Supplemental Papers —

Ninth Annual Meeting

"Transportation and Social Change"

September 4-5-6, 1968
Hotel Muehlebach
Kansas City, Missouri

TRF

TRANSPORTATION RESEARCH FORUM

The Integration of Port Functions: A Network Definition of Spatial Structure

by Ross Robinson[*]

I. Introduction

Since port time costs are a significant proportion of total shipping costs[1] in foreign trade, and because the trend to larger vessels demands rapid turnaround at terminals, the problem of minimization of port time becomes increasingly critical. Where a situation exists—as it does in southern British Columbia—in which the total foreign trade flows are handled by a considerable number of ports, the need to rationalize the inter-port movement of shipping and hence also to minimize the total port time incurred becomes a planning problem of the first order.

Moreover, when planning authorities are faced with budget constraints for developmental planning of ports in a network as in southern British Columbia, the optimization of port investment cannot be achieved by piecemeal planning focussed on only one or two ports. Further, where such a network exists without any sort of administrative cohesion and in which development policies are at best unco-ordinated and at worst in serious conflict, the optimization of investment in port facilities on a regional basis presents an extremely complex situation.[2]

Both problems—the reduction of inter-port movements of shipping within a limited area in order to minimize port time costs and the optimization of port investments[3]—point to the need for some sort of integration of port functions, both as the administrative and operational levels.

This paper demonstrates that the basis for the integration of port functions in southern British Columbia is inherent within the movement patterns created by foreign trade shipping. It is concerned with first defining the foreign trade shipping network in which the ports of British Columbia are elements and

---

[*] *Secretariat, United Nations Conference on Trade and Development, Geneva. Much of the research for the paper was completed while the author was in the Department of Geography, University of British Columbia, Vancouver, in* 1966-1967.

[1] See for example, R. O. Goss, "The Turn round of Cargo Liners and its Effect Upon Sea Transport Costs", Journal of Transport Economics and Policy, Vol. 1, No. 1, 1967.

[2] c.f. M. F. Tanner and A. F. Williams, "Port Development and National Planning Strategy—The Implications of the Portbury Decision", Journal of Transport Economics and Policy, Vol. 1, No. 3, 1967, for a discussion of the British experience.

[3] The appraisal of investments remains an open problem. c.f. R. O. Goss, "Towards an Economic Appraisal of Port Investment", Journal of Transport Economics and Policy, Vol. 1, No. 3, 1967. For a general discussion see
H. M. Weingartner, "Criteria for Programming Investment Project Selection", Journal of Industrial Economics, No. 1, Vol. XV, 1966, and
G. D. Quirim, The Capital Expenditure Decision, Richard D. Irwin, Inc., Illinois, 1967.
The use of dynamic programming models is still in initial stages. See for example:
Odd Gulbrandsen, "Optimal Priority Rating of Resource Allocation by Dynamic Programming", mimeographed paper, Institute of Transport Economy, Oslo, 1967 and Transportation Science (forthcoming) and
Irma Adelman and F. T. Sparrow, "Experiments with Linear and Piece-Wise Linear Dynamic Programming Models", in I. Adelman and E. Thorbeck (Ed.), The Theory and Design of Economic Development, John Hopkins Press, Baltimore, 1967.

second, with establishing a methodology to define the basic elements of spatial structure on which integration, both administrative and operational, might depend.

II. The Ports in a Transport Network

In 1965 the Port of Vancouver handled 11.4 million tons of foreign trade cargo, 49.4 per cent of the total flow from the ports of British Columbia.[4] New Westminster and Victoria both recorded gross tonnages of slightly more than 1 million tons, 8 other ports handled over a half a million tons and of the 45 ports which shipped foreign trade tonnages, 22 handled in excess of 100,000 tons. In terms of volume and the number of shipping points, the port economy is particularly vital. The spatial concentration of foreign trade flows is even more significant. Within 100 miles sailing distance of Vancouver, 60 per cent of all the ports handled 81 per cent of the flows in 1965. The inclusion of 4 other ports, among them Port Alberni and Toquart, within a radius of 200 miles, excluded only 12 per cent of total tonnage.

Such spatial concentration obviously gives rise to a considerable amount of inter-port shipping in the process of loading and discharging of cargoes and that for a proportion of the total shipping, cargo is loaded and/or discharged not in one port but in several within easy sailing distance. There exists therefore, not a series of port operating independently of each other but a system of ports linked together in a transport network, albeit one in which the lines of the network are "imaginary" routes.[5]

The set of ports and the set of paths (links) which ships trace out in moving between them may be abstracted into a set of ports and lines describing a planar graph or digraph.[6] Real values may be then assigned to the lines in terms of the number of ships moving from port to port, either directional volumes or total numbers, or in available cargo space or in any other suitable measure. Real values may also be assigned to the nodes, either in terms of tonnages loaded or unloaded, total number of ship calls or other measures derived from network values. Furthermore, the digraph is capable of complete description in matrix expression and may be manipulated in order to define the elements and the basic framework of spatial structure.

III. Graph Formulation and Matrix Expression

The port network may be regarded as a digraph D consisting of a set of points $P_1 \ldots P_n$ with a subset of "directed lines" or "lines" (representing the movement of foreign trade shipping between the ports) between any pair of points. If P_1 and P_2 are two points in a relation the line (P_1, P_2) designates the ordered pair whose first element is P_1 and whose second element is P_2. Not every point in the graph is connected or adjacent to all

---

[4] c.f. Shipping Report 1965, Part II, International Seaborne Shipping, Dominion Bureau of Statistics, Ottawa, 1966.

[5] K. J. Kansky, Structure of Transportation Networks: Relationships Between Network Geometry and Regional Characteristics, University of Chicago, Department of Geography, Research Paper No. 84, 1963, p. 2.

[6] See for example, F. Hararay, R. Z. Norman and D. Cartwright, Structural Models; an introduction to the theory of directed graphs, Wiley and Sons, N.Y., 1965. For a comprehensive Bibliography on Network analysis see Peter Haggett, "Network Models in Geography", in R. J. Chorley and P. Haggett (Ed.) Models in Geography, Methuen and Co. Ltd., London, 1967.

other points. Nor are the relationships which exist between any ordered pair of elements necessarily symmetric—$P_1 \rightarrow P_2$ (P_1 is related to P_2) but not $P_2 \rightarrow P_1$. Moreover the intensity (the value assigned to a line) may differ with the orientation of the line. A link is a line (P_2,P_3) joining two points in a graph. A path from point P_1 to P_n is a collection of links (P_1,P_2), (P_2,P_3) . . . . (P_1,P_n). A directed path from P_1 to P_n is a collection of directed lines (P_1, P_2), (P_2 P_3), . . . (P_7, P_n).

The graph formulation of the network may be now represented in matrix form. The digraph D is completely described in the adjacency matrix A(D) = [a_{ij}], an nxn matrix in which the a_{ij} cell has a positive value if the ports represented in the i^{th} row and the j^{th} columns are linked or zero if they are not linked. The diagonal elements a_{ii} in all cases of irreflexive graphs will be zero but may be arbitrarily defined in other cases. The row totals, $\sum\limits_{t=1}^{n}$ and the column totals $\sum\limits_{j=1}^{n}$ define the number of lines (or their intensity) connected with each point. Each row in the matrix indicates the distribution of lines **from** that point, each column indicates the lines which are connected **to** that point and the sum is the indegree of the point.

IV. The Adjacency Matrix

For every foreign trade vessel entering Canadian waters and for all subsequent movements of that vessel, whether from port to port or from berth to berth, the services of a pilot are required. Every movement of a vessel is therefore fully documented[7] and it is possible to trace its sequential movements. For the aggregate movement pattern of all vessels this not only gives the total number of times a link was travelled—thus giving a measure of the intensity of the link—but also provides a measure of "status" for the point or port—the total number of connections to or from the port, effectively the column or row totals (or the sum of both) in the adjacency matrix.

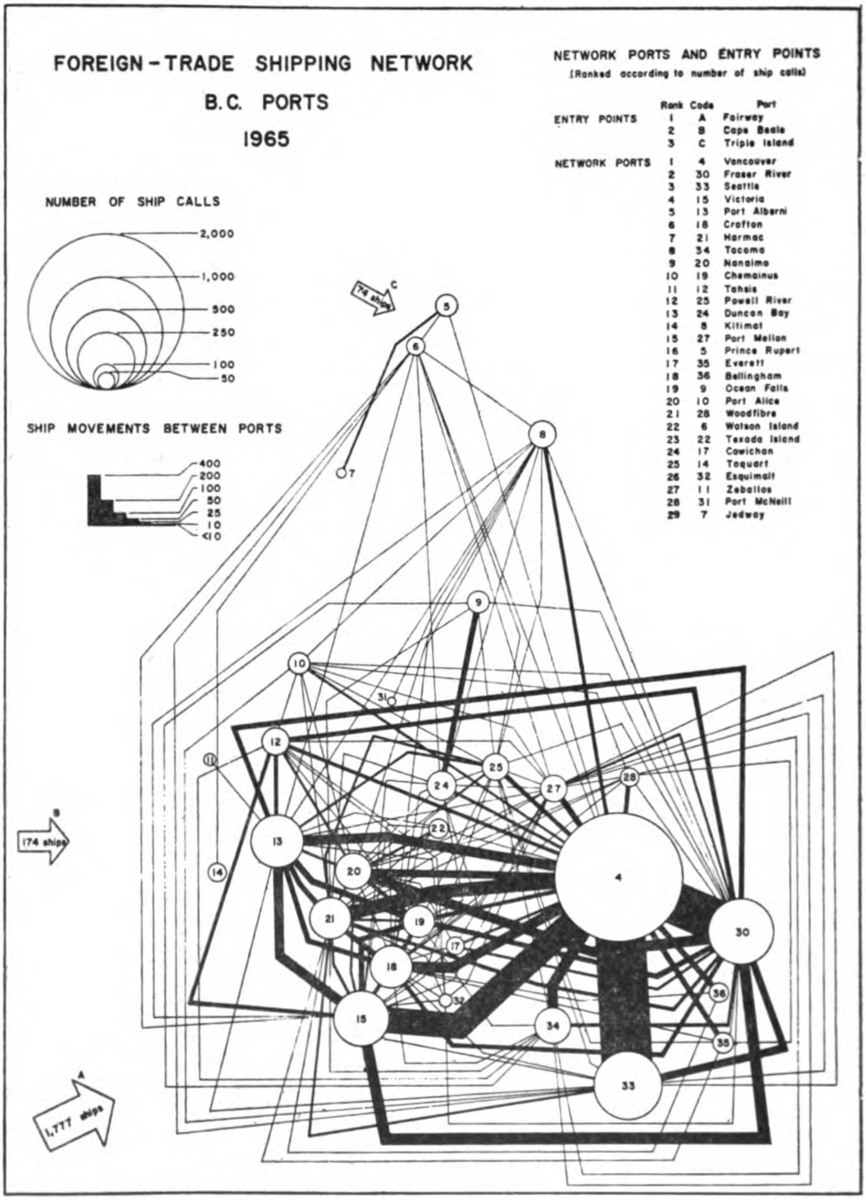
In 1965, the year chosen for the analysis, 2402 foreign trade vessels[8] entered the B.C. Pilotage District. Data for each of these vessels and assembled, coded and punched onto cards for computer processing. Each card listed the name of the vessel (in effect a number identifying the vessel), N.R.T., G.R.T., date of entry and the sequential patterns of movement from the initial entry point to every port or berth change to the final exit point.

On the basis of this data a series of matrices were developed. Two initial matrices of dimension 46 x 46 and in which the a_{ij} cells defined the number of vessels which travelled the links (P_1,P_n) and (P_n,P_1) respectively, were computed. The resulting **directional** intensities for each link were then aggregated in a third adjacency matrix A(D) = [$_{ij}$] in which the entries represented the total number of ship movements between any two ports or points.

---

[7] **Pilots' Source Form**, Department of Transport, Ottawa. The sorting and coding of the forms—about 10,000 for 1965—was a time and labour intensive operation. Since the cards were filed chronologically rather than by vessel it was necessary to sort them into correct movement sequences for each vessel.

[8] The figure excludes Passenger Liners.



NETWORK PORTS AND ENTRY POINTS
(Ranked according to number of ship calls)

	Rank	Code	Port
ENTRY POINTS	1	A	Fairway
	2	B	Cape Beale
	3	C	Triple Island
NETWORK PORTS	1	4	Vancouver
	2	30	Fraser River
	3	33	Seattle
	4	15	Victoria
	5	13	Port Alberni
	6	18	Crofton
	7	21	Harmac
	8	34	Tacoma
	9	20	Nanaimo
	10	19	Chemainus
	11	12	Tahsis
	12	25	Powell River
	13	24	Duncan Bay
	14	8	Kitimat
	15	27	Port Mellon
	16	5	Prince Rupert
	17	35	Everett
	18	36	Bellingham
	19	9	Ocean Falls
	20	10	Port Alice
	21	28	Woodfibre
	22	6	Watson Island
	23	22	Texada Island
	24	17	Cowichan
	25	14	Toquart
	26	32	Esquimalt
	27	11	Zeballos
	28	31	Port McNeill
	29	7	Jedway

FIGURE 1

Figure 1 is a diagrammatic representation of the computed matrix and effectively delineates the aggregated pattern of shipping movements within the coastal waters of British Columbia and adjacent areas. It is based on the actual number of ship movements and ship calls. The following points may be noted.

(i) The pattern of linkages is obviously dominated by the Port of Vancouver at which 1899 or approximately 80 per cent of all ships called in 1965.

(ii) Two ports, Fraser River (New Westminster) and Seattle, both have above one third of Vancouver's total calls: another two, Victoria and Port Alberni have more than 300 calls and eight other ports have total calls in the 100 to 200 range. There is thus a small cluster of ports adjacent to Vancouver which have an average of one ship call per day. Within the whole area about 20 ports have an average of above one ship call per week.

(iii) The relative strength of various shipping paths is easily observed. The significance of the Vancouver-Seattle movement (and to a lesser extent the Vancouver-Tacoma, Bellingham and Everett links) is possibly surprising though it underlines clearly the need to consider Vancouver's relationships with the adjacent U.S. ports.

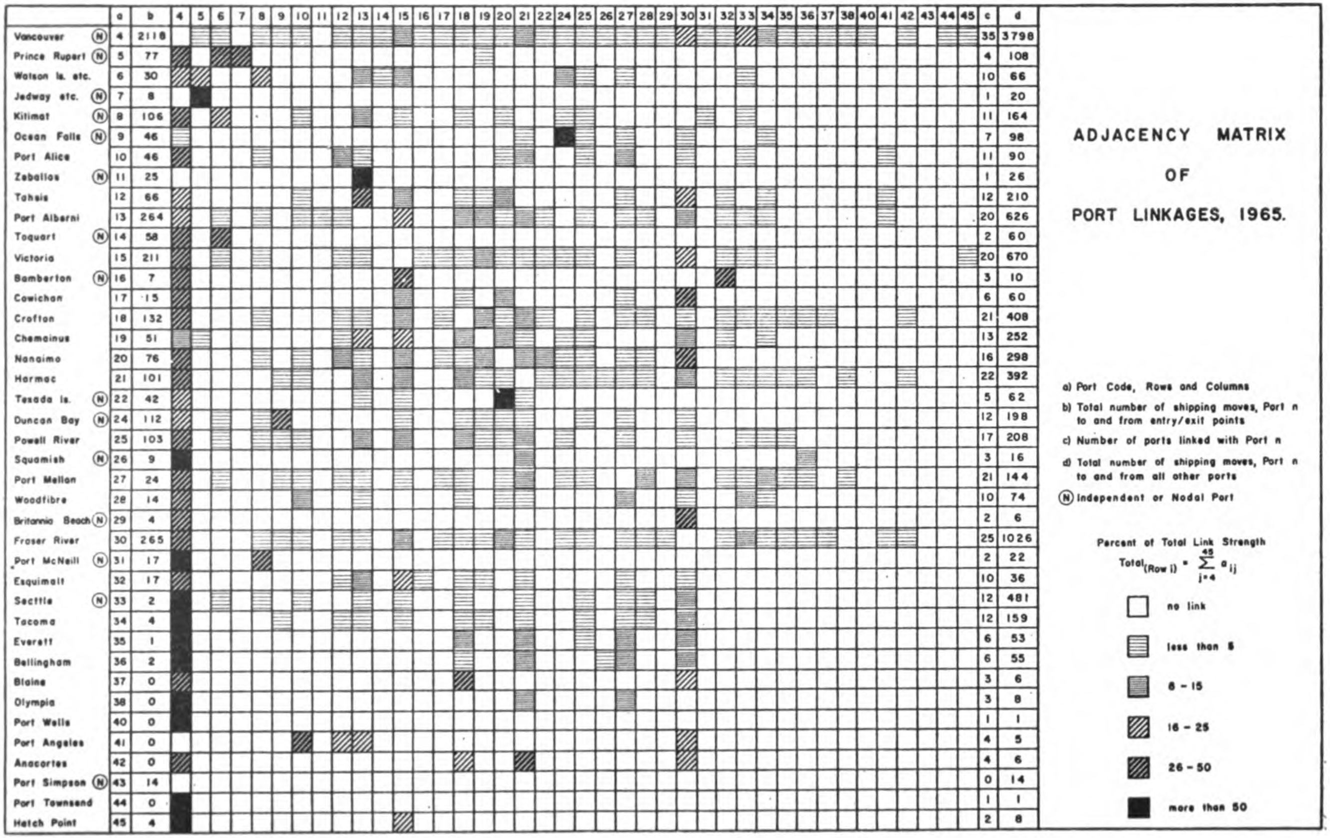
(iv) Although strong orientations to Vancouver are evident in the cluster of B.C. ports there are also direct links of some relative importance between other ports.[9] Thus the New Westminster links with Victoria, Seattle, Nanaimo, Port Alberni and Tahsis and to a lesser extent Harmac and Crofton etc. may be noted. The Ocean Falls-Duncan Bay and the Prince Rupert-Jedway links, while not heavily travelled, are relatively important for the respective ports.

Figure 2 further clarifies some of the relationships shown in the previous diagram and shows both the **patterns** of linkage orientation (which ports are linked) and the **strength** of the orientations. The matrix has been derived from the original matrix $A(D) = [a_{ij}]$. The values in each row cell have normalized on the basis of the row total ($\text{Total}_{(\text{Row}_i)} = \sum_{j=4}^{4s} a_{ij}$) for each port. The cell is properly interpreted as follows: "the total strength of the link (P_1,P_2) represents t per cent of the total linkage strength of P_1 to all ports or t per cent of all shipping moves between the two ports". The shading in the diagram is graduated according to the relative strength of each link in Port n to all other links for that port.

Some of the relationships may be noted briefly. Column (c) indicates the number of ports to which each port is linked in the study area and in effect is an indication of the degree of connectivity within the system. As is expected, Vancouver's linkages are most highly diffused and again ports with high rank have many linkages. Crofton, Harmac and Port Mellon indicate a well-connected pattern as do the adjacent ports. Prince Rupert demonstrates clearly its isolation from the southern area. Everett, Bellingham and Seattle have relatively low connectivity values indicating strong orientations within

---

[9] The network lends itself to further detailed analysis. An extension of the data would provide—in, for example a multiple regression or factor analytic model—the background for computational analysis of the causal basis of the linkages.



ADJACENCY MATRIX

OF

PORT LINKAGES, 1965.

		a	b	c	d
Vancouver	Ⓝ	4	2118	35	3798
Prince Rupert	Ⓝ	5	77	4	108
Watson Is. etc.		6	30	10	66
Jedway etc.	Ⓝ	7	8	1	20
Kitimat	Ⓝ	8	106	11	164
Ocean Falls	Ⓝ	9	46	7	98
Port Alice		10	46	11	90
Zeballos	Ⓝ	11	25	1	26
Tahsis		12	66	12	210
Port Alberni		13	264	20	626
Toquart	Ⓝ	14	58	2	60
Victoria		15	211	20	670
Bamberton	Ⓝ	16	7	3	10
Cowichan		17	15	6	60
Crofton		18	132	21	408
Chemainus		19	51	13	252
Nanaimo		20	76	16	298
Harmac		21	101	22	392
Texada Is.	Ⓝ	22	42	5	62
Duncan Bay	Ⓝ	24	112	12	198
Powell River		25	103	17	208
Squamish	Ⓝ	26	9	3	16
Port Mellon		27	24	21	144
Woodfibre		28	14	10	74
Britannia Beach	Ⓝ	29	4	2	6
Fraser River		30	265	25	1026
Port McNeill	Ⓝ	31	17	2	22
Esquimalt		32	17	10	36
Seattle	Ⓝ	33	2	12	481
Tacoma		34	4	12	159
Everett		35	1	6	53
Bellingham		36	2	6	55
Blaine		37	0	3	6
Olympia		38	0	3	8
Port Wells		40	0	1	1
Port Angeles		41	0	4	5
Anacortes		42	0	4	6
Port Simpson	Ⓝ	43	14	0	14
Port Townsend		44	0	1	1
Hatch Point		45	4	2	8

a) Port Code, Rows and Columns

b) Total number of shipping moves, Port n to and from entry/exit points

c) Number of ports linked with Port n

d) Total number of shipping moves, Port n to and from all other ports

Ⓝ Independent or Nodal Port

Percent of Total Link Strength

$\text{Total}_{(\text{Row } i)} = \sum_{j=4}^{45} a_{ij}$

☐	no link
▤	less than 5
▦	5 – 15
▨	16 – 25
▩	26 – 50
■	more than 50

FIGURE 2

the total pattern. Again, the bulk commodity mineral ports effectively indicate lack of network orientation. Ocean Falls and Kitimat both have values which imply either strong orientation or lack of network ties.

V. The "circuit" matrix

The adjacency matrix thus defines the extent of the network and establishes the relative intensities of particular path links. But it does not adequately account for the fact that foreign trade vessels may include several ports in their shipping "circuit". It is important that a ship calls at Vancouver, then Crofton, Harmac and Nanaimo in its shipping "circuit": it is significant too, not only that the circuit is made up of three distinct links, but also that these few ports together provide the ship with its operational focus.

Let M be a digraph consisting of the set of ordered pairs (P_1,P_2), (P_2,P_3) . . . . $(P\ ,P_n)$ which represents the graph defined by any one foreign trade vessel in its sequential movements to and from ports within the study area. Each point (port) is linked to one other point directly and all other points indirectly in 2-link, 3-link and n-link sequences. An exponential factor is defined in which each 1-link sequence is weighted with a value of unity and all other sequences a value inversely proportional to a factor of 2 raised to the power (d-1), when d is the number of links in the sequence (P_1,P_n). The direct link (P_1,P_2) will be weighted unity. Indirect links (P_1,P_3), (P_1,P_4), (P_1,P_5) . . . . (P_1,P_n) will be weighted by the factor $(\frac{1}{2^{d-1}})$ or 0.5, 0.25, 0.125, 0.0625 etc., respectively.

The exponential factor is arbitrary. A weighting factor inversely proportional to (d) was thought to give too much emphasis to extended multi-link sequences. The more classical gravitational factor in which the distance component is squared resembles the factor described but gives low values to relatively short multi-link sequences. The exponential factor described is a compromise between these two.

There is a further problem in the derivation of the factor. It assumes, implicitly, that the significance of a port is directly related to its status within a multi-link sequence. But the fact that a vessel calls at A before B and C may not necessarily mean that B and C are less significant than A.[10] The sequence of calls for any vessel may of course be determined by any number of variables—the type of cargo to be loaded, the pattern of cargo discharge at destination ports, cargo availability at alternate outlets, queuing problems within the port system and so on.

Nonetheless, the weighting procedure does in fact reflect the actual patterns of ship calls, whether or not sequence is related to tonnage handled. Moreover, it does give greater weight to short multi-link paths than to attenuated sequences with the implicit assumption that the fewer the number of ports involved in a sequence, the more important the port is as a focus of foreign trade flows. Again, the assumption is not demonstrated to be correct. Where bulk cargoes are being handled it will be essentially the case; for

---

[10] What is needed is an index which relates to the tonnage loaded or unloaded at the port, either in absolute terms or as a proportion of all cargo handled.

general cargo it may be less so, not only because a vessel may load a variety of commodities but also because it may service a range of origin and destination ports, each having different cargo requirements. But in any case such an evaluation of sequence does take into account the circuitry of shipping patterns.

Matrix $M = [m_{ij}]$ is formulated on the basis of the exponential weighting factor for link strength outlined above. The matrix is symmetrical so that $m_{ij} = m_{ji}$ and $m_{ii} = 0$. Thus each m_{ij} element is the sum of the directional values derived from m_{ij} and m_{ji}. The m_{ij} elements do not therefore represent the number of ships moving on the paths (P_1,P_2) and (P_2,P_1) but are evaluated in terms of the number of ships operating within a pattern of multi-link sequences. The matrix is then normalized on the basis of the maximum row total so that each element is proportional to this total. A set of rules, which would define the basic framework of the spatial organization of shipping movement and port activity, may now be formulated and applied to the matrix.

The structure of the commodity flow and the characteristics of foreign-trade shipping to handle the flows in the study area implies that, rather than operating as part of a single network the shipping patterns are structured in a series of networks which focus on a single port or a series of ports. The initial problem is to define this focus which may be referred to as the **independent** or **nodal** port.

The exclusive characteristic of the nodal port within the system of ports is that the network orientation is externally rather than internally structured--that is, that relatively the values attributed to the internal linkage pattern will be less than those for the external links.

From the data available all shipping entered and left the study area from one of four points, three in British Columbia and the hypothetical point to account for departures form U.S. waters Thus the external linkages —those with the Pilotage Stations (which in this context is synonymous with foreland ports as well as movements between the ports, are known.

The matrix M thus yields a value for the total number of linkages, weighted for multi-link sequences and normalized according to the procedures outlined above, from any one point to and from any other point. The sum of the rows thus yields a value, which may be termed the Total Network Value of the Port. By obtaining separate values for the external linkage values (the sum of the obtained values of linkages from the nth port to and from the Pilotage Stations) and the internal network value (the sum of the obtained values for linkages of the nth port with all other ports), see Table 1.

Each nodal port may or may not be the focus of a series of linkages or flows and the second step requires the definition of the network or links which are oriented to these ports. Again, the orientations of the largest flows will delineate the essential structure of the network. Thus inspection of the m_{ij} elements in each row of the matrix for any port n reveals the strongest link values between that port and any other port. The orientations established by inspection are shown in Figure 3.

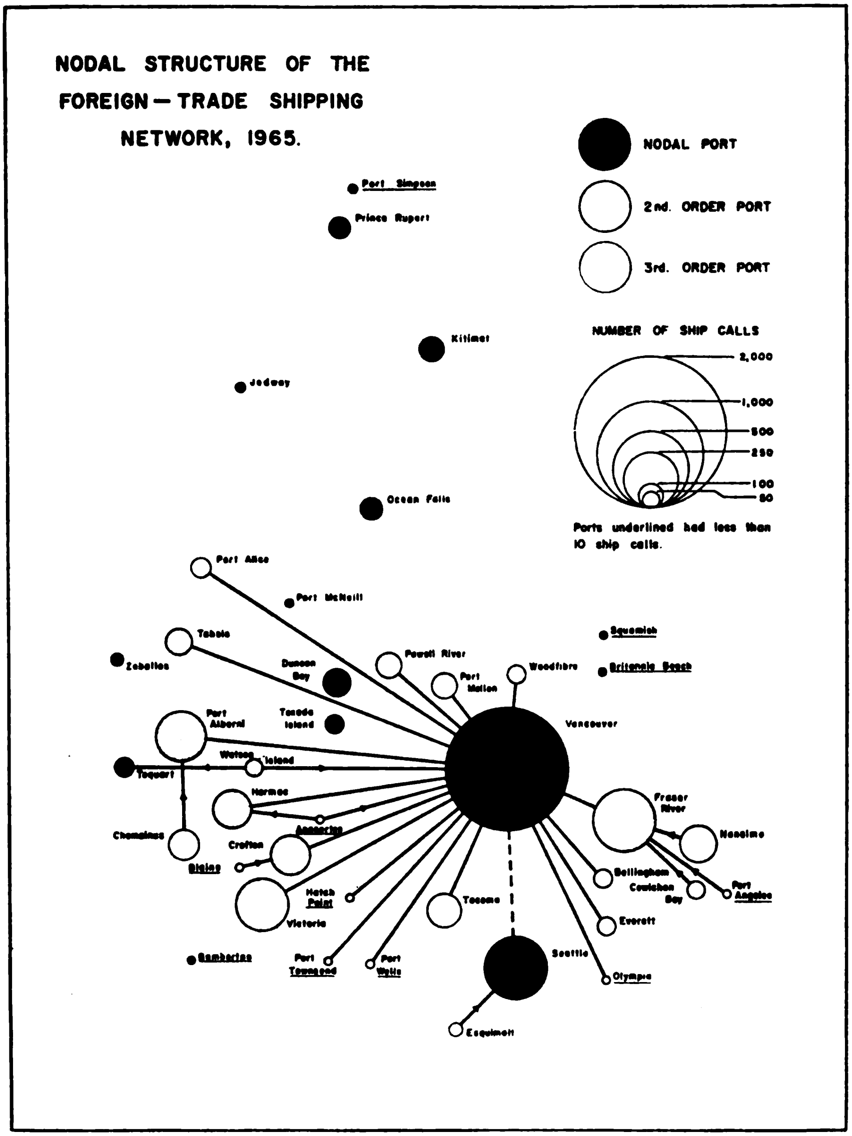


FIGURE 3

VI. Conclusions

The adjacency matrix formulation of the linkage pattern demonstrates that the network defined by the movement of foreign trade shipping between the ports in the study area is an intricate one. The pattern of maximum intensity linkages (Figure 1) does in fact show the strongest orientation and the move in significant ports are evident. Matrix refinement to evaluate the "circuitry" of shipping behaviour and to clarify network structure is even more significant.

The following conclusions may be noted.

(i) That although there exists a fairly extensive pattern of interaction among the ports there is a group of ports which operates in a highly directional network and function as independent points within the regional framework—they are effectively nodal ports but do not support an internally-oriented network—though this does not mean that other linkages are absent. There are fifteen such ports defined within the study area.

TABLE 1

Total Link Strengths Between all Ports in the Study Area

Rank	Port	Total Network value of port	External link value	Internal Network value	Independent or Nodal Port
1.	Vancouver	1.000000	0.545948	0.455052	*
2.	Fraser River	0.325636	0.100564	0.225072	
3.	Victoria	0.217558	0.075741	0.141817	
4.	Port Alberni	0.196155	0.078256	0.117899	
5.	Seattle	0.168991	0.036124	0.132867	*
6.	Crofton	0.130263	0.045747	0.084516	
7.	Harmac	0.126577	0.038342	0.088235	
8.	Nanaimo	0.101874	0.029289	0.072585	
9.	Chemainus	0.088643	0.021855	0.066788	
10.	Tahsis	0.071600	0.021616	0.049984	
11.	Powell River	0.060970	0.029647	0.031323	
12.	Tacoma	0.056752	0.012760	0.043992	
13.	Duncan Bay	0.055341	0.033767	0.021574	*
14.	Port Mellon	0.046073	0.011967	0.034106	
15.	Kitimat	0.045635	0.028002	0.017633	*
16.	Ocean Falls	0.028850	0.015033	0.013817	*
17.	Prince Rupert	0.028250	0.019900	0.008350	*
18.	Port Alice	0.026252	0.013025	0.013227	
19.	Woodfibre	0.023905	0.007092	0.016813	
20.	Cowichan	0.020242	0.005994	0.014248	
21.	Watson Island	0.019653	0.009791	0.009862	
22.	Bellingham	0.019536	0.003211	0.016325	
23.	Everett	0.019511	0.003518	0.015993	
24.	Texada	0.016530	0.011529	0.005001	*
25.	Toquart	0.013846	0.013281	0.000565	*
26.	Esquimalt	0.010841	0.004732	0.006109	
27.	Zeballos	0.005990	0.005764	0.000226	*
28.	Jedway	0.005877	0.003165	0.002712	*
29.	Port McNeill	0.005708	0.004239	0.001469	*
30.	Squamish	0.004295	0.002600	0.001695	*
31.	Port Simpson	0.003165	0.003165	0.000000	*
32.	Olympia	0.002826	0.000396	0.002430	
33.	Bamberton	0.002656	0.001865	0.000791	*
34.	Hatch Point	0.002317	0.001074	0.001243	
35.	Anacortes	0.002275	0.000212	0.002063	
36.	Blaine	0.002190	0.000466	0.001724	
37.	Port Angeles	0.002091	0.000170	0.001921	
38.	Britannia Beach	0.001660	0.001024	0.000636	*
39.	Port Wells	0.000339	0.000113	0.000226	
39.	Port Townsend	0.000339	0.000113	0.000226	

Of these fifteen, eight are essentially exporters of high-bulk minerals. Their nodal status clearly demonstrates the significance of specialized shipping flows and the importance of bulk carriers operating on highly directional routes. The iron-ore ports—Zeballos, Toquart, Port McNeill, Jedway and the Texada Island Points—are all serviced by large vessels, some of which have been specially built—e.g. the M.S. Texada, a 65,000 ton carrier operating from Texada mines to Japan. This type of shipping service is not characteristic for the ports handling smaller volume flows of limestone and copper ores—Bamberton, Squamish and Britannia Beach.

Sheer physical distance and isolation is a factor of prime importance in explaining low levels of interaction for Prince Rupert, Kitimat and Ocean Falls with the southern cluster of ports. But the specialization of production within a corporate structure, and thus also the specialization of shipping flows both in terms of commodity flow structure and of charter arrangements for shipping services, is also important for Kitimat and Ocean Falls. Thus Alcan's operations at Kitimat are largely independent of production raw materials within the study area. The Ocean Falls plant is, however, part of the Crown Zellerbach operation and has strong internal ties, particularly with Duncan Bay. Moreover, both these operations are highly linked with the parent operation in the San Francisco Bay area and are serviced by chartered shipping with regular runs every 10 to 14 days—e.g. the "Rondeggan", "Besseggen" and the "Duncan Bay", carrying pulp southwards and fuel oil on its northern run. Thus, both Ocean Falls and Duncan Bay, though highly linked function as independent ports. The isolation of Prince Rupert and its dependence upon grain movements effectively create independent status.

Port Simpson, a relatively small node, is virtually completely independent. It is serviced by the Japan Line and exports lumber direct to Japan.

(ii) That the Vancouver node is the effective focus of a relatively extensive network of ports. It is apparent that distance is not the critical factor in defining the network limits—the greater proportion are within a 100 miles sailing distance of Vancouver but Port Alice, the furthest removed is almost 350 miles. Moreover, size in terms of tonnage handled or number of ship calls, is variable. What is significant however, is that Port Alberni, Victoria, and Fraser River (or New Westminster) three of the largest concentrations in the southern area, are oriented towards Vancouver.[11] Furthemore there is evidence of some more sophisticated spatial ordering of port linkage structures. Thus for example, Vancouver is closely linked to Fraser which in turn is the focus of flows from Nanaimo, Cowichan Bay and Port Angeles in third-order relationships. Chemainus and Port Alberni and Blaine and Crofton are similarly linked.

(iii) That, in effect, the ports defined within this network operate as ex-

---

[11] It is likely that with the increased use of bulk lumber carriers Port Alberni will become increasingly less dependent on Vancouver. New Westminster and Victoria, on the other hand, will probably become increasingly dependent.

tensions of the berth complex in Burrard Inlet. Vancouver is thus not only a high-tonnage port and attracts a considerable shipping volume: but it is also the operational focus of a network of ports each of which is more strongly oriented to—or more dependent upon—Vancouver than it is to sustaining its own shipping services.

The spatial evidence thus points to an operational integration of port facilities and shipping. Whether or not it points to an optimal condition within the system, either in terms of port time or in the optimization of investment in port facilities, is an entirely different question which must be approached through more sophisticated linear dynamic programming models. The need for administrative and planning authority to co-ordinate port development within the region is nonetheless clearly apparent.