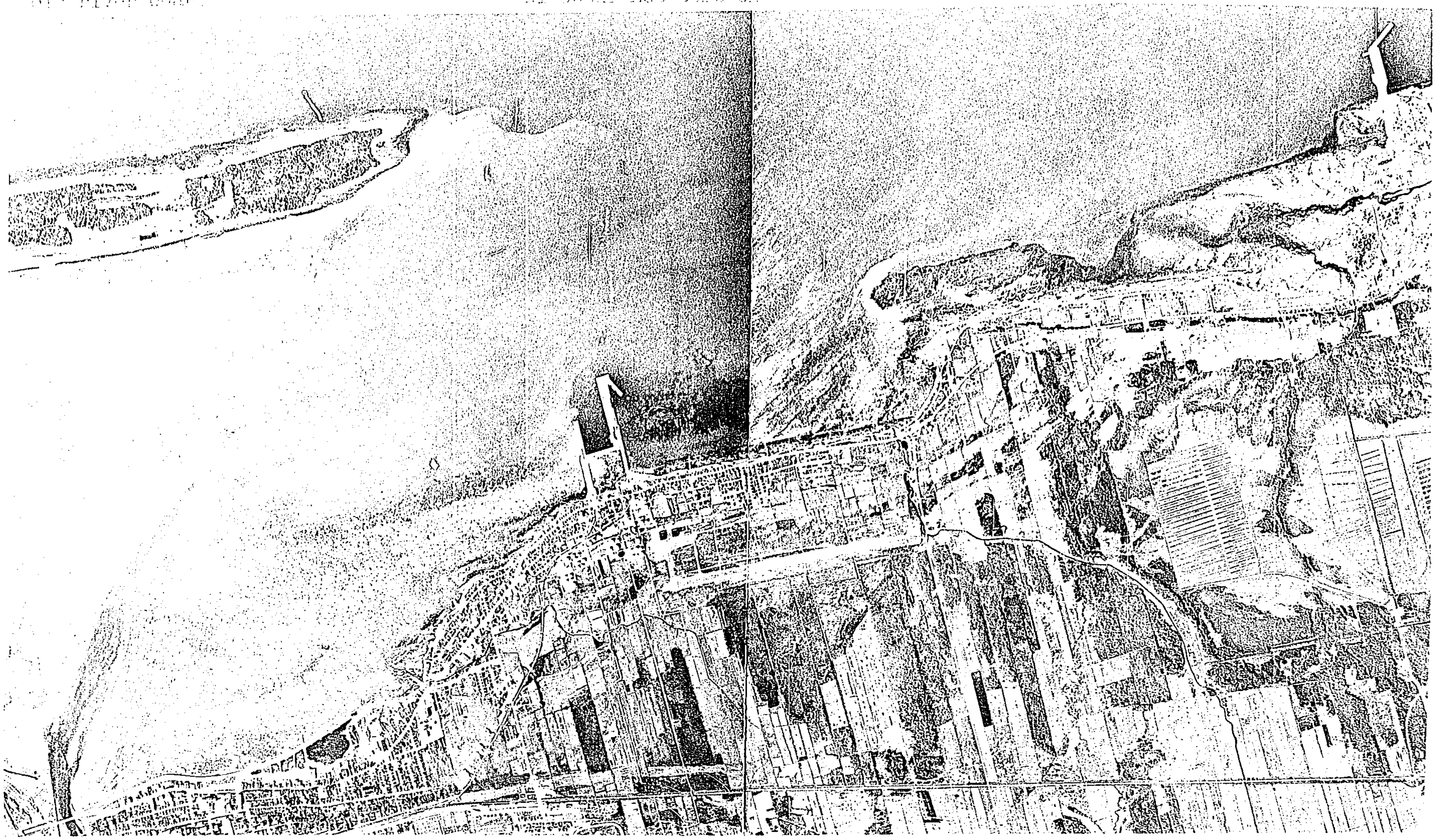


Plate 3 : RIMOUSKI



STAGES IN THE DEVELOPMENT OF PORT FACILITIES

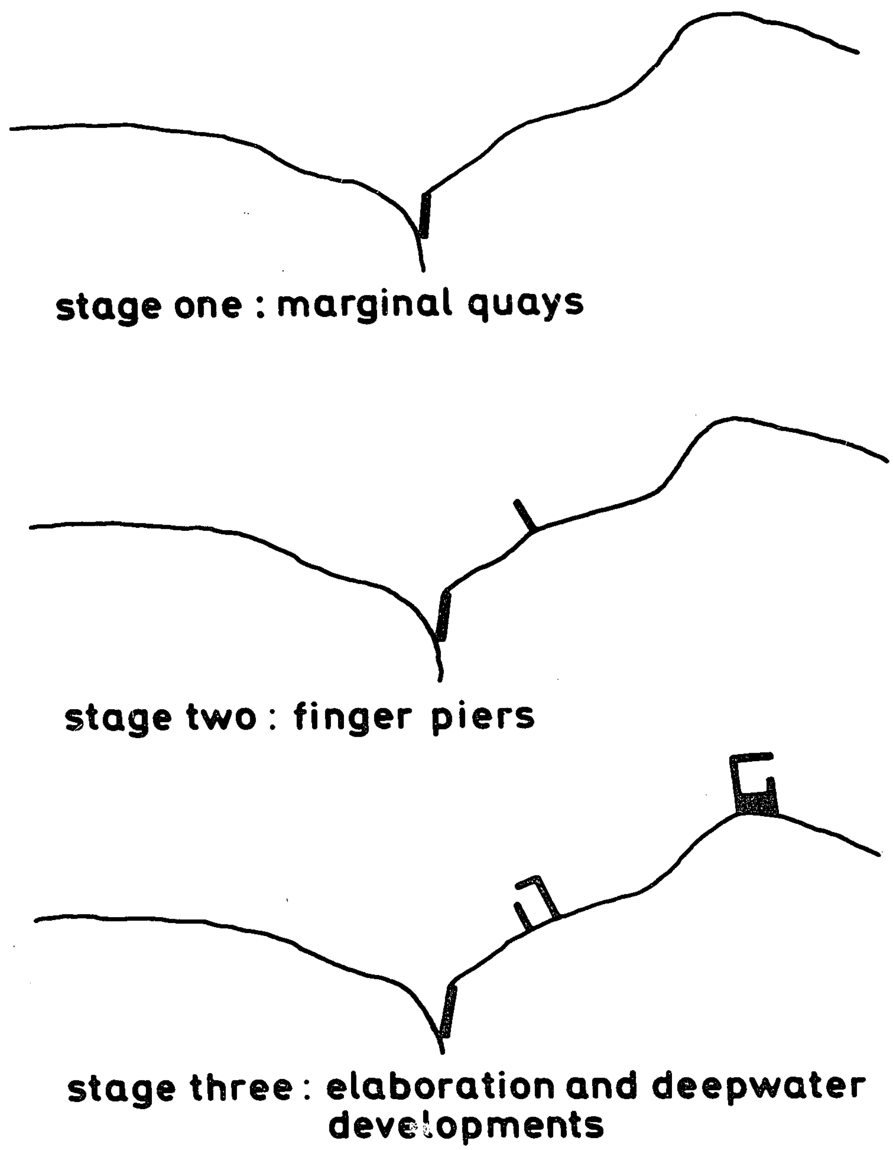


Fig. 6

F. Conclusion.

This chapter has presented a description of the ports through an outline of selected attributes. It has been shown that the attributes suggest a complex and variable structure. However, underneath this facade lie many interesting patterns which would seem to indicate an underlying order:

> "That there is more order in the world than appears at first sight is not discovered until the order is looked for" (Hanson in Haggett,1965,2).

The four attributes of the system indicate structural, functional, spatial and temporal properties that are seemingly interrelated.

For the sake of preserving consistency in the organisation of this dissertation, explanations of the patterns have not been attempted. Relationships between these attributes and key variables will be undertaken in subsequent chapters.

CHAPTER FOUR

PORT ACTIVITY RELATIONSHIPS

A. Introduction

This section seeks to explain the patterns of port activity described in the previous chapter. Many researchers, Hoyle(1967) and Forward (1967) for example, have suggested that port size is related to variables such as hinterlands and harbour facilities. Fig.7 is an attempt to summarise the relationships other port geographers have proposed. It may be noted that the trade flow is seen to be at an equilibrium position between the six elements.[7] Although there is a large body of research in port geography which appears to substantiate these associations, testing has not been rigorous and has been restricted to individual case studies. Here, an attempt is made to test these relationships by quantitative analysis and employ the results to explain variations in the size attributes of the ports for the year 1966.

The year 1966 was selected for a number of reasons. It represents a recent year for which a wide range of data was published: a partial census; Scott's Industrial Directory of Quebec; the St. Lawrence Pilot; and at the time this research began, 1966 was the most recent year for which published D.B.S. data on shipping were available. The selection of this particular year does not seem to have produced any bias in the analysis as it appears to have been a fairly representative year of shipping.

Although other studies (Weigend,1958) have indicated that six

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[7] The author would like to thank Dr. B. Massam for suggesting this diagram.

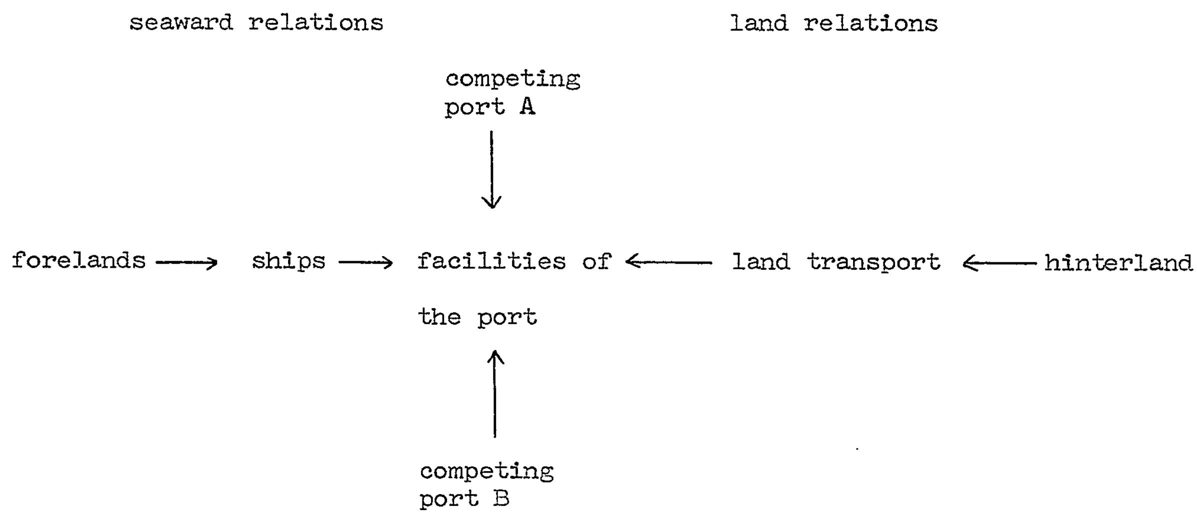


Fig. 7. Elements Influencing the Trade Activity of a Port.

major elements relate to port activity, the problem of selecting suitable criteria to represent each of these components has been largely ignored. The first step in the analysis, therefore, is to identify those measures of the elements that correlate most highly with wharfage totals. Spearman's rho rather than Pearson's product-moment coefficient of correlation is employed because all the variables are not normally distributed. Most of the variables possess distributions that are positively skewed. Furthermore as Cole and King (1968,152) have commented:

> "It is the general impression of the authors from the work they have done in which the Spearman rank correlation test and product-moment test have been applied to the same data that the results do not usually differ appreciably".

B. Relationships Between Port Activity and Independent Variables.

1. The Hinterland Variables.

a) The hypothesis.

Because the hinterland is the trade area of a port, it may be looked upon as the generator of traffic, whether the cargoes shipped through the port are produced there (exports), or are consumed within that region (imports). Strong positive relationships between hinterland size and port activity are hypothesised therefore.

b) The spatial form of hinterlands in the study area.

It has been noted already that the local hinterland boundaries are discrete for the most part. These local hinterlands are associated with the pulpwood trade. Fig.8 reveals that there is considerable variation in the degree of primary hinterland penetration of the interior of the South Shore-Gaspé region, however. The region is characterised

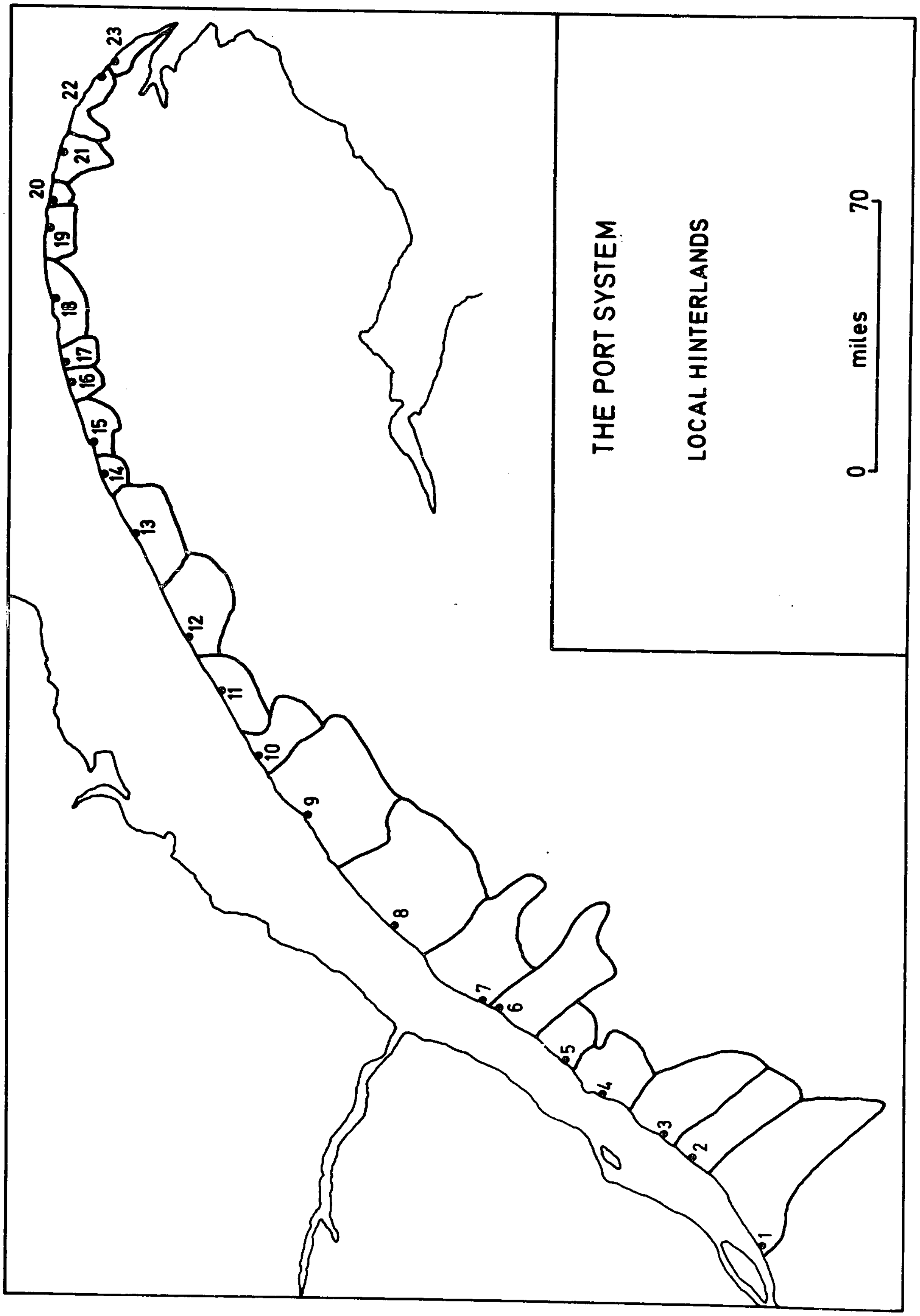

THE PORT SYSTEM
LOCAL HINTERLANDS
0
70
miles
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

Fig. 8

by a narrow coastal strip, where most of the available flat land is found, bounded on the south and east by mountain systems. The extent of the coastal strip is greatest in the south-west, and virtually disappears east of Ste. Anne des Monts, where low-lying land is found only in a few valley embayments. There are two exceptions to this pattern, the valleys of the Matapédia and Madawaska which are utilised by road and rail systems to gain access to the south shore of the Gaspé and the Maritimes. From Fig.9 it may be observed that four out of the five ports possessing third order functions are located where roads penetrate the interior and cross the mountain spine. The surprising exception is Rimouski, the major port of the region.

The pattern of primary hinterlands differs not too greatly from an 'expected' distribution obtained when areas closest to each port are delimited, see Fig.10. The major exception is Berthier, the most westerly of the ports. The area immediately to the west of Berthier, and for which Berthier is the nearest port, lies outside the actual hinterland of the port, producing a strangely truncated umland. This may be explained by the proximity of pulp and paper mills in Quebec City, so that wood is trucked directly to the mills there instead of being transferred to ships.

The pattern of competitive hinterlands is more complex, with the umland of Rimouski overshadowing all others. As noted already the best indicator of tertiary port functions is petroleum, and variations in the trade areas of this commodity account for the complex patterns

Fig. 9

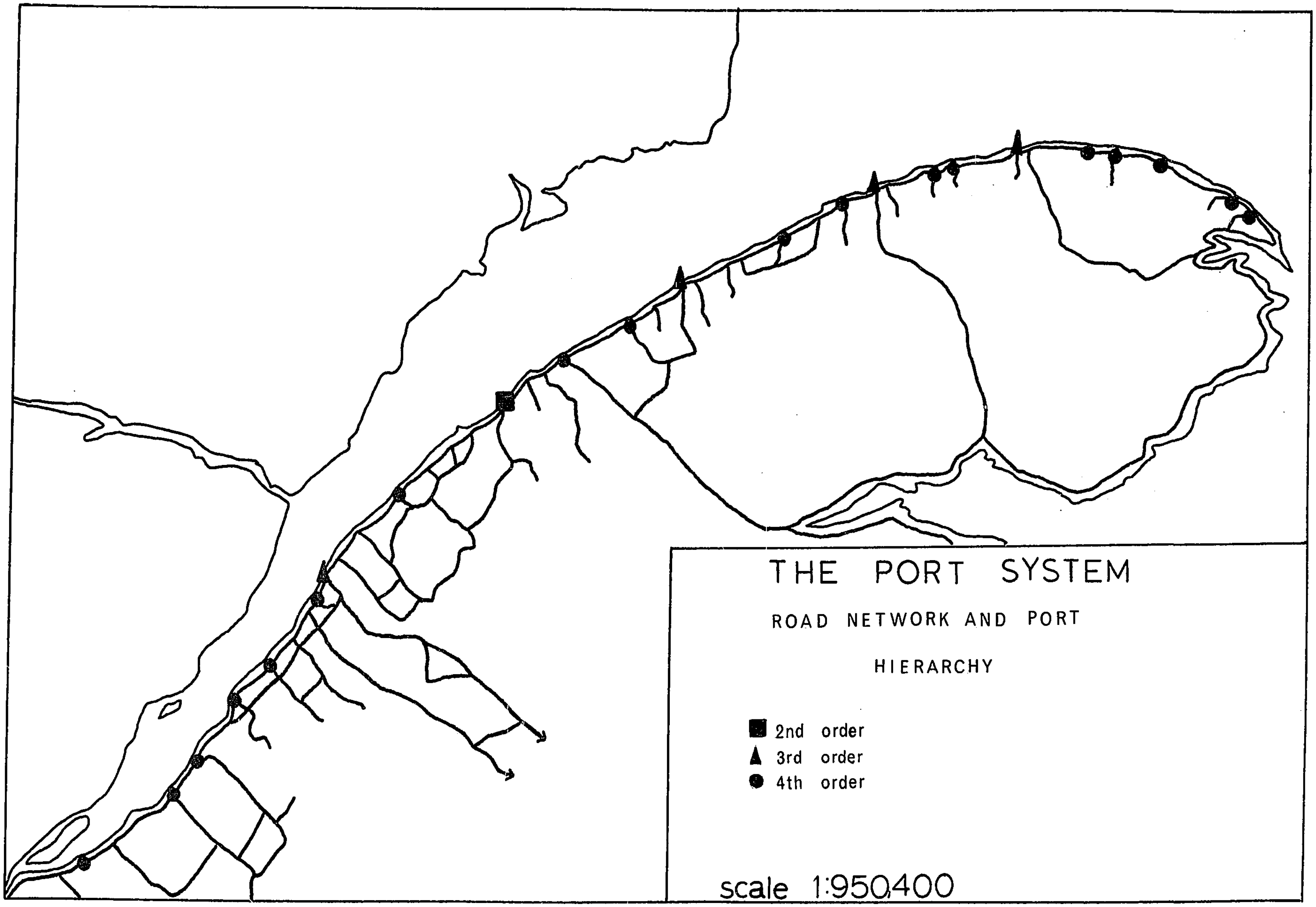
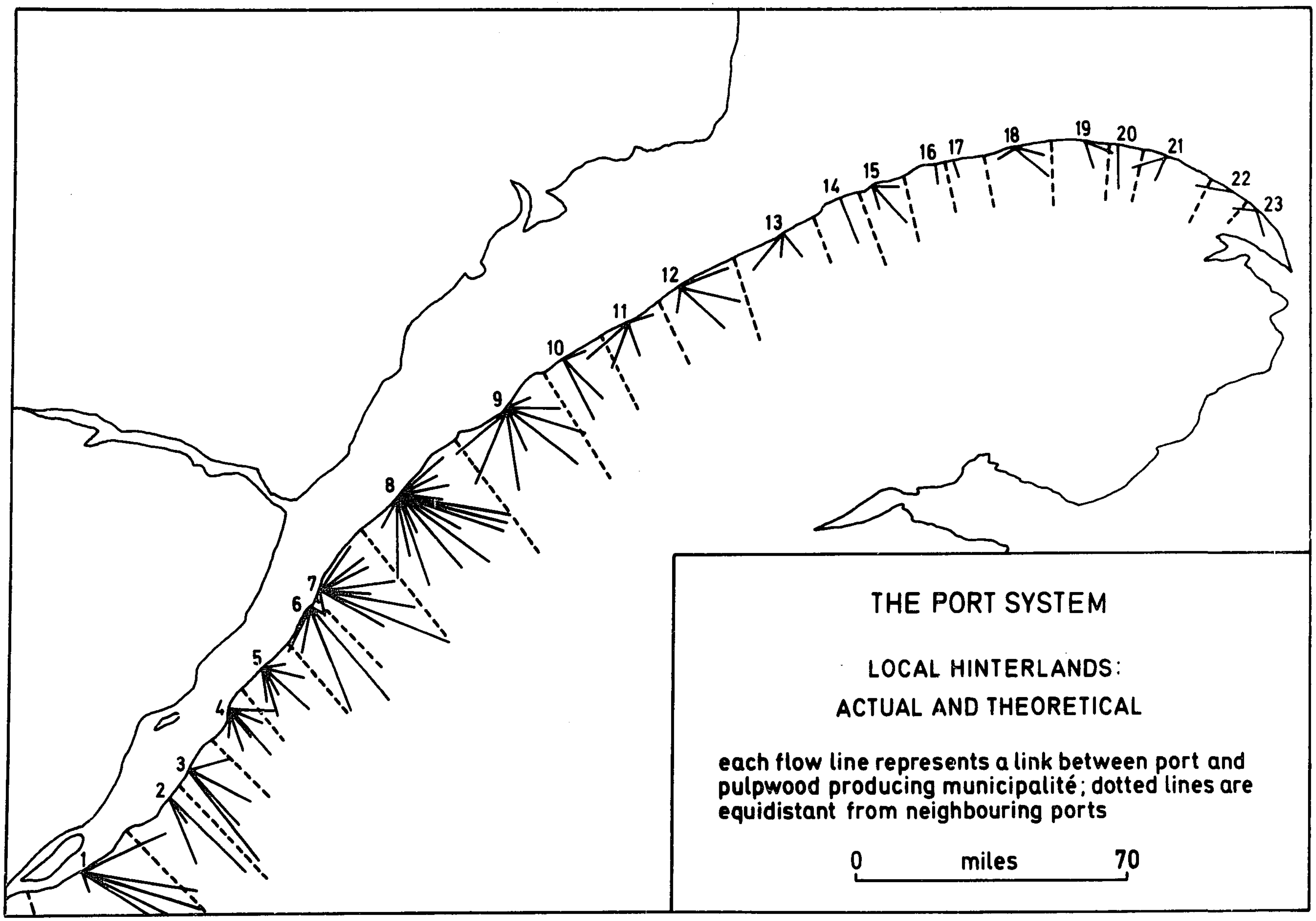

THE PORT SYSTEM
ROAD NETWORK AND PORT
HIERARCHY
2nd order
3rd order
4th order
scale 1:950,400

Fig. 10


THE PORT SYSTEM
LOCAL HINTERLANDS:
ACTUAL AND THEORETICAL
each flow line represents a link between port and pulpwood producing municipalité; dotted lines are equidistant from neighbouring ports
0 miles 70
1
2
3
4
5
6
7
8
9
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19
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22
23

revealed in Fig.11. Each port's petroleum hinterland represents the marketing area of different petroleum companies. Each company has a different distribution and marketing policy. The majors, Imperial Oil, Shell, Texaco, as well as Golden Eagle, import exclusively through Rimouski, and distribute throughout the region by train and truck. B.A. (now Gulf Oil) and Irving use Rimouski not only as a major distribution centre, but also as a transfer point and ship out to Rivière du Loup and Matane (Irving), and Ste. Anne des Monts and Mont Louis (B.A.).

c) Selection of hinterland measures.

Fourteen variables representing aspects of hinterlands of the ports in the study area were selected to test the hypothesis. Two of them give a crude measure of the extent of the total area served by each port. X_{22}, represents the size of the hinterland. It was determined by marking the boundaries of each port's trade area on topographic map sheets of the I:250,000 series. A planimeter was used to calculate the area in square miles. X_{20} represents the maximum range of each port's hinterland. It is based upon the distance by road to the furthest point of the trade area. Another variable representing the competitive hinterlands of the ports is X_{23}. This indicates the population of the maximum umland, and was obtained from the 1966 Census by summing the population totals of the parishes and municipalities in each port's hinterland.

In order to discover the extent to which size and quality of the local hinterlands might influence the ultimate size of ports (i.e. did Rimouski develop as the largest port because its local trade was more extensive in the first place?), variables measuring the nature of the

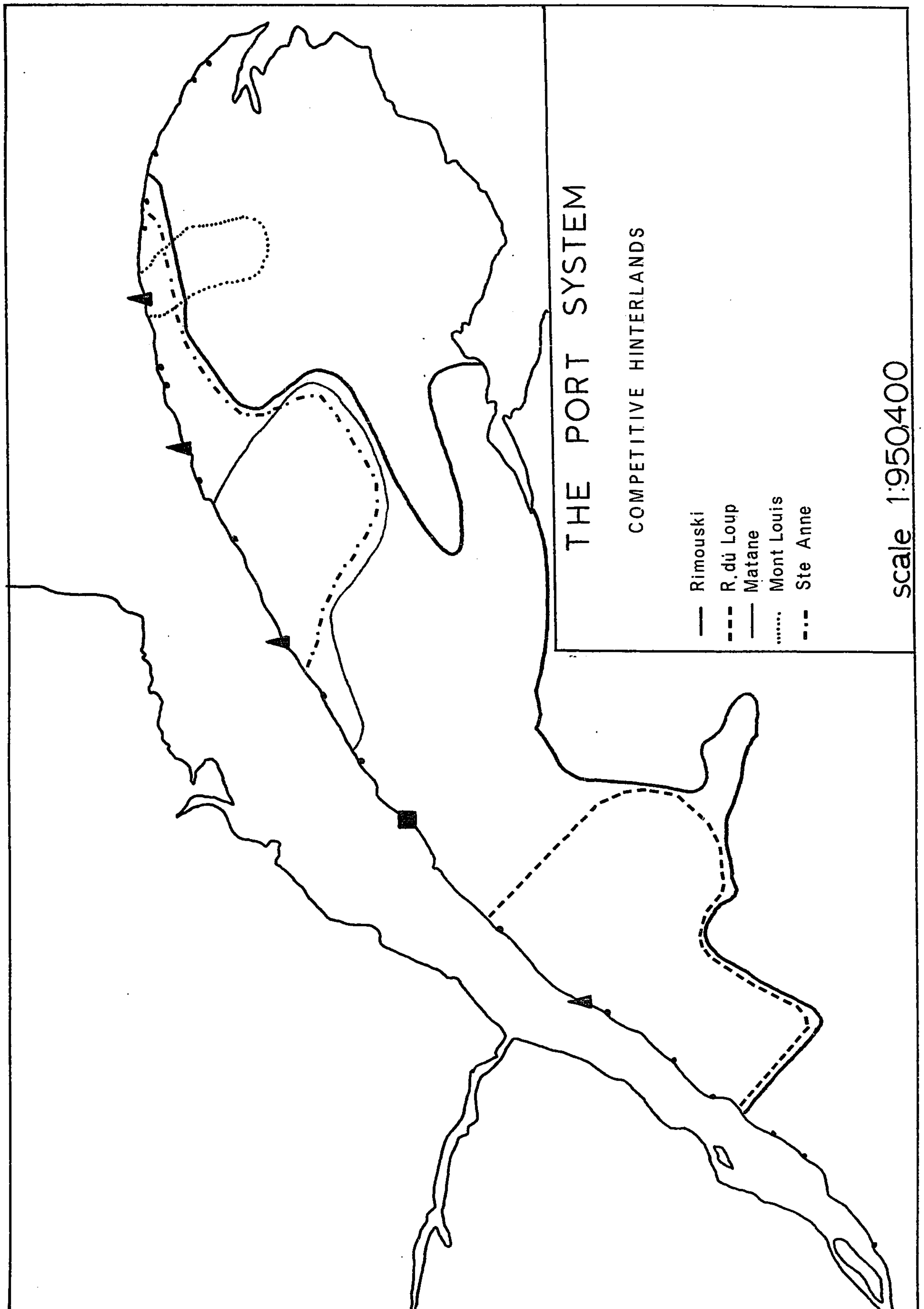
THE PORT SYSTEM
COMPETITIVE HINTERLANDS
Rimouski
R. dü Loup
Matane
Mont Louis
Ste Anne
scale 1:950400

Fig. 11

local umlands are included. (Note that local hinterlands represent the only areas served by eighteen of the twenty-three ports active in the study area). An advantage of dealing with local hinterlands is that their boundaries are discrete, so that no problems exist concerning the assignment of individuals. Because of overlapping competitive hinterlands, the same individual could be counted several times if it were located in the competitive zone of several ports.

Although in this group of measures of the primary hinterlands both area and population parameters are included again as X_{18} and X_{19} respectively, most of the variables deal with aspects of the regional economy. The same procedure as described in the case of X_{23} was followed to provide measures of farming, but great difficulty was encountered in the case of manufacturing data. The range of data published by D.B.S. on the industrial structure of the study area at the scale required is limited. The disclosure laws effectively prohibit publication of the type and number of industries, number of employees, and value added at any level lower than the county unit, far too large for the needs of this study. Thus in the case of measures of industry in the region, the less reliable and complete Scott's Industrial Directory of Quebec was used.

X_{17} population of port town. (Census of Canada 1966).

X_{18} area of local hinterland (Calculated from questionnaires and field survey).

X_{19} population of the local hinterland 1966. (Census of Canada 1966).

X_{34} number of manufacturing establishments 1966. (Scott's Industrial Directory of Quebec).

X_{35} number of manufacturing employees 1966. " "

X_{36} farm population 1966. (Census of Agriculture 1966).

X_{37} area of woodland 1966 " "

X_{38} area of farms 1966 " "

X_{39} % of farmland wooded 1966 " "

X_{40} tonnage of commodities from local hinterland (analysis of primary D.B.S. shipping data)

A final variable, X_{15}, measures the length of the river on which the port town developed. It was included as a surrogate for the extent of natural access to the interior. In the previous chapter it was noticed that most ports developed where a tributary joined the St. Lawrence, and one of the suggested advantages was access to the interior.

d) Results.

Table 7 presents the results of the correlation tests. Several interesting associations are revealed. Very weak correlations between port activity and measures of the economy of hinterlands are indicated. This finding contrasts with the relationships suggested by other researchers concerning the role of the economy of the hinterland. While lack of precision in the measures of the variables themselves or errors in data gathering may account in part for the weak relationships, more basic explanations need to be uncovered.

TABLE 7

HINTERLAND VARIABLES: COEFFICIENTS OF CORRELATION (SPEARMAN)

		X_2 wharfage
X_{15}	length of river	.53
X_{17}	pop. port city	.76
X_{18}	area of local hinterland	.61
X_{19}	pop. local hinterland	.44
X_{20}	maximum range	.56
X_{22}	area maximum hinterland	.64
X_{23}	pop. maximum hinterland	.56
X_{34}	number of manufacturing estabs.	.33
X_{35}	number of manufacturing employees	.28
X_{36}	farm population	.47
X_{37}	area of woodland	.42
X_{38}	area of farms	.36
X_{39}	% of farmland wooded	.30
X_{40}	tonnage of cargoes from local hinterland	.74

$n = 23$

coefficients $>$ .53 are significant at the 99.5% confidence level.

A surprising result is the relatively high correlation between size of port town (X_{17}) and port activity. This strong relationship suggests that a mutual interaction (Buckley, 1967) exists. Not only does the port town generate trade, but it may be observed that the port itself is important to the economy of coastal settlements. Local employment is generated directly and indirectly by ports. The direct effect of the port on local employment is expressed by labour demands in the harbour (quite small in the minor ports in the study area), in the ancillary services created by shipping (e.g. chandlers), and in the storage, handling and processing of commodities shipped (e.g. petroleum depots). Indirectly, the injection of large quantities of capital for harbour construction and repair stimulates a section of the economy by supporting a local construction industry.

It is evident that of all the variables, those representing the maximum hinterland areas are most highly associated with port size. Both area and population of the total hinterland are related significantly to port activity. However, the success of X_{40}, indicates that local trade is an important aspect of the function of ports.

2. Land Transport.

a) The hypothesis.

Only rarely are production or consumption points at dockside. Most commodities produced or consumed in the hinterland have to be transported by land transport systems to the port. Hence it is hypothesised that significant positive relationships will be found between port size and the extent of road and rail networks in the hinterland.

b) Results.

This is a very difficult hypothesis to test. In most areas land transport systems compete with water transport for the trade of hinterland regions. Thus on the one hand land transport may be seen as a positive factor affecting the size of ports, on the other either road or rail systems may divert trade from ports.

This conflict is reflected in the very poor correlations derived when miles of road and rail in the hinterlands of each of the ports are compared with port size. X_{21}, road mileage, produces a correlation coefficient rho of .44, and X_{24}, rail mileage, produces a coefficient rho of .11. Only the correlation between X_{21} and wharfage is significant at the 95% confidence level.

c) Competition from land transport.

Comparative freight rates are usually taken as measures of the degree of competition between different transport systems. Most economic geography texts base their comparisons of water, road, and rail transport in terms of cost/distance measures in the manner portrayed in Fig.12. This represents a gross oversimplification. In the study area competition between different transport systems as expressed by freight rate differentials is very complex. Although B.A.E.Q.(1965) managed to unravel many of the complexities of the freight rate structure, their findings could not be presented in a way that would permit derivation of quantifiable measures of association with port size.

Several different sets of freight rates may be applied to commodities shipped by land transport.[8] The first group depend upon the type of product. Differential rates apply to different classes of goods - hence these rates are called class tariffs. The criteria for establishing the class of a product are factors such as weight in relation to volume, fragility, and value. Furthermore large shipments of the same type of product will result in lower rates, because the larger shipment will be assigned a lower class grouping. Thus, butter falls into class 100 for shipments of less than a car load of 20,000 lbs, whereas if shipped in lots greater than car load, butter is rated as a class 55 product. These classes represent a proportionate sliding scale, so that rates are set for class 100 only. To find freight rates on butter shipped in quantities greater than car load, it is necessary only to calculate 55% of the class 100 distance rate.

A second group of freight rates, called special rates, apply

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[8] This section draws freely on the findings of B.E.A.Q.(1965,79-118)

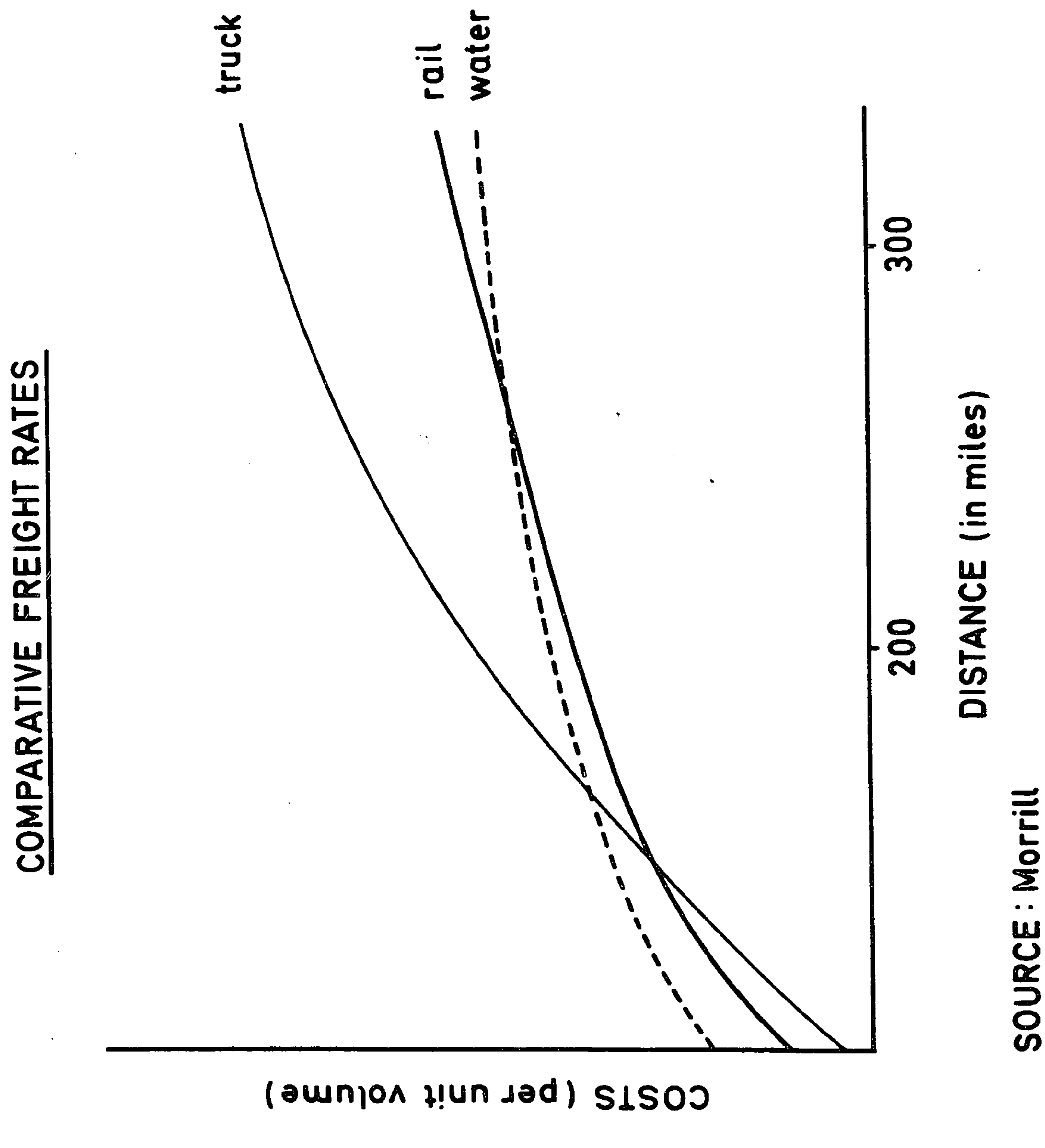
COMPARATIVE FREIGHT RATES
truck
rail
water
300
200
DISTANCE (in miles)
SOURCE : Morrill
COSTS (per unit volume)

Fig. 12

where large quantities are shipped between specific points. The rates are not determined in any particular systematic fashion. Many of the goods transported to and from the study area take advantage of these lower charges e.g. building materials, timber, fish, meat, butter and cheese. These special tariffs completely invert geographical distance. It may be much cheaper to transport a product between Montreal and Rimouski than Montreal and Rivière du Loup, if the former shipment was based on special rates, while the latter was rated by class tariffs.

Both of these rates are employed by rail and trucking systems. However, the railroads also take advantage of being permitted to charge convened rates. These are fixed rates agreed upon by the shipper and the railway for any shipment of a particular product between specific points. The oil companies have obtained such rates for the distribution of petroleum from Rimouski.

Only class tariffs are available in published form, the other cases being for the most part impossible to obtain. It may be noted, however, that public carriers are subject to rates established at certain base points only:

> "le tarif 200G qui régit le déplacement des commodités de ou vers le territoire-pilot prévoit cinq localités d'entête: Rivière du Loup, Rimouski, Mont Joli, Matane, et Amqui. Cela signifie que tout déplacement de produits effectuée entre deux points du territoire non inclus dans ces localités se calcule au millage" (B.E.A.Q.,1965,102)

Geographic distance thus reasserts itself.

The complex patterns produced by the application of these different freight rates is complicated further by the effect of government subsidies. The study area is part of the region benefitting from the Maritimes Freight Rate Act (M.F.R.A.). The provisions of this act allow for subventions on transport of goods which amounted to a 30% reduction of freight rates in 1966. These reductions do not apply to trucking however, and are applicable only to goods being shipped out of the region. Consequently, any product being shipped by rail from the study area to other parts of Canada obtain a 30% reduction in rates for that portion of the trip lying within the area benefitting from M.F.R.A. (everywhere east of Lévis). These reductions are not available on return trips.

d) Conclusion.

The difficulty of measuring freight rates of the land transport systems meant that comparisons of port activity and competition from land transport were not possible. While omission of quantifiable relationships between size of ports and this element represents a loss of accuracy in this part of the analysis, further investigations into the role of land transport and the port system will be found in Chapter V.

3. Facilities.

a) The hypothesis.

The term facilities is employed to cover all features, equipment, installations, and labour in the harbour itself. The facilities of a port permit the transfer of goods from ships to land transport systems, and vice versa. Facilities may be seen therefore to influence the amount of trade a port may handle. A strong positive relationship may be hypothesised between measures of port facilities and trade.

b) Selection of the variables.

The choice of suitable measures of port facilities is influenced by the nature of the facilities themselves and by the availability of data. Thus studies of facilities in Great Britain might consider number of cranes possessed by the port, whereas in Canada such a variable would be meaningless as ships' gear is used for the most part in handling general cargo. Because the ports in the study area are small, they possess few of the facilities found at larger ports such as Montreal. Few of the ports possess storage sheds, and Rimouski is the only one whose berths are served by rail. Consequently, to make correlations as meaningful as possible only features common to all the ports have been selected.

Length of wharves (X_{11}) is an obvious measure of port facilities. Such a variable influences the number of berths available and the ability of ports to accommodate vessels. This measure was obtained from the St. Lawrence Pilot of 1966.

Despite the apparent attractiveness of this variable, it possesses one limitation. It is possible for ports to possess long wharves not for the purpose of providing extensive berthing space, but to extend out to deeper water so as to accommodate vessels that would otherwise be excluded from the port.

Depth of water in the harbour, X_{10}, may be inferred to have a bearing on trade. Since ports with shallow water alongside berths are able to accommodate shallow draught vessels only, this limitation should be expressed in trade activity. Several problems are presented by this measure however. All the ports are tidal, and the tidal range is extremely variable, being much greater in the upstream portions. Also because wharves generally extend out into deeper water, there are great differences in depths alongside different berths. In an attempt to standardise this measure, the data, which were again obtained from the St.Lawrence Pilot of 1966, represent the maximum depth available at wharfside at mean low water.

A desirable variable would be a measure of shelter. One of the basic reasons for a port's existence is to provide ships with shelter from storms, tides, and currents. It has been shown that natural shelter was a prime factor in the selection of the original port site. As the need for more space and greater depths asserted itself, artificial shelter was provided. Unfortunately it has been impossible to obtain any quantifiable measure of shelter, whether natural or artificial. Discussions with engineers in the Department of Public Works indicated that the question was too complex and that there are too many variables to be considered. There is no measure of shelter that could be applied to all the ports in the study area.

Measures of the quality of port facilities were sought. Comparisons based upon length of wharves may not be meaningful if there is a wide variation in the state of repair of the docks. The files of the regional office of the Department of Public Works were made available and from these records four variables were obtained. X_{12} represents the total amount of money spent by D.P.W. since records began. This figure includes both capital and maintenance costs, as well as expenses incurred in dredging operations. X_{13} represents the amount spent in the period 1946 - 1966, since large sums may have been spent a long time ago, but lack of recent expenditures could résult in decrepit facilities today. X_{14} indicates the percentage increase in expenditures between 1946 - 1966. These three variables are not completely satisfactory indicators of quality of facilities, since amounts spent by D.P.W. are influenced by the extensiveness of facilities there. Thus a relative measure, X_{16}, was obtained. This variable represents the amounts spent between 1946 - 1966 per unit length of wharf, and was obtained by dividing X_{13} by X_{11}. The presumption is that the more spent per foot of wharf the higher the quality of the facilities.

TABLE 8

FACILITIES VARIABLES: COEFFICIENTS OF CORRELATION(SPEARMAN)

		wharfage X_2	
X_{10}	depth of water	.43	
X_{11}	length of wharves	.76	
X_{12}	total expenditures D.P.W.	.79	
X_{13}	increase D.P.W. expenditures 1946-66	.75	
X_{14}	% increase D.P.W. expenditures 1946-66	-.17	
X_{16}	amount spent per foot of wharf, 1946-66	.61	n = 23

coefficients > .53 are significant at the 99.5 % confidence level.

c) Results.

Two of the variables do not perform well. No relationship between X_{14} and port activity is indicated. This poor correlation may be explained by imperfections in the data. Several of the smallest ports registered very large percentage increases over the 20 year period because amounts invested prior to 1946 were so small.

The weak performance of depth of water in explaining port activity is more surprising. Part of the reason is the physical structure of the estuary of the St.Lawrence. Ports located closer to the Gulf of St.Lawrence have access to deeper water, regardless of their size. A further factor is that the relationship may not be a simple linear one; this question will be explored further in the next chapter where step functions are explained.

The remaining variables correlate significantly with port size. Extent of facilities (X_{11}) is more highly related to wharfage totals than quality of facilities (X_{16}). However, it is interesting to note that amounts spent on wharf construction, a composite measure of both extent and quality of facilities, performed best of all.

4. Competition from Other Ports.

a) Hypothesis.

While significant relationships between the intrinsic qualities of facilities and port size have been revealed, it is felt that an element in the performance of a port must be its competitive position compared with other ports. Ports compete with each other for the waterborne trade of a region, and their relative success may be measured by their trade totals. It is hypothesised, therefore, that port activity is positively related to the strength of a port's competitive position.

Ideally the competitive position of ports should be reflected in variations in costs of transferring products to and from regional hinterland markets and foreland areas. Unfortunately actual cost data are unobtainable. Here, distance is utilised as a substitute measure, and it is assumed that distance of a port from its competitors is a factor in trade. It would appear to be an appropriate measure of a port's competitive position because ports compete spatially, and transport costs are largely based upon distance measures.[9]

b) Selection of the variables.

Nine variables were derived from distance measures to test the hypothesis. Actual road distances between wharves were obtained (using the odometer of a car), instead of relying on published distances between port settlements. Several harbours are some distance from the centre of town, e.g. Rivière du Loup.

X_{25} represents the distance to the nearest port. It is hypothesised that proximity to a competing port will limit port activity. This hypothesis would seem justified in light of the spacing regularities noted in the previous chapter.

Variables X_{26} - X_{30} inclusive indicate distances to the nearest larger port. Each variable represents a different attribute of port size. It is implied here that the competitive position of a port will be seriously

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[9] This is justified in light of quotation p.76.

reduced whenever it is close to a larger port. X_{33} could be interpreted in a similar way. This variable represents the distance to the nearest port of higher order in the functional hierarchy.

X_{31} and X_{32} are based upon port facilities, depth of water and extent of wharves respectively. It is suggested in the case of these variables that trade will accrue to ports possessing superior facilities, and thus proximity to a port with better facilities will hinder the development of trade.

TABLE 9

COMPETITION VARIABLES: COEFFICIENTS OF CORRELATION (SPEARMAN)

	wharfage X_2	
X_{25} distance nearest port	.17	
X_{26} distance nearest port handling more commodities	.73	
X_{27} distance nearest port generating higher wharfage totals	.78	
X_{28} distance nearest port handling greater vessel tonnage	.69	
X_{29} distance nearest port handling more vessels	.68	
X_{30} distance nearest port handling greater tonnage of cargo	.72	
X_{31} distance nearest port with deeper water	.31	
X_{32} distance nearest port with longer wharves	.32	n = 23
X_{33} distance nearest port of higher functional order	.61	

coefficients $>$ .53 are significant at the 99.5 % confidence level.

c) Results.

Examination of the correlation coefficients rho indicates that of the various sets of variables, those measuring distances to ports of greater size perform best. Distance from the nearest port (X_{25}) reveals little relationship with port activity. The nearest port under these conditions could in fact be a smaller, less efficient port, and this vagueness is reflected in the poor correlation. Measures of port facilities too perform poorly. Proximity to a port with superior facilities was not found to be significant, therefore.

Of the variables measuring distance from a larger port, X_{27} produces the highest simple correlation with wharfage. The hypothesis that the probabilities of a port attaining great size are seriously reduced when that port is close to a large port is substantiated.

5. Vessels.

a) Hypothesis.

In Chapter III, vessel size and numbers had been discussed as attributes of port size, indicative of, rather than causally related to, port activity. However, as carriers of the waterborne trade of ports, vessels may be seen as factors in port growth. Thus although vessel frequencies and size may be looked upon as being <u>products</u> of port activity (because the availability of cargo attracts vessels), it must be recognised that their very presence <u>generates</u> trade and enhances the competitive position of the port. Economies of vessel size (Heaver,1968) are considerable and have obvious repercussions on the competitiveness of those ports that can generate sufficient trade to attract the largest vessels in the first place, and which possess the physical facilities to accommodate them. Thus great advantages are conferred on those ports that can attract a large number of vessels, and, in particular, vessels of a large net registered tonnage. The hypothesis to be tested in this section is that strong positive relationships exist between vessel traffic and port activity.

b) Selection of the variables.

Because of the detailed investigation of primary D.B.S. data referred to in Chapter II, it was possible to produce five variables. It will be remembered that details of the movement of every ship in each of the ports in the study area were obtained. Thus not only was it possible to produce such gross measures as total tonnage of vessels (X_3), number of ships (X_4), and the derivative data on mean vessel size (X_6), but two other variables based on data not published anywhere. Size of the largest vessel handled by the ports in 1966 is presented as X_5, and actual tonnage of the largest cargo shipment is included as X_8. Both of these variables have been included because of the importance of economies of scale implied in the hypothesis.

TABLE 10

VESSEL VARIABLES: COEFFICIENTS OF CORRELATION (SPEARMAN)

	wharfage X_2	
X_3 total n.r.t. of vessels 1966	.88	
X_4 number of vessels 1966	.82	
X_5 size of largest ship handled 1966	.70	
X_6 mean vessel size (X_3/X_4) 1966	.41	n = 23
X_8 tonnage of largest cargo shipment 1966	.65	

coefficients > .53 are significant at the 99.5% confidence level.

c) Results.

Some very high correlation coefficients are indicated in Table 10. Only the variable measuring mean vessel size is not significantly related to port activity. This poor result may be accounted for by imperfections in the measure itself. Mean ship sizes at many of the larger ports (which attract the bigger vessels) are deflated by arrivals of large numbers of 'goélettes' - the small 100 n.r.t. ships used in the pulpwood trade.

Of all the variables, net registered tonnage is most highly associated with port activity. The hypothesis appears to be substantiated, therefore. Larger ports attract great numbers of ships of a large net registered tonnage.

6. Forelands.

a) Hypothesis.

The foreland of a port is its overseas trade area. It may be noted that the ports on the south shore of the lower St. Lawrence River are small and possess relatively simple foreland relationships. By the nature of their trade most of the ports are linked with comparatively few other regions. The pulpwood is shipped to either Port Alfred, Quebec City, or Trois Rivières, and this represents the limit of the trade of several of the ports. Trade with other ports across the river on the north shore of the St. Lawrence is quite extensive, with large quantities of local agricultural produce and timber being shipped. In addition, large tonnages of general cargo and petroleum are shipped there from

Rimouski. Trade with Montreal is characterised by imports of general cargo at ports east of Matane, and petroleum imports at Rimouski. Links between ports in the region and areas beyond the St.Lawrence are few. The major item in this trade is petroleum imported from refineries in the Maritimes and the Dutch West Indies. However, Rimouski exports timber to the United Kingdom, and explosives to Newfoundland and South America.

It is hypothesised, therefore, that a strong positive association exists between foreland size, as measured by the number of different ports traded with, and wharfage.

b) Results.

The number of different ports trading with each of the ports in the study area was obtained from primary D.B.S. data. This variable(X_9) when correlated with wharfage (X_2), produces a statistically significant coefficient rho of .80. This suggests that the hypothesis cannot be rejected, that the foreland component is related significantly to port activity. However, this high correlation does not suggest that there is a causal relationship between the foreland component as measured here, and port trade. The association is seen more as an indication of a mutual interaction between the two variables. Thus the number of ports traded with may be a corollary of port size rather than a cause.

C. Multivariate Analysis.

The analysis so far has been concerned with measuring hypothesised associations between port size and various separate components. A further product has been the identification of particular measures of the components which generate the most meaningful correlations. A general conclusion is that although there are variations in the strength of the different correlations, each of the elements is related significantly to port activity.

It should be evident that although individual elements correlate highly with port size, the performance of a port must be seen as the product of several, if not all, of these components.

> "The majority of spatial distributions in which geographers are interested are typically so complex in their structure and relationships that they cannot be explained satisfactorily in terms of one variable".(King,1969,135).

Variations in port activity can only be explained through use of multivariate techniques. A type that has been used very frequently in geography is multiple regression analysis.

Multiple regression differs in a number of ways from the correlation analysis presented earlier. It assumes that there is some functional relationship between dependent and independent variables:

$$Y = f(X_1) + f(X_2) + \dots + f(X_n) + \varepsilon \qquad (2)$$

Correlation implies no such functional dependence, although it is very commonly used to search for possible relationships, and, as illustrated, is an effective technique for 'sorting out' associations (Krumbein and Graybill,1965,236). Because in most regression analyses the functional relationships are assumed to be linear, the model becomes:

$$Y = a + b_1X_1 + b_2X_2 + \dots + b_nX_n \qquad (3)$$

Both dependent and independent variables are required to be normally distributed and measured on interval or ratio scales.

These requirements of regression analysis necessitate careful selection of variables. The selection procedure was based on the results of the correlation analysis. However, because the data used in the correlations rho were not distributed normally, transformations were necessary. Two criteria were employed: for each of the elements held to be related functionally to port activity, the variable or variables most highly correlated with wharfage totals were chosen; these variables were then transformed, but if this was unsuccessful the next most highly correlated variable was included. It will be remembered that most of the variables possessed positively skewed distributions, and thus simple log transformations were found to be sufficient to achieve normalcy as tested by scatter diagrams.

On this basis the following variables were obtained:

Y = log wharfage	As indicated in Chapter III, wharfage is the best measure of port size, and is here used as the dependent variable.
X_1 = log vessel tonnage	This was the most highly correlated of the vessel component variables.
X_2 = log population of maximum hinterland	Although area of maximum hinterland correlated more highly, its distribution could not be normalised despite several different transformation procedures.
X_3 = log population of port town	The highest single correlation between port activity and the hinterland element was produced by this variable.
X_4 = log quality of facilities ($ spent 1946-66/ length of wharves)	While not the highest simple correlation, was held to be the best measure of quality of facilities.
X_5 = log length of wharves	Included to provide a measure of the extent of facilities.
X_6 = log distance nearest larger port	This was the most highly correlated of the variables measuring competition from ports.

It must be noted that the original variables have now been renumbered; thus X_{23}, population of the maximum hinterland, is the rank order equivalent of the normally distributed transformed variable X_2.

Using the transformed data, Pearson's product-moment coefficients of correlation were obtained and compared with the performance of the rank order coefficients in Table 11.

TABLE 11

COMPARISON OF r AND rho COEFFICIENTS OF CORRELATION

		X_1	X_2	X_3	X_4	X_5	X_6	
wharfage	rho	.88	.56	.76	.61	.76	.78	n = 23
	r	.87	.56	.77	.65	.76	.83	

coefficients > .53 are significant at the 99.5% confidence level.

The high degree of agreement between the two sets of correlation coefficients substantiates the statement of Cole and King (1968,162) made earlier, and reinforces the significance of the results obtained from the Spearman correlation analysis.

A stepwise procedure was employed in the multiple regression analysis. This is a technique of adding one independent variable at a time and generating a series of intermediate regression equations. It is an iterative procedure that has been used frequently in recent geographical studies(Olsson, 1965), and because of its computational complexity requires use of a computer. Most stepwise regression computer programmes add variables generating the highest partial correlation coefficients. However, the algorithm followed in this study employs analysis of variance (Yates,1967). Independent variables are introduced in order of importance in accounting for variance reductions in the dependent variable. The programme was selected because of its availability at the Sir George Williams University computer centre, and although the computational procedure differs from typical stepwise regressions based on partial correlation coefficients, the results should be comparable.

The computer is programmed to continue in the stepwise regression until all variables are included. It then proceeds to calculate the residuals from the regression, using the final regression equation. Because there is no guarantee that the results would be statistically significant, the computer was programmed to terminate the stepwise iteration when the F test fell to 1.0. Below this level any variable introduced would not account for any significant variance reduction. Thus the residuals were determined only from variables statistically significant in the regression equation.

The results of the stepwise multiple regression analysis are contained in Table 12. In step one, the vessel size variable is introduced. This variable alone accounts for 76% of total variation in port activity. Its inclusion reduces to 2.287 the residual sums of squares.

The second variable entered is the measure of competition from other ports. The regression equation incorporating variables X_1 and X_6 now accounts for 82% of total variation in port size. These two variables together now reduce the unexplained variance about Y to 1.66.

The remaining two variables added represent measures of the extent and quality of facilities. By the time the stepwise iteration is completed, their inclusion raises the coefficient of determination to .901.

The complete multiple regression equation becomes:

$$\hat{Y} = -1.44 + .277X_1 + .326X_4 + .618X_5 + .627X_6 \qquad (4)$$

As shown in Table 12 this is a very powerful explanatory model, accounting for just over 90% of variation in port activity in the study area. As the F tests of variance and the t tests of the beta coefficients indicate, the model is significant at the 97.5% level.

It is noteworthy that neither of the hinterland variables were entered. This suggests that the hinterland element (as measured by these two variables) is not a factor in the statistical explanation of port activity on the south shore of the lower St.Lawrence River. This appears to contradict the importance usually given the hinterland component by port geographers. This regression analysis suggests that vessel size, quality and extent of facilities, and competition from other ports are the major elements explaining port activity in the study area.

The next step is to produce predicted wharfage totals from the regression model. These predicted values are compared with the log transformed wharfage data and the residuals from the regression listed in Table 13.[10] The residuals, as deviations from predicted values, are mapped in Fig. 13.

---

[10] It may be noted that the paper that introduced residual mapping to geography (Thomas,1960) contains an inaccurate explanation of positive and negative residuals.

TABLE 12

STEPWISE MULTIPLE REGRESSION ANALYSIS

INITIAL TABLEAU

variable	mean	standard deviation
Y	3.256	.663
X_1	3.956	.718
X_2	3.817	.634
X_3	3.298	.436
X_4	2.652	.446
X_5	3.041	.276
X_6	1.377	.385

N = 23

SYY = 9.683

STEPWISE PHASE

STEP	VARIABLE ENTERING	SSE	R^2	CONSTANT	F LEVEL	REGRESSION COEFFICIENT		T VALUE
1	X_1	2.278	.7638	.0605	67.9058*	X_1	.8078	8.240*
2	X_6	1.656	.8289	.2037	7.6185*	X_1	.5263	3.956*
						X_6	.6847	2.760+
3	X_5	1.266	.8693	-1.116	5.8660*	X_1	.3900	2.956*
						X_5	.6541	2.421+
						X_6	.6103	2.717+
4	X_4	.959	.9009	-1.4416	5.7523*	X_1	.2770	2.180+
						X_4	.3236	2.398+
						X_5	.6180	2.553+
						X_6	.6276	3.122*

FINAL TABLEAU

SSE .959 R^2 .9009 Constant -1.4416

	X_1	X_4	X_5	X_6
regression coefficient	.2770	.3236	.6180	.6276
standard error of coefficient	.1270	.1349	.2420	.2010

* significant at the 99.5% confidence level

\+ significant at the 97.5% confidence level

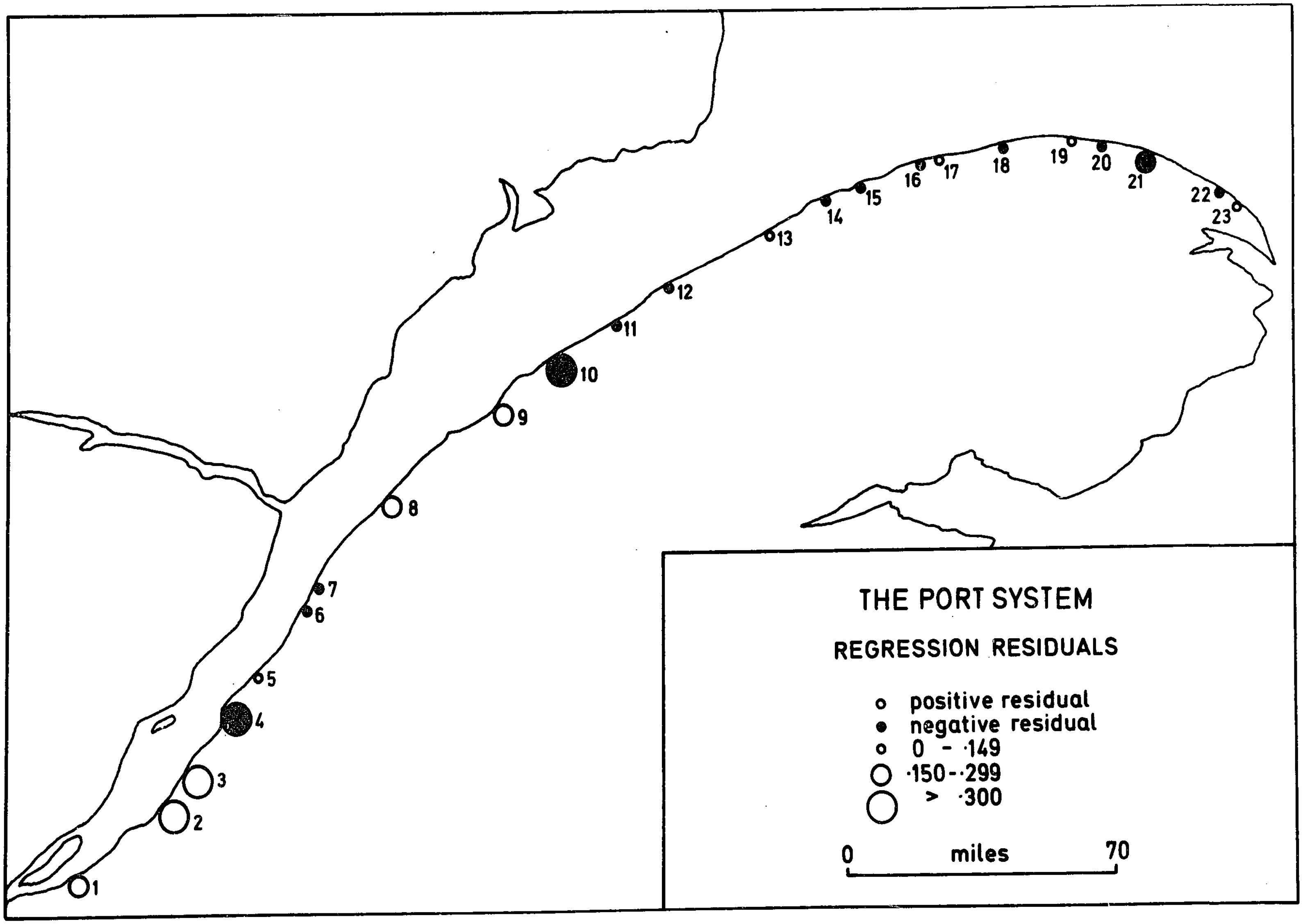
Considering that the regression model accounts for 90% of total variation in port size, it is not surprising that the residuals, as expressions of unexplained variation or error term, are small, the largest being 16%. Under these circumstances it is to be expected that strong patterns of positive or negative residuals will not be evident.

> "If the residuals do show a strong pattern, then it may be that the explanatory model being considered is not a very powerful one since the variables in it are not accounting fully for spatial variations in the independent variable" (King,1969,149).

Only four values are in excess of .3000 from the predicted wharfage total. There is no clear pattern of positive and negative residuals. This suggests that the model is sound with no under or over prediction in any one part of the region.

There appears to be no influence of port size or function on the extent and nature of the residuals. Of the major ports in the study area the model has overpredicted Matane by .236 and Rivière du Loup by .045, while underpredicting Rimouski by .171.

Fig. 13


THE PORT SYSTEM
REGRESSION RESIDUALS
positive residual
negative residual
0 - ·149
·150-·299
> ·300
0
miles
70
1
2
3
4
5
6
7
8
9
10
11
12
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14
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22
23

The only observation that could be interpreted as a slight trend is the occurrence of higher residuals in the upstream portions of the region. When the distance of each port from Quebec City is correlated with the size of its residual, a coefficient (rho) of .55 is obtained.[11] This trend could be taken as representing the error created by the exclusion of the land transport competition component from the model. It will be remembered that the area west of Matane is the only region served by rail.

Despite the strong explanatory performance of the multiple regression analysis, several specific criticisms must be levelled against it. The most important of these criticisms focus on the extent to which the independent variables are truly independent. This question has both statistical and conceptual ramifications.

Multiple regression analysis requires the variables to be independent of each other. Where independence is not evident the problem of multicollinearity is encountered. This seems to have been ignored by most geographers who have used multiple regression techniques (Olsson,1965). Where multicollinearity is encountered the regression coefficients have large standard errors (King,1969,162-3).

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[11] Significant at the 99.5% confidence level.

TABLE 13

RESIDUALS FROM THE REGRESSION

PORT	WHARFAGE	PREDICTED	RESIDUALS	RESIDUALS AS A PERCENTAGE OF WHARFAGE
Baie des Sables	2.9042	3.0320	-.1278	-4.5
Berthier	3.0246	2.8455	.1790	5.9
Cap Chat	3.5770	3.6126	-.0356	-1.1
Chloridorme	2.8965	3.1047	-.2082	-7.2
Grande Vallée	3.4449	3.5150	-.0701	-2.0
Kamouraska	3.1981	3.0504	.1476	4.7
L'Islet	3.1965	2.7386	.4578	14.3
Madeleine	2.9170	2.8214	.0955	3.4
Marsoui	3.0686	2.9405	.1280	4.2
Matane	3.8512	4.0877	-.2365	-6.4
Méchins	3.3288	3.2037	.1250	3.9
Mont Louis	4.0273	4.0814	-.0541	-1.2
Notre Dame du Portage	2.3541	2.4660	-.1119	-4.6
Rimouski	4.9872	4.8161	.1710	3.4
Rivière au Renard	3.4012	3.3372	.0639	1.7
Rivière du Loup	4.1038	4.1486	-.0448	-0.9
Rivière Ouelle	3.0952	3.4966	-.4014	-12.9
Ste Anne des Monts	3.4448	3.5380	-.0932	-2.6
Ste Flavie	2.3096	2.6835	-.3739	-16.0
St Jean Port Joli	3.6682	3.3471	.3210	8.7
St Maurice de l'Echourie	2.0645	2.1246	-.0601	-2.8
Ste Marthe de Gaspé	2.3404	2.4449	-.1045	-4.2
Trois Pistoles	3.6932	3.4598	.2333	6.2

Although the problems of multicollinearity are recognised by econometricians, no hard and fast rules have been devised to indicate the extent of the problem. There merely seems to be a concensus that multicollinearity is acute where the correlation coefficients of independent variables are in excess of .75.

TABLE 14

MATRIX OF INTERCORRELATIONS BETWEEN INDEPENDENT VARIABLES

	X_1	X_2	X_3	X_4	X_5	X_6
X_1	1.0					
X_2	.536	1.0				
X_3	.761	.628	1.0			
X_4	.572	.232	.505	1.0		
X_5	.665	.523	.728	.416	1.0	
X_6	.766	.590	.667	.424	.575	1.0

$n = 23$. Coefficients $> .54$ are significant at the 99.5% confidence level.

Table 14 reveals that although the independent variables are clearly not linearly independent, only two of the coefficients are in excess of .75. Furthermore, inspection of Table 12 shows that the standard errors of the regression coefficients are small, especially when compared with the observed mean value of the dependent variable. These observations would appear to indicate that although the problem of multicollinearity is present, it is not acute. It may be noted also that the question of multicollinearity is irrelevant as long as the regression model is used only to predict port activity.

The extent of intercorrelation does mean that simple correlation coefficients between wharfage totals and the independent variables may be misleading. For example, the high correlation between wharfage and population of the port town is accounted for in part by the other variables acting in association. Coefficients of partial correlation provide the means of removing intercorrelation, because they measure the association between two variables with all others held constant. Here fifth order partials must be determined to measure the relationships between port activity and the six independent variables considered in this section:

TABLE 15

COEFFICIENTS OF PARTIAL CORRELATION

$r_{01.23456}$	.419
$r_{02.13456}$	.240
$r_{03.12456}$	.077
$r_{04.12356}$	.524
$r_{05.12346}$	.455
$r_{06.12345}$	.577

Such high order coefficients of partial correlation create problems of interpretation:

> "Because of difficulties of interpretation, partial correlation coefficients involving elimination of more than one variable are infrequently calculated". (Ferguson, 1966,389).

Table 15 reveals, however, that all partials are considerably lower than the simple correlation coefficients of Table 11. Also it may be noted that vessel size (X_1), which was the first variable entered in the multiple regression analysis because of its high simple correlation coefficient, possesses a smaller partial coefficient than several other independent variables. Distance from nearest larger port (X_6), the second variable entering in the stepwise multiple regression analysis, generates the highest partial correlation coefficient. Clearly the four independent variables contained in the regression model possess much higher coefficients of partial correlation than the variables representing the hinterland element (X_2 and X_3). This substantiates the claims made earlier concerning the role of the hinterland in determining port activity in the study area.

Conceptually the question of independence is encountered because the regression model suggests that port activity is 'caused' by variations in vessel size, extent and quality of facilities, and the competitive forces of other ports. This is untenable. It has been suggested already that many of the relationships are seen more as mutual interactions. Thus not only is the trade performance of a port influenced by its facilities, but the size of the port itself affects the quality and extent of facilities.

A further limitation of the regression analysis is the suitability of the surrogates selected. The effects of vessel size on port trade can be revealed only partly by gross vessel tonnage data for example. It is possible that more refined measures of the hinterland element would have produced more significant results.

Despite these limitations, it may be concluded that the regression analysis has produced a statistical model explaining over 90% of total variation in port activity in the south shore of the lower St. Lawrence River area. This must be regarded as a satisfactory performance.

D. Functional Relationships.

So far this chapter has been taken up with analyses of relationships between size attributes of ports and various elements. The product of this investigation, the multiple regression equation, has been shown to be a powerful explanatory model. In this final section of the chapter an outline of the relationships between functional attributes of ports and the components is presented.

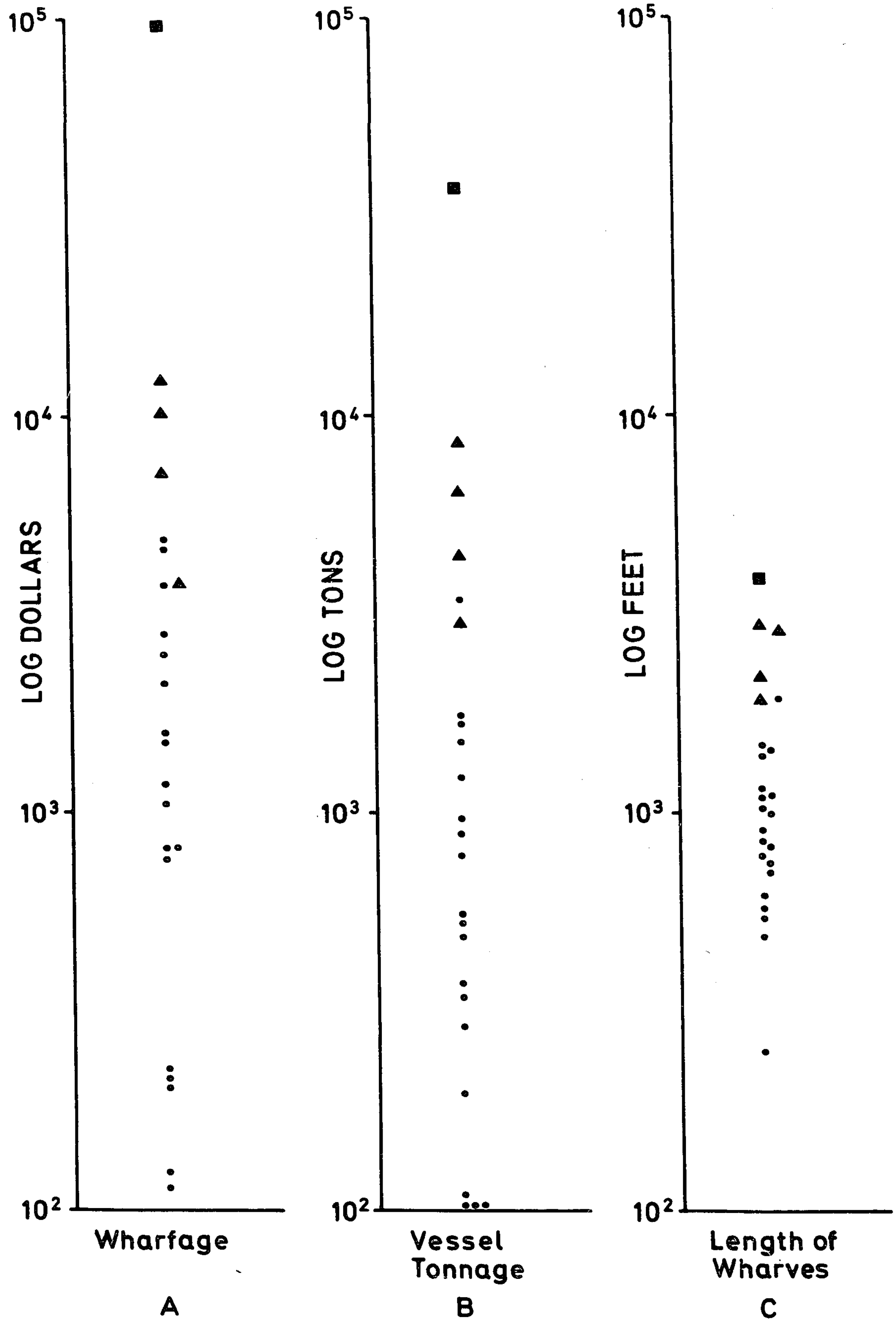
A deductive functional classification was presented in Chapter III which suggested a hierarchy of port functions. In this section the degree of correspondence between the hierarchy and values of the elements is investigated. On theoretical grounds these relationships might be expected to be stepped in character (Haggett, 1965,114-25).

Because of the nature of the problem, no statistical tests that might be interpreted with confidence could be applied. The functional hierarchy recognised only three classes of ports in the study area, containing one, four and eighteen ports each. The fact that one class contains only one port precluded the use of the Chi-square test. Instead the data representing each of the variables used in the regression analysis are arrayed in bar graph form on logarithmic paper. Symbols representing functional classes identify the ports.

The type of problem discussed here is similar to those in urban geography concerning the relationships between city size and the central place hierarchy. In attempts to fit discontinuities in size to functional classes and measure the range and thresholds of each functional class, the work of Berry (1967) and his associates has been outstanding.

The eight bar graphs (Fig. 14) indicate that Rimouski, the 2nd order port, lies well beyond the range of the other ports, and a distinct threshold level exists. The evidence from 3rd and 4th order ports is more complex. In the case of distance from the nearest larger port in the functional hierarchy, 3rd order ports are larger than all 4th order ports. Even in the other examples the general trend is for ports of higher functional order to be greater, even if the threshold levels are not so clear. In these other cases entry zones of varying widths rather than simple threshold levels may be observed (Haggett and Gunawardena, 1964).

The overall conclusions of the evidence presented in the bar charts is that there is general empirical support for the recognition of relationships between the functional hierarchy and port size, as well as strong associations with vessel size, facilities, and competition from other ports. It must be noted that the variables that produce the strongest relationships with port function are precisely the same elements which



PORT HIERARCHY: FUNCTIONAL RELATIONSHIPS

Fig. 14

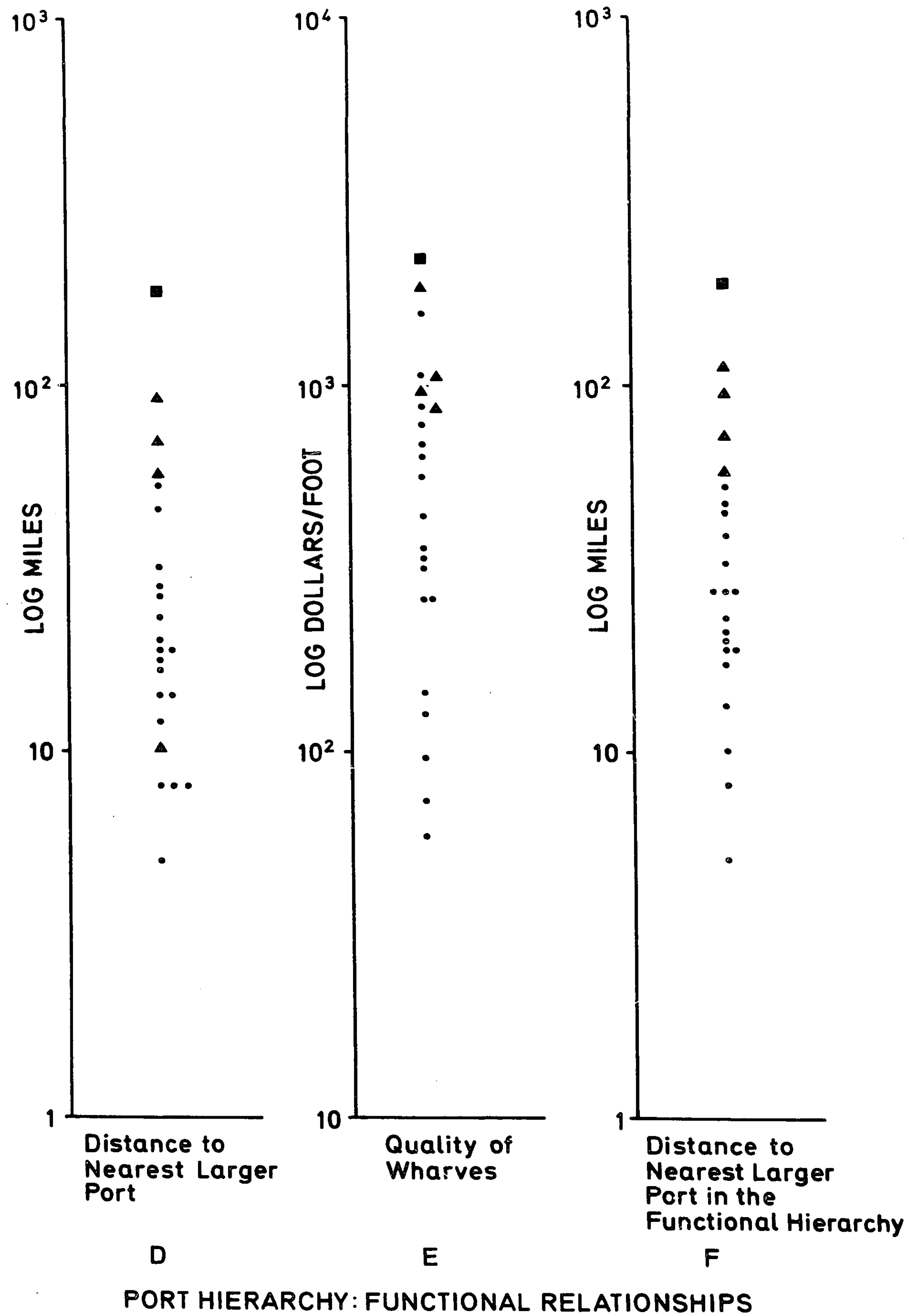
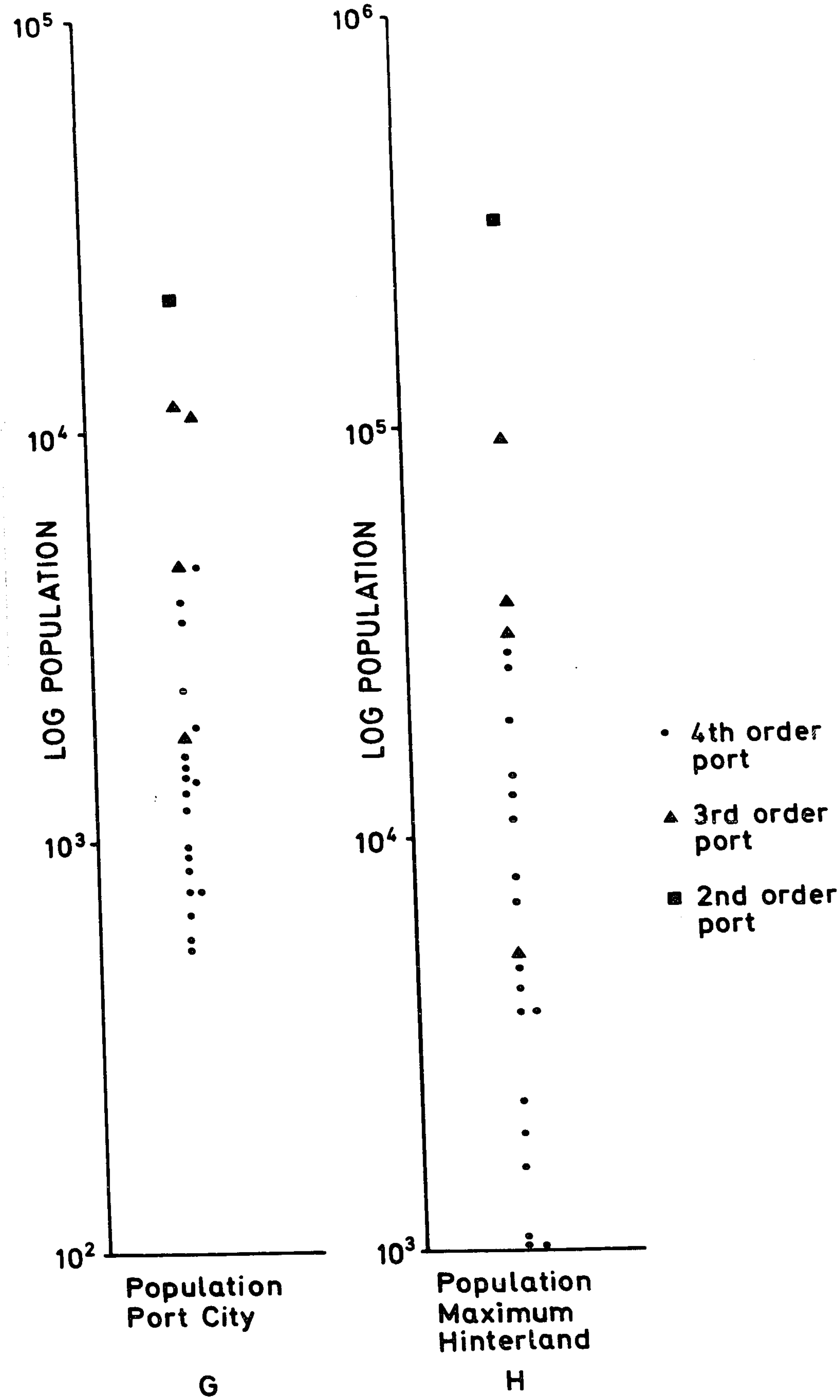

10³
10²
10
1
LOG MILES
Distance to Nearest Larger Port
D
10⁴
10³
10²
10
LOG DOLLARS/FOOT
Quality of Wharves
E
10³
10²
10
1
LOG MILES
Distance to Nearest Larger Port in the Functional Hierarchy
F
PORT HIERARCHY: FUNCTIONAL RELATIONSHIPS

Fig. 14



PORT HIERARCHY: FUNCTIONAL RELATIONSHIPS

Fig. 14

were found to be most significant in the regression analysis. Only the hinterland component failed to produce really marked associations with functional class.

The significance of these observations is that as the analysis progresses to examine the port system in more general terms, with a consequential loss of precision, the functional hierarchy, as a generalisation itself (being the product of classification), can be utilised to extend knowledge of the structure and performance of the system.

CHAPTER FIVE

STRUCTURE AND EVOLUTION OF THE PORT SYSTEM.

A. Introduction.

While important relationships between key elements and size attributes of ports have been recognised, and a model producing high statistical explanations of trade in individual ports has been formulated, the micro level study presented in the previous chapter is restricted both temporally and spatially. Because of its concern with measuring relationships at one point in time, the analysis has been static. Although it was argued that selection of the year 1966 did not introduce bias, the research was not of the type capable of revealing processes of change.

The second limitation is that the associations uncovered refer to one area only. It is most unlikely that the regression model will be applicable to ports elsewhere. The reason is that the nature and extent of associations between the variables and port activity will differ according to the particular circumstances.

Here, a systems framework is proposed to overcome the limitations of the micro level models. As Harvey (1969,450) has noted:

> "The intimate connection between systems analysis and the analysis of complex structures makes this approach very attractive to those disciplines dealing with phenomena that are highly interconnected. Given the multivariate nature of most geographical problems, it is hardly surprising that systems analysis provides an appealing framework for discussing these problems".

There has been much discussion of systems concepts in recent geographic literature (McDaniel and Eliot-Hurst,1969). Geography appears to be following the trend of several other disciplines. A good introduction to the approach is given by Buckley(1967), a sociologist, and Harvey (1969) has outlined the use of systems concepts in other fields. While there has been much exhortation to follow systems approaches, actual examples in geography are rare (Berry,1964).

There are numerous definitions of a system and an even larger number of interpretations of these definitions (Young,1964). In this study the system is defined as the ports operating on the south shore of the lower St.Lawrence River. The attractiveness of a systems approach is that it deals with 'wholes' (all the ports in the system) rather than separate parts, it focusses attention on organisation and structure, and it is concerned with interrelationships between elements and objects rather than with the objects themselves.

> "Systems theory is basically concerned with problems of relationships, of structure, and of interdependance rather than with the constant attributes of objects. In general approach it resembles field theory except that its dynamics deal with temporal as well as spatial patterns". (Katz and Kahn, 1969, 90).

The first part of this chapter explores the important interrelationships between elements that influence the performance of a system of ports. Evidence from the ports in the study area is presented to explain the nature of the organisation of a port system. These results are then employed to produce a process model of port development, which is presented as a highly generalised conceptual device.

It must be realised that concern with changes in the whole port system necessitates a loss in precision. Considering the difficulty of measuring the elements, and the limited technical ability to handle all the variables that would have to be treated in order to predict accurately changes in the system, it is inevitable that the analysis must become more general. Furthermore if the research presented here is to have wider application, certain specific assumptions will have to be relaxed in order to derive more general conclusions.

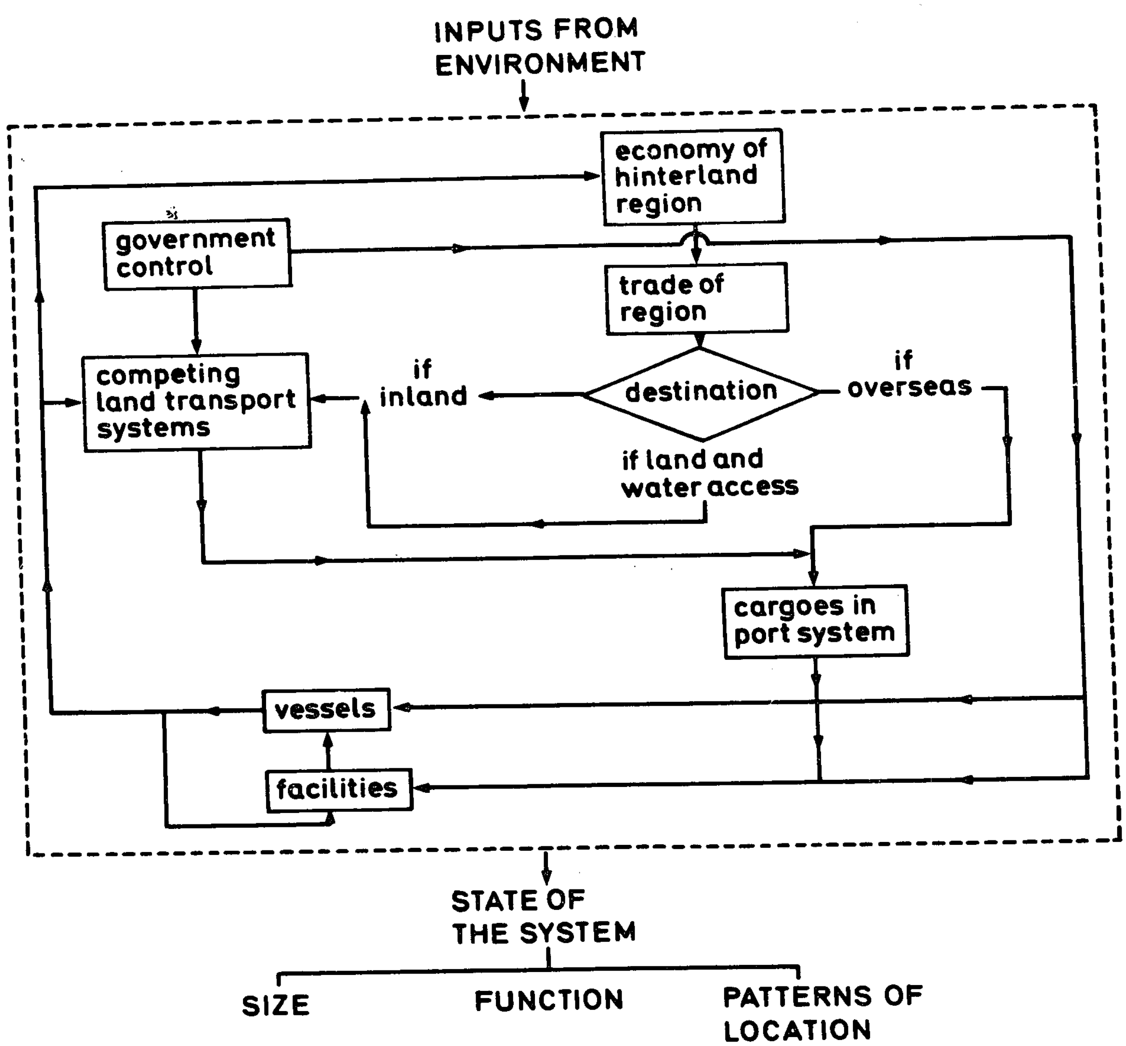
B. Structure of a Port System.

The analysis in this section is based on the premise that the 'state' of a system of ports at any point in time is a function of the nature of the interrelationships between key elements in the system. It is claimed that changes in the condition of the elements will force readjustments in the associations between those elements and others to which they are linked. Thus processes of evolution of a port system are seen to hinge upon the nature of the components and the strength of the relationships between them.

To investigate the organisation of a port system a morphological model is introduced in Fig.15. This model incorporates the main components of the port system and indicates the direction of the relationships between them. Evidence from the ports in the study area will be presented to suggest how the system is structured.

1. Relationships between Hinterland and Trade

The structural model presents the picture of a highly integrated and interdependent system. Knowing where to begin the analysis is a real problem in these circumstances. Here, a start is made with the hinterland component, whose influence on the port system is to determine the type and nature of the trade generated. Expressed in very simple



MORPHOLOGICAL MODEL OF A PORT SYSTEM.

Fig. 15

terms, surplusses produced by the economy of the regional hinterland are exported, and deficits lead to imports. These relationships are shown very clearly in the study area. Because the region is underdeveloped and poor its trade potential is small. The economy is based upon the exploitation of natural resources, despite the fact that the resource endowment is meagre. The primary sector in each of the counties exceeds the provincial average by a considerable margin (see Fig.16). Farming, forestry, fishing, and mining represent the traditional economic activities of the region.[12]

Only the forest resource is relatively abundant on the south shore of the lower St.Lawrence River. Forest industries account for a significant percentage of total employment in all counties, and almost 25% of the labour force in the interior counties of Matapédia and Témiscouata. In addition, the woodlots of farmers represent an important source of income throughout the region.

The forests also form the basis of much of the industrial development in the region. Manufacturing activity is very limited (only Montmagny approaches the Quebec average in secondary industries), and is concerned mainly with the processing of forest raw materials. The leading industries are sawmilling, pulp and paper, and furniture fabrication.

Farming is hampered by an adverse physical and economic setting. Poor soils, short growing season, high humidity, and remoteness from large urban markets are the chief reasons for the difficulties of farming

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[12] A good review is presented in Pépin (1960,102-301).

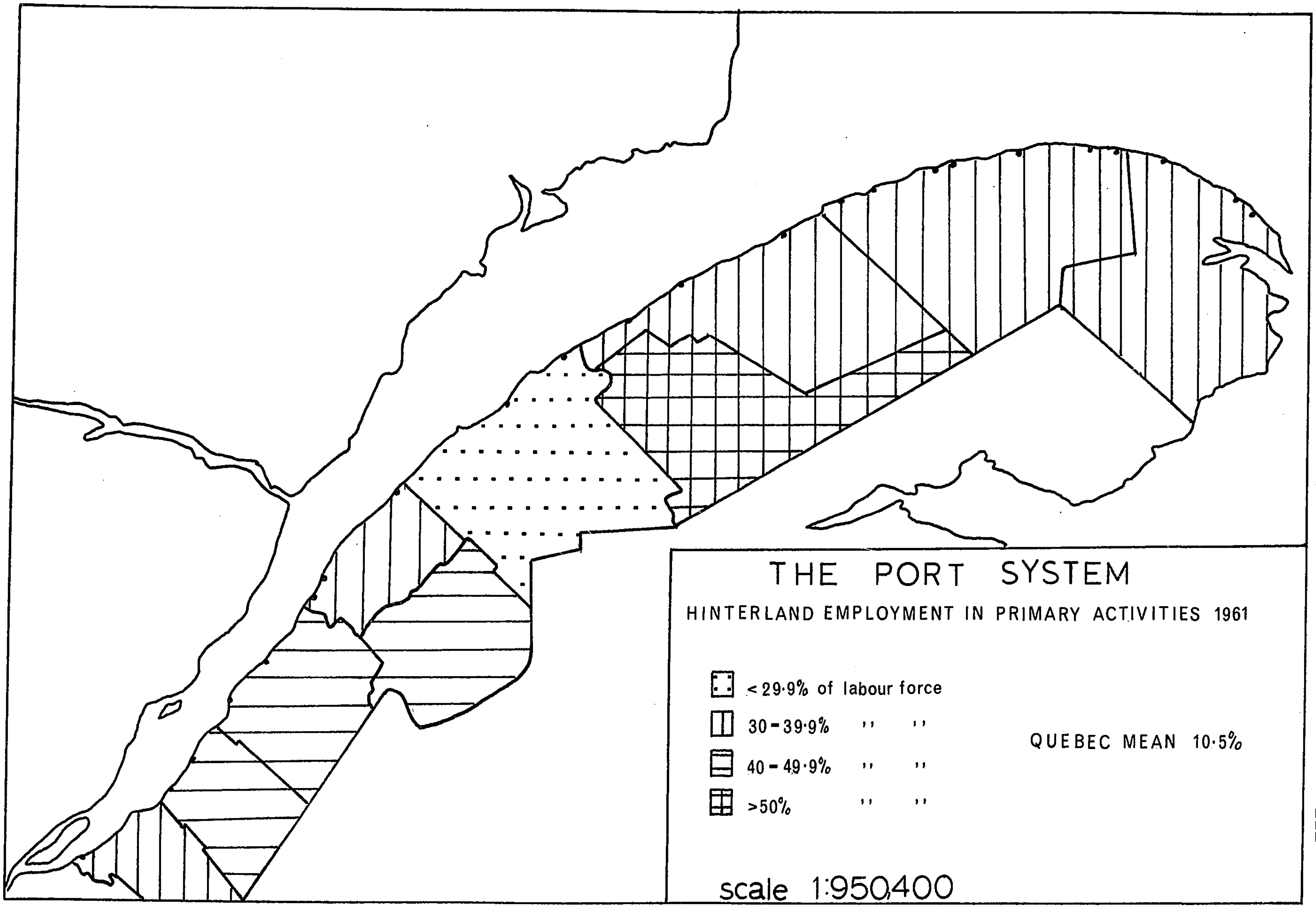
THE PORT SYSTEM
HINTERLAND EMPLOYMENT IN PRIMARY ACTIVITIES 1961
< 29·9% of labour force
30 – 39·9% " "
40 – 49·9% " "
>50% " "
QUEBEC MEAN 10·5%
scale 1:950,400

Fig. 16

in the region. As a result, agriculture generates few surplusses and produces meagre returns for most farmers, despite its widespread geographical occurrance.

Fishing tends to be a seasonal and part-time occupation in most areas. Traditional methods of inshore fishing are practised, with little investment. Recent attempts to rationalise the industry have met with some success. The aim of the government has been to concentrate investment at one point, Rivière au Renard, rather than attempt to assist every fishing village. Because of the capital investment in deep sea trawlers and a large fish processing plant, Rivière au Renard has developed as the leading centre in the region. Other villages, by comparison, are languishing.

Although mineral resources are quite widespread, they do not occur in sufficiently large deposits to warrant exploitation. The only exception is at Murdochville where large copper deposits are mined, and support an important smelter. Elsewhere there are several small scale enterprises of little significance that exploit minor local ore deposits and peat.

Even this very superficial review of the economy of the hinterland region of the ports is sufficient to indicate that only small amounts of trade are generated. Surplusses are few, and are restricted to crude or processed forest products, with much smaller quantities of fish and agricultural goods being traded. Because there is little secondary industry and because incomes in the region are low, demands for goods produced outside the region are limited. Finished manufactured goods represent an important segment of imports, while the biggest single item imported is petroleum.

2. <u>Relationships between trade generated by the hinterland and cargoes entering the port system</u>.

The cargoes entering the port system are but a fraction of the total trade produced by the economy of the hinterland region. The share of the trade captured by the ports is dependent upon the degree of competition from other transport systems. It has been noticed already that competition from land transport is a very complex element. In order to facilitate discussion of its impact, three types of trade produced by the hinterland may be recognised. There is the trade which has to be shipped by water routes because it is destined for points inaccessible by land transport. These may be commodities that are shipped to places where there are no road or rail links, such as the eastern portions of the Quebec North Shore region, or to overseas destinations, such as Europe. It is obvious that water transport in most cases represents the only feasible link between producing and consuming areas. Where such circumstances prevail there will be a direct relationship between the hinterland component and the amount of trade entering the port system.

In most instances, however, these simple relationships are blurred by the second type of trade which embraces the commodities that may be transported to their destinations by either land or water systems. Here the amount entering the port system is ideally a function of competition between competing networks as expressed by freight rate differentials. While in practice competition is a very complex factor, it may be generalised that the less bulky, higher value commodities are transported by road or rail, leaving the low value, bulk items to enter the port system.

The routing of this group of commodities may be determined by corporate decisions. Large vertically integrated organisations have been shown to play an important role in route and mode selection. Certain routings and mixed-mode transfers that do not appear to be the most economic, may be explained by considering the organisation of the corporate decision making agency. Frequently decisions made by corporations controlling through transport systems result in investments in one mode or route that entrench the arrangement and make changes difficult and costly.

A final type of trade generated by the hinterland region includes those goods whose destinations or points of origin are not on water routes. Consequently, all these commodities will be handled by land transport systems.

Changes in the destination patterns of goods generated by the hinterland region will produce variations in the share of trade captured by the port system. Increases in overseas markets or enhanced demands for goods produced overseas will obviously affect the ports in a positive way. In a similar fashion, the percentage of the total trade directed through ports will diminish with increases in the efficiency of road and rail networks. Extensions of railway lines or roads, reductions in land freight rates, or increases in government subsidies will reduce the amount of trade entering the port system.

The B.A.E.Q.(1966,56) study produced an estimate that 43% of all trade generated in the Gaspé region is carried by ships (see Table 16). It is not surprising therefore, that the analysis of the performance of individual ports had failed to identify high correlations between port size and various measures of the hinterland component. Over half the trade of the region is diverted by other transport systems.

Table 17 lists the leading items carried by each of the competing transport systems in the region. These classes may be viewed as the products of competition between road, rail, and water transport networks. Although this table seems to substantiate generalisations made earlier that land systems handle higher value and less bulky commodities, it may be noticed that there are several instances of overlap. Most of these examples of duplication may be interpreted and explained by referring to the tripartite classification proposed earlier. The case of pulpwood, a low value and bulk item which is shipped by both rail and water, may be explained because most of the rail traffic is to interior pulp mills in New Brunswick. While most of the timber produced by local sawmills is transported out of the region by road and rail, quantities are shipped by vessel to ports across the St.Lawrence on the north shore, and to the United Kingdom. Much of the high value general cargo carried by water transport may be accounted for in a similar way, and also by trade with the easternmost ports in the study area where there is no rail competition.

Only in the case of petroleum is route selection and mode split determined by vertically integrated companies controlling through transport systems. Most of the other goods are handled in small shipments. Even

TABLE 16

PERCENTAGE OF TOTAL TRADE CARRIED BY THE COMPETING TRANSPORT SYSTEMS.

	Receipts	Shipments
Road transport	14	13
rail	29	58
water	57	29

source B.A.E.Q. Les Transports p.56

TABLE 17

LEADING COMMODITIES CARRIED BY THE COMPETING TRANSPORT SYSTEMS

	Receipts	Shipments
Rail	construction materials	timber
	chemicals	pulpwood
	fertilizers	
	manufactured goods	
Road	food products	timber
	construction materials	food products
	household goods	
	misc. metal products	
Water	petroleum	pulpwood
	construction materials	timber
	misc. general cargo	petroleum
		copper ingots
		general cargo

where the total commodity flow is large, as in the case of pulpwood, decisions made over routing and mode selection are extremely fragmented. Thus the concern of the pulpwood merchant is to buy as much pulpwood as possible from the farmers and co-operatives, and to transport it as cheaply as possible to the nearest port. There he receives payment and then it is the concern of the vessel owner to ship the pulpwood to the mills.[13] With decisions fragmented over a large number of individuals or companies at each stage in the movement of pulpwood from farm to mill, it is not surprising that there is no concern with evaluating costs and routes between production and consumption points.

In contrast the oil companies control every step in the transfers of products, from crude oil sources to the refinery, and ultimately through the distribution channels to the consumers. The selection of water transport in the region is based upon the economies of shipping refined products from the refineries. The different marketing policies of the companies within the study area have been described already in Chapter IV.

3. Relationships between cargo and port facilities.

The type and quantity of cargoes directed to a water route play an important role in determining the extent and nature of port facilities. While ports receive occasional shipments of diverse cargoes, most of the business that is handled tends to be of a regular type, and the ports establish facilities to expedite this trade. Certain types of cargo require specialised storage and handling facilities. This is particularly noticeable in the case of bulk commodities, where economies

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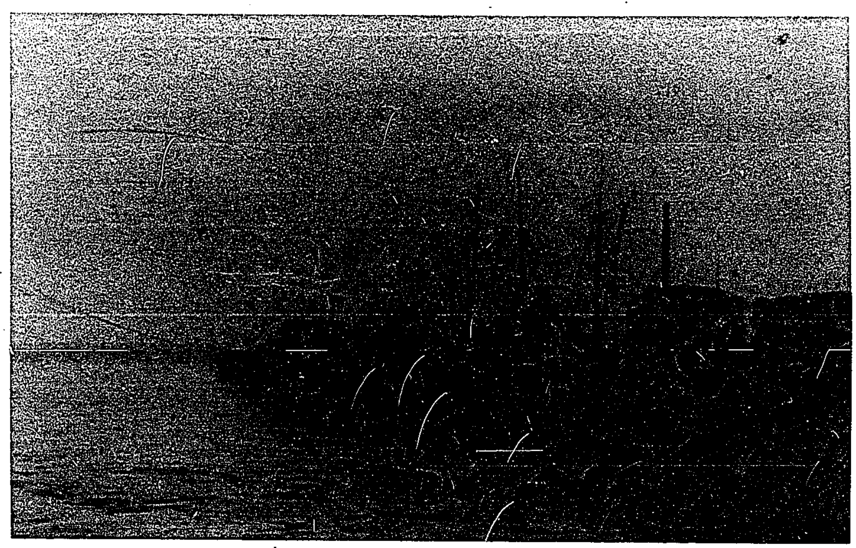
13 Personal communication, Anticosti Shipping and Consolidated Bathurst Cos

of port operation necessitate transfers of large quantities at minimum cost and time. Good examples are provided by grain elevators and iron ore docks. Even general cargoes may require specialised storage facilities, such as refrigerated warehouses, and special loading gear, such as heavy cranes for containers.

These relationships are only partly evident in the port system on the south shore of the lower St.Lawrence River. In the case of petroleum, specialised storage and handling facilities are provided. Where relatively large quantities of general cargo are handled, at Matane, Rimouski, Ste. Anne des Monts, and Grande Vallée, storage sheds have been constructed. In other cases, however, cargoes are handled on an 'ad hoc' basis. Even in the pulpwood trade, which is very extensive, the logs are tipped directly into the holds of vessels by the trucks which bring the wood from the cutting areas. Only in rare instances are mechanical grabbers used to load the vessels (see Plate 4). Occasional shipments of food products and building materials employ ships gear, and require no storage facilities as they are trucked directly to and from wharves.

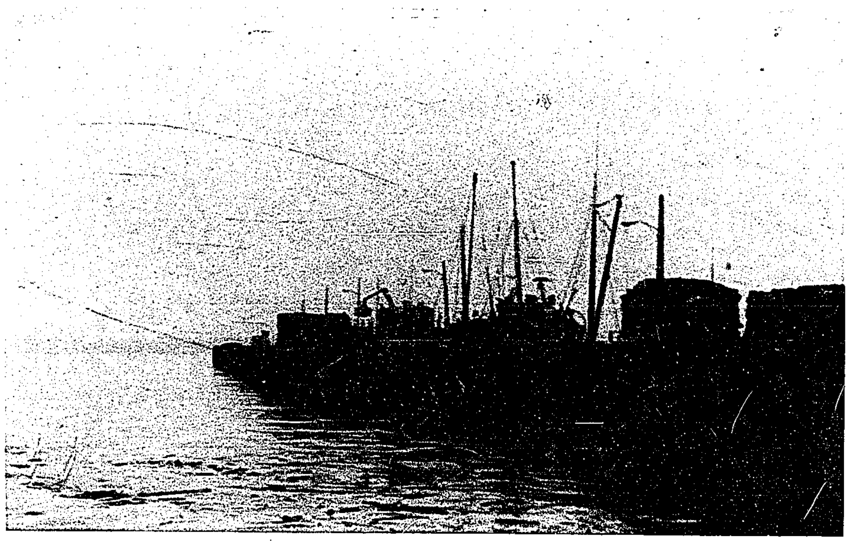
The nature of the relationships between cargoes and port facilities indicates that should significant changes take place in the type or quantities of cargoes, ports would have to adjust their facilities to handle the new trade. The literature on ports is replete with examples of this process. Two of the best known cases in Canada occurred across the St.Lawrence where Sept Iles, a former fishing settlement, was transformed into a major port as a result of the exploitation of iron ore in the

Plate 4



Loading Pulpwood, St. Jean Port Joli

Plate 4



Loading Pulpwood, St. Jean Port Joli

Ungava Trough; and Baie Comeau became a major port centre because of industrial development which resulted from local hydro electricity generation.

There could be grounds for suggesting that improvements to facilities of ports will attract greater quantities of trade. However, it is felt that where this occurs it is produced by other factors as well. Availability of facilities themselves will not generate trade and attract cargoes. An excellent example of this is provided in the study area and was a case which became the object of considerable public controversy with the publication of the report of the Auditor-General of Canada in the spring of 1970. In the period 1967-8 over eight million dollars were spent on the construction of a deepwater harbour at Gros Cacouna, just below Rivière du Loup. As noted in the report of the Auditor-General, no trade has developed there since completion of the project.[14]

4. Relationships between cargo and vessels.

Parallel to the relationships between cargoes and facilities are the effects of cargoes on vessels. The type, volume, and mode of occurrence of cargo has a profound influence on ships. While there are

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14. It may be noted that a confidential study was commissioned prior to construction to investigate the possibilities of utilizing the site. A linear programme study indicated that with continued expansion of economic development in the lower St.Lawrence region, the optimum location for a new oil refinery would be at Rivière du Loup. Thus it was suggested that the Gros Caconna site, with its deepwater access should be selected. The linear programme study indicated that a less optimal site would be near to Quebec City. In fact the Quebec City site was selected in 1968.

many vessels that handle a wide range of commodities, economies of vessel operation work increasingly in favour of the ship designed specifically to accommodate certain types of cargo only. Cargo carrying capacities of specialised vessels are much greater than general purpose ships of equivalent size, and this clearly affects the revenue potential of the vessels.

Another type of economy are the considerable economies of vessel size (regardless of the type of vessel).[15] With negligible increase in operating costs, larger vessels transport much greater quantities of cargo each voyage. The extent to which these economies of scale may be realised depends in part upon the type of cargoes to be transported. In general, crude products are those cargoes most easily transported in bulk, and the largest vessels afloat are carriers of oil, ores, and grain (see Fig.17).

The ability of a port system to achieve economies of vessel size depends upon the availability of cargoes in sufficient quantities. Where resources are meagre, output is small, or where demands for goods are at a low level, these economies will be unobtainable. However, size of shipment at any port in the system is influenced not only by the economy of the region but also by the nature of the geographical distribution of production and consumption centres. A relatively large regional trade flow will not necessarily produce large shipments at individual ports if the centres of production or consumption are widely dispersed. Whereas a relatively small regional trade flow may permit

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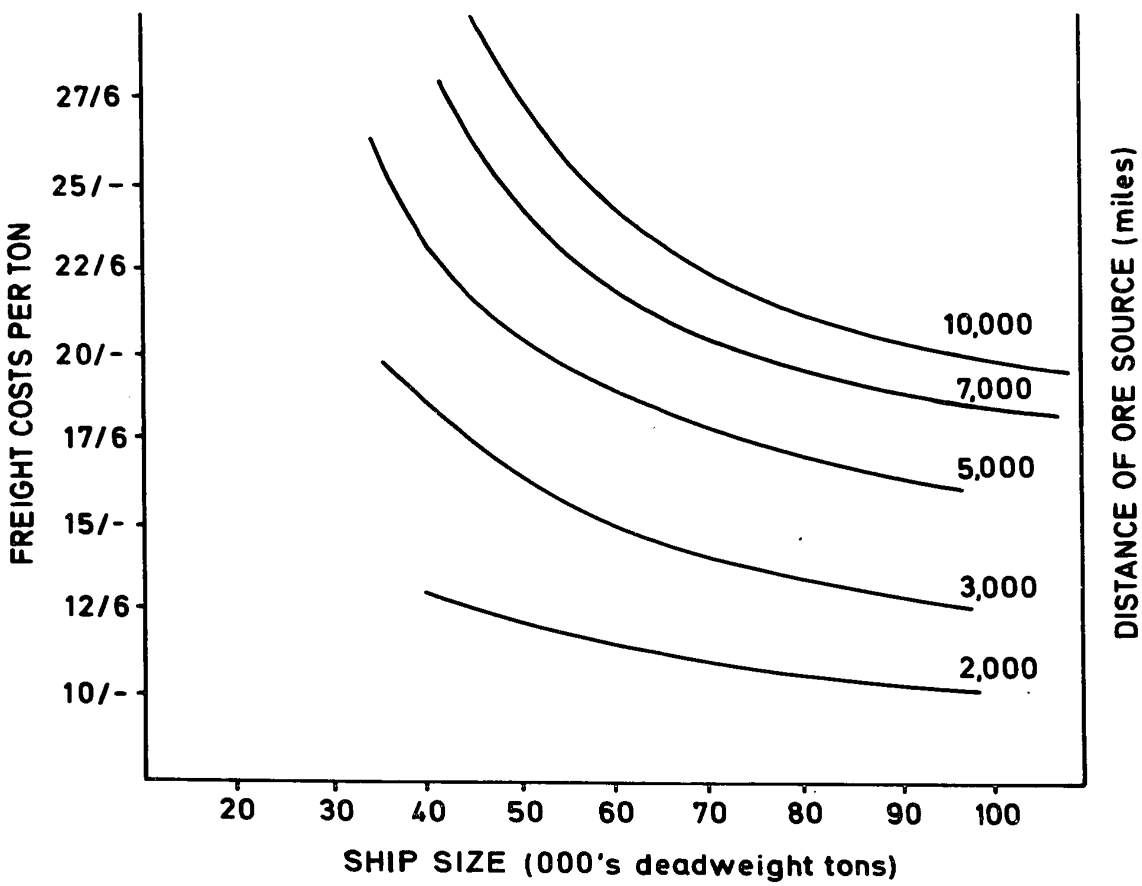
[15] Heaver's (1968) work provides an excellent in depth study.

FREIGHT COSTS AND SHIP SIZE



SOURCE: Meredith and Wordsworth

Fig. 17

economies of scale to be realised if the centres of supply and demand are concentrated.

To clarify the rather complex relationships between cargoes and vessel size, application of Weber's (1929) simple classification of goods entering the industrial system is suggested. With slight modifications to the original definitions, the four following classes of cargoes are proposed to explain certain aspects of the port system:

localised goods, those commodities produced or consumed in a few well defined localities only; e.g. ores.

ubiquitous goods, those goods consumed or produced practically everywhere in the region; e.g. food products.

gross products, a term applied here to low value commodities which are difficult or expensive to transport; e.g. cement, pulpwood.

pure products, are those cargoes easily and cheaply transported; e.g. petroleum.

This simple classification may be used to gain new insights in the relationships between cargoes and other components.

Where the hinterland region produces goods entering the port system that are localised and gross, relatively few ports will be able to participate in the trade. If the volume of trade was sufficient, bulk carriers could be employed in these few ports, and economies of scale could be achieved.

Where the cargoes are ubiquitous and gross it is very unlikely that large vessels could be employed unless output (or demand) over the entire region was sufficiently large to permit all the ports in the system to accumulate sufficient quantities to support large bulk carriers.

If the trade consists of commodities that are ubiquitous and pure, the cargoes could be transported to certain ports in the system, where they could be accumulated and made available in sufficiently large shipments to warrant transport by large vessels. In a similar way economies of vessel size may be achieved where cargoes are localised and pure. Despite being available at certain points only, these cargoes could be transported considerable distances to appropriate ports because of their purity.

This classification of cargoes is a gross oversimplification, of course. No attempt was made to define each group in a precise way. Furthermore it is probably more realistic to envisage cargoes occupying cells in a matrix rather than four broad class groupings:

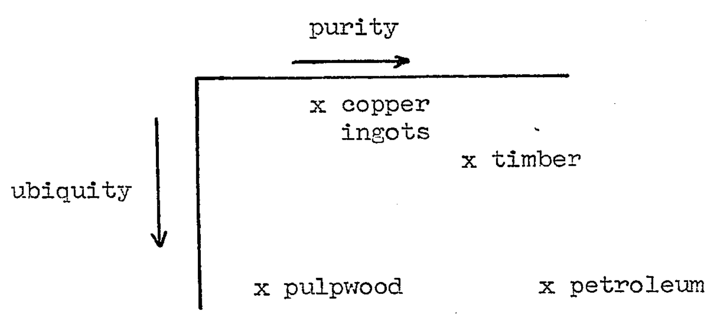


Fig.18 Cargo-type Matrix

Nevertheless the classification does allow some of the broad and general relationships to be conceptualised, and in a later section of this chapter will be employed to explain actual conditions of trade in the ports in the study area.

5. <u>Relationships between facilities and vessels</u>.

Referring to the model of the organisation of a system it may be observed that cargoes are not the only element to influence vessels, because facilities themselves affect vessel size and type. Depth of water in the approach channels and alongside berths may well preclude the realisation of economies of scale. Despite availability of cargoes in sufficient quantities, shallowness of water in the harbour will exclude the large vessels of deep draught from this potential trade. In this way facilities have a negative effect on the port system.

Facilities influence vessels in an equally important way through terminal charges. Each time a vessel calls at a port, terminal costs, in addition to regular operating costs, are incurred. At the same time no revenues are being generated because the ship is stationary. A major concern of ship operators, therefore, is to keep the amount of time spent in port to a minimum. Quick turnabouts are sought, but can be accomplished only where port facilities are sufficient and efficient.

The extent to which quick turnabouts are possible also depends upon the type of trade (see Table 18). Clear advantages are possessed by bulk carriers because loading and unloading of such ships is highly mechanised. Vessels handling general cargo are at a considerable disadvantage and incur high terminal costs. Goss (1967) has produced an estimate that if the amount of time an average freighter spends in port could be reduced from 60% to 20%, its annual carrying capacity would be doubled.

For general cargo, therefore, ports traditionally have been

TABLE 18

PROPORTION OF TIME SPENT IN PORT BY REPRESENTATIVE CLASSES OF VESSEL

	PASSENGER LINER	CARGO LINER	DEEP-SEA TRAMP	GENERAL PURPOSE TANKER
Percentage at sea	63	40	57	81
Percentage in port	37	60	43	19

source: Report of the Committee of Inquiry into the Major Ports of Great Britain. 1962, p.112

TABLE 19

MEAN VESSEL SIZE ASSOCIATED WITH SEVERAL CARGO CLASSES, LOWER ST.LAWRENCE REGION

Cargo class	pulpwood	timber	agricultural produce	ingots	petroleum
mean vessel size (tons)	189	419	233	516	3172

general cargo
286

source: Primary D.B.S. data.

bottlenecks, where a large part of total transport costs are incurred and where delays are expected. In recent years there has been a dramatic breakthrough however. Probably the most important revolution in shipping since the development of steam powered ships has been the introduction of through transport concepts. In the last ten years great changes in cargo handling methods have taken place with developments in unitised cargo. Whether in the form of pallets, containers, or Roro (Roll-on, Roll-off), speed of throughput at unitised cargo berths has increased dramatically. Berth throughputs have been investigated in a number of studies by operations researchers (Bertlin,1966; Arthur D. Little Ltd., 1967), who have shown that containerisation can lead to savings of up to 80% of cargo handling costs. It has been demonstrated also that container berth throughputs exceed land and sea transport capacities, so that at the moment maximum economies of through transport seem best achieved by operating container berths at below capacity.

Relatively few ports in the world are capable of deriving benefits from these changes in cargo handling. Unitisation is applicable only where the volume of trade is sufficient to warrant massive expenditures in facilities. Consequently dramatic increases in berth throughputs have been restricted to the major ports of the world.

In an attempt to reveal the relationships between the vessel component and other elements discussed so far, Table 19 has been included. It shows variations in the size of ships engaged in different types of trade in the study area. It is most evident that the port system on the south shore of the lower St.Lawrence River is served by small vessels.

In contrast, Heaver's (1968) report and other studies have referred to situations where ships in excess of 100,000 n.r.t. were considered; the difference is one of scale only, the principles are the same.

Of the six groups, one half represent commodities that are ubiquitous:- pulpwood, being produced throughout the entire region; petroleum, consumed in all populated sections; and general cargo, an amalgum of largely manufactured goods for consumption in the region.

Very large quantities of pulpwood are produced in the study area both by individual farmers, co-operatives, and the large paper companies. Pépin (1960,160) estimates that fifteen per cent of all pulpwood cut in the province of Quebec is produced in the region. It might be thought that considerable economies of vessel size could be achieved because of the quantity produced, but as shown in Table 19, the mean size of the ships engaged in this trade is only 189 n.r.t., the smallest of all categories. Most of the trade is carried by 'goélettes', the traditional wooden coastal vessels of limited carrying capacity. While representing a link with the past - they were only motorised quite recently - two factors account for their small size. Pulpwood is a gross product, being bulky and low value. The logs cannot be transported great distances, and as noticed already, they are trucked to the nearest port. Consequently, the tonnage available at each of the large number of terminals is relatively small. The second factor is a product of the depth of water available at most of the ports. Only seven of the ports active in 1966 possessed depths at low water in excess of twenty feet, and there were ten ports with 'maximin' depths of less than ten feet. The 'goélette' is supremely suited to such conditions, arriving with the tide, loaded while still afloat, and remaining high and dry at low tide.

In direct contrast petroleum is a relatively pure commodity. It is easily transported in bulk by road and rail. Economies of vessel size are realised to a greater extent than with any other commodity through the use of relatively large coastal tankers serving five of the ports only.

The third ubiquitous commodity, general cargo, is pure too. However, because the quantities transported are so small, largely as a result of competition from other transport systems, there is no possibility whatsoever of scale economies being achieved. Most of the general cargo is carried by small package freighters belonging to Agence Maritime which operate between Montreal, Quebec, Rimouski, and the ports east of Matane, and Anticosti Shipping Company, plying between Rimouski, Grande Vallée and Anticosti Island, with occasional shipments to the Quebec North Shore.

The remaining commodity groups are localised goods, either in their patterns of production or consumption. Copper Ingots are quite gross and are shipped from Mont Louis on a seasonal basis. Small coastal freighters handle the relatively small volume of trade. A similar restriction on amounts of trade influences the shipments of timber and agricultural products, despite differences in the degree of purity of these goods.

6. Relationships between vessels and facilities.

Facilities have been shown to influence vessel size and type, but it must be recognised that ships themselves affect the nature and form of facilities. Handling gear, dimensions of berths, as well as depths of water maintained in the harbour are influenced by the types of vessel served. For example, dredging of approach channels and berths may be required to permit access by ships of a certain size. Meredith and Wordsworth (1968) have calculated the increase in harbour costs which result from increases in vessel size (see Fig.19). If these added expenditures are passed on by the port authority to the user in the form of increased harbour dues, increases in harbour costs may ultimately outweigh economies achieved through increased ship size.

7. <u>Relationships between vessels and other components</u>.

The efficiency of water transport, as revealed through economies of vessel size, and efficiency of port operation, exerts a major influence on the comparative position of alternate transport systems. It has been shown that a certain percentage of the trade of a hinterland region is subject to competition between land and water transport. Improvements in port efficiency, through the use of containers or the employment of more mechanised handling facilities, and use of larger ships, will improve the competitive position of water transport, and divert more trade to the port system away from road and rail routes. A greater volume of trade in the port system would generate other economies of scale, and unless the land transport systems reacted to lower their rates, water transport would be able to benefit from a multiplier effect. Of course, a negative multiplier would take effect if the competitive position of water transport deteriorated.

Where the level of efficiency of water transport is great enough, new transport orientated industry could be attracted to the hinterland

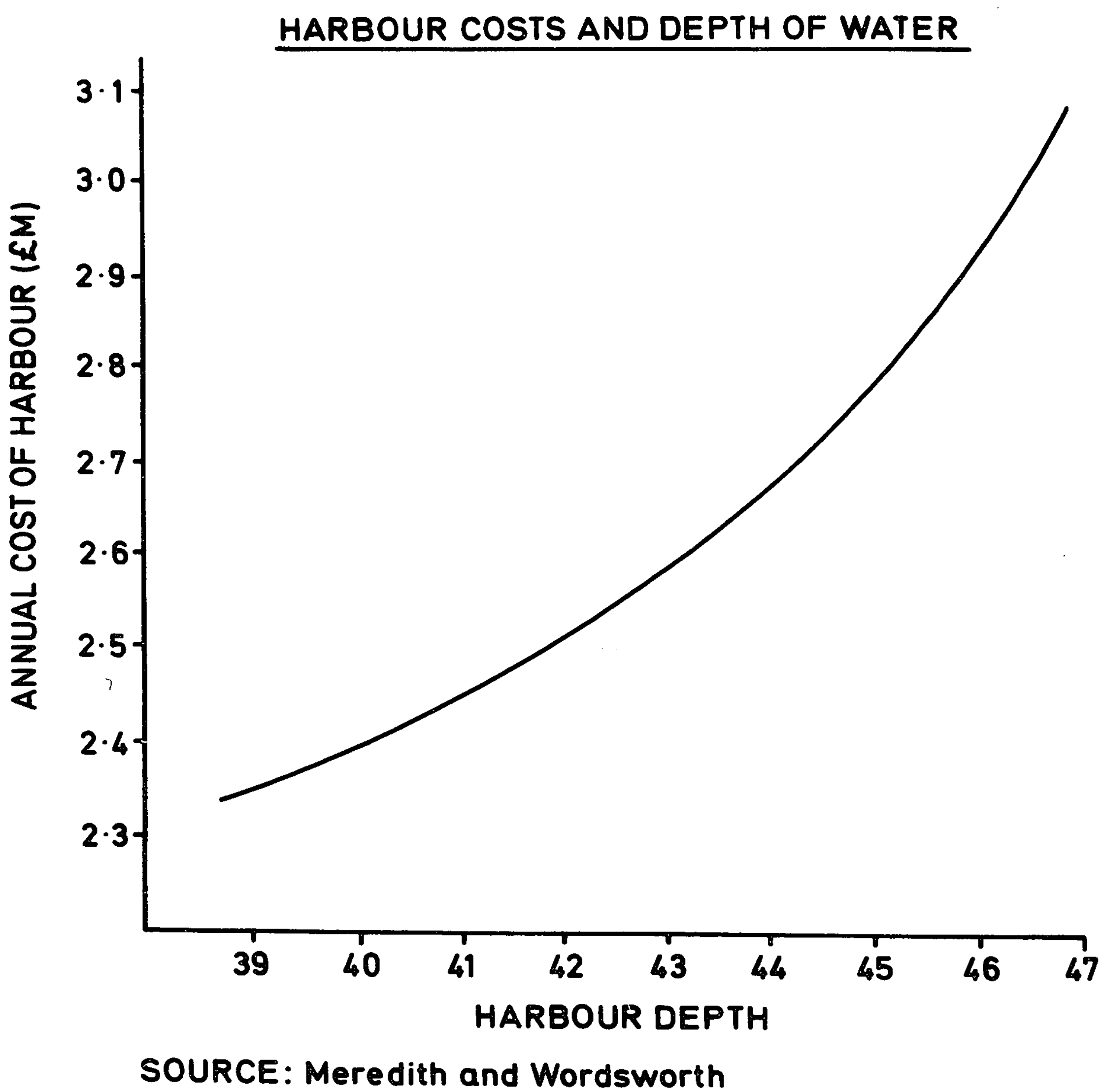

HARBOUR COSTS AND DEPTH OF WATER
ANNUAL COST OF HARBOUR (£M)
3·1
3·0
2·9
2·8
2·7
2·6
2·5
2·4
2·3
39
40
41
42
43
44
45
46
47
HARBOUR DEPTH
SOURCE: Meredith and Wordsworth

Fig. 19

region. Such industries are those for which transport costs form a high percentage of total costs. Petroleum refineries, flour mills, and sugar refineries are examples of the type of industry commonly located in the major port cities of the world. When the competitiveness of the port system is capable of attracting such industries, new trade possibilities are created and port activity is enhanced still further.

8. Relationships between the government and the port system.

A final component that has been referred to only rarely by port geographers is the role of government. Occasional references to particular relationships have been made in other parts of this dissertation, but it is felt that the importance of the government's role is so great and diffuse that it warrants recognition as a separate element in the system.

The role of government was alluded to in chapter three where the analysis focussed on spending on harbour construction. While there are several ports that were built and are operated by private interests, most of the ports in Canada are publicly owned. Practically all the ports in the study area were built with capital from the federal government, and all the ports now receive capital investment and operating monies from Ottawa. The twenty-three active ports in 1966 represented an investment of approximately thirty-six million dollars. This amount is reflected in the extent and quality of facilities, which the earlier analysis revealed to an important factor influencing port activity.

This investment is important in a way not discussed so far. The vast sums of money spent on harbour construction and maintenance have not been matched by the trade performance of the ports themselves.

The revenues generated by the ports are so small that if harbour construction were to be costed on economic grounds alone, few of the ports would possess any facilities at all. The cost of the ports is out of all proportion to the benefits derived when measured in terms of wharfage. Table 20 reveals the cost/benefit situation over the last 20 years.

The government effectively subsidises water transport through continued expenditures on harbours. This permits uneconomic ports to continue operating. Thus the number of ports is partly a function of the extent of government support. By permitting sub-marginal ports to continue to operate, the government is maintaining the state of the system, and protects it from the full force of competition from other transport networks.

The point must be made that continued government support for harbour construction is not made on economic grounds. The federal government is subject to lobbying by the owners of the 'goélettes', through their association, L'Association des Propriétaires de Navires du St.Laurent Inc, to keep open the small ports they require. The major pressure, however, comes from the locally elected members of Parliament, who have used this aspect of federal spending as a means of dispensing patronage. There is little doubt that payment to local companies or individuals for the construction of wharves has been used extensively to repay political favours. Incidental to the patronage is the stimulus to the local economy of continued spending by the Department of Public Works.

More indirect as far as the port system is concerned, is the role

TABLE 20

COST/BENEFIT SITUATION FOR THE ACTIVE PORTS 1946-1966

port	Cost of construction and maintenance	Wharfage generated
	$	$
Baie des Sables	400,874	4,696
Berthier	79,847	6,805
Cap Chat	800,145	29,968
Chloridorme	578,686	5,192
Grande Vallée	722,534	18,107
Kamouraska	93,907	12,175
L'Islet	170,643	9,909
Madeleine	391,390	5,516
Marsoui	747,405	11,470
Matane	5,144,618	98,518
Méchins	1,126,043	28,846
Mont Louis	1,771,064	74,576
N.D. du Portage	199,092	2,684
Rimouski	8,214,298	709,330
Riv.au Renard	1,109,794	13,560
Riv. du Loup	2,763,536	75,164
Riv. Ouelle	251,893	4,951
Ste.Anne des Monts	1,902,741	47,770
Ste.Flavie	58,175	1,319
St.Jean Port Joli	260,173	34,546
Ste.Marthe	270,028	4,255
St. Maurice	27,936	1,710
Trois Pistoles	625,626	23,338

Sources:D.P.W. files; Wharfage data.

played by the government in enhancing competition from rail transport. As noted already the Maritimes Freight Rate Act applies to shipments of goods from the region to other parts of Canada and the U.S.A. Without the thirty per cent reduction in freight rates it is likely that the effectiveness of rail competition would be reduced. M.F.R.A. is certainly an important factor in the railway's high percentage share of total shipments from the region (see Table 16).

A similar indirect link with the port system may be observed in the case of federal labour laws. The government's attempts to establish certain minimum working standards in the country through Bill C 126 were strongly opposed by the owners of the 'goélettes'. The owners of these small vessels, through their association, lobbied to obtain exemptions from provisions of the National Labour Standards Code, such as the 48 hour work week.[16] Application of all the provisions of Bill C 126 would have crippled the already marginally operating ship owner.

C. Organisation of the System.

The model presented indicates that the port system is the product of the organisation of components that are interrelated in a complex fashion. The state of the system at any point in time is determined by the level of organisation of the various elements. It is an open system in that it receives information (energy) from various sources - economy of the hinterland, competing transport systems, government -

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[16] Annual Report for 1966 of L'Association des Propriétaires de Navires du St.Laurent Inc.

which is then processed through the channels of the system to produce levels of port activity and determine patterns of spacing and function.

It is believed that this study represents the first in port geography to examine a whole port system, but several geographers have referred to the types of relationships implied here. Weigend (1958,200), for example, after describing the concepts of hinterland, facilities, carrier, maritime space and foreland, remarked

> "a change in the organisation and function of any or all these elements affects the entire structure".

However, like other port geographers Weigend's main concern was with the elements themselves rather than the relations between them.

The description and explanation of the model presented in Fig.17 indicates that the relationships between system components are complex. This complexity is a feature of higher order systems, contrasing with the rigid and simple associations between mechanical systems such as a heating system. The model presents a situation which has been described by Rapoport and Horvath (1959,59) as "organised complexity". Systems analysts refer to the relationships between components of the type described as information transmissions.

> "Information is not a substance or a concrete entity but rather a relationship between sets or ensembles of structured variety" (Buckley,1967,47).

Very frequently two elements are not related by variables that assume a continuum of values. The simple cause and effect relations or correlations which have occupied an important place in the so-called 'New Geography' (Gould,1969) and which imply simple linear relations, are by no means universal. Information links in systems include relations such as step functions and triggering mechanisms (Buckley,1967,47). Thus certain variables may have no appreciable effect upon others until its value has been increased to a certain critical level. High correlations will not be revealed despite high potential interaction being built up. An excellent example is provided by the depth of water variable which produced poor correlations with port activity in Chapter IV. Within a certain range (and in particular at the lower end of the depth spectrum) changes in water depths produce negligible effects on vessel size and port activity. The dredging of channels by one or two feet may not produce changes in the organisation of the system. It is as if there were certain threshold levels that must be exceeded before significant changes are produced. Once this threshold depth is crossed very large quantities of information may be generated to produce major changes in the organisation of the system. The final change in depth might be quite small, but its effects would be out of all proportion to its extent.

With the exception of the 'goélettes', most of the small vessels operating in the lower St.Lawrence region draw more than 10 feet of water. Thus even if access to ports such as Rivière Ouelle or St.Jean Port Joli were deepened by as much as 8 feet these other coastal vessels would still be excluded. Deepening of the St.Lawrence Seaway by a similar amount would completely transform trade patterns on that system, and would negate present advantages possessed by the port of Montreal(Slack,1963,11-13).

As open systems, ports react to intrusions of information from the environment by elaborating and their structure to a higher and more complex level. Systems of ports are negentropic in their organisation therefore. The nature and extent of the relationships between elements at any point in time determines spatial patterns, size distributions, and functional levels of the ports in the system.

Two types of open, negentropic systems are recognised. A homeostatic system adjusts to changes, and has been defined as one which maintains

> "a constant operating environment in the face of random external fluctuations" (Rosen,1967,106).

Probably this is the type of system to which Weigand (1958,200) referred, where changes in the form of any one of the components produces changes in the state of the system. The notion of a system leading to a balance has led to much confusion where the concept of equilibrium is mixed with that of a 'steady state'. Equilibrium implies that should changes take place in a system, it always returns to a fixed point. Body temperature is a good example of an equilibrial state. Deutsch (1956,161) has criticised these notions:

> "Altogether, in the world of equilibrium theory, there is no growth, no evolution, no sudden changes, no efficient prediction of the consequences of 'friction' over time".

Steady state however implies that homeostasis is not dependent upon a fixed level, that changes in the system will balance each other out, and may result in a new level being reached.

> "It means a condition, a condition which may vary, but which is relatively constant". (Cannon,1939,20)

Buckley (1967,58) refers to these conserving, deviation-counterbalancing processes as morphostatic. Chorley (1962) has made use of such processes in his attempts to introduce systems concepts to geomorphology.

A second type of system has been referred to as 'adaptive' by Rosen (1967) and 'morphogenetic' by Maruyama (1963). Morphogenesis encompasses those processes which tend to elaborate the system's form, structure or state. Here changes lead to an amplification of the system so that it achieves a more complex form. A very simple example of morphogenesis given by Maruyama (1963,165-6) may be used to indicate the main features of the process. Assuming,

> "... at the beginning, a large plain... entirely homogeneous as to its potentiality for agriculture. By some change an ambitious farmer opens a farm at a spot on it. This is the initial kick. Several farmers follow the example and several farms are established. One of the farmers opens a tool shop. This tool shop becomes the meeting place of farmers. A food stand is opened next to the tool shop. And gradually a village grows. The village facilitates the marketing of agricultural products, and more farms flourish around the city. Increased agricultural activity necessitates the development of industry in the village, and the village grows into a city".

The key to the difference between a homeostatic and a morphogenetic system is the presence of different types of feedback relations. Feedback is where one element influences itself. In simple homeostatic systems, balance is achieved through negative feedback, which counterbalances the changes felt. In economic geography an example of negative feedback is provided by the profit maximisation school of industrial location theory, where competition over space leads to a reduction in excess profits until spatial equilibrium is reached.

The process whereby morphogenetic systems elaborate their structure is provided by positive or amplification feedback. Referring back to the simple example provided by Maruyama (1963,166):

> "If a historian should try to find a geographical 'cause' which made this spot a city rather than some other spots, he will fail to find it in the initial homogeneity of the plain. Nor can the first farmer be credited for the establishment of the city. The secret of the growth of the city is in the process of deviation-amplifying mutual positive feedback networks rather than in the initial condition or in the initial kick. This process, rather than the initial condition, has generated the complexly structured city".

This notion has already been introduced to geography by Pred (1967) as the process of cumulative causation.

An important methodological implication of these systems concepts is that the researcher is freed from the restrictions of traditional causal analysis. Classical causality has held that similar conditions produce similar effects, and conversely that dissimilar results are due to different conditions. Traditional causal principles were relaxed under the systems analysis of von Bertalanffy (1960). From studying morphostatic systems, he introduced the concept of equifinality, where different initial conditions could lead to similar end structures. This has already been introduced to the literature of geography (Greer-Wootten, 1965,4). However, morphogenetic systems indicate that the opposite may be achieved as a result of positive feedback. This has been called multifinality (Maruyama,1963,166), where similar initial conditions may lead to dissimilar end effects. Thus similar states of economic development may be produced in a number of ways (equifinality), while homogeneous plains may produce different industrial and urban patterns (multifinality).

Two feedback loops are indicated in the structural model of the port system. The first is the feedback between vessels and facilities, whereby facilities restrict (or admit) vessels of a certain size and type, and ships themselves influence the type and nature of facilities possessed by the port system. Thus there is a degree of self regulation between these important elements. Increases in trade or new government policies towards water transport will generate information exchanges between the vessel and facilities components and produce homeostatic adjustments in the system. This loop provides the means by which ports achieve equifinality in the development of their facilities. Equifinality is what Bird (1963,417) suggested in his model of 'Anyport':

> "There is one main reason why major ports should show similar features of layout, arranged in different ways, *even if they grew up independently on widely different sites*. All ports serve the same world fleet of shipping........" 17

The second feedback loop is where the level of efficiency of water transport reacts both with the competing transport systems and the hinterland region's economy to produce new levels of trade in the port system. This is a much more important loop because the state of one component alone influences the levels of most other elements. In contrast, the first feedback loop merely produces changes in a localised part of the system.

This second loop permits the system to elaborate and alter its level of organisation through the process of morphogenesis. A process of cumulative causation, akin to Pred's (1967,24-29) model of the evolution of an industrial complex, may change the efficiency of water transport which then directs more hinterland trade through the

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[17] italics added

port system, and permits greater economies to be realised. This amplification feedback loop creates conditions of multifinality which explains why in so many similar regions the size and shapes of hinterlands, and levels of trade in ports are so varied.

The key role played by the vessel component in both major feedback loops is important. Although changes in the states of other elements may be critical to the performance of the port system, none have the overall dynamic effect as the vessel component. This fact is reflected in the multiple regression analysis where the vessel element was revealed to be very significant in explaining variations in port activity.

D. Changes in the State of the System.

It has been shown that the state of a system of ports is a function of the levels of organisation of its elements. Urban geographers (Berry, 1964) who have considered a systems framework have indicated that one expression of the state of a system is the rank size distribution. It has been noticed already that the ports which make up the system in the study area possess a size distribution that is markedly primate.

In open negentropic systems with negative feedback a steady state is achieved through homeostasis. It could be expected, therefore, that the form of the size distribution of ports would remain fairly constant unless the system became closed (an unlikely event), or developed positive feedback in its structure. The model indicates that amplification feedback develops only when economies of scale in vessels are realised.

When the yearly wharfage data for a 15 year period are plotted on log probability paper, a stability in the form of the system is revealed (see Fig. 20 for the rank-size distribution for four of the years). Although there has been an overall growth of the port system in terms of wharfage generated, the system has been able to retain its form and maintain a steady state. This confirms the observations of researchers such as Lampard (1968) who have investigated changes in urban rank size distributions over time.

The stability of the form of the port size distributions over a 15 year period is remarkable in light of the considerable changes in the system. Basically two sets of changes may be observed: those in the condition of the elements, and the resultant changes in the objects of the system.

Table 21 shows that in the period 1951 to 1966 the economy of the hinterland region of the ports changed significantly. Each county recorded a considerable increase in its tertiary sector. The increases seem to have been achieved at the expense of primary activities, which, although still accounting for a higher percentage of the labour force than the Quebec average, no longer occupied the leading position in the economy, except in the interior counties of Matapédia and Témiscouata. The transformation of the economy of the region had obvious effects on trade levels. Increased employment in the tertiary sector created demands for goods that the simple local economy could not produce. It would appear that with the exception of petroleum, new trade imports were handled by other transport systems. Food products and manufactured goods are

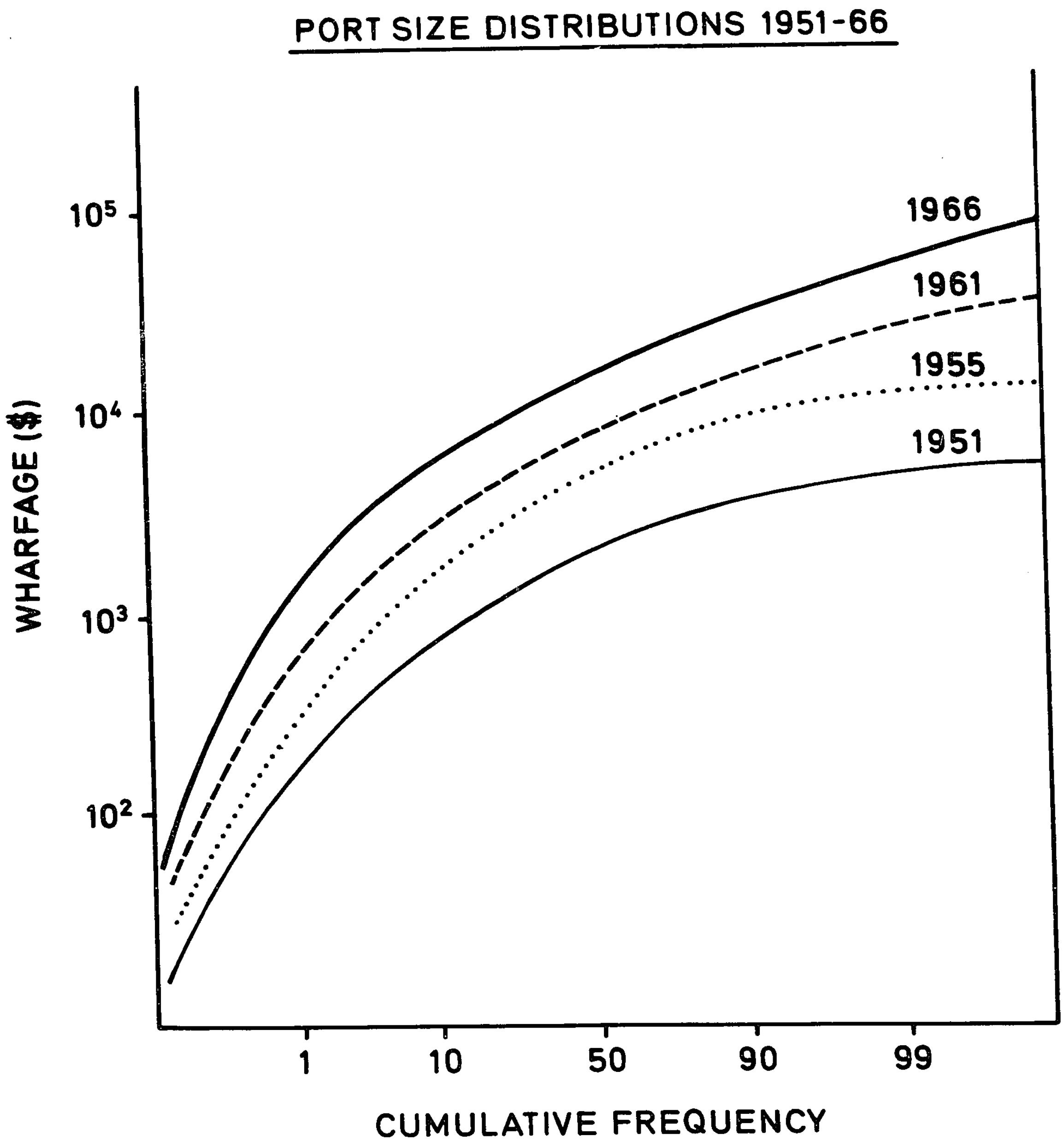

PORT SIZE DISTRIBUTIONS 1951-66
WHARFAGE ($)
10^5
10^4
10^3
10^2
1966
1961
1955
1951
1
10
50
90
99
CUMULATIVE FREQUENCY

Fig. 20

TABLE 21

CHANGES IN EMPLOYMENT IN SECTORS OF THE ECONOMY
BETWEEN 1951-1961

		Primary	Secondary	Tertiary
Gaspé Ouest	1951	48.6	19.0	32.4
	1961	35.6	16.3	48.1
Gaspé Est	1951	47.1	19.3	33.7
	1961	35.8	17.3	46.9
Kamouraska	1951	47.2	20.8	32.0
	1961	42.2	14.6	43.2
L'Islet	1951	50.6	22.0	27.4
	1961	40.5	19.9	40.6
Matane	1951	44.4	21.0	34.7
	1961	33.6	15.4	51.0
Matapédia	1951	57.3	12.7	30.0
	1961	50.0	11.2	37.8
Montmagny	1951	38.8	32.1	29.1
	1961	32.7	33.1	34.2
Rimouski	1951	36.5	21.2	42.3
	1961	29.0	15.2	56.8
Rivière du Loup	1951	40.0	21.4	38.6
	1961	35.9	13.4	51.7
Témiscouata	1951	53.2	19.1	27.7
	1961	45.7	14.9	40.4
Quebec	1951	17.1	39.9	43.0
	1961	10.5	33.5	56.0

Source: Census of Canada

transported more economically by train and truck.

The port system has felt increased competition from land transport. Enhanced rail competition resulted from an increase in Maritime Freight Rate Act subsidies in 1957 which raised from 20% to 30% the reductions in rates on freight shipped out of the region. The considerable growth in the trucking industry affected the ports east of Matane in particular, because there had been no other means of transport and most of the trade had been carried by coastal vessels. Although ships still handle all the pulpwood exported from that area, most other items of trade, such as timber, food products, consumer goods, are now transported by truck.

With the exceptions of pulpwood and petroleum the changes outlined above resulted in reduced demands for water transport. Between 1951 and 1966 the number of vessels operating in the lower St.Lawrence region declined from 86 to 69. Many of the owners of the 'goélettes' found the competition too severe especially for the trade of occasional shipments of general cargo.

One of the most obvious effects of changes in the elements of the system was the reduction in the number of ports. In the fifteen year period under review seven ports became inoperative. Furthermore, there were considerable fluctuations in the rankings of ports still active. Table 22 shows that all the ports other than Rimouski changed their rank position in the system, some by wide margins.

Despite all these changes the system has been able to maintain its approximate form. It is evident that the system of ports in the study area did not have any opportunities to establish positive feedback

TABLE 22

CHANGES IN RANK OF PORTS IN THE STUDY AREA, 1951-1966

	Highest Rank	Lowest Rank	Shift
Rimouski	1	1	0
Matane	2	4	2
Méchins	3	12	9
Rivière du Loup	2	7	5
Ste Anne des Monts	3	9	6
Mont Louis	2	7	5
Rivière au Renard	7	16	8
Trois Pistoles	5	14	9
Grande Vallée	7	27	20
Kamouraska	10	17	7
Marsoui	7	28	21
Petite Vallée	17	30	13
Chloridorme	13	20	7
Baie des Sables	12	21	9
Cap Chat	6	16	10
Ste Felicité	14	28	14
N.D.du Portage	17	26	9
L'Islet	10	18	8
St.André	19	28	9
St.Ulric	20	29	9
Rivière Ouelle	14	27	13
Madeleine	11	27	16
Ste.Marthe	13	28	14
Ste.Annede la P.	12	26	14
Ste Flavie	22	27	5
Berthier	12	27	15
St.Maurice	18	29	11
Anse à Valleau	23	30	7
St.Roch	22	28	6
St.Jean Port Joli	4	19	13

source: Sessional Papers Office,House of Commons during this fifteen year period. Instead, the organisation of the system was concerned with adjusting to changes in the trade produced by the hinterland region, and adapting to competitive impulses from land transport. The tendency has been for the negative multiplier to have been operating in the structure of the system, and were it not for continued government support through construction and repair of wharves, it is probable that still more ports would have become redundant.

E. Processes of Port Evolution.

In the search for explanations of how patterns of ports develop the work of Peter Rimmer (1967d) merits attention. He is the only geographer to have approached this topic, and he has presented a generalised model of port evolution. Rimmer's work represents one of the few attempts in port geography to proceed beyond the identification of generic relations. In the following section Rimmer's model will be described and evaluated in light of the analysis presented in this study. Then a genetic model of port development will be introduced. As a macro level summary of the processes involved in the evolution of a port system, it is intended to have a more general application than the Rimmer model.

1. The Rimmer Model.

Since 1966 several important papers examining ports in Australia and New Zealand have been presented by Rimmer (1966,1967a,1967b,1967c,1967d). He has been concerned with the problems of measuring port status, the identification of regularities among ports, and the ways in which ports develop. In an attempt to provide a framework for his studies, Rimmer selected the model of transport evolution in under-developed countries that had been formulated by Taaffe, Gould and Morrill (1963, 503-29).

Taaffe et al. created and inductive model of transport development based upon empirical studies of route development in West Africa (Gould, 1960). From the initial phase of small scattered ports, routes connecting the coastal settlements with growing interior locations expand in three stages. Rimmer (1967b, 1967d) elaborated this model to encompass not only land connections between ports and the interior, but also the extension of shipping routes in the maritime space.

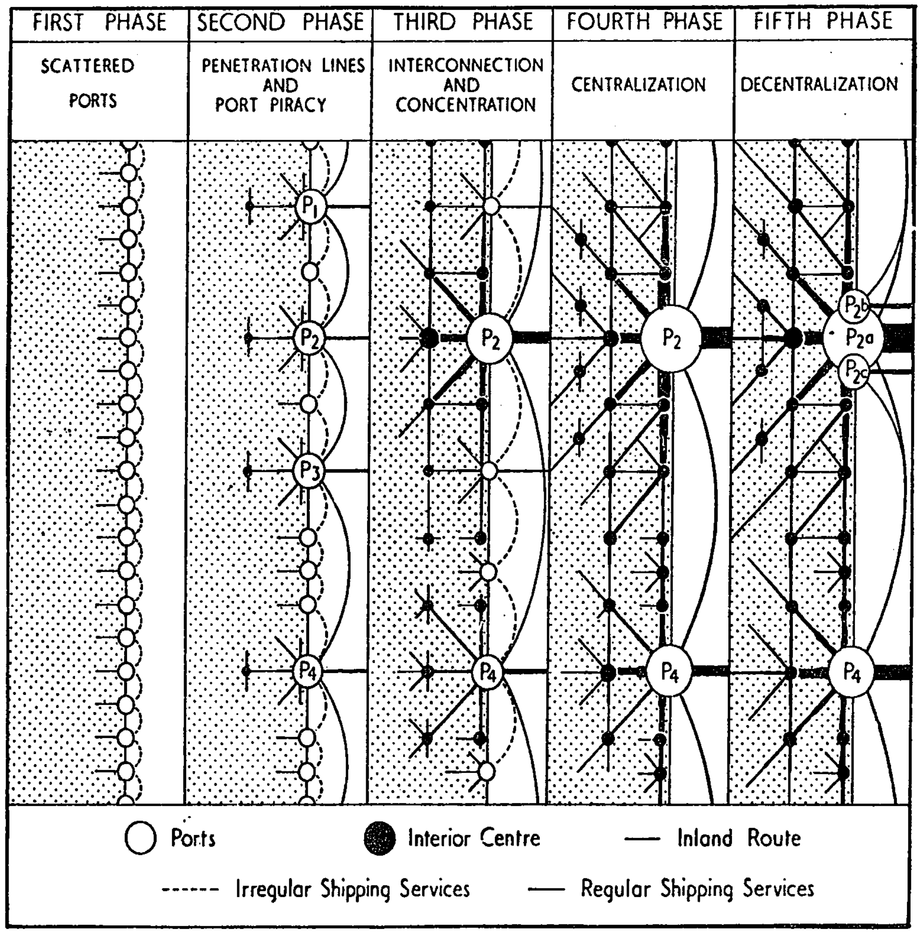
Rimmer (1967d) identifies five stages in his refined model (see Fig.21). Phase one begins with the same conditions as the Taaffe model, where scattered ports serve limited hinterlands and are linked by irregular visits of coastal trading vessels. Stage two is identified as the beginnings of interior penetration by the land transport network. Now certain ports are able to expand at the expense of others so that four larger ports emerge as centres of four separately developing transport nets.

Phase three continues the expansion of the land transport system with the interconnection of ports. This drastically reduces the number of ports and concentrates trade at P2. Of the larger ports only P4 retains its position because it remains an isolated node in a separate transport network.

By the time interconnection is completed in phase four, P4 has established itself as a viable port serving its own distinct hinterland, and thus is not too much influenced by competition from P2.

Fig. 21

RIMMER'S MODEL OF PORT DEVELOPMENT



The final stage is where P2 is forced to decentralise because of its size and nature of its trade. Specialised sub ports at P2b and P2c are now established to handle the bulk commodities which require more space and deeper water, leaving P2a to accommodate the general cargo trade.

Rimmer's model represents a pioneer attempt to generalise and introduce model building to port geography. However it suffers from a number of limitations. There are several undefined assumptions indicated in the model, and it embraces a very narrow set of factors which influence port development The conditions created, therefore, tend to be narrow in their scope and applicability.

The model assumes a spatial and functional hierarchy. The spacing of ports at each stage in the development of the system is regular, and as the sequence develops ports become larger in a hierarchical manner. Both these assumptions were never justified by Rimmer, and as far as is known have never been subject to examination prior to this dissertation. It has been shown tentatively, for example, that ports are not regularly spaced, at least in the early stages in development. In another study Rimmer (1967c,28) proposed the use of tonnage of commodities as the most suitable measure of port activity because it

> "... is the most expressive of the primary functions of a port - the reciprocal transfer of cargo between ships and shore".

However, identification of hierarchical levels based on tonnage of cargo is very difficult because this measure frequently assumes a continuum of values.

The major criticism is that Rimmer includes only a very narrow range of possibilities for port growth. The model suggests that the evolution of the system is due solely to extensions of the internal transport network. This is a gross oversimplification. It excludes the possibility that the land transport system may in fact compete with ports for a certain percentage of the total trade of the region, so that extensions of the internal lines of communication may cause the port system to decline. It ignores the very important fact that growth of trade may result from economic expansion in the port city itself, and there is no mention of transfers between vessels. This is an example of the difficulty involved when a model designed for one set of circumstances is applied to a different milieu. The Rimmer model is too similar to the Taaffe, Gould, Morrill (1963) original to indicate reasonably port evolution. While representing a novel approach to the study of ports, the idealised sequential model is 'noisy'.

2. A systems model of port development

Processes of port evolution may be understood in terms of changes in the organisation of the system. Modifications to the structure of the system and changes in information levels between elements may be seen to precipitate alterations in the patterns of port activity. While these changes may be conceptualised, it is not possible to show how the port system develops in any more precise terms than in the Rimmer model. At the present level of understanding of the system, prediction of changes in port activity, measured in tons of cargo, or value of commodities, is unattainable. What can be presented is the evolution of a system measured in the general terms of functional levels.

The model presented below differs from Rimmer's idealised sequence in two ways. It embraces a larger number of factors that influence port development, and it is not a typical 'stage' model. Rimmer's model produced a number of stages through which the port system evolved. Although he was aware of the limitations of the true stage model -

> "It is probably most realistic to think of the entire sequence of port development as a process rather than a series of distinct temporal phases" (Rimmer, 1967d,44)

it implies that all ports evolve in a like manner (equifinality), and that the system ceases to develop after it has reached the 'final' stage. The sequence presented here is only one example of change in a port system. Processes of evolution are fluid because environmental changes may alter information flows between elements at any time and in a great variety of ways. Relaxation times vary greatly and different port systems may evolve in a number of different ways (multifinality). The sequence of states described in the model correspond to the conditions of the system after there has been a change in its organisational structure.

Assume: i) a situation where there is a relatively even coastline, but where the distribution of potential harbour sites is random.

ii) along the coastal area the population is relatively evenly dispersed.

The purpose of making these prior assumptions is to create an area more irregular than an isotropic surface, yet where there are no great breaches of the coastline nor great concentrations of population. Thus the model is not presenting the unreal conditions of Christaller's 'flat featureless plain', but does not go so far as to propose conditions which could generate agglommeration economies and restrict the probabilities of random location of port development.

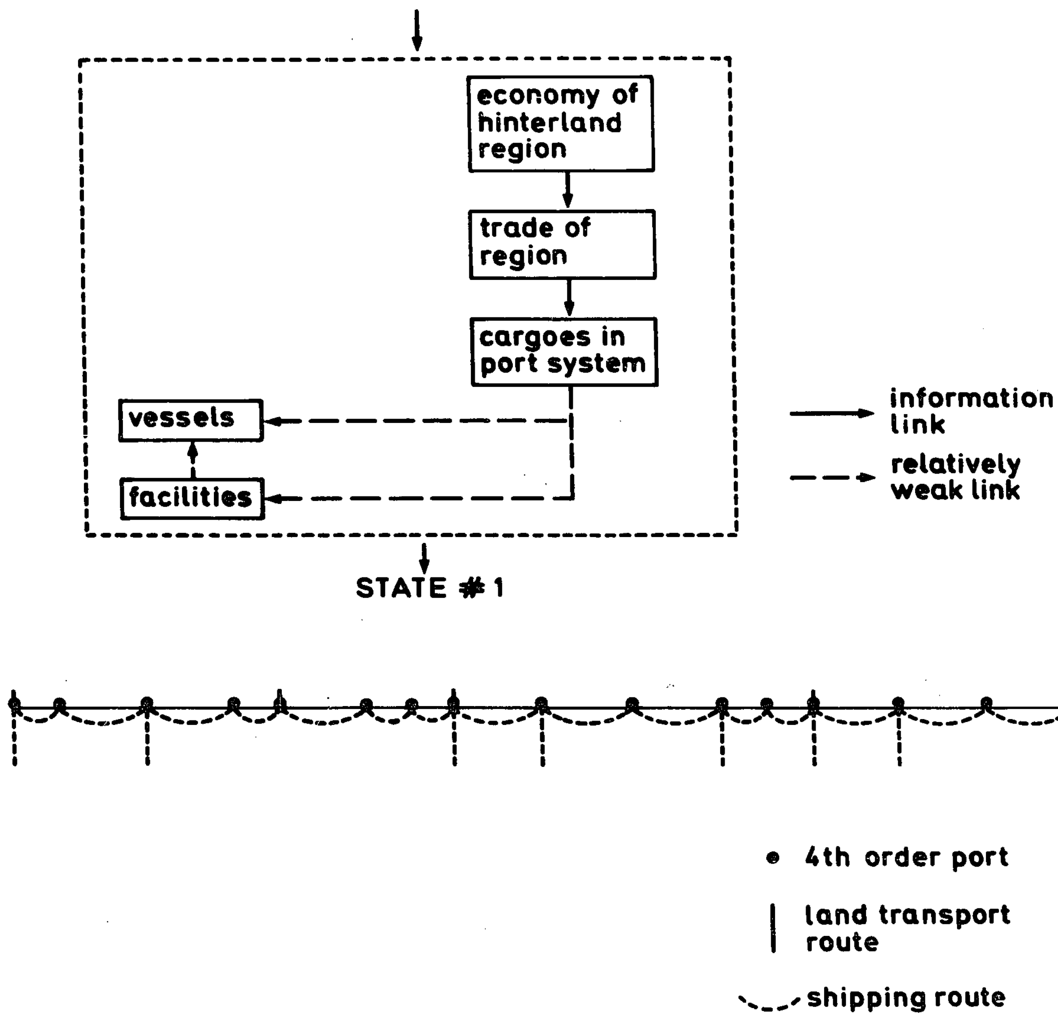
iii) in the coastal area land transport is undeveloped.

Thus there are no links between ports, merely minor connections between coastal settlements and the narrow inhabited coastal strip which forms the hinterlands of the ports.

iv) the economy of the region is simple and dominated by primary activities.

This is indicated as a result of the three other assumptions. Under the circumstances envisaged the region would be relatively underdeveloped.

a) Under these conditions water transport is the only means of exporting surplusses and importing goods not produced locally. There will be a tendency to exploit natural harbour sites at each of the coastal settlements. Indeed availability of a harbour would be a determining factor in the choice of sites for coastal settlements engaged in fishing. A larger number of small ports emerge each serving its own limited hinterland. As indicated in Fig.22 all the ports perform 4th order functions.



ORGANISATION OF THE SYSTEM AND PATTERN OF PORTS AT STATE ONE

Fig. 22

As a system, the ports in the first of the 'states' are structured in a simple way. However, this phase represents the condition where entropy is greatest. Spatial distributions are irregular, due to the exploitation of a large number of natural harbour sites. Spatial patterns of port activity are also very disorganised. Each port handles all the trade of its own hinterland, so that trade totals at individual ports depend upon the productivity of that umland. Facilities are only partly influenced by trade totals and vessel size, because depths of water and lengths of wharves reflect individual local site conditions.

The nature of the economy of the region and the restricted size of the hinterlands creates conditions where small vessels predominate. The amounts of trade at each port are so small that economies of scale cannot be realised, and the facilities available are so variable that only small vessels can operate throughout the entire system. The coastal trade is a major element in the shipping patterns of the region.

The way in which this port system evolves depends upon the order and nature of environmental stimuli felt. The sequence presented below is by no means exclusive.

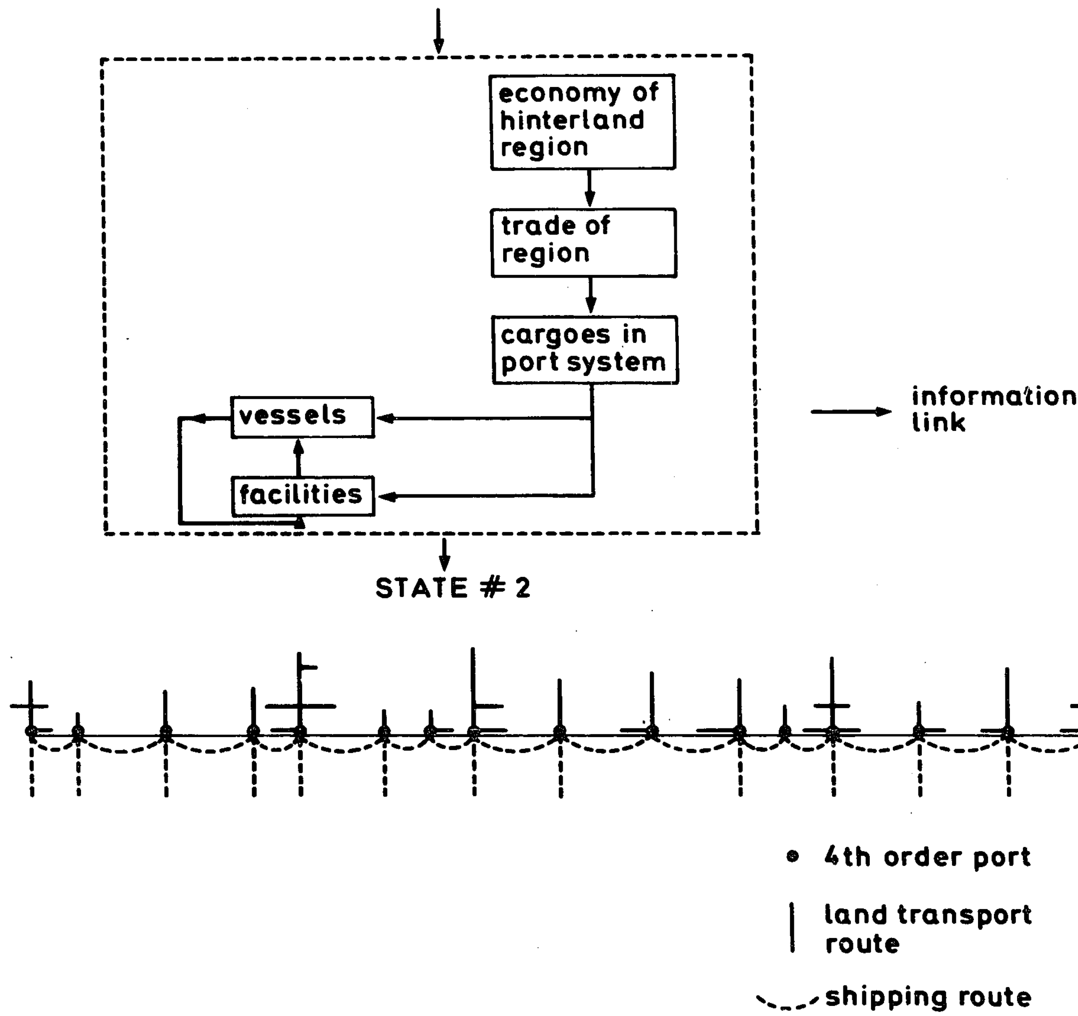
b) Assuming that the system of ports presented in the first state is now influenced by changes in the local economy. The simple economy of the hinterland region now develops new capital intensive industries, such as manufacturing and mining, which are quite localised in their patterns of location. Trade may also expand through extensions of the interior transport network to exploit new market areas (Fig. 23).

Development of the economy of the region leads to a concentration of trade at certain ports, but no change in the functional order is indicated. All ports still perform 4th order functions, and the spatial patterns of the ports are still random. However, certain changes are taking place in the structure of the system, as increased trade totals at certain ports lead to an expansion in vessel size and necessitate improvements to facilities to accommodate the new shipping. This is reflected in the structural model of the system at state two which indicates greater information linkages between cargoes, facilities, and vessel elements.

In this phase a great deal of information is being built up. Those ports that now handle the localised goods in addition to their former ubiquitous trade, are developing facilities to exploit the situation when the system's functional structure is changed. Certain coastal settlements are becoming nodal points in an expanding transport network.

c) The major single effect on the system of ports is the interconnection of the port settlements by land transport links. The information that was being built up is now triggered to alter the organisation of the system and its functional structure (see Fig. 24). The dynamic impact of this step is comparable with the importance of the 'take off' stage in Rostow's (1960) model of economic development.

Interconnection produces two sets of competition which have already been shown to be of considerable importance to the



ORGANISATION OF THE SYSTEM AND PATTERN OF PORTS AT STATE TWO

Fig. 23

performance of the system. On the micro level ports now compete with each other for the trade of the region. This competition is analogous with 'systems tension' (Buckley, 1967, 51-2). It is through tension that complex adaptive systems are able to exchange large quantities of information, and systems analysts recognise that 'tension' is the process by which triggering effects are generated.

> "Interactions among components mediated by the selective 'triggering' of information flows are possible, of course, only because the system components are themselves organised and relatively unstable, or 'sensitive', or in 'tension', such that they react easily to a small influence of the correct type (or code) and can release much larger amounts of bound energy than embodied in the triggering signal:" (Buckley, 1967,48).

Competition between ports leads to the establishment of a functional hierarchy. Although gross products may be still handled by the 4th order ports, purer commodities produced in the region are now transported greater distances to certain ports only, usually those possessing superior facilities.

At the macro level the expansion in transport links generates competition between different systems. Water is no longer the only means of transporting goods to or from the hinterland region. The coastal trade is cut into as a result of the inter-connection of the land transport net, and those small ports which formerly handled occasional shipments of pure commodities disappear. Thus, competition between ports develops a functional hierarchy, while competition between land and water systems affects the number of ports operating in the region.

The availability of a range of routes and modes encourages vertically integrated organisations to evaluate the competing transport systems in light of their own requirements. Decisions made by these institutions at this stage of the evolution of the system may have a lasting influence because of investments in terminals and carriers.

Competition elaborates the organisational structure of the port system (see Fig.24). It becomes increasingly negentropic with spatial patterns of port distribution becoming more regular. Negative feedback dampens variations in relationships between port size, and the facilities and vessels components, so that size distributions assume a more distinct and regular form

d) Fig.25 shows the effects of increased vessel size on the port system. This factor has become one of the major influences on ports since the 1950's. Data from the Rochdale Report (Great Britain 1962,16) reveal the beginnings of the growth in size of ships registered in Great Britain:

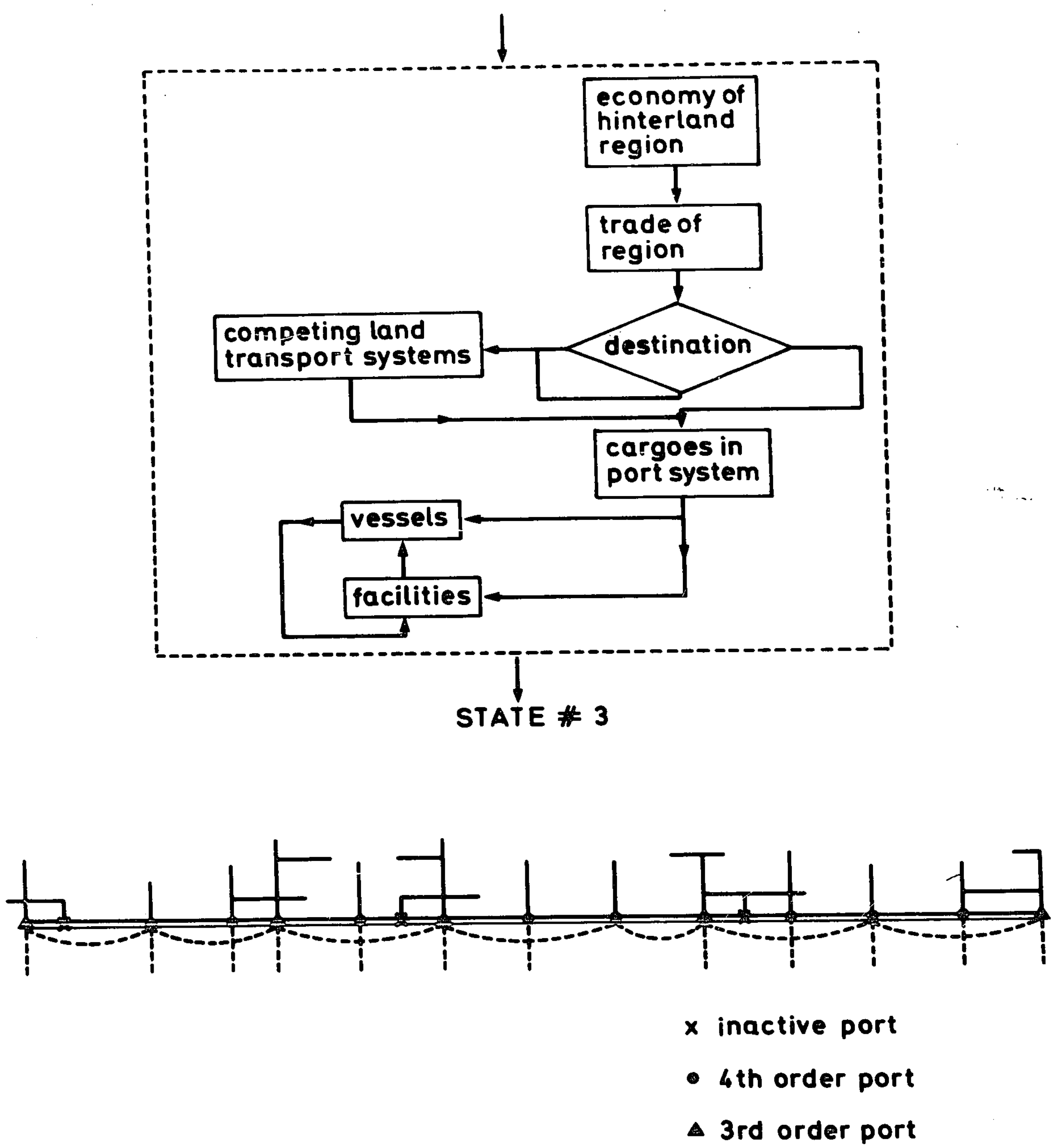
Table 23

Increases in the average size of foreign-going ships owned and registered in the U.K.

September 1939 to June 1961

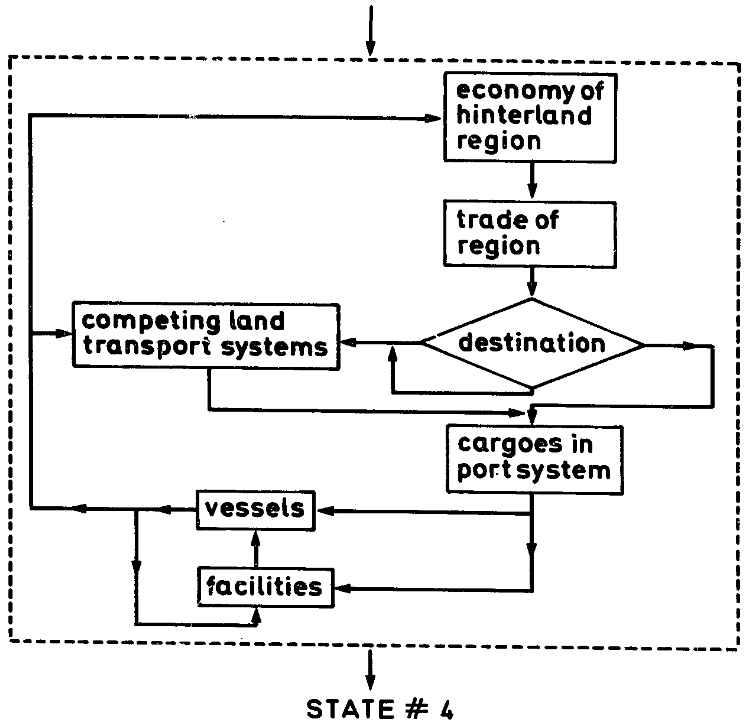
	percentage increases
passenger cargo liners	37
cargo liners	14
tramps (including ore carriers)	52
tankers	82

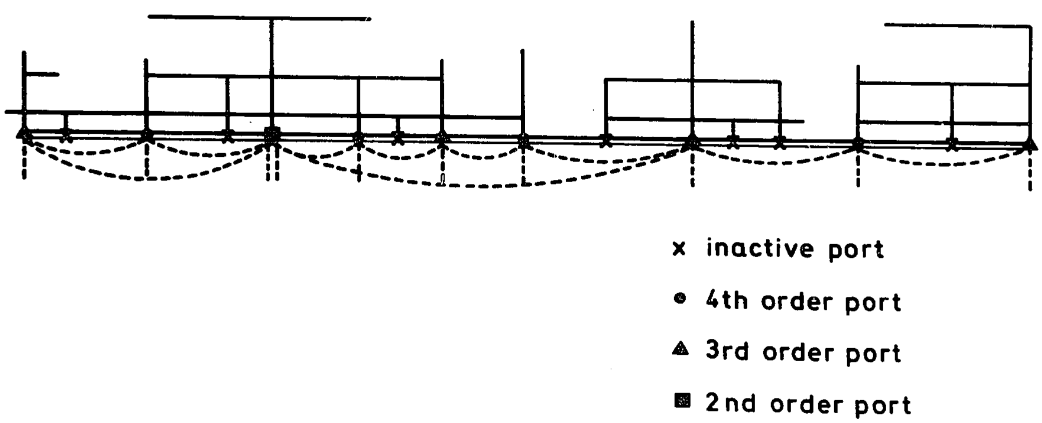
Source: Report of the Committee of Inquiry into the Major Ports of Great Britain, p.16



ORGANISATION OF THE SYSTEM AND PATTERN OF PORTS AT STATE THREE

Fig. 24





ORGANISATION OF THE SYSTEM AND PATTERN OF PORTS AT STATE FOUR

Fig. 25

Although there has been an increase in size of all types of vessel in recent years, the greatest changes have been recorded by the tankers and bulk carriers.

> "Prior to 1944 the largest tanker was the 22,600 ton 'John D. Archbold' built in 1921. The 23 year reign of the 'John D. Archbold' was ended by the completion of the 23,000 ton 'Phoenix' in 1944. During the next 23 years supertankers have been replaced by mammoth tankers, and the super-mammoth tankers (over 150,000 tons); perhaps soon the new term behemoth tankers over 275,000 tons will be necessary". (Heaver,1968,1).

The port system is affected considerably by these changes in vessel size. Economies of scale achieved by ships place great emphasis on port facilities. Only those ports which possess superior facilities or already generate sufficient trade to warrant expansion of existing facilities are able to take advantage of these changes. As the smallest ports possess the poorest facilities there is a strong tendency for them to be forced to cease operating. Increases in the size of ships make it more advantageous to transport goods from the hinterland region to certain ports where the cargoes are collected to form large enough shipments.

These changes may cause companies and institutions to reconsider their transport arrangements. It has been noted that route selections and mode split decisions made by vertically integrated organisations result in investments that entrench and stabilize particular transport arrangements. Costs of switching from one established system to another are great. Thus for an institution to consider diverting commodities from the existing arrangement to the port system, there would have to be economies (achieved through reductions in shipping rates or in turnabout times) exceeding the threshold costs of making the switch.

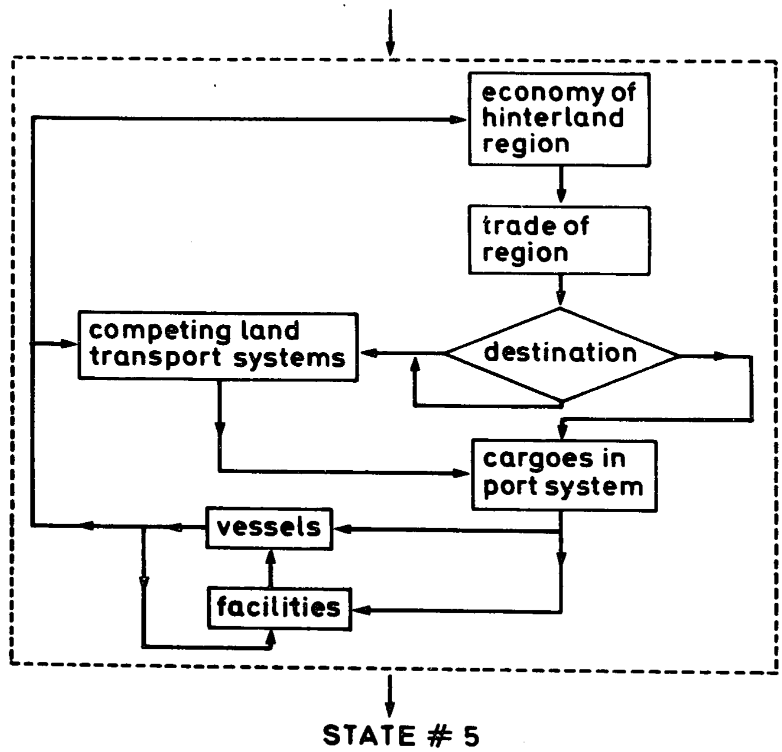
Economies of scale of ships favour the development of new functions at key ports. The few ports possessing the best facilities develop the trans-shipment trade, where goods brought in by very large vessels are transferred to smaller ships for local distribution. These ports are raised to a 2nd order level. (Fig.25)

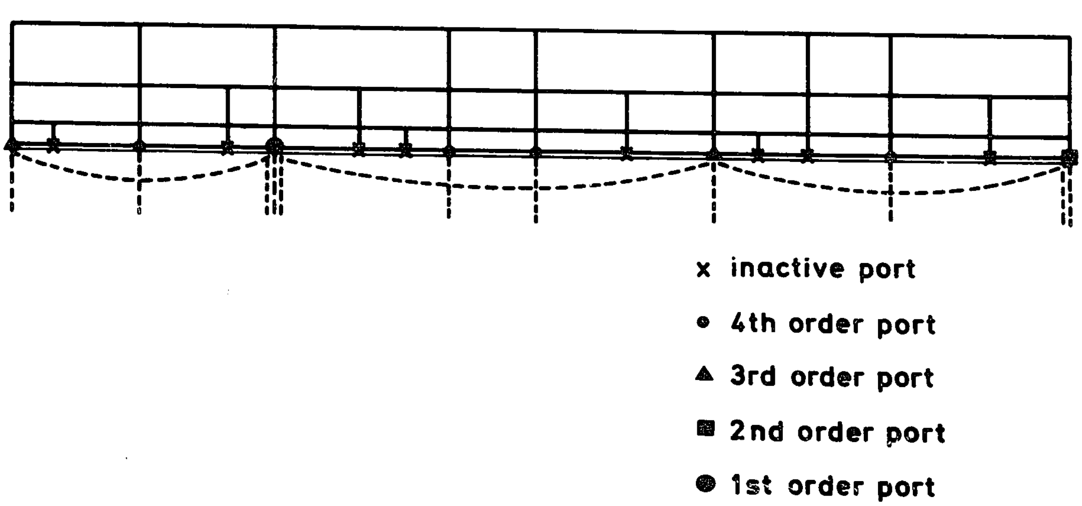
As indicated in the structural model, increases in vessel size generate strong positive amplification feedback throughout the port system. Increased efficiency of water transport favours the development of new trade at the larger ports. New industry could be attracted to the hinterland region to exploit the advantages of cheaper transport. The system becomes increasingly efficient, causing declines in the marginal ports, but at the same time generating great expansion of trade at the few ports capable of accommodating the larger vessels.

e) Increased efficiency of water transport may be combatted by the land systems through rate reductions (such as occurred in rail rates when the St. Lawrence Seaway opened) or by extending and improving land transport networks. The final state discussed here focuses on the effects of complete interconnection of the land transport network and further improvements in its efficiency.

Whereas increased vessel size favoured the higher ordered ports at the expense of the smallest, enhanced competition from land transport alters the structure of the higher ordered ports only. Effects on the smaller ports tend to be minor because by this step in the port system's evolution, the ports performing 4th order functions only handle gross commodities produced in their immediate hinterland areas, cargoes that cannot be transported by any other transport system. However, the improvements in the land transport network increases the competitive position of road and rail, so that a wider range of pure commodities are 'captured' by land systems. Thus complete interconnection does not have a great effect on the number of ports in the system, but produces downward changes in functional levels. (Fig.26)

The exception is where pure commodities produced in all parts of the hinterland region and destined for points not accessible by land routes, are transported to one port only. Such cargoes are now economically transported great distances to this one port because of the efficiency of the land transport system. The port which handles the trade originating from all parts of the hinterland area achieves its position because of the extensiveness of its facilities, the availability of frequent sailings, and possession of the whole infrastructure of administrative agencies such as customs brokers, shipping agencies etc. which are required to expedite general cargo





ORGANISATION OF THE SYSTEM AND PATTERN OF PORTS AT STATE FIVE

Fig. 26

trade. Thus the port that has been able to build up its position during earlier phases of development of the system attains the position of primate port.

It is very difficult to test the model in the study area. The full range of data that is required to determine the functional levels of all the ports is not available prior to 1965. While it has been possible to obtain wharfage data for a fifteen year period, this gives no indication of types of cargo handled nor origin-destination patterns.

It is clear from the fragmentary evidence gathered that the interconnection of the ports did not have the fall effects predicted by the model. The first complete interconnection was provided by the road constructed around the Gaspé peninsula in the 1920's. Its quality was so poor however, and trucking so underdeveloped, that it is not surprising that all the ports operating in the region continued to perform 4th order functions only.

By 1951 only the ports of Rimouski and Rivière du Loup had acquired 2nd and 3rd order status respectively. With continued improvements in the road network, especially in terms of paving and removal of dangerous bends, expansion in the trucking industry, and economic development, two other ports, Matane and Mont Louis, achieved 3rd order status in the 1950's. Ste. Anne des Monts attained this order in 1962.

It is noticeable that the development of the functional hierarchy appeared initially in those areas that road and rail networks were most extensive. It is only recently that the hierarchy has spread into the less accessible eastern sections of the study area. In this respect the hypotheses proposed in state three are substantiated. It would appear that delays in the spatial and temporal implementation of processes in parts of the system are due to variations in relaxation times. A very tentative and premature suggestion is that the types of changes proposed in the model affect the largest ports first, and then slowly filter through the rest of the system. This would be comparable with the findings of studies of innovation waves that have revealed how rates of acceptance of new ideas, techniques, and goods are influenced strongly by the urban hierarchy (Gould, 1969, 94). Of course this is a very tentative and speculative hypothesis that requires much more investigation before it can be proposed with confidence.

As noted earlier, the full impact of competition from land transport systems has not materialised. Many small ports continue to operate, contrary to what is proposed in state three and despite uneconomic conditions. This is because of government support. The role of the government has tended to protect the port system from growing competition, and thereby delay changes.

3. Conclusion.

The model presented here is a simple descriptive device that displays rather complex structural relationships, and varied spatial patterns. It provides a framework for understanding how port systems develop under different conditions. The patterns of evolution of each system will tend to be different, but the model is sufficiently flexible to indicate conditions of multifinality.

CHAPTER SIX

FUTURE OF THE PORT SYSTEM

A. Introduction.

It was suggested in the previous chapter that the system of ports on the south shore of the lower St. Lawrence River is inefficient. The present chapter explains what this means in practical terms, and reviews the main causes of inefficiency. With this background an attempt is made to indicate how improvements can be carried out, and various alternative strategies are described. The models presented in the thesis are evaluated in light of their uses and usefulness in creating a more rational pattern of ports. It must be realised however, that this section is seeking to suggest how the ports <u>should</u> develop to achieve certain objectives in a normative sense, rather than how they <u>will</u> develop. This is an important distinction. It is clear from the analysis of the state of the ports in 1966 that the system is particularly resilient to change. Improvements in the economic conditions of ports would be very slow if left to 'natural' processes. Suggestions for accelerating the processes are made here so that a more efficient [18] system of ports can be realised with much shorter relaxation times.

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18. Efficiency is a very difficult term to define because it can be interpreted in many ways. For the government, an efficient port is one which generates adequate returns (whatever level may be set) on the investment. To the shipper, efficiency is measured in the speed and cost of handling cargoes. For the vessel owner an efficient port is one achieving fast turnabouts. In the context of this dissertation, an efficient system is defined as the number of ports required to handle the transfer of goods traded in the study area at minimum cost.

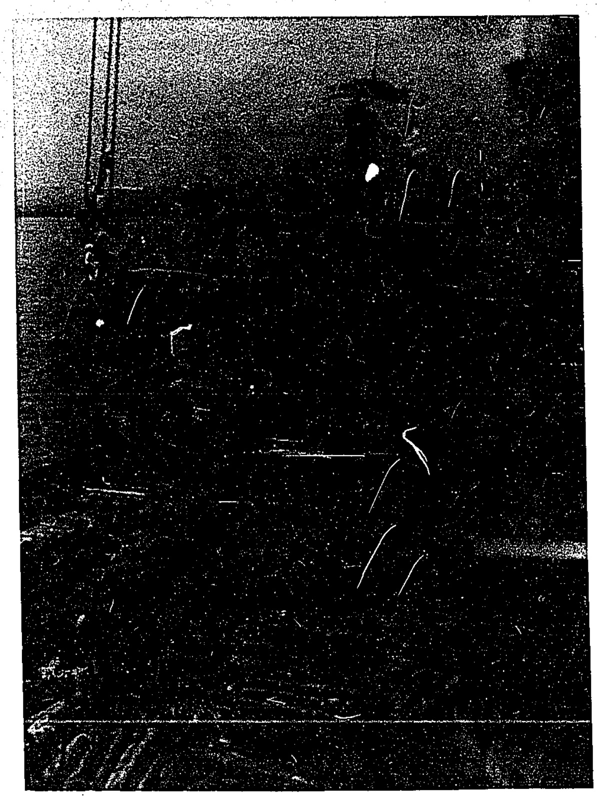
B. The Bases of Inefficiency.

The structure of the ports system indicates that causes of inefficiency are complex. It has been shown that although the ports are facing increased competition from other transport systems, the full impact of this competition has been 'cushioned' by extensive government support for the harbours. Continued government support for harbour construction and maintenance has resulted in the continued operation of a large number of ports. Although the twenty-three operating in 1966 represent a fraction of the number that have been active in the past, there are still too many ports handling too little cargo.

The continued operation of a large number of ports in the region retards improvements in vessels. Most of the vessels operating in the port system are small wooden coastal vessels, the 'goélettes' capable of carrying little more than 200 tons of cargo each voyage. In an era when vessel sizes have been increasing dramatically elsewhere, the 'goélette' represents an uneconomic relic of the days of sail. Yet these small vessels continue to function in the coastal trade mainly because of the volume of cargoes at many of the ports is insufficient to attract larger ships. The present hinterlands of many of the ports are too small to generate larger trade flows.

While the 'goélettes' are versatile, capable of handling a wide range of trade from livestock to pulpwood, and can operate in harbours where water depths and shelter provisions vary so greatly, they contribute still further to the inefficiency of the system because techniques of loading them are crude and costly. The most important

Plate 5



Stacking Logs, Berthier

Plate 5

Stacking Logs, Berthier

commodity carried by the 'goélettes' is pulpwood. The logs are simply tipped into the holds by the trucks which bring the pulpwood from the producing areas. Then a gang of four to six men stack the logs into neat rows (see Plate V). This extremely time consuming job is necessary because the carrying capacities of the vessels, small as they are, would be greatly reduced if the logs were unstacked. By careful loading the vessels can carry more each voyage that would otherwise be possible.

One large forest products company, Consolidated Bathurst, and its subsidiary, Anticosti Shipping Co. have experimented with alternate methods. They employ a 2,216 ton vessel into which the logs are dumped without stacking. Although stacking would increase the number of cords of wood the ship could carry in one voyage, this is more than offset by the rapid turnabout achieved and by the consequential increased number of voyages that are possible each season. With marginally greater operating costs and much lower terminal costs, this ship carries more pulpwood per trip than any 'goélette'.

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19. Personal communication from Anticosti Shipping Ltd.

C. General Strategy

An attempt is made now to suggest how the problems outlined above can be resolved. The models presented earlier are tested to see how well they can assist in developing alternate patterns. It will be remembered that models on two levels were produced. At the micro level, a multiple regression equation was formulated to explain variations in port activity, and at the macro level, models of the structure and the evolution of a port system were presented. The two sets of models are quite different so that their uses and usefulness will not be in comparable areas.

The usefulness of the systems model has been demonstrated to a certain extent already. It has been employed as a diagnostic tool, revealing how and where problems of efficiency exist. It is unlikely that such an understanding of the problems of the ports would have resulted from a more traditional geographic analysis with its emphasis on individual ports. Similarly, the regression analysis and the micro level model fail to indicate the nature and extent of inefficiency within the port system.

The macro level systems model can be used also to provide a framework for understanding the factors that must be considered in changing the system, and in predicting the likely outcome of those changes. It is held to be of utmost importance that the element which is a basic cause of the system's inefficiency is the one that is most malleable. It is claimed that by manipulating government spending a certain amount of control can be exerted to evolve a more rational pattern of ports in the study area.

Cuts in government spending would have a drastic impact on the economic well-being of the ports in the system, and also upon the economy of the local hinterland region. Clearly government spending must be maintained, but instead of stretching expenditures over a large number of ports, the system would benefit by concentrating investment at fewer ports. This means that several ports would have to be closed. Closure of any port would disturb the 'state' of the system, so that a basic problem is to identify the ports least likely to benefit from changes in the rest of the system, ports that may be called 'non-viable'.

The regression model could be used as one means of recognising non-viable ports. Despite the limitations of the regression analysis that have been referred to already, the regression equation explained ninety percent of the variation in port activity. Negative residuals identify those ports that do not perform as well as expected. Some subset of the total set of ports generating negative residuals can be regarded therefore as non-viable. However, should all the ports with negative residuals be classified as non-viable, or those below one standard error? The question of determining how many ports should be closed is not one that the regression analysis can answer. The approximate number of ports that should be closed needs ascertaining prior to the actual selection procedure.

It is claimed that this can be determined only by examining the nature of the basic functions of the ports, i.e. the trade of the local hinterlands. This is the trade that would be most affected by changes in the numbers of ports. The leading commodity in the local hinterlands of the ports in the study area has been shown to be pulpwood. If the number of ports is to be reduced, there will be an obvious increase in the distances separating ports. Closure of too many ports could greatly augment costs of transporting pulpwood from the cutting areas. This would place pulpwood produced in the region at a cost disadvantage compared with other producing areas in Quebec. Production in the study area would then fall, and as a result quantities available at each of the remaining ports would be insufficient to achieve greater economies of scale in shipping. It follows that reductions in the number of ports would be such that, although pulpwood will have to be transported greater distances, the increase in costs of trucking the pulpwood to be ports should not exceed the economics achieved through more efficient loading procedures and greater vessel size.

$$(C_1 - C_2) \leq (t_1 - t_2) + (s_1 - s_2) \quad (5)$$

where C = total costs of transporting pulpwood
t = trucking costs
s = shipping costs (including terminal charges)
1 = present time
2 = in the proposed system

In 1966 the margins of pulpwood production were forty miles from the nearest port. (Note that most pulpwood was transported much shorter distances). Taking this distance as a guide, the distance separating ports in a more rational system may be determined if the shape of the hinterland areas is given. This is an area of port geography that has received scant attention. Very little is known of optimal sizes and shapes of hinterlands. Most research has been concerned with delimiting hinterland boundaries.

Bird (1970, 12-14) has suggested that hinterlands may be triangular in shape. From the evidence of ports in Queensland, Australia, he indicated that the boundaries of the hinterland of Brisbane (the largest port) diverge inland, while the smaller ports possess hinterland boundaries that converge inland. A triangle would appear to be of doubtful merit as the basic shape of a hinterland. It presents the problem of conceptualising how a small port (with its converging triangular hinterland) can develop into a large port possessing a triangular umland whose boundaries diverge inland.

Were the hinterlands of the ports to approximate to a semi-circle of radius forty miles, ports would be spaced eighty miles apart. Thus in the 425 mile long coastline in the study area only five or six ports would be required to perform local functions. However, such semi-circular hinterlands would ill serve the region (see Fig. 27). Despite several conceptual limitations, Thiessen polygons provide a purely geometrical procedure to determine the form of hinterlands.[20] Where a land area is bounded on either side by seas, the ports competing for the trade of this region will possess hinterlands rectangular in shape (see Fig. 27). Here the area within the intersecting boundary line of the Thiessen polygon lies nearer to the enclosed port than any other port.

Spacing of ports with rectangular hinterlands now depends not only on the maximum range of 4th order commodities (forty miles), but also on the depth of interior penetration. Referring to Fig. 27, let A-B be the distance along the coast from the port A to the point B, which is the boundary of the hinterland (and will be equidistant from port A's nearest neighbour X). B-C represents the distance equivalent to the depth of interior penetration. In the study are this is thirty-five miles approximately. Point C is the most distant point from port A, and thus A-C is set at forty miles. Simple trigonometry reveals that in these circumstances the distance A-B

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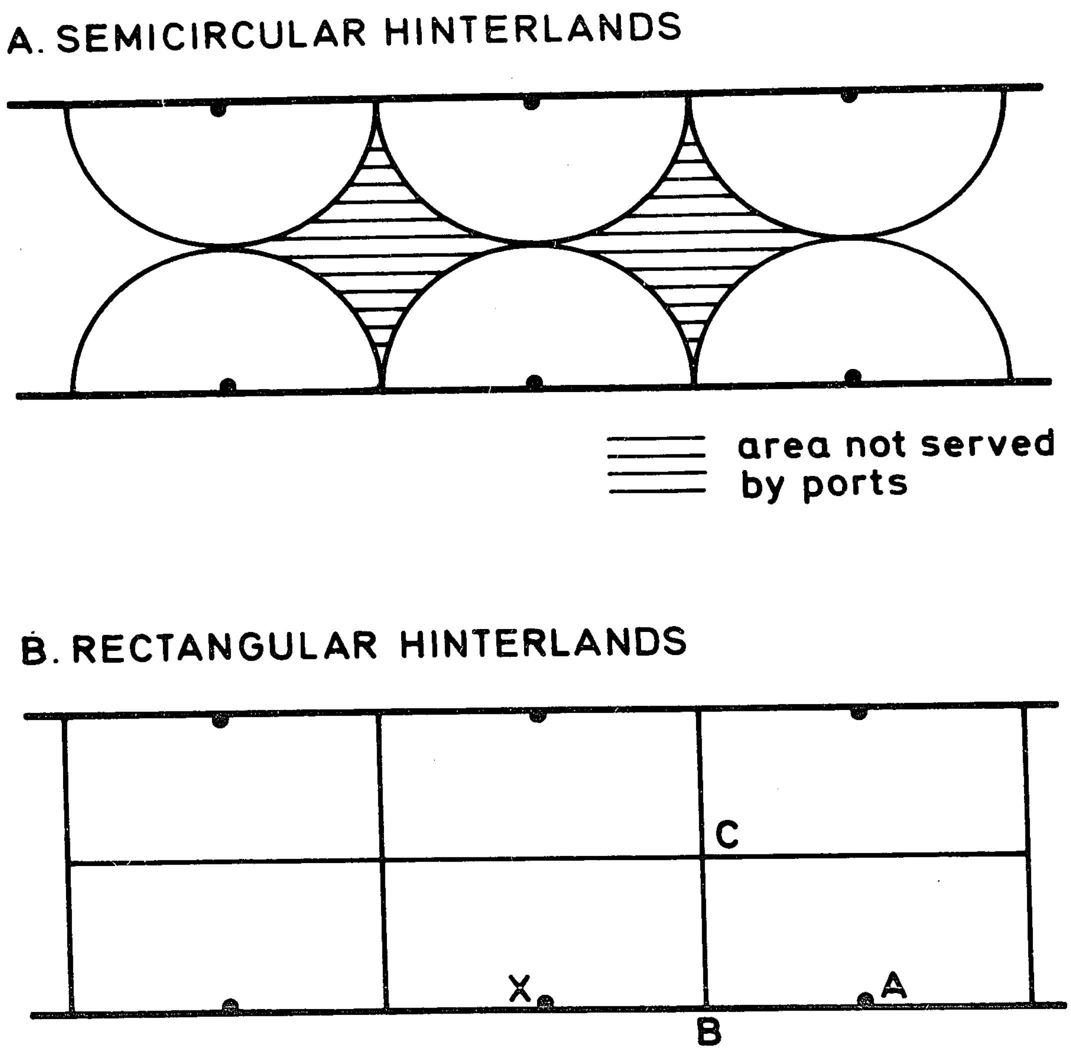
20. For a definition and a review of their limitations see Haggett (1970, 247-8)



THEORETICAL HINTERLAND SHAPES

Fig. 27

is 19.4 miles. Thus, given the assumption that the shape of port hinterlands approximates to a rectangle, that the maximum range of primary commodities is forty miles, and that the depth of hinterland penetration is thirty-five miles, ports should be spaced 38.8 miles apart. In the 425 miles of coastline in the study area eleven ports may be taken as the number that are required. This is just under one half of the number of ports active in the region in 1966, a drastic reduction and indicative of the inefficiency of the present system.

It is not claimed that a spacing of ports 38.8 miles apart is optimal. This figure only represents a basic feasible solution given the set of constraints mentioned. Much further research is required before optimal shapes of hinterlands can be decided. Furthermore the distance constraints merely represent approximations within which a basic feasible solution was sought. It would be more realistic to envisage the ports on a cost or on an accessibility surface rather than as the Euclidean plane considered in the analysis.

D. Alternative Patterns

1. Deductive approach

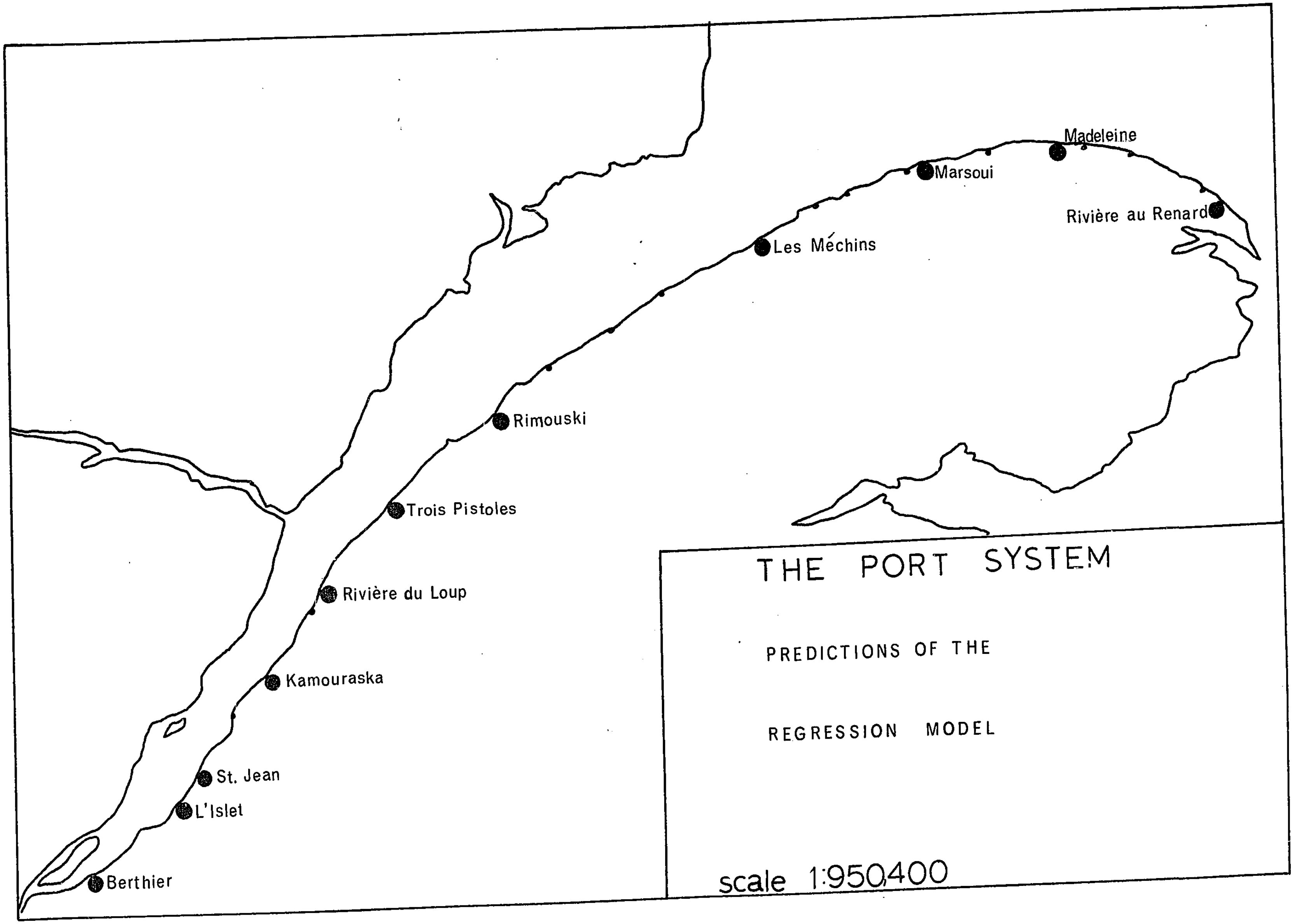
It has been indicated above that a more rational system should include approximately eleven ports. This means that twelve ports active in the present system would have to be closed. These non-viable ports may be identified by the regression model as the twelve ports possessing the largest negative residuals. The equation (4) produces thirteen ports with negative residuals, i.e. $Y < \hat{Y}$. Thus only Rivière du Loup, as the port with the smallest negative residual, would be included in the proposed system along with the ten ports with positive residuals (see Fig.28).

This selection procedure is based upon a statistical model whose reliability has been questioned earlier. Even excluding the criticisms that have been levelled against it, the proposed pattern of ports produced by the regression equation is unsatisfactory. Three of the five ports possessing third order functions would be closed according to the regression model. This is hardly practical considering the amount of capital already invested in Matane, Ste. Anne des Monts, and Mont Louis, and any steps to close them would invoke considerable local opposition from vested interests.

The pattern suggested by the selecting the ports with positive residuals (and Rivière du Loup) does not make spatial sense, especially in the westernmost area. There three ports would be retained in a section of the coast only thirty-one miles long. Furthermore there would be no facility in the eighty-five miles between Rimouski and Les Méchins. While it is not to be expected that a 38.8 mile spacing can be maintained exactly, these examples are gross deviations.

Apart from the statistical limitations of the regression model itself, a major reason for its lack of success in producing acceptable results is that it represents a particular combination of elements at one time period only, a period that has been shown to be inefficient. The model cannot be expected therefore to identify the ports possessing the combination of elements that will be favoured in

Fig. 28


Madeleine
Marsoui
Rivière au Renard
Les Méchins
Rimouski
Trois Pistoles
Rivière du Loup
Kamouraska
St. Jean
L'Islet
Berthier
THE PORT SYSTEM
PREDICTIONS OF THE
REGRESSION MODEL
scale 1:950,400

the new system. The system model indicates that relationships between elements will differ greatly under different sets of conditions. Thus a model that attempts to explain port activity at one time only cannot be used to select the ports best retained in a new system.

2. Empirical Selection

It is suggested that a more practical procedure for determining more rational spatial patterns is to evaluate the merits of each port empirically. Selection should proceed by comparing the traits of the ports operating in 1966 with the factors to be favoured in the new system, given that if any port is taken out, the balance of the system will be disturbed. The point of reducing the number of ports is to concentrate cargo at fewer ports so that greater economies of scale in vessels may be achieved. The macro model suggests that these proposed changes will place increased emphasis on facilities. In addition, however, decision making will be influenced by the existing trade patterns and by the amounts of capital already invested in the harbours. It has been shown that the government is subject to considerable pressure from local interests, so that the proposed changes should represent a solution that is both economic and practical. A final consideration is that the proposed pattern should ensure that all sections of the region are served effectively by ports, and here a spacing of ports at 38.8 mile intervals may be used as a guideline.

The government is committed already to ensure the future of the three ports, Rimouski, Rivière du Loup and Matane. These are the three largest ports, and apart from investment considerations, their closure is inconceivable. All three perform essential functions that have a significance for all or large sections of the south shore of the lower St. Lawrence region. In addition all three are important ferry ports, terminals of trans-St. Lawrence Ferries. Recent investment in these ports has been directed at exploiting natural advantages of local site conditions. Thus the Pointe au Père wharf not only provides Rimouski with deepwater facilities but ensures year round operation for the port. The new harbour at Matane will increase the depth of water available from fourteen feet to forty feet, and at the same time will overcome the continual problem of silting in the old harbour. Gros Cacouna provides Rivière du Loup with the deepest harbour in the entire St. Lawrence, a facility that cannot be neglected much longer.

Nowhere is the problem of selecting the ports that should continue to operate greater than in the section of the coast above Rivière du Loup. In the 112 miles between Lévis and Rivière du Loup there were six active ports in 1966. A limitation of all but one of these ports is the shallowness of existing harbours. Although Berthier can accommodate vessels with a draught of up to fifteen feet, all the others have 'maximin' depths of less than six feet, and two are completely high and dry at low tide. Obviously these ports would have great difficulty in accommodating vessels larger than the 'goélettes' to which they are restricted at present.

In terms of natural facilities, the harbour at Berthier would appear to be the most viable. However, as noted in Chaper Four, Berthier is only twenty three miles from Quebec City, and all the pulpwood produced in the area to the west of the port is trucked directly to the mills. At present Berthier serves the area to the east, but with the completion of the four lane divided highway, part of the Trans Canada Highway, Berthier stands to lose more trade. It may be concluded that Berthier's proximity to Quebec City precludes its inclusion in a concentrated port system.

Berthier's nearest neighbour to the east is L'Islet, whose harbour provides 'maximin' depths of six feet. Although this presents the second deepest harbour of the ports between Levis and Rivière du Loup, it is achieved through a very long wharf extending one thousand feet into the river. Furthermore, this wharf was in a very poor state of repair in 1966. While L'Islet could benefit from the closure of Berthier (by capturing most of the hinterland trade of Berthier), its viability can be assessed only by comparison with its nearest neighbour St. Jean Port Joli. These two ports are only eight miles apart. It is inconceivable therefore that both could be expected to continue to operate in the proposed system. While the maximin depth of water at St. Jean is just four feet, the wharf is only six hundred feet long, and is in a good state of repair. St. Jean is much the more active port, handling three times the tonnage of L'Islet in 1966. The port town itself is larger and developing faster than L'Islet, and an important consideration is that two of the largest pulpwood producing areas, Ste. Perpetué and St. Pamphile municipalities, lie in the existing hinterland of St. Jean. It would appear therefore, that the first port below Quebec City on the south shore of the lower St. Lawrence River should be St. Jean Port Joli. This choice would appear to be justified further by the fact that six out of the eight pulpwood merchants operating in the hinterland region of the three ports under review use the port of St. Jean. Thus it may be expected that the selection of St. Jean would be approved by these local vested interests.

Throughout the thesis the term Rivière Ouelle has been applied to two separate harbour installations. At the village of Rivière Ouelle is a lateral quay affording berthage space for one 'goélette' only. Even these small coastal vessels encounter great difficulties in reaching this quay, having to warp up the river at the highest tide. A newer government wharf has been built at Pointe à l'Originaux, some four miles from the village along a poor quality road. Here a small wharf extends out to two feet of water at mean low tide. These wharves are of too poor quality and are located in too close proximity to St. Jean to merit retention in the proposed system.

East of Rivière Ouelle is the port Kamouraska, which in 1966 handled 20,000 tons of pulpwood. Despite its large trade flow, the facilities in the harbour of Kamouraska are poor, and are hardly capable of accommodating vessels larger than the 'goélette'. The existing harbour is reached only via the narrow streets of the town, providing poor access to trucks. Yet the size of its trade and its location midway between St. Jean and Rivière du Loup are seen as factors warranting the selection of Kamouraska, despite the poor facilities. This decision depends upon the feasibility of greatly extending facilities, providing better road access, and setting aside sufficient pulpwood storage space.

The choice of Kamouraska precludes selection of Notre Dame du Portage, a small port eight miles from Rivière du Loup. The efficiency of the proposed system cannot afford to maintain this port, one of the smallest and least effective in 1966.

It is proposed, therefore, that two 4th order ports should continue to operate on the south shore of the St. Lawrence between Quebec and Rivière du Loup. Located fifty-two miles from Quebec City, St. Jean Port Joli is further from its nearest western neighbour than is considered efficient. It may be justified because improvements in the road net are likely to divert trade in the western area. Kamouraska is thirty-three miles from St. Jean and twenty-seven miles from Rivière du Loup. Based on 1966 data the trade that could be expected to accrue at these two ports is 30,000 tons for Kamouraska, and 40,000 tons for St. Jean. These totals have been obtained by reassigning to Kamouraska and St. Jean the tonnage shipped through the six ports in 1966. It is claimed that these projected totals are sufficient to warrant increases in vessel size, and thereby offset increases in land transport costs of the primary cargoes.

In the seventy miles of coast between Rivière du Loup and Rimouski there was only one port operating in 1966. Trois Pistoles possesses the largest local hinterland of any port in the present system, and is an established major pulpwood centre. Although it lacks deepwater facilities, the harbour possesses extensive storage space, an important consideration when large quantities of pulpwood are handled. Trois Pistoles represents one of the few fourth order ports that are unquestionably viable entities. Its trade in 1966 totalled 40,000 tons of pulpwood, and the port is the focus of activity of several of the largest pulpwood merchants in the entire region. Its function as a ferry port is an added reason for its continued operation. However, its retention in the proposed system is dependent upon improvements to its facilities, especially the provision of deeper berths.

Between Rimouski and Matane there are two minor fourth order ports, Ste. Flavie and Baie des Sables. Despite its proximity to two of the largest urban and industrial centres in the study area, Mont Joli and Price, the port of Ste. Flavie is very minor. Its facilities comprise one 800 foot long wharf, with shallow water alongside, providing very exposed berthage. In 1966 the trade of Ste. Flavie totalled 5,000 tons of pulpwood. This small trade total, when viewed with the poor facilities and the proximity of Rimouski, cannot justify the retention of Ste. Flavie in the proposed system.

The case of Baie des Sables is less obvious. A small port, handling 7,000 tons of pulpwood in 1966, it could benefit from the closure of Ste. Flavie. Furthermore the 1,200 foot long wharf extends into relatively deep water (seventeen feet), and an ell end provides a modicum of shelter. The wharf is important to the local community in another way as it is used by the local inshore fishermen. Obviously the closure of the wharf would be a serious economic blow to the town. However, in terms of trying to improve the efficiency of the entire system of ports, little can be said in favour of the continued operation of Baie des Sables. Matane is just nineteen miles away, and the potential trade available to the port would be sufficient only to provide four or five sailings per year for the larger vessels envisaged in the system. Whether the government would consider such infrequent use as sufficient to warrant continued port investment depends upon how far it is willing to subsidise the local fishing industry as well.

Thirty miles east of Matane the small port of Les Méchins handled 8,000 tons of pulpwood in 1966. The harbour is one of the most sheltered of those reviewed so far, and its facilities comprise a well constructed 1,000 foot long wharf allowing berthage for vessels drawing up to sixteen feet. Although the size of its pulpwood trade is comparable with Baie des Sables, this subjective empirical evaluation proposes that Les Méchins should be retained. Part of the justification is the quality of the facilities - they require little more investment, but an important factor is that the harbour is used by the local ship repair industry. Quantities of cargoes that are required by the local factory are brought in by ship, and the wharf is used by vessels awaiting repair or scrapping. This added local function is reflected in the wharfage revenues generated by Les Méchins - $2,100 in 1966 compared with $802 for Baie des Sables. Thus, although from the point of view of its pulpwood trade, Les Méchins is not comparable with the three other 4th order ports selected so far, it deserves to be retained because of other local functions.

Continuing eastwards, two ports are located within ten miles of each other. Cap Chat and Ste. Anne des Monts are fourth and third order ports respectively. From the point of view of preserving the spatial efficiency of the system, clearly there can be no grounds for the continued operation of both ports. Yet Cap Chat, the less obvious candidate for retention possesses several valuable attributes. Besides shipping large quantities of pulpwood, Cap Chat also serves a local saw mill, so that it represents an important 4th order port. Its facilities are in a good state of repair and its harbour is one of the deepest in the entire system. Yet of the two ports, it is evident that apart from depth of water considerations and shelter provisions, Cap Chat is at a disadvantage. Thus if Cap Chat was in almost any other location, it would be an obvious choice for inclusion in the proposed system, but because of its close proximity to Ste. Anne des Monts, its continued operation cannot be recommended.

The selection of Ste. Anne des Monts may be justified on a number of grounds. Not only is its local trade extensive (30,000 tons in 1966) and diverse (pulpwood to general cargo), but it performs a regional function (petroleum distribution). Furthermore, the potential for expansion is much greater at Ste. Anne than Cap Chat, for in the mountains of the interior region, several promising ore bodies have been encountered, and there is a possibility that Madeleine mines could be developed. If this were to happen, Ste. Anne des Monts, as the closest harbour, would be the logical port of shipment. The government itself would find justification for selecting Ste. Anne over Cap Chat - the two and one half million dollars already invested there.

Between Ste. Anne des Monts and Mont Louis two small ports, Ste. Marthe and Marsoui, handled less than 4,000 tons between them in 1966. Although they both serve local saw mills, it is clear that such small volumes of trade cannot warrant their continued operation. Here again the problem of the local economy complicates a seemingly simple decision. It can be expected that the local industries will object strongly to the closure of these ports. But the final solution can be resolved only by the government deciding how far it is willing to improve the port system at the expense of creating some local hardship.

Mont Louis represents a case with few difficulties. Already the facilities of the port permit economies of scale to be realised. Its thirty foot deep harbour allows 6,000 ton tankers to unload refined petroleum, and Mont Louis is one of the ports where pulpwood is being shipped in 2,000 ton ships. Its local trade amounts to 50,000 tons, and its link with Murdochville increases the total activity of the port to 70,000 tons, representing a wharfage of $11,000. Clearly Mont Louis represents a viable port and should be included in the proposed system.

East of Mont Louis the problems of selecting ports becomes easier. Madeleine, Chloridorme and St. Maurice de l'Echourie are too small to be considered viable. Their purely local functions generate small trade flows, none in excess of 5,000 tons. Their trade could be redirected to other more viable ports in the region without too much dislocation. Once again, however, the final decision is clouded by the other use to which these harbours are put. Each of these centres is a small community of part-time inshore fishermen who depend on the wharves for unloading their catches. Closure of the harbour would be a serious economic blow to these local inhabitants. Certainly on grounds of the trade function there can be no justification for the continued operation of the ports.

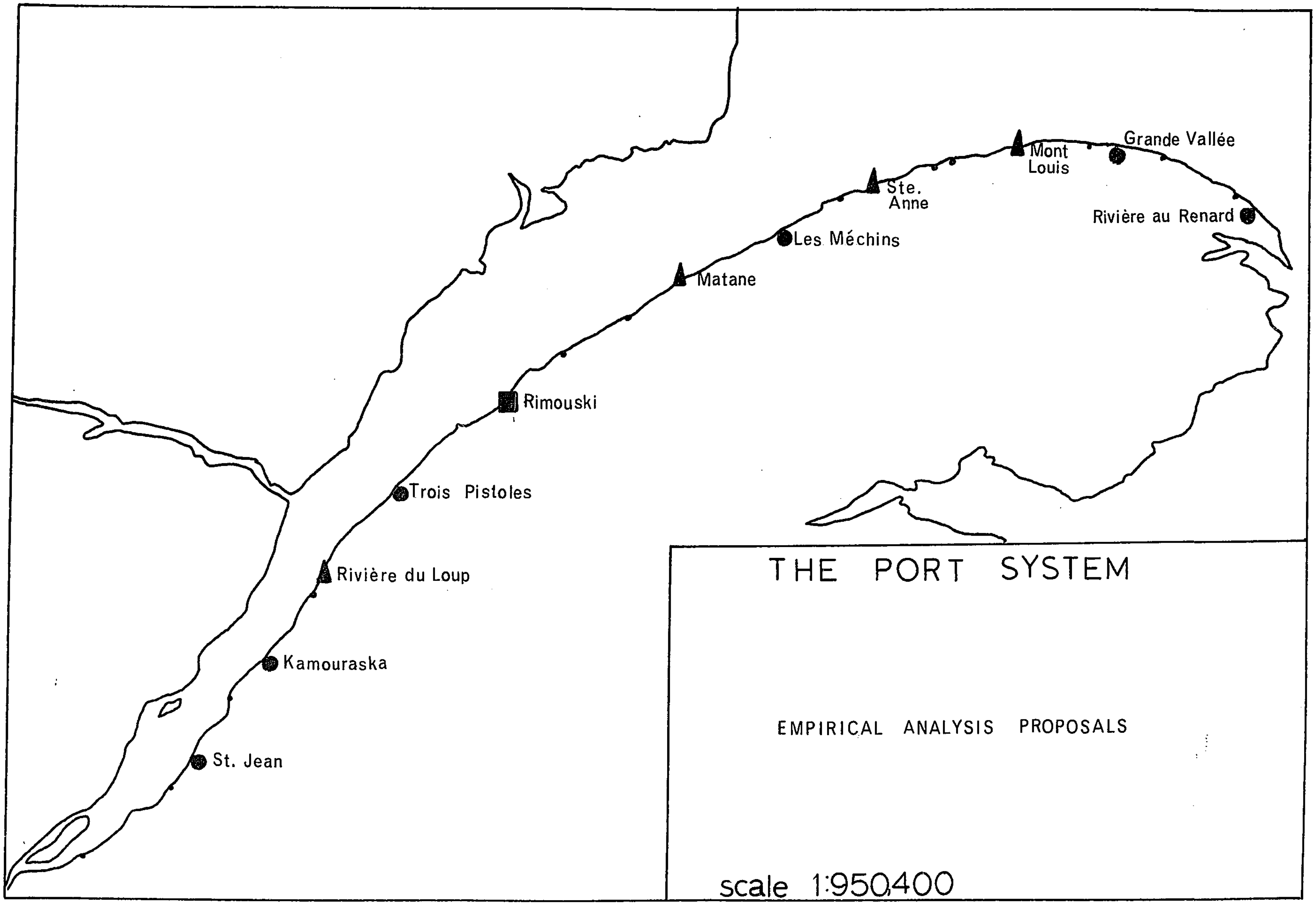

Grande Vallée
Mont Louis
Ste. Anne
Rivière au Renard
Les Méchins
Matane
Rimouski
Trois Pistoles
Rivière du Loup
Kamouraska
St. Jean
THE PORT SYSTEM
EMPIRICAL ANALYSIS PROPOSALS
scale 1:950,400

Fig. 29

Thirty-one miles east of Mont Louis is the active port of Grande Vallée. With a wharf providing depths of twenty four feet alongside berths, and with very good shelter, Grande Vallée handled 30,000 tons of cargo in 1966 and generated $3,000 in wharfage. The port performs three functions. Large tonnages of pulpwood are shipped to Port Alfred, general cargoes for local consumption are unloaded on a regular basis from coastal vessels, and supplies for Anticosti Island are shipped out. With the projected closure of Madeleine thirteen miles to the west and Chloridorme thirteen miles to the east, Grande Vallée could increase its trade by 9,000 tons. Like Trois Pistoles, therefore, Grande Vallée is a fourth order port whose selection for the proposed port system presents no problems.

This leaves the future of Rivière au Renard to be decided. Although the volume of cargoes handled in 1966 was relatively small (5,000 tons), and the tonnage that is likely to be gained by the proposed closure of its nearest neighbour, St. Maurice, is negligeable, Rivière au Renard is a port that will be retained. This affirmative judgement is based upon the actions taken already by the government to rationalise the fishing industry. Large recent investments have provided the port with excellent wharves affording deepwater and sheltered berths. Thus while there might be grounds for doubting the viability of the harbour on the grounds of its trade potential, decisions made in a completely different context have endowed Rivière au Renard with excellent port facilities that trading vessels will continue to utilise.

LIMITATIONS AND IMPLICATIONS OF THE SELECTION PROCEDURE

The empirical selection procedure has been based upon the considerable practical experience gained during the research. It goes beyond the approaches employed already by the government, because the analysis has considered the relative merits of all the ports in the region, and not merely the three largest. Port viability cannot be determined in isolation. A comprehensive and relative survey, such as the one in this section, is required if the system is to be improved.

The survey is limited because it has considered a partial range of factors only. The review has selected the eleven ports which the analysis suggests <u>should</u> continue to operate in the new system. A question that remains is whether or not these particular ports <u>could</u> exist. It has been explained that many of the ports chosen would be incapable of accommodating the larger vessels envisaged in the new system. Questions of improving and extending existing facilities can be answered only by civil and marine engineers. Thus a more complete investigation is required, in which the skills of other specialists can be employed to improve the efficiency of the port system.

This review has revealed that considerations other than increasing the efficiency of the port system are involved. Closure of ports would have an important impact on the local economy. Small local manufacturing industry and the inshore fishing industry would be most directly affected by the dislocations. It must be realised however, that continued support for the fishing industry through maintenance of wharves could gravely retard attempts to improve the port system. It is the continued operation of these fishing wharves that maintains the state of the system, and delays changes. It is apparent that the policies of governments at various levels should be co-ordinated with respect to water transport and fishing.[21]

This review suggests that the government possesses a degree of cybernetic control over the port system in the study area. It is implied that the system could be made to be more efficient by a policy of redirecting investment and concentrating on eleven of the ports. Not only would this policy improve and extend existing facilities, but it would also allow the remaining ports to increase trade (by capturing most of the trade of ports made redundant), and thus permit greater economies of scale in vessels to be realised. It is anticipated therefore that a policy of rationalising the port system would lead to reductions in terminal and freight costs, placing shipping in a more competitive position. These improvements would benefit the economy of the region, and although it is unlikely that the government would ever be able to recoup its investments through wharfage charges, the cost/benefit situation would improve greatly.

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21. In addition to the objections from fishermen, it is almost certain that these proposals would be opposed by the owners of the 'goélettes'. The government would have to accommodate these vested interests, possibly by offering investment grants for the purchase of larger ships.

No changes in the functional levels of ports would evolve in the proposed system, despite the general downward trend envisaged in the process model. Certainly Ste. Anne des Monts and Mont Louis would barely qualify as third order ports because their new local hinterlands would extend almost as far as the boundaries of their total trade areas. The major effect on the system would be the great decline in the number of fourth order ports (as predicted in the dynamic model). The proposed system would comprise one second order port (Rimouski), four third order ports (Rivière du Loup, Matane, Ste. Anne des Monts, Mont Louis), and six fourth order ports (St. Jean, Kamouraska, Trois Pistoles, Les Méchins, Grande Vallée and Rivière au Renard).

CONCLUSION

This final chapter presents a review of the research. It provides perspective on the scope, methods, and results of the analysis. An attempt will be made to evaluate critically the dissertation and to indicate those areas that require further investigation.

A. THE CHOICE OF THE STUDY AREA.

Although the selection of the study area gave rise to several problems, the south shore of the lower St. Lawrence River has proved to be a useful testing ground. By most standards the ports are small, but this has simplified investigation of the locational and functional attributes of ports. In contrast, all the other general studies referred to have dealt soley with ports at the upper end of the size spectrum, so that Bird, Carter, and Rimmer have had to establish arbitrary cut off points. By ignoring the smaller ports their explanations of port systems have been incomplete.

Where the selection of the study area proved to be disadvantageous was in the field of data availability. The Dominion Bureau of Statistics, which is the only source of most of the essential data on ports, does not publish details of port activity for all the ports on the south shore of the lower St. Lawrence River. The Dominion Bureau of Statistics too has an arbitrary cut off point. This necessitated data collection from non-traditional sources, the Sessional Papers Office of the House of Commons, for example.

In addition the primary source of the Dominion Bureau of Statistics was investigated so that new measures of port activity, not normally published, were obtained, such as mean tonnage of vessels employed in different types of trade. However, the lack of published data for all the ports over a reasonably long time period made it very difficult to test the process model of the port system.

The experience obtained from the research suggests that further investigations of port systems must give considerable attention to the selection of study areas. Certainly all the ports in the region must be considered, no matter how large or small, because spatial patterns and functional levels will be meaningless if biassed samples are drawn. Care must be taken also that a full range of data for all the ports is available, especially over a longer time period than the three years to which this dissertation was restricted.

B. THE APPROACH.

A systems approach was employed as a means of investigating the types of unsolved problems in port geography revealed in Chapter I. Systems concepts focus attention on 'wholes' and relationships between elements, precisely the areas neglected by port geographers. The findings of the research indicate that Harvey (1969,469) was correct when he stated that "...the attempts to use systems concepts will be worthwhile, if only because it provides the necessary framework for asking the kinds of questions that seem particularly relevant to the study of 'organised complexity' with which geographers deal".

It is not claimed that a systems approach is the only means of dealing with ports, because experience from other disciplines such as Biology indicates that it is but one of several accepted approaches.

By stressing the interrelatedness of elements, systems concepts have proved to be particularly relevant in this study. While concern with relationships has occupied a large percentage of recent research in geography, these correlation studies have been restricted to linear relations, or relations that could be transformed to linear approximations. On the other hand systems research allows variables which produce low correlations to have much significance through such mechanisms as step functions and triggering effects. As noted already, the importance of the depth of water variable was explained by these mechanisms.

Use of a systems approach is not without its limitations. It is very difficult to break down and present a system in a logical manner because of the interrelatedness of the elements. Thus attempts to analyse the structure of a system can lead to complex descriptions and hide the essential wholeness of the system.

In this study systems concepts rather than systems techniques were employed. Systems research has built up an elegant mathematical methodology that permits precise measurement and manipulation of information levels, structural links and entropy functions. As already indicated, however, the data restrictions and the limited technical ability precluded full use of these techniques. Nevertheless the success of the approach to port geography using systems concepts indicates that further research should begin to investigate the applicability of the mathematical techniques that have been built up in other disciplines.

C. THE GENERALISATIONS.

If the selection of the study area and the approach followed has been of value, the contribution of this dissertation will be measured by the results produced. The research has been concerned with deriving more general explanations of ports than those produced by most earlier studies. It is by these generalisations that this work must be judged therefore.

It was indicated in Chapter III that generalisations were possible because several basic regularities in the port system were uncovered. In addition, the problems of measurement were discussed and four attributes of ports examined. It was noted that a number of measures could be employed to indicate port size, but that wharfage represented the most versatile measure for the ports in the study area.

Port size distributions were noted that compared with urban rank-size regularities. Later investigation showed the form of the port size distribution in the study area to be remarkably stable over a twenty year period, despite significant changes in rankings and number of ports. It was suggested that the port size distribution represents the steady state of a homeostatic system. These results, however, are clearly very tentative. There is a need to extend port size distribution studies through a series of case studies of different port systems. It may be rewarding to compare the findings with urban rank size patterns.

Variations in port size, as measured by wharfage, were investigated using correlation analysis. A large number of variables were selected to represent each of the elements utilized by other researchers in explaining variations in port size. Having identified the best measures of each of the elements, multiple regression analysis was used to derive a statistical model. In this model, which explained over ninety percent of variance in port activity, the vessel component, measures of the quality and extent of facilities, and the degree of competition from other ports were shown to be the leading elements in the port system. The surprising result was the insignificant role of the hinterland component, despite the high place assigned to it by other port geographers. This was explained in Chapter V where it was noted that the amount of trade entering the port system is but a fraction of the total trade generated by the hinterland region. The importance of the hinterland component depends upon the degree of competition from land transport systems. The key role of the vessel element was also explained in this chapter where it was shown to occupy a central position in two major feedback loops of the system.

A functional classification of ports was developed, which, for the first time in port research, produced a measure of functional importance. The classification indicated a hierarchical arrangement of ports in the study area. Because the functional order of a port was related to the type of area served, function could be compared with the size and spatial properties of ports.

Functional classes of ports were found to possess distinct spatial attributes. It was revealed tentatively that low order ports exhibit a more random pattern of location than ports of higher order which tend to be more regular. This was related in Chapter V to the type and nature of the geographical occurance of cargoes and the extent of competition from the land transport systems, all of which was summarised in the dynamic model of port system evolution. As noted earlier, however, these observations must be regarded sceptically because they are based on a very small sample. There is a need to test further spatial properties of ports through a series of case studies.

Functional importance was found to be highly related to the same components utilised in the multiple regression model. In some instances distinct hierarchical levels were revealed, although in others entry zones were noted. The success of the relationships uncovered earlier in the dissertation permitted use of the functional hierarchy in the model of port development.

Although the functional classification was used with considerable success throughout the thesis, it suffers one major practical limitation. It is not an attribute of ports that can be derived easily. Considerable prior investigation is required to determine the hinterlands of ports, upon which the taxonomy depends.

This may be possible in studies which deal with contemporary situations, but where dynamic aspects have to be considered it is very difficult to determine accurately functional levels for all the ports in a system, except where very detailed origin-destination records are kept.

Incidental to these comments, the functional hierarchy explains why other port geographers have experienced difficulty with the hinterland component. In all the major studies examining port hinterlands, the ports selected were amongst the largest in the world. Most would be first or second order ports therefore. It is not surprising that there should be so much overlap (competition) between their hinterland boundaries.

The functional hierarchy recognised in this dissertation should be applied in other regions. It is unlikely that a perfectly divisible hierarchy will be obtained, and it may be necessary to extend the number of functional classes recognised. It is claimed, however, that this taxonomy will be found to be of much wider use than its predecessors.

D. THE MODELS.

Four models embracing different aspects of the port system were presented. Two summarised rather static relations, whereas the others were dynamic. Of the models dealing with processes, the one explaining the development of port facilities was more comparable with generalisations produced in earlier studies. The model of port morphology was similar to Bird's (1963) 'Anyport'. While Bird touched upon the main reason why the morphology of ports should be comparable, a fuller explanation based upon systems concepts was presented here. Convergent development of port facilities was seen as evidence of equifinality which operates in the port system through negative feedback.

The regularities in port morphology suggest that harbour development may be susceptible to simulation. It may be possible to formulate a monte carlo process model which could simulate extensions of harbour installations given an initial physical setting. Physical limitations in the harbour may be regarded as constraints limiting (or facilitating) extensions in port facilities.

By far the most specific model was the regression equation which explained ninety percent of the variation in port size for 1966. As such it was the most accurate model, but it was shown to possess certain limitations. The independence of the variables was questioned, and it was suggested that more refined data could make the functional relationships more realistic. It was revealed that the model was restricted both temporally and spatially because its applicability was limited to the ports on the south shore of the lower St. Lawrence River at one time period only. The poor performance of the regression model in selecting ports for inclusion in a future port system was explained in these terms.

Further research should investigate the possibility of utilizing principal components analysis. This may be employed prior to the multiple regression phase to obtain composite variables or 'components' that are linearly independent. Thus the problem of multicollinearity that was raised in this study should be overcome.

The two remaining models are those most open to modification and further verification. The general morphological model of the structure of a port system revealed the organisation of the components influencing the performance of an entire system of ports. Many new insights were obtained using systems concepts. For example, the role of negative feedback in port morphology, step functions in the relationships between port size and depths of water, and triggering mechanisms in the case of interconnection of coastal settlements by land transport systems. However, while an attempt was made to justify the types of information linkages proposed, there is a need to expand detailed knowledge of the extent and nature of these links. It is argued that if this structural model can be tested further, port geographers will be in a much stronger position to predict changes in the port system.

The functional classification formed the unit of measurement of port activity in the dynamic model of port development. This was presented as a versatile conceptual device explaining how ports evolve with many degrees of freedom. As it is based upon the relationships between components that have been shown to exist, it is hoped that this model will have a wide application in a variety of different environments. It is not an inductive model based upon the development of ports in the study area, but rather a deductive formulation that evolved from the analysis of information linkages there. At the moment these relationships are expressed in very general terms only, but once an attempt is made to quantify these information linkages, it may be possible to formulate an axiomatic model of high predictive power.

E. CONCLUSION.

This thesis is seen as a continuation of the pioneer work of Rimmer and Bird in the search for spatial regularities and structural relations in systems of ports. While new perspectives have been provided, it appears that this research has uncovered as many problems as were solved. It may be that this dissertation has filled only a small portion of the huge gaps in our knowledge of ports, but it is hoped that they can be seen more clearly than before, and that this study has made a contribution towards their eventual solution.

APPENDIX A

Data Array

PORT	X_1 number of commodities	X_2 wharfage (\$)	X_3 vessel tonnage	X_4 vessel numbers	X_5 size of largest vessel (tons)
1. Berthier	2	1,058	5,470	49	121
2. L'Islet	1	1,572	3,810	31	141
3. St. Jean	2	4,658	12,103	100	256
4. R. Ouelle	1	1,245	3,423	31	236
5. Kamouraska	1	1,578	9,420	95	120
6. N.D. Du Portage	1	226	784	8	122
7. R. du Loup	4	12,700	64,596	105	10,144
8. Trois Pistoles	2	4,935	15,717	156	350
9. Rimouski	8	97,087	381,160	480	13,976
10. Ste. Flavie	1	204	1,980	24	96
11. B. des Sables	1	802	2,943	24	157
12. Matane	5	7,099	30,762	70	2,274
13. Les Méchins	2	2,132	4,815	23	2,216
14. Cap Chat	2	3,779	17,016	26	2,216
15. Ste. Anne	3	2,785	82,682	56	2,798
16. Ste. Marthe	1	219	1,086	10	132
17. Marsoui	1	1,171	786	3	262
18. Mt. Louis	6	10,649	44,371	75	6,344
19. Madeleine	1	826	5,218	5	2,216
20. Gr. Vallée	4	2,786	34,568	85	2,216
21. Chloridorme	3	788	8,771	11	2,216
22. St. Maurice	1	116	610	3	256
23. R. au Renard	3	2,519	8,868	30	562

PORT	X_6 mean vessel size (tons)	X_7 cargo tonnage	X_8 tonnage of largest shipment	X_9 number of ports traded with	X_{10} depth of water(feet)
1.	111	10,018	225	3	15
2.	122	7,510	425	1	6
3.	121	23,680	521	4	4
4.	110	6,800	300	1	2
5.	106	20,175	250	1	0
6.	98	1,665	220	1	0
7.	615	87,952	7,285	13	17
8.	100	36,840	796	5	0
9.	794	520,603	28,048	37	23
10.	82	4,875	200	1	2
11.	122	6,955	360	1	17
12.	439	35,573	3,300	9	16
13.	209	7,673	838	4	23
14.	654	24,925	3,766	4	27
15.	1,457	36,607	4,160	6	25
16.	109	3,975	450	2	10
17.	262	425	70	1	7
18.	592	69,287	15,597	6	30
19.	1,043	4,825	3,312	1	0
20.	407	28,315	3,840	5	24
21.	797	5,736	1,750	3	17
22.	203	1,025	450	2	15
23.	354	4,825	450	4	20

PORT	X_{11} length of wharves (feet)	X_{12} dollars spent by D.P.W.	X_{13} amount spent 1946-66 ($)	X_{14} % increase in expenditures	X_{15} length of river (Miles)
1.	566	234,934	79,847	34	0
2.	1,380	483,990	170,643	35	0
3.	600	349,373	260,173	74	0
4.	980	731,913	251,893	34	40
5.	1,000	180,966	93,907	52	23
6.	630	241,188	199,092	83	0
7.	2,800	4,091,418	2,763,536	68	50
8.	1,890	818,025	625,626	76	20
9.	3,760	11,484,836	8,214,298	72	65
10.	800	106,722	58,175	55	7
11.	1,114	504,359	400,874	79	0
12.	2,850	6,526,602	5,144,618	79	60
13.	1,098	1,312,636	1,126,043	86	1
14.	1,422	1,012,116	800,145	34	0
15.	1,800	2,241,393	1,902,741	85	50
16.	765	302,620	270,028	89	10
17.	1,068	895,237	747,405	83	19
18.	2,100	1,888,515	1,771,064	94	25
19.	246	401,190	391,390	98	70
20.	825	824,164	722,534	88	15
21.	900	602,727	578,686	96	5
22.	480	31,748	27,936	88	1
23.	1,400	1,583,833	1,109,794	70	10

PORT	X_{16} quality of facilities $ per foot	X_{17} population of port town	X_{18} area local hinterland (sq.miles)	X_{19} population local hinterland	X_{20} maximum range of hinterland (miles)
1.	141	970	637	26,751	50
2.	125	854	276	8,103	34
3.	433	3,335	572	19,790	37
4.	256	1,512	185	13,671	20
5.	94	937	167	7,072	18
6.	316	595	366	11,819	40
7.	987	11,637	470	23,362	74
8.	331	4,710	887	28,958	40
9.	2,184	20,330	833	38,510	165
10.	72	767	215	14,595	17
11.	359	1,207	158	4,521	15
12.	1,805	11,109	535	18,527	46
13.	1,025	1,438	194	3,913	16
14.	562	3,856	190	4,967	12
15.	1,057	4,827	218	6,473	24
16.	352	565	66	565	9
17.	698	656	177	1,026	17
18.	843	1,802	227	2,208	28
19.	1,594	777	72	777	7
20.	875	1,461	87	1,901	13
21.	643	1,600	78	1,600	10
22.	58	2,338	43	2,338	12
23.	792	2,888	83	4,984	15

PORT	X_{21} road mileage in local hinterland	X_{22} area maximum hinterland (miles)	X_{23} population of maximum hinterland	X_{24} rail mileage in local hinterland	X_{25} distance nearest port (miles)
1.	240	637	26,751	50	23
2.	135	276	8,103	13	8
3.	230	572	19,790	33	8
4.	102	185	13,671	16	12
5.	80	167	7,072	24	12
6.	175	366	11,819	48	8
7.	293	2,912	92,729	57	8
8.	465	887	28,958	34	27
9.	475	11,275	312,366	35	17
10.	175	215	14,595	37	20
11.	135	158	4,521	25	19
12.	233	1,631	31,794	8	19
13.	67	194	3,913	0	17
14.	64	190	4,967	0	10
15.	86	1,687	38,456	0	10
16.	27	66	565	0	5
17.	33	177	1,026	0	5
18.	30	251	5,236	0	18
19.	14	72	777	0	14
20.	30	87	1,901	0	14
21.	18	78	1,600	0	14
22.	16	43	2,338	0	8
23.	35	83	4,984	0	8

PORT	X_{26} distance nearest port handling more commodities	X_{27} distance nearest port handling greater wharfage	X_{28} distance nearest port handling greater vessel tonnage	X_{29} distance nearest port handling more ships	X_{30} distance nearest port handling greater cargo tonnage
1.	23	23	23	23	23
2.	8	8	8	8	8
3.	54	54	54	54	54
4.	12	12	12	12	12
5.	12	27	27	27	27
6.	8	8	8	8	8
7.	70	70	70	27	70
8.	27	27	27	42	27
9.	184	184	184	184	184
10.	20	20	20	20	20
11.	19	19	19	19	19
12.	56	56	56	56	56
13.	17	17	17	17	17
14.	10	46	10	10	10
15.	39	10	112	39	39
16.	5	5	16	16	16
17.	18	18	5	5	5
18.	93	93	39	31	93
19.	14	14	14	14	14
20.	32	32	32	32	32
21.	14	14	14	14	14
22.	8	8	8	8	8
23.	19	19	19	19	19

PORT	X_{31} distance nearest port with greater water depths	X_{32} distance nearest port with longer wharves	X_{33} distance nearest port of higher order	X_{34} number of manufacturing establishments	X_{35} number of workers in manufacturing
1.	23	23	23	53	1,872
2.	23	46	46	15	549
3.	8	8	54	26	500
4.	21	12	39	16	448
5.	12	27	27	10	212
6.	8	8	8	11	195
7.	70	70	70	32	543
8.	27	27	27	33	493
9.	151	184	184	53	991
10.	20	20	20	19	625
11.	37	19	19	2	21
12.	19	56	56	20	326
13.	17	17	17	2	26
14.	49	10	10	3	156
15.	10	39	113	3	114
16.	16	5	5	0	0
17.	5	18	21	1	60
18.	93	93	93	0	0
19.	14	14	14	0	0
20.	32	14	32	2	40
21.	14	28	45	1	1
22.	8	8	27	4	44
23.	19	19	19	2	55

PORT	X_{36} farm population	X_{37} area woodland in local hinterland (acres)	X_{38} area farmland in local hinterland (acres)	X_{39} %farmland wooded	X_{40} tonnage of cargo generated in local hinterland
1.	6,107	56,663	131,551	43	10,018
2.	3,577	14,621	69,781	20	20,175
3.	4,352	50,021	98,775	51	23,680
4.	3,041	15,348	53,425	28	6,800
5.	3,532	14,621	69,781	20	20,175
6.	4,167	37,951	105,223	36	1,665
7.	6,555	60,267	175,784	34	28,410
8.	11,542	129,070	315,578	40	36,840
9.	8,764	80,722	204,498	39	64,555
10.	3,001	21,922	71,977	30	4,875
11.	3,387	35,268	100,598	35	6,955
12.	3,755	29,847	87,308	34	20,839
13.	1,019	3,999	12,458	32	7,673
14.	638	6,336	12,923	49	24,925
15.	658	4,987	13,086	37	31,324
16.	81	1,808	2,721	66	3,975
17.	64	1,049	1,930	54	425
18.	335	2,028	3,872	52	54,711
19.	59	219	1,742	12	4,825
20.	136	714	1,263	56	28,315
21.	254	145	1,280	11	5,736
22.	42	17	122	13	1,025
23.	267	438	1,956	22	4,825

APPENDIX B

Sample Questionnaire

Cher Monsieur,

Je suis en train d'étudier les ports de la région du bas St. Laurent. La commodité commune à presque tous ces ports est le bois de pulpe, et alors je m'intéresse aux mouvements de ce produit. Vous m'aideriez beaucoup en repondrant à cette questionnaire.

En 1966 chargiez-vous du bois de pulpe à bateau? oui.... non....

Si oui, quel(s) quaie(s) serviez-vous? a)........................

b) ....

c) ....

d) ....

D'où venait-il, le bois de pulpe? quaie a) ....

(indiquez les municipalités d'origine). ....

....

....

b) ....

....

....

....

c) ....

....

....

....

d) ....

....

....

....

Pourquoi serviez-vous des ces ports particulièrement? Soyez aussi précise que possible.

Merci pour votre co-opération.

APPENDIX C

Sample of Wharfage Charges

SIDE WHARFAGE : Levy based upon size of ship and length of stay in port. Starts from $1.50 per day for ships less than 50 feet long, and increases on a proportionate scale.

TOP WHARFAGE : manufactured goods 40c per 40 cubic feet

coal	10c	per ton
cement	15c	per ton
fish	10c	per ton
cereals	15c	per ton
cattle	25c	each
oil	$\frac{1}{10}$c	per gallon
woodpulp	10c	per cord
timber	20c	per 1000 feet

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