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### HISTORICAL TEMPORAL SHIPPING (HITS)

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Prepared for:

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Submitted by:

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		TABLE OF CONTENTS	
			Page
	List d	of Tables	iii
	List d	of Figures	iv
	Refere	ences	vii
	I.	Introduction	1
		1. Purpose 2. Scope 3. Background	1 1 2
	II.	The Lloyd's Data Base	4
		1. Logical Structure of Data Base	4
		<ol> <li>Auxiliary Tables</li> <li>Conclusions</li> </ol>	12 14 14
	III.	Trend and Growth Analysis	16
		<ol> <li>Discussion of Available Sources</li> <li>Method and Sources Finally Used</li> </ol>	16 35
	IV.	Distribution Methodology	38
		<ol> <li>ORE Outputs and Cubic Splines</li> <li>Distribution and Sources of Fishing and Oil Rigs</li> </ol>	38 79
	۷.	Outputz	81
		1. Availability - Administrative 2. Availability - Technical	81 81
	VI.	Discussion of Validity of Results and Sample Outputs	82
	VII.	Computer Programs	94
		<ol> <li>Overview and Program Flow</li> <li>Function of Each Program</li> <li>Detailed Table Descriptions NCOLSSION for While Section D</li> </ol>	94 103 106
	VIII.	Conclusions DC But Sector B	117
	Append	UNAUTICATION USIT ICATION	A-1
	Distri	bution List	D-1
		i B	

the second

Appendices Page Constant of Α. Program ALPHA A-1 A-7 Β. Program BETAl A-10 C. Program BETA A-16 D. **Program BETA2** A-18 -----Ε. Program GAMMAl A-21 F. Program GAMMA2 G. A-24 Program DELTA1 ------A-26 H. Program DELTA2 A-28 I. Program DELTA3 A-29 J. Program GAMMA ĸ. Program EPSILON A-42 -----A-48 L. Program THETA1 A-50 Μ. Program X13 TABLE A-51 N. Program SEXTILE TABLE A-52 0. Program THETA Ρ. The DATA FILES A-55 ROUTING TABLE (Final Version) A~55 1. 2. A-57 ROUTING TABLE (Original Version) A-58 3. ROUTING TABLE (Mediterranean Additions) 4. MEDITERRANEAN PORT/Route Renumbering Table A-59 5 A-60 5. ROUTE TREES (Original Form) A-62 6. ROUTE TREES (Final Version) -----A-64 7. SIGLUM TABLE A-66 8. SIGLUM INDICES A-68 9. ENVELOPE -A-70 10. PORT DISTANCE TABLE A-71 11. ESTIMATED TRAVEL TIME TABLE - Barout A-73 12. PORT TABLE A-74 13. PORT HASH TABLE A-76 14. SEXTILE ARRAY 15. A-77 CUBIC SPLINE POINTER TABLE A-78 16. PROTO ROUTING TABLE 17. A-80 SHIP DAYS TABLE 100

and a state of the state of the

ななななどのないである

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#### LIST OF TABLES

		Page
Table 2-1	Sample Listing for DOT Input Tapes	7
Table 2-2	Illustrative Examples of Ship Match-up for Successive DOT Tapes (for weeks 51 & 52)	11
Table 6-1	Correlation Coefficient Among Various Studies	88
Table 7-1	Sample of Port Table	106
Table 7-2	Listing of Canonical Ports	107
Table 7-3	Routing Table Sample	109
Table 7-4	Sample of Route Trees	110
Table 7-5	Siglum Table Sample	111
Table 7-6	Sample Data from Inverse Siglum Table and Siglum Map	112
Table 7-7	Sample Data from Port Distance Table(Fall)	113
Table 7-8	Sample of Estimated Travel Time Table (Spring)	114
Table 7-9	Sample Data from Proto48	115
Table 7-10	Sample Ship Days Table	116

Contraction of the second s

Contraction of the second

transfer to

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Cuch bu

4.3

iii

LIST OF FIGURES Page Figure 3-1 Histogram of Shipping Traffic from 21 U.S. Pacific Coast to Kobe Histogram of Shipping Traffic from Figure 3-2 22 U.S. Pacific Coast to Manila Figure 3-3 Histogram of Shipping Traffic from 23 U.S. Pacific Coast to London Histogram of Shipping Traffic from Figure 3-4 24 U.S. Pacific Coast to Rio Figure 3-5 Histogram of Shipping Traffic from 25 U.S. Pacific Coast to Capetown Histogram of Shipping Traffic from Figure 3-6 U.S. Pacific to Naples 26 Figure 3-7 Histogram of Shipping Traffic from 27 U.S. Pacific Coast to Piraievs Figure 3-8 Histogram of Shipping Traffic from 28 U.S. Pacific Coast to Bombay Histogram of Shipping Traffic from Figure 3-9 29 U.S. Pacific Coast to Honolulu Figure 3-10 Histogram of Shipping Traffic from 30 U.S. Pacific Coast to Sydney Figure 3-11 Histogram of Shipping Traffic from 31 U.S. Pacific Coast to Balboa Figure 3-12 Histogram of Shipping Traffic from 32 U.S. Pacific Coast to Singapore Figure 3-13 Histogram of Shipping Traffic from 33 U.S. Pacific Coast to LeHarve Figure 3-14 Histograms of Shipping Traffic from 34 -U.S. Pacific Coast to Rotterdam

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		LIST OF FIGURES (contd)	
			Page
Figure	4-1	Tree Structure	41
Figure	4-2	Route Histogram Cells	45
Figure	4-3	Projection of Area onto Route Perpendicular	45
Figure	4-4	Single Column Cut of Route Envelope	46
Figure	4-5	Histogram of Two Columns of Data	46
Figure	4-6	Envelope for Case a	52
Figure	4-7	Example of a Route with Several Segments	53
Figure	4-8	Outline of Envelope and Geometry for Case b	55
Figure	4-9	Outline of Envelope and Geometry for Case C	57
Figure	4-10	Definition of Angle a <sub>0</sub> and Upcrossing Point	61
Figure	4-11	Planar Projection of the Earth, Degree Coordinate System	65
Figure	4-12	Components of a Typical Route Segment	68
Figure	4-13	Case 1: One edge of the 1° square lies in the cut	69
Figure	4-14	Case 2: The cut lies inside a portion of the 1° square	69
Figure	4-15	Case 3: A rectangular region lies in the cut	70

è

1150.00

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1

2 ....

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Schemole -----

Π

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Case 4: A triangular region lies in Figure 4-16 the cut 70 Figure 4-17 Case 5: A polygonal region lies in the cut 71 Case 6: Region of the 1° square lies in Figure 4-18 the upper portion of the cut 71 Figure 4-19 Three edges of the square lies Case 7: in the cut 72 Figure 4-20 Case 8: The whole 1° square lies in

, **V** 

in the cut

LIST OF FIGURES (contd)

Page

.

t t

.

U

0

0

T

Figure	4-21	Case 9:	A polygonal region lies in the cut	74
Figure	4-22	Case 10:	The cut lies completely in the l'square	75
Figure	4-23	Case 11:	A polygonal region lies in the cut	76
Figure	4-24	Case 12:	Three regions of the l° square lie outside the cut	77
Figure	6-1	Compariso With Stan	ons of CHURCH ANCHOR Versus HITS dard Deviations	83
Figure	6-2	Ratio of = 8 for 5	HITS/CHURCH ANCHOR With Median x 5° Square Densities	84
Figure	6-3	Histogram Relative	of Normalized HITS Densities to CHURCH ANCHOR Densities	85
Figure (	6-4	5 x 5° Sq ANCHOR, R	uares Comparison of HITS, CHURCH MS, and CHURCH OPAL	87
Figure	6~5	Total Shi Via Direc	pdays Between Canonical Ports t Routes (December)	90
Figure (	6-6	Distribut By 1 x 1°	ion In The Aleutian Island Square (Merchants)	91
Figure (	6-7	Oil Rigs	In the Gulf of Mexico	92
Figure (	6-8	Fishing V Gulf of M	essels Distribution For The exico (Summer)	93
Figure 1	7-1	Data Sets	, Program Interrelationships	95
Figure 7	7-2	Indexing	Relationships Among The Tables	.00

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#### CHAPTER I

#### Introduction

#### 1. <u>Purpose</u>.

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It is the purpose of this report to provide information on the shipping densities in  $1^{\circ} \times 1^{\circ}$  squares throughout the world. This report explains the techniques and procedures by which these densities were generated. The data generated in meeting this objective is stored in machine readable format and is available from Planning Systems Incorporated.

#### 2. Scope.

This report describes in rather substantial detail the procedures by which shipping densities in 1° x 1° squares are available. The basic data base which was employed was the 1972 Lloyd's Shipping Index indicating the disposition of 18,000 ships per week in the 2,425 Lloyd's ports. The 1972 data base was updated to 1977 using a trend and growth analysis which is discussed in some detail in the report. Five different types of vessels are considered in the analysis. These are merchant vessels, tankers, super-tankers, fishing vessels, and oil rigs. The distributions of the individual types of vessels are given for each month of the year, each quarter of the year, and an annual average. Thic results in 17 distributions per type of vessel.

The report describes the methodology for distribution of the updated port traffic throughout the world. It is heavily dependent upon a preceding volume issued by Planning Systems Incorporated "Ocean Route Envelopes", (ORE)<sup>22</sup> published on 19 April, 1977. The resulting distributions consist of well over 12,000,000 individual pieces of data. Due to this enormous data base, it is impossible to present all distributions and possible combinations in a printed format within the body of this report.

Therefore, only examples are presented. However, any distribution or combination of distributions may be obtained in machine readable format directly from Planning Systems Incorporated.

#### 3. Background.

The primary purpose of this project was to quantify the distributions of all ships in the oceans of the world at various times of the year. One of the necessary tasks to accomplish this objective was to employ and develop seasonal route envelopes which would allow the movement of ships between the world's ports. The routes themselves are subject to a very detailed development and have been presented in a previous report: Ocean Route Envelopes published by PSI.

World shipping densities are seasonally dependent and are due to two palmary factors:

- 1. The seasonal variation of the routes by which ships move between world ports .
- 2. The seasonal variation in port traffic.

The first part of this problem, addressed in the ORE report, dealt exclusively with the logic and mathematical quantification of the development of the temporal world shipping routes. The second part of the problem is the world port activity. This activity has been provided through a numerical quantification of 1972 Lloyd's Shipping Index. The index gives the locations of approximately 18,000 ships per week. In the preparation of this report it was necessary to update this 1972 data to the year 1978. A number of techniques were employed based upon industrywide sources. Therefore, the shipping densitites are considered to be 1978 information. This report, HIstorical Temporal Shipping (HITS), discusses the existing Lloyd's data base, the trend and growth analysis, the distribution methodology to establish the shipping densities, and the type of outputs. In addition to the data, it provides information on the development of the computer programs which were necessary in developing such a large and extensive data base.

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### CHAPTER II The Lloyd's Data Base

#### 1. Logical Structure of Data Base.

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The DOT Marine Traffic Generator Input Tapes provided the majority of the raw data on ship movements necessary to generate the shipping density for this study. These tapes were originally prepared by the Department of Transportation for use by the Marine Traffic Generator, and included data from Lloyd's Shipping Index for 1972.

These tapes were used in the study by Program Gamma to accumulate the total time spent by ships passing between each pair of ports in the DOT Marine Traffic Generator port table. Later programs then converted this information into shipping density fields.

The Lloyd's Shipping Index contains a weekly record of movements of many merchant vessels (approximately 18,000). It records the egress port, entrance port, and port of last call for each ship, along with the date of egress. An additional date field may fill one of several purposes, depending upon the setting of various flags. Possible interpretations are date of arrival at entrance port, date of arrival at port of last call, date of departure from port of last call, date of passing port of last call, or date of presence in the port of last call. Each ship is identified by name, flag, gross tonnage, year built, and type (tanker or non-tanker), and is recorded each week in approximately the same position within the Shipping Register?

Each of the 52 tapes contains movement reports received during the corresponding week of 1972. However, the actual date of the ship movements recorded can be as much as several months

prior to the date of report itself. Frequently, the same data will be repeated in several successive weekly tapes without change. Furthermore, as the length of a voyage can be appreciably longer than the weekly reporting intervals, no one tape will necessarily contain sufficient data to permit reconstruction of the ship's route and travel time. At the opposite extreme, only one voyage with a maximum of three ports (only two with dates) could be included per ship per week, so that numerous short-haul trips were completely ignored. This latter phenomenon was aptly illustrated by ships that were recorded as having arrived in port in one weekly issue and then as departing from a different port in the following week's issue, with no intermediate voyage recorded.

A possible fundamental weakness in the data base used arises from the selective nature of the reporting. Lloyd's was almost completely dependent for its data upon sailing reports from the various harbour masters. The completeness of the data thus depends in most cases upon the diligence of a single reporting source and the completeness of his information. Numerous reports exist in the shipping index of ships sailing off to nowhere or arriving from points unknown. There are no checks against consistent underreporting of traffic from a specific port and, in particular, sailing reports for Communist owned ships between most Communist ports are conspicuously absent. Date information, too, is frequently missing. This weakness in the data collection is reflected by the incompleteness of the final shipping index. The number of ships reported each week (approximately 13,000) is much smaller than the total number of elligible ships from Lloyd's and no one ship is necessarily monitored continuously throughout the course of the year.

T Π

In order to extract the maximum amount of information from Lloyd's shipping index, it was necessary to correlate corresponding reports from successive weekly issues. This was done by matching the ship reports on the basis of the identifying information (name, weight, type, flag, and year built). The reported ship movements could then be compared to eliminate overlapping reports, supplement incomplete information, and simulate some unreported voyages. As movement reports (except for expected destination) were normally received after the movements reported, the tapes were processed backwards, beginning with the shipping index tape for the last week of December 1972, and proceeding backwards to January of that year.

The nature of the data is illustrated by the first 50 records from the DOT input tapes for weeks 51 and 52 shown in Table 2-1. Some sample match-up procedures from these lists are shown in Table 2-2. An examination of the missing data list in the notes to Table 2-1 reveals 122 missing or antiquated items of data among the 100 reports, for an average of 1.21 missing or antiquated data per report. Quite clearly, it is only the exceptional report which is complete and up-to-date.

Table 2-1 Sample Listing for DOT Input Tapes

DOT INPUT TAPE FOR WEEK 51, 1972 K I .7 护 G H BCD E A. E. S. I 0 DA 57 001579 RUTTE DEC 11 LONDO AR **DEC 12** H. HELD 4 0 GE 67 000211 KOTKA DEC 05 MAAST DEC 14 4 AR ANTWE A. N. KEMP I 1 LI 50 018127°NEW Y DEC 06 ARUBA 1 DA 66 052673°PHILA NOV 29<sup>5</sup>ESCRA 0 DA 66 000499 WESTE NOV 175TORRE A. P. MOLLER I AAGE ANDREASEN AR. DEC 03 5 **HHP** 0 GE 32 000330dHARTL DEC 09 BREME 0 DA 55 000300 HULL AASE HOU DEC 14 GUNNE **DEC 14** AR. 0 RU 62 0046520G9RST ABAGURLES SEP 225ARCHA 0 RU\_61 004638 ANTWE DEC 09 LENIN ABAKANLES 0 PH#64 003989 BANGK ABASIN 2XARAC AR KARAC JUL 25 1 RU 71 003469£MALMO DEC 13 KLAIP ABAVA 1 BR 72 001584cHAVRE DEC 08 DAKAR ABBUTSFORD DEC 16 AR 0 DU 71 027614 MELBO NOV 145LONDO ABEL TASMAN AR **DEC 16** ABERTHAW FISHER 0 BR 66 002355 ROTTE NOV 295ASHDO AR. DEC 18 1 DU 59 012226dSTANLO DEC 06 CURAC ABIDA 0 RU#60 0044490MERSI DEC 03 ISTAN ABIDIN DAVER DEC 06 AB-ABIDJAN 0 LI 67 003048 DUALA DEC 07 BREME AR ABIDJ **DEC 10 4** ABIQUA 0 AM 43 014640<sup>f</sup>CHITT DCT 255GALVE AR CORPU DEC 09 0 SG 61 002683¢KRIST 2TROND 0 FR 61 006451 HAVRE DEC 01 BUEND DEC 11 ABLE REEFER AR. SD PALMA ABLON **DEC 12** 0 BR 40 001934eCARTA ABOCOL NOV 225TAMPA <sup>2</sup>DUALA ABDISSD 0 IV 55 004939 AMSTE SD ANTWE **DEC 16** 0 CY 58 000499 IZMIR NOV 28 BREME 1 RU 64 003390 LONDO DEC 14 BALTI 0 EG 60 001946 LATTA 2 ALEXA ABOTA AR . DEC 14 ABRENE ABU SIMBEL AR DEC 09 3 AR SINGA ABUGAWA MARU 0 JA 65 001782¢ 2 i DEC 08 0 NO 69 0368620ROTTE SD SHEER ACADIA FOREST DEC 12 NEW D DEC 13 1 LI 59 016808¢CARAC DEC 12 ACAMAR 3 0 JA 51 006493 KDBE ACAPULCO MARU NOV 055TOWN AR REUNI DEC 14 4 AVACUS # 1 BR 58 012326 \$ SARNI DEC 07 ARUBA PD ESCOU DEC 13 4 ACHAIDS 0 LI 50 005455°TARRA DEC 12 KAISE SD CEUTA DEC 15 4 1 BR 58 012326 HAMILO SD LANDR **DEC 14** ACHATINA. 0 18<sup>11</sup>47 023629 ARENA NOV 29<sup>5</sup>GENDA ACHILLE LAURD SD MALTA DEC 18 4 ACHILLES 1 AM 60 024471 FRANC DEC 10 ALASK6 0 BR 72 016406cDSAKA DCT 075 ACHILLES 3 0 DU 59 006134 DEMER DEC 08 BREME SD MICHA DEC 16 ACHILLES ACHILLES 0 GE 64 000500 RDTTE DEC 14 LISBD 1 GR 56 031571 KARLS DEC 12 MARSAB ACHILLET ACRADINA b 1 IT 60 022955 UMM S DEC 13 GENDA 0 CY 39 002920 2 ACHILLEUS \_\_\_\_\_i 2 CAR PIRAE DCT 08 99 DEC 02 ARGEN AR MURDR DEC 18 ACHILLEUS 0 GR 65 021505 NAGDY DEC 09 CURAC 1 DU 58 012221 MANIL ACILA DEC 17 FREDE ACMAEA 1 DU 59 012222 ROTTE 0 CH 65 010869 JOHN N DEC 13 3 AR PHILA ACONCAGUA **DEC 17** 0 FI 60 005402 HELSI NOV 225CASAB AR. **DEC 14** ACONCAGUA ACONCAGUA VALLEY 0 SW 68 009611 HAMBU DEC 16 CASAB 0 PD 58 002963 MDCAM NOV 305BREME AR LISBO ACORES DEC 15 1 PA 58 020519 EUROP DEC 18 BANDA ACQUARIUS

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Table 2-1 Sample Listing for DOT Input Tapes (contd)

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on				D	DT INF	TUY	TAPE	FOR	WEE	K 52,	1	972	л	ĸ	I	
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	ACMAEA	1	DU	59	01222	2	ROTTE	DEC	17	COPE	N	AR		DEC	20	
	ACONCAGUA	0	CH	65	01096	9	JOHN N	DEC	13	ARIC	Ĥ	AR	NEW Y	DEC	19	4
(*****	ACONCAGUA	0	FI	60	00540	5	HELSI	NOV	553	TRIP	n	SD	LA GO	Dec	22	4
	ACONCAGUA VALLEY	0	SW	68	00961	1	HAMBU	DEC	16	CASA	B			-		•
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Notes to Table 2-1 (Samples from DOT Input Tapes for Weeks 51 and 52)

## Column Headings

A	Ship's name		
B	Ship's type	(1 = tanker,	0 = non-tanker)
C	Ship's flag	(abbreviated)	1
D	Ship's year	built (last t	wo digits)
Е	Ship's weigh	ht (in gross t	cons)
F	Port of orig	jin	
G	Date of depa	arture	
H	Port of dest	tination	
Ī	Code determ:	ining meaning	of column (k)
J	Port of last	t call	
K	Code IV column(I)	Contents of column(s)	Meaning
	SD	used	date of departure from port of last call
	PD	used	date when port of last call was passed
	AR	used	date of arrival at port of last call
	AR	empty	date of arrival at destination port
	IN	used	ship was in port of last call on reported date

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1	No departure port	(4 cases in samples)
2	No departure date	(17 cases in samples)
3	No destination port	(14 cases in samples
4	No destination arrival o	late (64 cases in samples)
5	Antiquated date	(22 cases in sample)
6	Generic port name, not precisely identifiable	(l case)
rrespor	dence Difficulties Between	n Weeks 51 and 52
orrespor a	dence Difficulties Between Ship omitted in records from other week	n Weeks 51 and 52 (1 case in sample)
orrespor a b	dence Difficulties Between Ship omitted in records from other week Ship out-of place	n Weeks 51 and 52 (1 case in sample) (1 case in sample)
a a b c	dence Difficulties Between Ship omitted in records from other week Ship out-of place Duplicated data, no char	n Weeks 51 and 52 (1 case in sample) (1 case in sample) nge (12 cases in sample)
a b c d	dence Difficulties Between Ship omitted in records from other week Ship out-of place Duplicated data, no chan Unrecorded intermediate voyage	n Weeks 51 and 52 (1 case in sample) (1 case in sample) nge (12 cases in sample) (2 cases in sample)
a b c d e	dence Difficulties Between Ship omitted in records from other week Ship out-of place Duplicated data, no chan Unrecorded intermediate voyage Departure or arrival dat must be interpolated	<pre>h Weeks 51 and 52 (1 case in sample) (1 case in sample) hge (12 cases in sample) (2 cases in sample) He (4 cases in sample)</pre>

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### I. Ship's name spelled both with and without blanks

II. Other divergences between data for successive weeks

Table 2-2 Illustrative Examples of Ship Match-up from Successive DOT Tapes (for weeks 51 & 52)

ACHILLES ACHILLES	0 0	DU DU	59 59	006134 006134	Demer Demer	DEC DEC	08 08	BREME BREME	SD Ar	MICH <del>A</del> ANTWE	DEC DEC	16 22
ABUTA ABUTA	0 0	CY CY	58 58	000499 000499	IZMIR BREME	NOV Dec	28 16	BREME BENGH	ĥR		BEC	14
ABOCOL ABOCOL	0 0	BR BR	40 40	001834 001834	CARTA TAMPA	VDM	55	tampa Cartac	AR		DEC	16

- 1. Same voyage: Departure and destination ports are the same from both week's reports. Merging data may permit missing dates and other data to be filled in, and gains routing information through successive port-of-last-call reports.
- 2. Two voyages: Destination port from weeks 51 and departure port from week 52 match. Merging data from successive weeks allows for disjoint time interval of voyage, and reporting interval, and may permit interpolation of missing dates.
- 3. Three voyages: Destination port from week 51 does not match any port from week 52. An intermediate unrecorded voyage has occurred, which may be plausibly reconstructed.

2. <u>Technical Structure of The Data Base</u>.

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The 52 DOT Marine Traffic Generator Input Tapes were transscribed by hand from the Lloyd's publications. After having been initially keypunched, the cards are edited and copied onto 52 reels of 7-track, unlabeled magnetic tape at a recording density of 800 BPI and even parity. Data is recorded in external BCD code in unblocked, 84-byte fixed-length records, with data fields as specified in the original DOT specification (Marine Traffic Generator Documentation, p.25) and as illustrated in Table 2-1.

Although originally prepared for use with an IBM 7094 computer, these tapes are fully compatible with most data processing systems, including the IBM 360/370 series. Much the same data is duplicated on the 52 Marine Traffic Generator output tapes; however, these are much harder to utilize, as they are recorded in an internal 7094 format and use a record format no longer recognized by IBM. Furthermore, having been processed previously by the Marine Traffic Generator, these tapes could not be reused without risking accumulation of errors through successive layers of programming.

These input tapes were edited by two DOT programs whose purpose was to identify and eliminate major keypunch errors. In particular, data punched in the wrong field, gross date errors, and unknown or misspelled port names, should have been detected and corrected by these programs. The tapes used in this study represent the output of these editing programs.

Nevertheless, many simple errors remain in the tapes. These include:

1. Variations in spelling of ship's name, particularly insertion or emission of blanks after abbreviations,

2. Right-or-left shifted data, i.e., '01782 ' as a ship's weight,

3. Substitution of an incorrect letter or digit,

4. Duplication of a record on the same tape, usually when an initially mis-punched record was corrected and the original not removed.

Such errors are particularly serious when they affect the ship's identifying information, as these fields are used to match-up ships from successive weeks. To minimize the extent of this problem ships were matched via a statistical correlation on the identifying data.

In principle, each tape should have contained data on the same ships, in the same order. In practice, however, several types of violations of this rule could (and did) occur:

1. Misplaced records, out of the regular order

2. Omitted and inserted records, when no data was reported for a particular ship during a particular week.

The final run statistics from program GAMMA gives a count of records rejected due to excessive keypunching errors and of the number of new records which could not be matched. The results for week 47 can be taken as typical. Here, out of a total of 13,130 input records, 1 was mispunched beyond recovery, 20 were duplicates, 815 were out of order, and 4,644 did not match any entries from the previously processed weeks. Hence, only 7,650 records, or slightly over half, did not suffer from a serious problem in interpretation or matching, even before problems of incomplete data are considered.

The data for centain weeks were however, much poorer, due to hardware failure. In particular, the tapes for weeks 37, 36, 35, 31, 30 and 29 contained far fewer readable records than expected, less than 10,000 each, and weeks 28 and 27 were completely unprocessible. This reflects the deterioration of the tapes with age, with non-readable records being dropped on input by the processing system. In addition, difficulties are known to have occurred when the copies of these tapes used in this study were initially prepared by DOT. Fortunately, the other tapes were in much better shape.

Since it was beyond the limitations of this study to replace the missing data by re-punching the 70,000 or so missing records, little could be done to correct these technical difficulties.

#### 3. Auxiliary Tables.

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The major auxiliary table associated with the DOT input tapes is The Port Table, containing a list of all ports referred to in the reports contained on these tapes. Each port was identified by an abbreviation, which associated it with a specific entry in The Port Table. The Port Table contained the latitude and longitude of the port, along with an identifying number.

The original DOT Port Table contained a few errors or inconsistencies which were corrected for use in this study. Some latitutde and longitude information were incorrect. Many ports had several entries in the port table corresponding to differently spelled abbreviations used in the Input Tapes. These were corrected by assigning the same port number to all such variants, since they could not be deleted.

#### 4. <u>Conclusions</u>.

The DOT Marine Traffic Generator Input Tapes, compiled from Lloyd's Shipping Register, suffers from several weaknesses for the purpose of the present study. It is incomplete in regards to the number of ships monitored and the movement data for each ship. It is systemtically biased in this regard against short voyages and some classes of voyages between Communist ports. Technically, many of the tapes are in poor condition, two having been essentially unusable. Nevertheless, it was the best data available at the time of this study, and every effort was made to overcome its limitations.

Maximum information was extracted from the tapes by comparing data from successive weeks. The itinerary of each ship was reconstructed as well as practical, and the number of days spent by ships travelling between each pair of ports accumulated. This information was then used to produce the shipping distributions.

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### CHAPTER III Trend and Growth Analysis

#### 1. Discussion of Available Sources

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There were a number of very informative sources available to use on the World's Tanker Fleet. The "Analysis of World Tank Ship Fleet"<sup>1</sup> for the years 1974, 1975 provided data on the physical characteristics of the fleet; size, weight, capacity, speed, age, country of registry, etc. as well as very useful information on the economic life of tankers and the number of new construction orders placed in each of the years for 1964 to 1975. Some analyses of special vessels (i.e., O/B/O's,O/O's)were also given.

The "Analysis of World Tank Ship Fleet" is a Sun Oil Company publication. The Sun Oil Company published its first fleet analysis in 1947 and has continued to issue its analysis yearly since 1953. Each year the report has included the results of a research effort on tank ship economics. The research for 1974 was in the area of total carrying capacity of the fleet and the impact of fuel costs on the industry. The 1975 report contains a special section describing a method for using available information to predict tanker rates in the spot market.

"Shipping in the Seventies"<sup>18</sup> is a background paper prepared by the United Nations in order to assist consideration of shipping problems in general and the position of the developing nations in relation to them. Part One addresses the perspectives and problems in world shipping concentrating on technological progress, freight rates, optimum ships and scheduling. Part Two discusses implementation of the international development strategy in shipping and ports, with specific measures for implementation outlined. This brochure provided some insights into the future distribution of ship ownership.

"An Investigation: U.S. Import Dependence for Mineral Resources; Super-Bulk Carriers, and Deepwater Ports Development"7 is a Master's Thesis written by Lt. Commander Corydon Rouse Gifford as part of the requirements for his degree at the Naval Postgraduate School. His thesis examines "(1) the increasing import dependence of the United States on foreign sources of major bulk fuel and non-fuel mineral resources which appear to have potential requirements for deep-water ports or terminals, (2) principal bulk commodity ports and commodity movements, (3) trends in the construction of ocean bulk carriers, (4) the economics of "super" bulk carriers, (5) the consequences of the United States not providing adequate facilities to accomodate "super" bulk carriers and (6) recent events pertaining to deepwater port end terminal developments by the United States." We were quite interested in his assessments of the consequences of various courses of action the U.S. might be expected to pursue; for clearly the future distribution of tankers throughout the world, in fact the entire tanker industry will be ultimately related to the future course taken by the U.S.

"A Forecast of 1970-1985 World Shipping"<sup>28</sup> by Robert V. Wiederkehr, Sept., 1971 is a report prepared by SACLANT ASW Research Centre for NATO. This report is part of a study on the future use of shipping in the North Atlantic by NATO nations. It has the forecast numbers, average speeds, average tonnages, fleet capacities, annual trade, and fleet productivity of merchant shipping up to 1985.

"Trends in World Shipping with Particular Reference to Large Crude-Oil Carriers"<sup>3</sup> by Peter Burton, July 1974 is a second SCALANT ASW Centre manuscript. This document reviews and updates the previous SACLANT document. The forecast figures by Robert V. Wiederkehr were found to be low for tankers and bulk carriers and high for container ships. This paper studies the 1974 status and short term trends of World Shipping as a first

step in estimating total numbers and types of ships, and their concentration routes and in areas of importance to NATO in the eighties.

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"Shipping Statistics and Economics"<sup>19</sup> published monthly by H.P. Drewry (Shipping Consultants) Limited is a journal designed to provide shipping data and marketing trends to shipping companies. The November 1975 and March 1977 issues were used to provide us with insights into the changes in shipping trends from 1975 to 1977 and an overview of the market trends in those years. These journals included monthly tables on numbers of vessels by ship type. We used these numbers as part of our comparison analysis to arrive at realistic total ship numbers. The growth factors reflected there were instrumental in arriving at our own growth factors.

"Recent and Projected Trends in the Shipping Industry"<sup>13</sup> a technical paper produced July 28, 1976 by Tetra Tech, Inc. analyzes the effects upon shipping brought about by the various crises of the mid-70's. This paper updates a 1975, Tetra Tech report.

"A Statistical Analysis of the World's Merchant Fleets"<sup>24</sup> by the U.S. Department of Commerce is a world inventory of oceangoing vessels of 1,000 gross tons or more. The world totals for the various vessel types for the years 1972, 1974, and 1975 were taken from this source as it provided us with a consistant ship profile and data collection process.

The "Pacific Shipper"<sup>11</sup> is a weekly journal devoted to shipping schedules from and to the Pacific ports of the United States. It is a reliable gauge of the volume of shipping to major ports around the world from the U.S. Pacific ports.

In order to determine the volume of shipping to major ports around the world from the U.S. Pacific ports, an analysis of the "pink pages" of the Pacific Shippers was made. The following procedure was used:

- The Pacific Shippers (dated weekly from July of 1973 through June of 1977) were used. Only the copy for the last week of each month was examined.
- Traffic to the following ports from the U.S. Pacific Coast was examined: Kobe, Manila, London, Rio, Capetown, Naples, Piraievs, Bombay, Honolulu, Sydney, Balboa, Singapore, LeHarve, Rotterdam.
- 3. Since the traffic leaving the West Coast ports (San Francisco, Los Angeles, Portland, Seattle and Vancouver) is essentially identical, only traffic leaving the San Francisco - Oakland area was studied.
- 4. When the copy for the last week of a given month was analyzed, for example, the issue dated June 27, 1977, only ships leaving through the following month are recorded. For June 27, 1977, for traffic to London (page 130), there are 37 ships leaving San Francisco for London from July 1 through July 29. The 7 ships leaving between June 27-30 are not recorded for this issue (they were recorded for the May 30, 1977 issue). The 2 ships mentioned for August 2 and 4 are not recorded for this issue (they will be recorded for the July 25, 1977 issue).

Figures 3-1 to 3-14 are a collation in histogram form of the data extracted from the Pacific Shipper. A perusal of the histograms indicates:

 a. Steady volume of traffic from '73-'77 to Kobe, Rio, Capetown, Honolulu, Sydney.

 b. A steady increase in traffic from '73-'77 to Manila and Rotterdam.

c. Erratic traffic volume to Bombay.

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d. London, Naples and Piraievo all experienced an increase in the volume of traffic arriving at their ports in August of 1975. This is probably due to an increase in the reporting net of the Pacific Shipper. Balboa shows a similar increase at the same time although it was less dramatic.

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e. In October 1975, Singapore experienced the beginning of an increase in incoming traffic that has continued steadily. LeHarve showed the same phenomenon in September 1975.



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#### 2. Methods and Sources Finally Used

In order to project our 1972 data from the Lloyd's tapes to the year 1978 we need to estimate growth factors for the various ship categories in the major ocean areas of the world. The objective is to compare the total number of ships of a given class in a particular ocean area in the year 1972 with the same measurement in the year 1978. The ratio of these two numbers then being the growth factor.

The difficulty with this procedure is that no single definitive source exists for these measurements. Some sources give measurements for years other than 1972 and 1978. Since this report is being generated before 1978 statistics are available on any measurements for that year are projected measurements. Each source has its own procedure for collecting data and its own breakdown of vessel type, making it far too inaccurate to use data from one source for 1972 and estimates for 1978 from a second source.

We are most interested in merchant vessels and three classes of tankers. Tanker I's are small tankers with 1,000 to 70,000 dwt, Tanker II's are large tankers and combined carriers in oil and are between 70,000 and 300,000 dwt, Tanker III's are super tankers, that is tankers of over 300,000 dwt.

Since it is sufficient to consider only a world wide growth figure for merchant vessels<sup>10</sup> (see PSI report, "Ship Density Estimates for Traffic Along Selected Routes in the Year 1990"<sup>17</sup>) we estimated the grow h factor by using the number from "Statistical Analysis of World Merchant Fleet"<sup>24</sup> years 1972, 1974 and 1975 and extended them linearly to 1978. The growth ratio being the simple ratio of the 1972 figures and the projected 1978 numbers.

The tanker case is more complicated. The growth factors for these vessels are not uniform over the world. But while several of the sources 'give world wide figures no source gives comprehensive data for specific ocean areas. Certain areas reflect the same growth pattern as the world in general, such as the North Atlantic (see PSI report referred to previously)

### Tankers

World Totals

World Totals		Projected 1978	Growth <u>Factor</u>
	1972		
1,000 - 175,000 dwt	2,931	3,000	1.02
175,000 - 300,000 plus o/o	558	894	1.60

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Specific World Areas		Growth Factor	
	Tanker I	Tanker II	
Honolulu	0.94	0.94	
South Pacific	1.21	1.60	
U.S Japan	1.08	1.08	
Panama - West Coast	1.15	1.30	
North Atlantic & Remainder of World	1.02	1.60	

Merchants

		Projected	Growth
<u>1972</u>	1974	1978	<u>Factor</u>
12,889	13,253	13,600	1.06

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but other areas do not follow the overall pattern of the world. To overcome this limitation two types of growth factors were computed. The first is growth factors for world wide shipping in specific tanker categories. The second is growth factors for total shipping in specific ocean areas for which we could obtain reliable data. Specifically we used the Pacific Shipper to calculate growth factors for traffic to U.S. western ports from Honolulu, South Pacific, Japan and Panama. We collated the available data for the years mid 1973 to mid 1976 and used curve fitting techniques to eliminate seasonal fluctuations and obtained the yearly trends. Next we extrapolate backward to 1972 as our growth factor for these ocean areas.

However since super tankers were a rarity in 1972 but have undergone a dramatic, but erratic growth pattern in the ensuing years we do not attempt to compute a growth factor for these vessels.

In computing the world wide growth factors for the two smaller categories of tankers we were fortunate to find that the "World Shipping Statistics 1976"<sup>29</sup> carries statistics for the year 1972 and projections for 1978. The projections for 1978 are based upon their figures for 1976 plus orders for ships scheduled to be delivered by 1978. The growth factor is a simple ratio between the two years.

## CHAPTER IV Distribution and Methodology

#### 1. ORE Outputs and Cubic Splines.

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This chapter deals with the problem of distributing the densities across the routes by one degree squares. Various input tables were needed to accomplish this task. The use of the Port Table, Route Trees, Routing Table, Sextile Points and various mathematical methods for distributing the densities were obtained from the ORE report. Because of the multitude of ports and the number of routes connecting them, the use of the above tables provided us with a systematic way of handling the data.

The Port Table is a listing of 2,425 ports that were taken from the Lloyd's data for 1972 by the Department of Transportation. Due to the number of ports in existance a simplification was warranted in order to provide a more manageable data base. Therefore, a small class of major ports were determined from the 2,425 ports. These 69 ports are known as canonical ports. Also, each non-canonical port will be associated to one and only one canonical port. This is determined by searching for the closest canonical port in the area.

The information on the Port Table is of the form:

684 FREEPB FREEPORT, BAHAMAS 26N 78W 17 22

684 is the port number; FREEPB is the abbreviation of the port name and FREEPORT, BAHAMAS is the name of the port. On the right hand side we have the latitude and longitude of the ports location. The next integer, 17, corresponds to the canonical port to which Freeport, Bahamas is associated with. 22 represents the distance between the port and its canonical port. The units are that of a convenient metric.

Just as the number of ports were substantially reduced by considering a small set of canonical ports, so may the number of routes be reduced by considering a set of 85 canonical routes. The Routing Table is a 69 x 69 matrix whose  $(\alpha,\beta)$  entry symbolically represents the route from port  $\alpha$  to port  $\beta$ . The entries contain two pieces of information. The first is an alphanumeric followed by an integer, say m, which lies between 1 and 85. The possible entries in the table are as follows:

i) N=0 represents no route between the ports. This situation arises when  $\alpha = \beta$ , that is port  $\alpha$  equals port  $\beta$ .

ii) P=m represents the case where port  $\alpha$  and port  $\beta$  are not connected by a canonical route, that is, there exists at least one intermediate port between  $\alpha$  and  $\beta$ . The port m is the first intermediate port encountered. As one would expect, the route between  $\alpha$  and m is a canonical route. Thus, the first link of the overall route is from port  $\alpha$  to port m. Now, one must examine the route from port m to port  $\beta$ . If there is a canonical route then one is done, if not, continue recursively until the destination is reached.

iii) B=m designates that multiple routing exists. This case occurs when the route taken is dependent upon the ship type. For example, the shortest route between the Persian Gulf and Northern Europe is via the Suez Canal, yet large tankers and supertankers must go around the Cape of Good Hope. In this case the integer m designates the mth line in the Multiple Routing Table. This line will contain two entries, the first entry is the first intermediate port for the non-supertankers, and the second is for supertankers. Then one would proceed as in case ii.

iv) If a blank exists for the alphanumeric field, then the following number indicates which direct route is to be taken.

The set of 85 routes can be found by looking at the Route Trees Table. In many routes, seasonal variations affect the distribution of traffic across the route, on the other hand entire route envelopes are shifted by the changing of seasons. Therefore, we have four sets of Route Trees, a separate one for each season. One must note that the structure of the route trees does not change with seasons; however, the parameters contained within the tree structure, such as the latitude and longitudes do.

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In some cases, the traffic travelling in one direction uses a route quite different from the traffic moving in the opposite direction. One example of this is Route 23 (Punta Arenas -Torres Strait). The entrance route to Torres Strait is much farther north than the egress route. When this is the case, the tree is structured so that there are two routes between the ports. Since a tree is a graph without loops, this implies that there has to be two leaves for one of the ports. One leaf is the vertex used for egress routing, the other leaf is used for entrance routing. The distinction between entrance and egress routes is preserved in the tree structure by the ordering of the vertex indices. A binary branch is made with a terminal zero being added to the end of the egress branch point identifier, and a terminal one to the entrance branch point identifier. For example, Route 23 divides at Ident. 10 (Strait of Magellan). Ident. 100 is the egress branch point while Ident. 101 is the entrance branch point. All identifiers are written in base 2. Figure (4.1) shows the tree structure with identifiers for Route 23.

The identifiers describe the location of the turn point in the route tree structure. These identifiers are so linked that it is possible to progress either forward or backwards along the route in the tree structure. In order to move forward there are three possible circumstances: 1) You are at a turn point, in which case a zero is added after the last digit of your current vertex identifier in order to obtain the identifier for the next vertex along the route, 2) You are at a branch point, in which case a zero is added to continue down one branch of the route, or a one is added after the last digit of your current vertex iden-



### Figure 4.1

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### Tree Structures

tifier to continue down another branch, 3) You are at a route end. point in which case you must reverse direction in order to move along the route.

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To progress backwards along the route is much simpler than a forward progression. To retrace the route simply drop off the last digit of the current vertex identifier in order to obtain the identifier of the previous tree vertex.

The second and third columns of the Route Trees contain the latitude and longitude of the route point represented by the tree vertex.

The fourth column of the Route Trees refers to the vertex width. Its units are in latitudinal degrees, and it is a measurement of the routes width at the vertex.

The length of a route segment is contained in column five of the Route Trees. This length refers to the previous route segment when progressing forward through the route. The units are in latitudinal degrees.

The sixth column of the Route Trees contains the edge width which is again a measurement of the widest point on the previous segment. The units are also in latitudinal degrees.

The seventh and last column refer to the back pointers. When progressing backwards along a route the back pointers indicate the line in the Route Trees to which the present vertex is connected. Whenever one begins a new route the back pointer is set at zero.

An important factor in determining the route density is the route envelope. It is an area of the ocean between two ports where 95 percent of the ships will travel. The width of the route envelope may vary from route to route. In going from one port to another not all ships follow the best path. Different ship tracks will approximate the optimal path to a greater or lesser extent. The longer the distance between ports, the greater the probable deviation from the optimum. This is especially true for routes that cross large open oceans with no land navigation point available. Areas with unstable weather conditions also cause ships to deviate from the best path. Because of the effects of these variables, a route width is required in order to describe a route's envelope.

The distribution is found along a vertical cut. A vertical cut refers to a slice of the route taken along a fixed longitude. The reason for the cut is to take a look at the way the distribution function varies across the route. The densities along the section of the route under consideration are projected parallel to the route median and integrated to form the density distribution. The sextile points are points which divide the distribution into sixths. For a cut along a fixed longitude there are latitudes associated with these sextile points. The sextile points of the distribution and their corresponding latitudes are found and printed. These sextile point latitudes are used by a separate program to reconstruct the distribution using a Type I' cubic spline to connect the sextile points.

The Sextile Array, is a table containing the sextile points by route for a given season.

These sextile points are normalized to the interval [-1,1], and the five intermediate sextile points will describe the distribution (up to a linear transformation). On a route between 2 canonical ports the envelope is described by either a specific Type I' cubic spline for the given route or a general default spline.

In order to produce a histogram which represents the distribution of traffic across a route, it is first necessary to determine how the density varies across the route. The following method was used to accomplish this task.

Given a fairly well defined (e.g., Southern Hemisphere) route, and assuming the same distribution function is used along the entire route, choose a group of vertical columns of cells (Fig 4-2) which cross the route. These columns should be chosen in an area where there is a minimum of interference from other There should be no cross routes in this region, nor routes. should this area contain any other routes in close proximity. If only one vertical column is used, then this would automatically be a histogram, for the density histogram which we are seeking would merely be a projection of this column (assuming that the width of the route doesn't change). (Note: The histograms are somewhat more complex than shown, for to be exact the projection of a square of area onto the perpendicular of the route is not the standard step, but rather a trapezoid (Fig 4-3). This is probably sufficiently minor to be ignored, but is not computationally difficult.). As long as the route's distribution may be assumed locally constant, then the vertical column of Figure 4-4 is a cut of a "cylinder" type of distribution which is a function of only one variable, i.e., it is a slightly stretched version of the distribution, the elongation factor being sec  $\theta$ . In the case of more than one column (which will have better statistical confidence for distribution prediction) the columns can be combined appropriately using tan  $\theta$  to the histogram (Fig 4-5). With the elongation removed we now have the empirical representation of y( =  $\frac{\delta}{2}$  G(w) sin  $\pi\lambda$  say) so  $\delta$  and G(w) are "determined", through a smoothing operation discussed below.

The histograms are discrete, empirical approximations to the true distribution. This underlying distribution function does not have the step function for the histogram. From the physics of the situation, one may safely assume that there exists a density function for the distribution, and that it is continuous. To obtain the underlying distribution function, it is necessary to "fit" a smooth curve (the density function)  $\hat{h}(x)$  to the step function (i.e., the histogram). The density function will be the smallest closed set such that the density function is always zero outside that set.









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The use of interpolating functions are used to fit a smoothed distribution function  $\hat{H}(x)$  to an empirical distribution H(x). In order to use an interpolation function one only needs a net of points along the interval. Since the histogram itself is really a discrete data structure this approach is especially suitable.

Let  $M = \{(x_i, H(x_i))\}_0^N$  be a mesh of points from the histogram's distribution, and assume that the net  $\{x_i\}_0^N$  covers [-1,1], i.e,

 $x_{i-1} < x_{i}$  $x_{0} = -1$  $x_{N} = 1$ 

The smoothed density function should be continuous (by the nature of open ocean routes), and it is not unreasonable to assume it is  $C^1$ (i.e., has a continuous first derivative) on the interval [-1,1]. Thus the distribution function will be  $C^2$ [-1,1], (i.e., it will have a continuous second derivative on the interval [-1,1]). Let the class of possible distributions D<sub>3</sub> consist of those functions which satisfy four criteria:

i. It is C<sup>2</sup>[-1,1]

ii. It is a distribution function on [-1,1]

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iii. It's extension to a distribution function on the real line is C<sup>1</sup>

iv. It interpolates the mesh M

For an open ocean route envelope one would not expect a rapidly fluctuating density across a route cut. Based on this empirical observation and other inherent properties of the route, the criteria for minimization is chosen to be the integrated square derivative of the density function,

 $\int_{a}^{b} {\{\hat{h}^{\dagger}(x)\}}^{2} dx$ 

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This analytical expression is a measure of the fluctuation in the density function. Thus the chosen interpolating function  $\hat{H}(x)$  is that function from the set D<sub>3</sub> which minimizes the functional

 $\int_{a}^{b} \{\frac{d^{2}\hat{H}}{dx}\}^{2} dx$ 

Thus out of all functions satisfying conditions i through iv, that one which minimizes this functional will be the 'smoothed' distribution used to model the distribution of traffic across a route cut. Using the fundamental identity for cubic splines a generalization of Yolladay's Theorem can be developed. This generalization implies that if the optimization is done over all functions satisfying i, iii and iv, then the minimizing function is a Type I' cubic spline. Furthermore, the minimizing function is unique. {A cubic spline is of Type I' if the first derivative is zero at the endpoints a and b.} If, in addition, the Type I' cubic spline is monotonic, then it is also a distribution function, which is condition ii. In other words, it will satisfy the four conditions for inclusion in D<sub>3</sub> and it will be the (unique) distribution which minimizes the above functional. The monotonicity was assumed, however, in actual data reduction the cubic spline turned out to be monotonic in every case.

The mesh is obtained by using seven sextile points uniformly located along the distributed mass - i.e., the seven sextile points, which are found by solving the following equation for  $x_i$ 

$$H(x_i) = i/6$$
  $i = 0, 1, 2, ..., 6$ 

Now the equations of the cubic spline may be developed in an algorithmically implementable form. Since the interval [a,b] was defined to be the smallest closed interval containing the support of the distribution, it is immediately seen that

$$x_0 = -1$$
  
 $x_6 = 1$ 

Let  $\Delta$  denote the forward difference operator

 $\Delta \mathbf{x}_{j} \equiv \mathbf{x}_{j+1} - \mathbf{x}_{j}$ 

Define the fifteen quantities

 $\lambda_{j} = \frac{\Delta x_{j}}{\Delta x_{j} + \Delta x_{j-1}}$   $\mu_{j} = 1 - \lambda_{j}$   $c_{j} = \frac{1}{2} \left\{ \frac{\Delta x_{j}}{\Delta x_{j-1}} + \frac{\Delta x_{j-1}}{\Delta x_{j}} \right\} / \left\{ \Delta x_{j} + \Delta x_{j-1} \right\}$ 

for j = 1, 2, 3, 4, 5

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The cubic spline is given in terms of the seven coefficients  $\{m_i: i = 0, 1, ..., 6\}$ . Since we are dealing with a Type I' cubic spline two of these coefficients are fixed, viz

$$m_0 = 0$$
$$m_6 = 0$$

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The remaining coefficients are given by the linear system

 $\begin{bmatrix} 2 & \mu_1 & 0 & 0 & 0 \\ \lambda_2 & 2 & \mu_2 & 0 & 0 \\ 0 & \lambda_3 & 2 & \mu_3 & 0 \\ 0 & 0 & \lambda_4 & 2 & \mu_4 \\ 0 & 0 & 0 & \lambda_5 & 2 \end{bmatrix} \begin{bmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \\ m_5 \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{bmatrix}$ 

This matrix is nonsingular, and the system may easily be solved by tridiagonal matrix algorithms. The density function  $\hat{h}(x)$ of the distribution  $\hat{H}$  is then given by

$$\hat{h}(x) = m_{j-1} \frac{(x_j - x) (2x_{j-1} + x_j - 3x)}{(\Delta x_{j-1})^2} - m_j \frac{(x - x_{j-1}) (2x_j + x_{j-1} - 3x)}{(\Delta x_{j-1})^2} + \frac{(x_j - x) (x - x_{j-1})}{(\Delta x_{j-1})^3}$$

for  $x \in [x_{j-1}, x_j]$ 

This equation will be referred to as equation 4.1.

Thus the development of the route envelope's distribution is completed, with the underlying distribution being modelled by a Type I' cubic spline.

Now we will address ourselves with the problem of mathematically modelling the route envelope outline and the distribution of traffic along a 'cut' across the route. Given two ports A and B the envelope between the two ports will be determined by two mappings. One is from the distance space,  $\Delta$ , to a 'flat' earth (i.e., the plane R<sup>2</sup>) and one from the 'flat' to the 'round' earth (i.e., the sphere S). Thus the total mapping is the composition of the two mappings.

The distance space,  $\Delta$ , is

$$\Delta = \Lambda \times \Omega = \{(\lambda, \omega); 0 < \lambda < 1, 0 < \omega < 1\}$$

The parameter  $\omega$  corresponds to the stochastic aspect of the envelope, i.e., which route is taken. The value  $\omega = 0$  corresponds to the route along one edge of the envelope, and  $\omega = 1$  corresponds to the route along the other edge.  $\lambda$  denotes the normalized distance along the route (i.e., distance divided by the total length). Thus  $\lambda = 0$  corresponds to port A and  $\lambda = 1$  corresponds to port B.

The mapping from  $\Delta$  to R<sup>2</sup> will be considered in several cases, beginning with the most elementary and then generalizing.

#### Case a: Port-to-Port Segment.

In this case both ends of the cresent are points and there are no protrusions of land to cause land avoidance. On the flat earth the route envelope is bounded by sine waves. A rectangular coordinate system is established such that port A is at the origin and port B lies on the positive x axis. Let



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 $2\delta$  be the maximum width of the envelope. Let  $g(y;x_0)$  be the density function of the distribution of traffic across the route at a fixed distance  $x_0$  along the route  $(0 < x_0 < L)$ . Note that  $g(.;x_0)$  is a density function concentrated on the interval  $[-\nu,\nu]$  where

 $v = \delta \sin \frac{\pi x_0}{L}$ 

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Let  $H(z; \lambda_0)$  be the distribution function, scaled between [-1,1] so that

$$H(z;\lambda_0) = \int_{-\delta}^{+\delta z} \frac{\sin \pi \lambda_0}{g(y;L\lambda_0) dy} -1 \le z \le 1$$

and let  $G(\omega;\lambda_0)$  be the inverse function of  $H(2;\lambda_0)$ . Thus,  $G(.;\lambda_0)$  has domain [0,1] and range [-1,1]. Therefore, the mapping for this case from  $(\lambda,\omega)$  to (x,y) is

 $x = L\lambda$  $y = \delta G(\omega; \lambda) \sin \pi \lambda$ 

Case b: Sloped End Condition.

In this case, the lefthand point is still port A but the route is merely a segment of the total route (Fig 4-8), thus it ends at a turnpoint (e.g., strait, cape) in the ocean. As before 26 is the maximum envelope width, and now the end of the segment has a width of 2c rather than zero. Let L be the distance to the midpoint of this end segment. Note that if the angle of the end segment to the axis ( $\theta$ ) is not  $\pi/2$ , then the 'cuts' across the route envelope corresponding to a fixed distance  $\lambda$  are no longer perpendicular to the axis. For each



fixed  $\lambda_0 \varepsilon(0,1)$  let  $G(.;\lambda_0)$  be the inverse of the scaled distribution across the routes at the cut  $\lambda = \lambda_0$ . As before,  $G(.;\lambda_0)$  maps (0,1] onto [-1,1]. The angle  $\theta$  is measured counterclockwise from the exterior axis and is between 0 and  $\pi$ . Thus the mapping for case b from  $(\lambda,\omega)$  to (x,y) is

$$x = (L + \varepsilon G(\omega; \lambda)) \cos \theta \lambda$$
$$y = \varepsilon G(\omega, \lambda) \lambda \sin \theta + \phi G(\omega; \lambda) \sin \pi \lambda$$

where the constant  $\phi$  is determined from the following equation

$$\phi = \gamma \left( \frac{\zeta^2}{2\pi^2 \gamma^2} \right)$$

where  $\gamma = (\delta - \zeta/2)$ 

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and  $\zeta = \varepsilon \sin \theta$ 

# Case c: General End Conditions.

If both ends have nonzero width, the situation corresponds to Figure 4-9. Both angles  $\theta$  and  $\tilde{\theta}$  are measured counterclockwise from the exterior axis and are between 0 and  $\pi$ . The distance L is measured from the midpoint of one end to the midpoint of the other. The midpoint of one is taken as the origin, and the midpoint of the other as the positive x axis.

Let

 $\tilde{\zeta} = \tilde{\varepsilon} \sin \tilde{\theta}$ 

 $c = c \sin \theta$ 

Then with previous definitions, the mapping is

 $x = \tilde{c}\tilde{d}(\omega;\lambda)\cos\tilde{\theta} + (L+G(\omega;\lambda)\{c\cos\theta - \tilde{c}\cos\theta\})\lambda$  $y = G(\omega;\lambda)\{\tilde{c} + (c-\tilde{c})\lambda + \phi \sin\pi\lambda\}$ 



where  $\phi$  is a constant. Proceeding as in Case b, we find that  $\phi$  may be computed as

$$\phi \approx \gamma \left( 1 - \frac{(\zeta - \tilde{\zeta})^2}{2\pi^2 \gamma^2} \right)$$

where

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 $\gamma = \delta - (\zeta + \tilde{\zeta})/2$ 

Thus the general mapping from  $\triangle$  to  $R^2$  has been developed. Next is the mapping from the image of  $\triangle$  (in  $R^2$ ) into S.

The plane  $R^2$  had units of length attached to the parameters L,  $\delta$ ,  $\varepsilon$  and  $\tilde{\varepsilon}$ , but all equations were developed without recourse to specific dimensional units. References to angles will be made in terms of radian measure. The spherical earth has a well established coordinate system using latitude and longitude, which we will be using. Adopting the conventions that Southern latitudes and Eastern longitudes are negative, and that latitudes and longitudes is expressed in decimal degrees, we have the following coordinate representation of the earth (minus the two poles):

 $S \equiv \{(\alpha, \beta): -90 < \beta < 90, -180 < \alpha < 180\}$ 

Let  $(\alpha_1, \beta_1)$  and  $(\alpha_2, \beta_2)$  be the two endpoints (longitude-latitude pairs) of the route segment, then the route in  $\mathbb{R}^2$  will have to be mapped such that its endpoints (or midpoints of end segments) map into these two points. The procedure used to do this is as follows.

Assume that the points are not diametrically opposed on the sphere, so that there is a unique geodesic between them. If the route is not vertical, (which would send the great circle through the poles) then the geodesic route is a segment of a great circle, which has an equation of the form

 $\tan \beta = \gamma \sin \alpha + \delta \cos \alpha$  $= \sqrt{\gamma^2 + \delta^2} \sin (\alpha - \alpha_0)$ 

where the positive square route is taken. Substituting the two endpoints in this equation gives

 $\gamma = \{\cos \alpha_2 \tan \beta_1 - \cos \alpha_1 \tan \beta_2\}/T$  $\delta = \{\sin \alpha_1 \tan \beta_2 - \sin \alpha_2 \tan \beta_1\}/T$ 

where

 $T = \sin (\alpha_1 - \alpha_2) \neq 0$ 

To parametrically map the segment (0,L) of the x axis in the  $R^2$  space into the geodesic between the two points  $(\alpha_1, \beta_1)$  and  $(\alpha_2, \beta_2)$  consider three cases.

Case a.  $\beta_1$ ,  $\beta_2$  not both zero:

This is the general case, where at least one endpoint does not lie on the equator. The point where the great circle upcrosses the equator (i.e.,  $\frac{d\beta}{d\alpha} > 0$  at the crossing, see Figure 4.10) is  $(\alpha_0, 0)$ , and from the great circle equations we have

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$$\tan \alpha_0 = -\delta/\gamma$$

The correct inverse function is given by the argument function

$$\alpha_0 = \operatorname{Arg}(\gamma - i\delta)$$

Let the arc length s along the great circle be measured from the uperossing point  $(\alpha_0, 0)$ , increasing the westward direction. Let it be measured in units of latitudinal degrees (1 degree = 60 nm), so that the arc length of the entire circle is 360°. We wish to parameterize the route segment of the great circle using  $\sigma c[0, 1]$  such that  $\sigma = 0$  corresponds to the point  $(\alpha_2, \beta_2)$  and

$$\frac{d^2s}{d\sigma^2} = 0$$

Let  $s_i$  be the arc length (from the upcrossing) to  $(\alpha_i, \beta_i)$ , then by the law of cosines

$$\cos s_1 = \cos \beta_1 \cos (\alpha_1 - \alpha_0)$$
  
$$\cos s_2 = \cos \beta_2 \cos (\alpha_2 - \alpha_0)$$

To uniquely specify the value of s<sub>1</sub>  $\epsilon$ (-180°, 180°), use the relationship

$$\hat{s}_{1} = \operatorname{Arccos}\left(\cos \beta_{1} \cos (\alpha_{1} - \alpha_{0})\right)$$
$$s_{1} = \operatorname{sgn}(\beta_{1})\hat{s}_{1}$$

Specification of the correct value of  $s_2$  is somewhat more complicated since the route must be traversed the 'right way'




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around the earth, and there cannot be any discontinuities of  $2\pi$  (or rather 360°) in the arc length function:

$$\hat{s}_{2} = \operatorname{Arccos} \left( \cos \beta_{2} \cos (\alpha_{2} - \alpha_{0}) \right)$$
$$s_{2} = \operatorname{sgn} (\beta_{2}) \hat{s}_{2} + k.360^{\circ}$$

where  $k \in \{-1, 0, 1\}$  is chosen such that

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 $|s_2 - s_1| < 180^{\circ}$ 

Given a  $\sigma \in [0, 1]$ , let the arc length parameterization of a third point be

 $s_3 = s_1 + (s_2 - s_1) \sigma$ 

Then the corresponding point  $(\alpha_3, \beta_3)$  along the segment of the great circle satisfies

$$\tan \beta_3 \sin (\alpha_2 - \alpha_1) + \tan \beta_1 \sin (\alpha_3 - \alpha_2) + \\ \tan \beta_2 \sin (\alpha_1 - \alpha_3) = 0$$

If  $\beta_i$  is not zero, then sin  $s_i$  is nonzero. Since not both  $\beta_1$  and  $\beta_2$  are zero, the following equation can be used to find  $\beta_3$ ;

 $\sin \beta_3 = \sin s_3 \sin \beta_1 / \sin s_1$  $= \sin s_3 \sin \beta_2 / \sin s_2$ 

The inverse sine function is unique since

| B<sub>3</sub> | < 90°

The above relation follows from repeated application of the law of sines. Now, from the law of cosines

$$\cos (\alpha_3 - \alpha_0) = \cos s_3 / \cos \beta_3$$

thus  $\alpha_3$  is found using the relations

$$v = \operatorname{Arccos} (\cos s_0 / \cos \beta_0)$$

$$\alpha_3 = \alpha_0 + \text{sgn} (\sin s_3) \upsilon$$

{Note that unlike the previous applications of the law of cosines, to resolve the ambiguities it is necessary to use the sign of the sine}.

Case b. Both  $\beta$ 's zero.

In this case both points lie on the equator. Define

 $\hat{\alpha}_2 = \alpha_2 + k.360^\circ$ 

where the integer k is chosen such that

 $|\hat{\alpha}_2 - \alpha_1| < 180^\circ$ 

Then the parameterization of the route, in terms of  $\sigma \in [0, 1]$  is

 $\alpha_3 = \alpha_1 + (\hat{\alpha}_2 - \alpha_1)\sigma$  $\beta_3 = 0$ 

Case c. Equal a's.

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In this case both points lie on the same meridian, and the parameterization is

$$\alpha_3 = \alpha_1$$
  
$$\beta_3 = \beta_1 + (\beta_2 - \beta_1)\sigma$$

Hence in each case the parameterization of the segment has been specified.

Our attention is now turned to the perpendicular to the mean route. By this we mean the family of great circles that cut the given route at right angles. Before determining the equations for the general case, it is first necessary to give some definitions.

In the planar projection of the earth, the slope of a great circle route is  $\frac{d\beta}{d\alpha}$ , and it is (naturally) not constant. This slope represents the ratio of an infinitesimal change in vertical (ordinate) degrees to an infinitesimal change in horizontal (abscissa) degrees. On the spherical earth, however, degrees are not a uniform measure of distance. The slope of the great circle (on S) is  $\sec \beta \frac{d\beta}{d\alpha}$ , which represents the ratio of infinitesimal change in vertical (North-South) nautical miles to an infinitesimal change in horizontal (West-East) nautical miles. The slope of the perpendicular is the negative reciprocal of the slope of the great circle route (i.e.,  $-\cos \beta / \frac{d\beta}{d\alpha}$ ), thus changing back to a degree coordinate system (i.e., the planar projection), the slope of the perpendicular,  $m_1$  (as a ratio of infinitesimal degrees) is



Figure 4.11 Planer Projection of the Earth, Degree Coordinate System

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$$m_{1} = -\cos^{2}\beta / \frac{d\beta}{d\alpha}$$
$$= -\cos^{2}\beta \frac{d \tan \beta}{d\beta} / \frac{d \tan \beta}{d\alpha}$$
$$= -\cos^{2}\beta \sec^{2}\beta / (\gamma \cos \alpha - \delta \sin \alpha)$$
$$= 1 / \psi$$

where

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 $\psi = \delta \sin \alpha - \gamma \cos \alpha$ 

Let the angle the perpendicular makes with the horizontal (in the planar projection) at the intersection with the great circle route be  $\chi$  as shown in Figure 4.11. Then

$$\cos \chi = \psi / \sqrt{1 + \psi^2}$$
$$\sin \chi = 1 / \sqrt{1 + \psi^2}$$

where positive square roots are taken. The great circle perpendicular to the route at the point  $(\alpha_3, \beta_3)$  is given by the equation

 $\tan \beta_{1} = \widetilde{\gamma} \sin \alpha_{1} \div \widetilde{\delta} \cos \alpha_{1}$ 

where  $\tilde{\gamma}$  and  $\tilde{\delta}$  satisfy the equations

 $\tan \beta_3 = \tilde{\gamma} \sin \alpha_3 + \tilde{\delta} \cos \alpha_3$  $\sec^2 \beta_3 \tan \chi = \tilde{\gamma} \cos \alpha_3 - \tilde{\delta} \sin \alpha_3$ 

i.e.,

 $\tilde{\gamma} = \sin \alpha_3 \tan \beta_3 + \frac{\cos \alpha_3}{\psi_3 \cos^2 \beta_3}$  $\tilde{\delta} = \cos \alpha_3 \tan \beta_3 - \frac{\sin \alpha_3}{\psi_3 \cos^2 \beta_3}$ 

where  $\psi_3$  is  $\psi$  evaluated at the point  $(\alpha_3, \beta_3)$ .

Since the width of the route envelope will be small (compared to the radius of the earth) it may not be necessary to use great circles for the perpendicular displacements, but rather use rhumb lines. A rhumb line approximation to this perpendicular is given by the parametric equations

 $\beta_{1} = \beta_{3} + \tau \sin \chi_{3}$  $\alpha_{1} = \alpha_{3} + \tau \cos \chi_{3}$ 

where  $\tau$  is the parameter and  $\chi_3$  is  $\chi$  evaluated at  $(\alpha_3, \beta_3)$ . This equation, of course, is much simpler than the great circle perpendicular.

Now we have the necessary tools to begin distributing the densities. By use of the Cubic Spline Table each route will have a designated Cubic Spline associated with it, where the number of ship days will be distributed across a normal (i.e., a 'cut') to the median of the route envelope. Ultimately the density will be distributed to 1° squares. When doing this, the cut of width h (where h = edgelength x 5) will intersect the one degree square boundaries in a manner indicated in Figure 4-12.



It can be observed that various proportions of one degree squares are located within the cut. Now we will consider the various cases.

<u>Case 1</u>: Suppose that one edge of the 1° square lies in the cut, as in Figure 4-13. Given the coordinate of the vertices

of the one degree square, the equation of the side which intersects the cut is,

 $y = \left(\frac{y_r - y_s}{x_r - x_s}\right)x + y_s - x_s \left(\frac{y_r - y_s}{x_r - x_s}\right)$ 

or

 $y = \alpha x + \beta$ 



Figure 4-13. Case 1: One edge of the 1° square lies in the cut. where

$$\alpha = \left(\frac{y_r - y_s}{x_r - x_s}\right), \quad \beta = y_s - x_s \left(\frac{y_r - y_s}{x_r - x_s}\right)$$

Let h(y) denote the density function indicated in eq. 4.1 for the interval  $[y_{j-1}, y_{j}]$ . Upon integrating the density function in both directions one obtains

$$\int_{0}^{\alpha x+\beta} h(y) dy = H(\alpha x+\beta) - H(0);$$
  
=  $a_0 + a_1 x + a_2 x^2 + a_3 x^3$ 

where  $a_0$ ,  $a_1$ ,  $a_2$ ,  $a_3$ , are constants dependent on the cubic "pline, 1° sq. vertices, etc.



<u>Case 2</u>: Suppose that the cut lies inside a portion of the one degree square as in Figure 4-14. Similar to Case 1,  $y = ax + \beta$ 

represents the side of the square that intersects the interior of the cut. Let h(y) represent the density function. Upon integration in both directions one obtains:





$$\int_{\alpha x+\beta}^{y_{6}} h(y) dy = H(y_{6}) - H(\alpha x+\beta)$$
$$= a_{0} + a_{1}x + a_{2}x^{2} + a_{3}$$

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 $a_0, a_1, a_2, a_3$  are determined constants Volume =  $\int_{0}^{h} (a_0 + a_1 x + a_2 x^2 + a_3 x^3) dx = k_1$ 

<u>Case 3</u>: Suppose a rectangular region lies in the cut. Then the volume is  $y_A$ 





Figure 4-15. A rectangular region lies in the cut.

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<u>Case 4</u>: Suppose that a triangular region lies in the cut. The equations of the two lines were determined as in Case 1. Then the volume is, after integrating in both directions



Pigure 4-16. A triangular region lies in the cut.



<u>Case 6</u>: Suppose that the region of the 1° square lies in the upper portion of the cut as in the following figure



Figure 4-18. Case 6: Region of the 1° square lies in upper portion of the cut. Given the density function h(y), the corresponding volume is

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$$\int_{\gamma x+\delta}^{\gamma_{6}} h(y) dy + \int_{\alpha x+\beta}^{\gamma_{6}} h(y) dy$$
  
=  $a_{0} + a_{1}x + a_{2}x^{2} + a_{3}x^{3} + \tilde{a}_{0} + \tilde{a}_{1}x + \tilde{a}_{2}x^{2} + \tilde{a}_{3}x^{3}$   
Volume =  $\int_{0}^{x_{r}} (a_{0} + a_{1}x + a_{2}x^{2} + a_{3}x^{3}) dx + \int_{x_{r}}^{h} (\tilde{a}_{0} + \tilde{a}_{1}x + \tilde{a}_{2}x^{2} + \tilde{a}_{3}x^{3}) dx$   
=  $k_{1}$ 

<u>Case 7</u>: Suppose that three edges of the square lie in the cut, as given in the following figure



Figure 4-19. Case 7: Three edges of the square lie in the cut.

Let h(y) denote the corresponding density fucntion

$$\int_{\rho_{X}+\phi}^{Y_{6}} h(y) dy + \int_{\gamma_{X}+\delta}^{Y_{6}} h(y) dy + \int_{\gamma_{X}+\delta}^{\alpha_{X}+\beta} h(y) dy$$

Then the volume is

$$V = \int_{0}^{x_{p}} (a_{0} + a_{1}x + a_{2}x^{2} + a_{3}x^{3}) dx + \int_{x_{p}}^{y_{6} - \beta} (\tilde{a}_{0} + \tilde{a}_{1}x + \tilde{a}_{2}x^{2} + \tilde{a}_{3}x^{3}) dx + \int_{\frac{y_{6} - \beta}{\alpha}}^{x_{p}} (\hat{a}_{0} + \hat{a}_{1}x + \hat{a}_{2}x^{2} + \hat{a}_{3}x^{3}) dx$$

$$= k_{1}$$

<u>Case 8</u>: Suppose that the whole 1° square lies in the cut. Then the corresponding volume will be determined in the following manner



Figure 4-20. Case 8: The whole 1° square lies in the cut.

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$$\int_{\rho \mathbf{x} + \phi}^{\sigma \mathbf{x} + \theta} \mathbf{h}(\mathbf{y}) \, d\mathbf{y} + \int_{\gamma \mathbf{x} + \delta}^{\sigma \mathbf{x} + \theta} \mathbf{h}(\mathbf{y}) \, d\mathbf{y} + \int_{\gamma \mathbf{x} + \delta}^{\alpha \mathbf{x} + \beta} \mathbf{h}(\mathbf{y}) \, d\mathbf{y}$$

Then integrating in the x direction,

Volume = 
$$\int_0^{x_p} (a_0 + a_1 x + a_2 x^2 + a_3 x^3) dx + \int_{x_p}^{x_s} (\tilde{a}_0 + \tilde{a}_1 x + \tilde{a}_2 x^2 + \tilde{a}_3 x^3) dx +$$

$$\int_{x_{s}}^{x_{r}} (\overline{a}_{0} + \overline{a}_{1} + \overline{a}_{2} + \overline{a}_{3} + \overline$$

= k<sub>i</sub>

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Case 10: Given the region below the volume is:



Figure 4-22. Case 10: The cut lies completely in the 1° square.

The volume of the rectangular region is

$$\int_{0}^{y_{i}} \frac{-y_{i}^{-1}}{h(y) \, dy = a_{0}}$$

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then

Volume =  $\int_0^h a_0 dx = a_0^h$ 

The volume of the remaining region can be delt with as in Case 6.



Figure 4-24. Case 12: Three regions of the 1° square lie outside the cut.

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$$\int_{\rho x+\phi}^{\alpha x+\theta} h(y) dy + \int_{\rho x+\phi}^{\gamma} h(y) dy + \int_{\gamma x+\delta}^{\gamma} h(y) dy + \int_{\gamma x+\delta}^{\alpha x+\beta} h(y) dy$$

Volumn = 
$$\int_{0}^{\frac{y_6 - \theta}{\sigma}} (a_0 + a_1 x + a_2 x^2 + a_3 x^3) dx + \int_{\frac{y_6 - \theta}{\sigma}}^{x_p} (\hat{a}_0 + \hat{a}_1 x + \hat{a}_2 x^2 + \hat{a}_3 x^3) dx$$

$$+ \int_{x_{p}}^{\frac{y_{0}-\beta}{\alpha}} (\bar{a}_{0}+\bar{a}_{1}x+\bar{a}_{2}x^{2}+\bar{a}_{3}x^{3}) dx + \int_{\frac{y_{6}-\beta}{\alpha}}^{x_{1}} (\bar{a}_{0}+\bar{a}_{1}x+\bar{a}_{2}x^{2}+\bar{a}_{3}x^{3}) dx$$

Now all the densities have been distributed across the route. Then to find the total volume in the one degree square, you would sum up all the components comprising it.

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## Oil and Fishing Rigs

Next the question of distributing the Oil Rigs arises. The main data sources are the Register of Offshore Units Submersibles and Diving Systems 1977-1978<sup>14</sup> and The Ocean Industry<sup>5</sup>. In The Ocean Industry, the oil rigs are categorized according to types: submersibles, semi-submerisibles, jack-ups, drillships and barges. They also provide us with the geographical location in which they are presently working and the depth capability of the rig. This information is also given in the Register of Offshore Units. Therefore by correlating the two sources for the geographical location, one was better able to pin-point the location of the oil rig. According to Ocean Industry there are 439 units in existance right now. This figure also takes into account those oil rigs under construction, and those available for contract. Therefore the number of oil rigs in use is approximately 360. Most of the oil rigs tend to lie in distinct geographical locations, namely the Gulf of Mexico, the North Sea, the Caribbean, Suez, Red Sea, and the Persian Gulf.<sup>12</sup>

The sources of data for the fishing vessels are as follows: Soviet Fisheries Investigations in the Northeastern Pacific,<sup>23</sup> Fisheries Statistics of the United States 1970,<sup>6</sup> The Fish Resources of the Ocean,<sup>8</sup> Yearbook of Fishery Statistics,<sup>30</sup> 1971 Atlas of the Living Resources of the Seas,<sup>2</sup> Trends in Merchant Shipping<sup>15</sup> (1969-1980). In order to determine the actual distribution the total number of fishing vessels and the thousand of tons of catch is required. In order to illustrate the magnitude of fishery resources and their present state of exploitation, the available data have been grouped by regions in accordance with the breakdown adopted by FAO in the Yearbook of Fishery Statistics, 1971 Maps show the catch for each statistical area according to the four main groups: demersal or bottom-living fish, pelagic fish, crustaceans and cephalopods, and whales. The count for the total number of fishing vessels is obtained from Lloyd's Register of Ships. There are presently 21,261 fishing vessels, of which 76% of them are at sea yielding 16,159 vessels. The total world catch is 70,481,700 tons; therefore, the thousand tons of fish per catch per vessel is 2.43.

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The Yearbook of Fishery Statistics designates the total number of thousand tons of fish for each geographical area in the world. By using this information we are able to determine the number of vessels in each ocean area necessary to procure this catch.

Knowing the various times of the year in which the 4 classes of fishes are caught, enabled us to determine the seasonality factor. The fishing vessel distributions are done for the winter and summer for each one degree square.

Additional data was obtained by NOSIC, Naval Ocean Surveillance Information Center. The Red Flag Shipping data was used to supplement the Lloyd's Register tapes, in various geographical regions. The use of Red Flag Shipping data enabled us to more accurately depict the total shipping distributions. CHAPTER V Outputs

### 1. Availability - Administrative:

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Any types of data which can be culled from the description of the data base is available in machine readable format. The data can be provided upon request in any type of machine readable format: punched cards, magnetic tape, or disc pack. A request for data should be sent by letter to:

> Dr. Louis P. Solomon Suite 600 7900 Westpark Drive McLean, Virginia 22101 Tel: (703)790-5950

## 2. Availability - Technical:

The technical data is available on 7 track, 300 bpi magnetic tape. All the numbers will be available in E format. The actual distributions and their descriptors can be understood by considering not only the printout of the data, but also in conjunction with the body of this report.

#### CHAPTER VI

#### Discussion of Validity of Results and Sample Outputs

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The question concerning the validity of the 1° x 1° square distribution is the next problem that must be addressed. Presently, there is a paucity of data available exhibiting shipping distributions, which restricts the number of cases that can be checked. However, there has been extensive studies of shipping traffic in the North Pacific. They are: Church Anchor, Aircraft Surveillance of Shipping, Church Opal: Surveillance of Shipping, and the RMS study, Navy Interim Shipping Distribution.<sup>16,20</sup>

The Church Anchor Exercise presents the results of extensive aircraft surveillance of merchant vessels at sea in the North East Pacific during the month of September 1973. Sufficient observations were made to enable a statistical analysis of the data to be performed. The resolution of the Church Anchor Exercise is by 5° squares. The data for HITS by 5° squares in the same area, as that of Church Anchor, were analyzed and compared. The region considered is between 30° N to 55°N and 125°W to 180°W as shown in Figure 6-1. The top numbers in Figure 6-1, of each 5° x 5° square represents the number of ships observed in the Church Anchor exercise. The number directly beneath it represents the standard deviation of the observed results, and the bottom represents the HITS results. We have found that the HITS distribution to be statistically consistent with that of Church Anchor. The following observations were found:

- a. 30% of the data lies with 0.25 standard deviation by 5° square.
- 58% of the data lies wt-hin 0.75 standard deviation by
   5° square.
- c. 79% of the data lies within 1.0 standard deviation by 5° square.

d. 87% of the data lies within 1.25 standard deviation by 5° square.





Next the ratio of the HITS data to the Church Anchor data was considered. We can observe from the histogram, in Figure 6-2, that a majority of the data ratios lie within .75 and 1.25. This indicates that the HITS results are remarkably close to those of Church Anchor's.

Further analysis was done comparing the Church Anchor to the HITS data. In Figure 6-3 we have a histogram representing the normalized HITS density relative to Church Anchor's densities. This was obtained by the following method:

HITS Data - Church Anchor data

CA standard deviation for the square

This demonstrated that the data behaves like the normal standard deviation curve. This again validates the accuracy of the HITS results.

The Church Opal Exercise performed similar missions as that of Church Anchor. The surveillance of merchant vessels took place in September of 1975 in the North East Pacific. The number of merchant vessels were tabulated and analyzed. Figure 6-4 illustrates the findings of various studies for  $5^{\circ} \times 5^{\circ}$  square designated in the North East Pacific. Reading from top to bottom in a square, one can observe the results of the HITS, Church Opal, Church Anchor and RMS findings. The HITS results compared very well to that of Church Opal data.



The correlation coefficients were next performed on the Church Anchor, Church Opal, RMS and the HITS data. The following equation was used to determine the zero based correlation coefficient.

$$\theta_0^2 = \frac{(\Sigma \mathbf{x}_i \mathbf{y}_i)^2}{\Sigma \mathbf{x}_i^2 \Sigma \mathbf{y}_i^2}$$

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Studies	CHURCH OPAL REGION	CHURCI Mid Region	H ANCHOR Full Region
Church Anchor-Church Opal versus RMS	.704		
Church Anchor-Church Opal versus HITS	.839		
RMS versus HITS	. 626	. 724	. 543
Church Anchor versus HITS		.839	.799
RMS versus Church Anchor		. 898	.785

Table 6-1 Correlation Coefficients ( $\rho_0^2$ ) among various studies.

In the above table the Church Anchor-Church Opal entry signifies that the most reliable data between the two of them for each square was chosen for the Church Opal region. One can observe that the HITS data correlates better in the Church Opal region than RNS when compared to Church Anchor and Church Opal data. There is also a very high correlation in the HITS data versus the Church Anchor data in both the mid-region and full region. In conclusion, based on the data sources available and the analysis of the data, the HITS results have successfully modeled the actual shipping densities.

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This last part deals with some of the sample outputs of this study. Figure 6-5 designates the routes from the West Coast, U.S. to Vladivostok, Yokohama, and Shanghai. The number, 1539, between the route Shanghai and Seattle represents the ship traffic in total number of ship days for the month of October. Program Gamma produced the number of ship days of traffic from the Lloyd's tape between each of the 69 canonical ports for three class types. This output is placed in a table called the Proto-Routing Table. Next Program Epsilion further reduces this 69 x 69 array to ship days between canonical ports that are connected by a direct route. Therefore, Figure 6-5 represents the total number of ship days in the North East Pacific between the illustrated canonical ports. The next step is to distribute the number of ship days across the route by 1° square. This is done in Program Theta. This is shown in Figure 6-6. This is the 1° x 1° square distribution of merchant ships for October in the Aleutian Islands. The distribution is done by processing one route at a time and storing the densities in a (180 x 360) array called the Merchant Counts Array. This is ayain by class and by month.

Figures 6-7 and 6-8 show the number of oil rigs and fishing vessels in the Gulf of Mexico. The fishing vessel's distributions are done for the summer and winter, while the oil rigs are done annually. The oil rigs consist of jack-up, submersible, semisubmersible, drill ship and barges.



Figure 6-5





Figure 6-7



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# CHAPTER VII Computer Programs

1. Overview and Program Flow.

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This chapter deals with the various aspects of the programs implemented in this project. The program flow, function of each program, mathematical logic, and various checks and cases are considered.

The flow charts on the following pages depict data set and program interrelationships.







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# 2. Function of Each Program

<u>Program Alpha</u>: It obtains the ORE Routing Table (50x50) the Mediterranean Routing Table (24x24), and constructs the total Routing Table (69x69). Prints it out and stores it on a data set.

<u>Program Beta</u>: Converts original form of route envelope trees to the final form by converting degrees/minutes to decimal degrees, calculating edge lengths, inserting back pointers, and collecting leaf and route identifiers into two indices. These indices are the Index to Envelope by Route and the Index to Envelope by Siglum. A separate output tree is generated for each season.

<u>Program Beta 1</u>: Builds Siglum Table and Siglum Indices (Siglum Map and Inverse Siglum Table) from the Routing Table, except for moving the Multiple Routing Table from the Routing Table to the end of the Siglum Table.

<u>Program Beta 2</u>: It sums the edge lengths from the Route Envelope Trees (final form) to build the Fort Distance Table. It determines the total path length for each Siglum. It must run once for each season.

<u>Program Gamma 1</u>: Constructs the Port Hash Table from the Port Table. The Port Name Abbreviation is converted to

Hash Index by taking its S/370 numeric value, dividing by 2999, and using the remainder.

<u>Program Gamma 2</u>: Builds the Estimated Travel Times Table by tracing the Siglum Table and totaling Port Distances from the Port Distance Table. Assume a speed of 12 knots. For ships traveling from one canonical port to itself, a travel time of 0 days is recorded. This program must be run 4 times, once for each season. Program Gamma: It reads the Lloyds Tapes by week, in reverse order (i.e., week 52 is first). It compares the tape with the ships from the previous tape (i.e., the following week) for error control. Uses the (updated) Canonical Port Mapping Table to find the two associated canonical ports. If three ports are given (i.e., an intermediate port), determine which segment the ship will be on during the week. [If it is on both, it is treated as two separate voyages). If the associated canonical port indices for egress and entrance ports are  $\alpha$  and  $\beta$  respectively, and the type is  $\Gamma \in [1,3]$  (corresponding to the various ship types), then increment the  $(\alpha,\beta,\Gamma)$ -th. component of the Proto-Routing Table by the number of days in that week which the ship spent at sea. After processing all weeks for that month, write the Proto-Routing Table on disk. Zero out the matrix and begin to accumulate for the "next" (i.e., previous) month.

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<u>Program Delta 1</u>: Provides a visual check on the Route Trees to catch transcription errors. It plots each vertex of the given route and designates canonical ports by a C and a non-canonical port by a V. The great circle path is generated and displayed between each pair of vertices. A 5° allowance is allotted on either ends of the route for clarity. The program was used for each of the four seasons on all 85 routes.

<u>Program Delta 2</u>: Checks the canonical port mapping. The non-canonical ports are plotted using symbols to denote the various associated canonical ports. This provides a quick checking procedure to determine if in a given area there are more than one canonical port associated to it. It also spots typographical errors occurring in the port table. An example of this is the occurrence of a port in the middle of a large landmass. The program is run in two parts, once for canonical ports 1-34 and is repeated for canonical ports 35-69.

<u>Program Delta 3</u>: Checks the Routing Table. Prevents the occurrence of infinite loops, and does various checks on non-direct routes. In the case of multiple route the check was done manually. When an error is spotted, a corresponding message is written.

<u>Program Theta 1</u>: Generates a set of x values to be used in Theta for the distribution. It takes a set of data points and determines the Type I' Cubic Spline in which it interpolates. Then it uses two iterations of Newton's Method to determine intermediate values between any two successive sextile points. Thus producing a set of 13 x values. This is done for each season.

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Program Epsilon: This program reads a monthly Proto-Routing Table and from it generates a Ship-Days-Table.

<u>Program Zeta</u>: Inputs the oil rig densities in the one degree squares. It produces an 180x360 array containing the densities. (Only the yearly field is produced.)

<u>Program Theta</u>: Takes the Ship-Days-Table, created by Epsilon, applies the growth factor to the ship populations and converts the data from ship-days per route to shipdays per one degree square. The distributions are done between canonical ports, for the various types of vessels for each month. The array is known as the Merchants Count Array. <u>Program Iota</u>: Reads the Merchant Counts Arrays (180x360) for all the various types of vessels. It then sums them up to produce the seasonal and yearly Merchant Counts Arrays.

3. Detailed Table Description

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a. <u>Port Table</u>: Consists of a listing of 2,425 ports that were taken from Lloyd's data base for 1972 by the Department of Transportation. The information on the Port Table is in the form of Table 7-1 below.

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### Table 7-1 Sample of Port Table

509	DEMER	DEMERARA RIVER & DEMERARA	6N	58W	22	440
510	CEN H	CEN HELDER	52N	4F	33	44
511	DENNA	CENMARK	52N	4F	33	44
512	CERBY	DERBY	175	123E	6	348
513	DEFIN	ELRINCE & DERINCJE	- 4CN	29E	38	1
514	DESFA	PLERTC DESEACC	475	65W	27	217
515	DETRO	CETROIT & DETRCIT RIVE?	42N	83 W	20	56
516	CEVON	CEVENPERT (TASMANIA)	415	146E	12	4
517	DEVONT	DEVENPERT (TASMANIA)	415	146F	12	4
513	CFARI	AEU DHAHI	24N	54E	40	77

The description of the fields are as follows: the port number, the abbreviation of the port name, the actual name of the port. On the right side we have the latitude and longitude of the port's location, the canonical port number to which the port is associated and the distance between the port and its canonical port. From the 2,425 ports, 69 major ports were extracted. They are listed in Table 7-2, along with their latitude and longitude.

b. <u>Routing Table</u>: Consists of a 69 x 69 matrix entered in 69 groups of 69 elements. Each group spans three lines with 24 elements each on lines 1 and 2, and 21 elements on line 3. Each entry contains either a letter code or a two digit number. If a two digit number appears then that is the route number that connects the two ports, namely, port a and port b. If a letter appears then it can be one of the following:

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	Table /-2			
	Name Canonical Port	Lat.	Long.	į
Number	Name	18* 56'N	72• 51'E	
1	Bombay	6° 57'N	79• 51'B	٢
2	Colombo	22° 33'N	88° 19'E	L
3	Calcutta	1° 16'N	103° 50°E	
4	Singapore	69 9415	105° 50'E	
5	Sunda Strait	34" 32'S	115° 08'E	
6	Cape Leeuwin	14° 35'N	120° 58'E	Í
7	Manila	31° 14'N	121° 29' 30"E	ţ
8	Shang-hai	43° 06' 30"N	131° 53'E	
9	Vladivostok	35° 27'N	139° 39'E	
10	Yokohama	10° 33'S	142° 08'E	ę
11	Torres Strait	300 10'5	146° 26'E	:
12	Wilson Promontory	210 18' 30"N	157° 52' 15"W	
13	Honolulu	170 325	149° 34'W	
14	Papeete	17" J2 0	122° 22'W	
15	Seattle	47° JO N	122° 24'W	
16	San Francisco	37° 48 50 M	82° 20' 30"W	
17	Havana	23° 08'N	90* 03' 3C*W	
18	New Orleans	29° 57'N	93* 00'	
19	Straits of Florida	24° 25'N	740 01	
20	New York	40° 42'N	730 33'W	
21	Montreal	45° 30° 10° M	70° 31'W	
22	Panama	8° 53'N	73 32 W	
23	Valparaiso	33° 02'S	71 50 W	
24	Punta Arenas	53° 10'S	AG+ 301 20"W	
25	Belem	1º 27'S	40 30 20 11	
26	Rio de Janeiro	22* 53' 30*5	- 43" ++ " 	
20	Nontevideo	34° 54' 30"S	30 54 0C	
28	Pentland Firth	58° 42'N		
20	Fastnet	51° 20'N	9- 30 N	
30	Bishop Rock	49* 45'N	NA ARIS	
31	Strait of Gibraltar	35° 57'N	. 3" 43'W	
	Narseille	43° 19' 10"N	2. XT. 71.0	
36	Skagins Odde	57° 48*N	10" 44"S	
JJ 14	Napoli	40° 59' 19"N	14- 10. XU.P	
	Cape of Good Hope	34° 22'S	18" 23'E	
37	Leningrad	59° 55'N	30° 15'E	
30	· · · · · ·		· · · · · · · · · · · · · · · · · · ·	

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		Table 7-2(CO	NTD)	
iki yangi N	າໜ່າອະ	Name	Lat.	Long.
11	37	Arkhangel'sk	64° 32'N	40° 31'E
herd	30	Tstanbul	41° 01' 15"N	28° 59' 09"E
11	30	Port Said	31° 16'N	32° 19'E
	32	Al Basrah	30° 31' 30"N	47% 50' 30"E
3	4U A 1	Nome	64° 29'N	165° 25'W
L	42 42	Straits of Malacca (NW)	6° 50'N	95° E
,	43	Tiksi	71° 50'N	130° E
<b>{</b>	43 A 4	Cheluskin	77° 50'N	105° E
Sec.	45	Churchill	58° 46'N	94° 11'W
{ ·	46	Reykjavik	64° 09'N	21° 56'W
<b>k</b>	40	Dakar	14° 41'N	17° 26'W
ſ	48	Guayaguil	2° 12'S	79° 53'W
(	40 49	Petropavlovsk	53° N	158° 38'E
ł	50	Nagayevo	59° 33'N	150° 45'E
ŀ	51	Barcelona	41° 23'N	2° 10'E
1	52	Genova	44° 25'N	8° 57'E
	53	Livorno	43° 31'N	10° 18'E
••••	54	Messina	38° 15'N	15° 40'E
ļ	54	Oran	35° 40'N	0° 39'W
	55	Strait of Bonifacio	41° 18'N	9° 11'E
	57	Tarabulus	32° 52'N	13° 12'E
	58	Alexandria	31° 15'N	29° 55'E
1	50	Venice	45° 28'N	12° 23'E
	60	Trieste	45° 40'N	13° 45'E
r ·	61	Piraievs	37° 55'N	23° 40'E
L	62	Thessalonica	40° 38'N	22° 53'E
ه سم	63	Izmir	38° 24'N	27° 04'E
	64	Dardanelles	40° 03'N	26° 05'E
	65	Iskenderun	36° 40'N	36° 05'E
	66	Beirut	33° 58'N	35° 30'E
	67	Tel Aviv	32° 04'N	34° 42'E
	68	Strait of Otranto	40° 17'N	18° 34'E
	69	Strait of Sicily	37° 15'N	11° 15'E

• P means that ports a and port b are connected by an intermediate port namely the number that follows P.

. . . .

- Blank means that port a and port k are connected by a direct route namely the number following it.
- B means that a multiple route can be taken. The number following the B represents the line number in the Multiple Routing Table. It will consist of 2 entries, the first number is the first intermediate port to be taken by super-tankers while the second number is the first intermediate port to be taken by tankers.

 N means that there is no route between ports. This arises when port a equals port b.

Below is a sample listing of the Routing Table.

#### Table 7-3

> c. <u>Route Trees</u>: There are four versions of the Route Trees, one for each season. There are presently 85 routes connecting the 69 pairs of canonical ports. The table contains various information. Field one contains the vertex identifier which is in binary form, field two contains the latitude and longitude of the vertex identifier in decimal degrees. Southern

and eastern hemisphere are designated by a negative sign and North and West are positive. The third field represents the vertex width; i.e., the width of the envelope at the vertex. Field four is the edge length, which is the length of the previous route segment when progressing forward through the route. Field five is the edge width, which is the widest part of the envelope on the previous route segment while traveling forward through the route. The last field is the back-pointers, they indicate how the vertices are linked together. When progressing backwards along a route, the back pointers indicate the line in the Route Trees to which the present vertex is connected. Whenever one begins a new route the backpointer is set to zero and the identifier is 1. Table 7-4 is a sample of the Route Trees.

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### Table 7-4 Sample of Route Trees

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#### Fields

Line I I	II	III	IV	v	VI
28 1	1++3 - 20+170 -0	al. ale	139-33	b	0000
29 10	+40.60+100.0	34.330	31-30		4023
30 100	+40.56+224.6	40.000	25. 32	ຈໍ- ບັບ	0029
31 1000 ·	+41.00+122.3	64.000	11.78	1.00	00.0
32 101	+37.90+122.4	00.000	29.35	5.00	0029
33 11	++5.00-150.0	02.000	28.11	5.0.	ASUG
34 110	+35.43-139.6	50.50	10.99	3.33	0033
35 111	+31.00-131.0	00.230	19.24	2.)0	033
36 1110	+21.00-130.6	30.250	03.1.	0.25	0.005
37 11100	+31.23-121.4	ch.uob	08.37	1.01	3200
38 1	+01.25+079.7	sh.vub	33.00	0.00	0000
39 10	+03.21+079.4	10.000	00.47	5.13	0058
40 100	+ )7.00+030.1	ob.: 30	32.34	2.25	0039
<b>41</b> 1000	+36.51+31.4	14.536	31.24	3.33	1040
42 10:000	+11.30+145.0	4.5.4	25.92	1. 201	1041
43 100 00	+10.91-125.8	36.14	21. 3	4.JU	13+2
44 EUGE 104	+10-03-125-5	cb.250	33.33	0.23	1645 [
45 L0600000	+39.91-125.3	5020	69.93	3.12k	) 344 '
40 10J. JUUUU	+69.13-123.7	50.32b	J1. 30ĝ	0.12	1045 1
47 1000000000	+37.00-110.50	ulu. 2 50	07.24	3.53	1040
48 1030000000	+01.20-103.6	sh.cob	14.15	1.00	1447 -
49 1	+21-30+157-8	sb. Jub	<b>JJ-30</b>	J. Oul	) J J J J J
20 10	+ 5+.33+165.0	.ds.1.2b	33.47	+.UJL	1044 :
27 109	+03.03+107.81	64.000	05 <b>.</b> 67	e. ock	1053 1
<b>24</b> 1000	+6+-48+165-6	16_3.6	34.62	• . 3 di	mark

d. <u>Siglum Table</u>: This table is again a 69 x 69 matrix entered in 69 groups of 69 entries. Each group spans 4 lines with 18 entries on the first three lines and 15 entries on the last. The codes for the entries are exactly like those of the Routing Table except for the case where port a and port b are connected by a direct route; i.e., no intermediate stop. In this table the route numbers have been replaced by Siglia. To every ordered pair of canonical ports that are linked by a direct route a different siglum is assigned. Presently there are 501 siglia. The first pair of canonical ports that are connected by a direct route is the first siglum, the second pair is siglia number 2 and so forth. Table 7-5 is a sample of the Siglum Table.

#### Table 7-5 Siglum Table Sample

1P -2P 2P 2P - Ĥ 3P ЭP 2P 2P 2P £₽ 2P 2P 2P 2P 2P 39P 39 39P 398 398 39b 2P 39 3.96 39 3 -4P 2P 2P 39P 39P 39P 39P 39P 39P Sb 2P 39P 39P 39P 39 39b 392 390 39P 39P 39P 39P 39P 398 398 398 39b 398 39P 39 SH 7 SP 4P4P A. 6 SP 4P 4P 4P 5P 4P 4P 4P 42P 39P 39 39P 39P 39P 35P 392 35P 39P 35P 35P 36b 33b 39P 39P 39P 39P 39 qp 39 39P 30 10 11P 4 120 39P 399 39P 398 39P 39P 4P 4P 39P 39P 39P 39 C -395 33P 39P 366 366 39P 390 39P 39P 39P 300 39P 300 39P 39 ð 3 131 £. 14P 4P 4P 4P 48 JP 4P aP 40 4P 34 40 3 4p 2P 2F è 2P 2P 28 35P 35P 26 35P 35P 39 ЗP 38 2P **2**P 2P 3 15P ã ЗP F 2F 2P Sb 42 16P 35 2P **2**P 2P 55 2P 4P 4P 29 ĉР ЗP З 5 ЗP 2P 2P 2P 2P SP 2P 2P **2**P 2P 2P 2P 2P 2F 5 ŕ. 190 2 21P 17 18N 5 7 Û. 2Ŭ 22 23F 5 24P 11P 10P 13P 39P 39 P 39P 39P 39 25P 11P 11P 5P 39P 39P 5P 39P 39P 39P 39P 399 39 26P 39 1 395 39 27 28P 10 53b 33b 398 39P 39P 39P 22P 10P 10P 39P 39P 39P 39 Ċ 392 39P 300 39P 39 30P £ 2 4 31N 0 32 33 34P 4P 4 35P 6P 4P 11P 4P 4P 42 4 ÷ 4P 4P 4P 4P 11P 35P 2P 35P 35P 39P 366 36b 36b 36b 36b 36 36P 39 0 300 33 37 38P 4P 4P 39P 39P 39P 39P 39P 4P 49 4P 39P 39P 39P 39 

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e. <u>Siglum Tadices</u>: This table consists of two sub-tables; Inverse Siglum Table and Siglum Map. The Inverse Siglum Table is headed by 'INV#SGLM#TBL' followed by a list of number pairs. Each pair corresponds to a successive siglum, and contains two (2) digit numbers specifying the pair of canonical ports. The first entry, " 1 2", says that ports 1 and 2 are connected by a direct route and is designated as siglia 1. There are presently 501 sigla. The Siglum Map is headed by 'SGLM#MAP' and it contains 85 routes each requiring three lines. Each group contains a header entry plus 45 entries (15 per line). The header entry (the first entry of each group) specifies the number of port pairs linked by that route (or equivalently, the number of sigla assigned to each route). Table 7-6 is a sample of the two tables.

## Table 7-6 Sample Data from Inverse Siglum Table and Siglum Map

11.V /S	GL 4413	L									•
1 2	1.5	139	140	21	23	2 4	25	235	239	240	242
5 2	3 4	335	542	4 2	4 3	4 5	47	4 3	410	411	412
422	435	434	440	446	52	54	56	57	5 8	511	لأذلا
521	5-+0	6 3	57	612	ذدب	63+	7 4	75	7 5	7 U	115
711	713	149	75J	ć 4	ય ક	57	3 9	615	313	315	410
622	850	98	915	949	150	10 4	137	10 8	1012	1313	1015
1010	1955	1341	1047	1050	11 4	11.5	11 /	1112	1113	1114	1122
1123	1124	11.55	12 5	1210	1211	1213	121+	1222	1223	1224	1332

SGI	- 14 - 14	ар													
12	303	334	305	337	339	339	543	349	350	351	352	553	υ	0	ð
	C	C	3	0	ა	ა	0	υ	J	U	J	Ŭ	5	ŭ	Ō
	υ	C	0	U	C	C	J	0	0	C	3	Û	3	Ű	Õ
4	04	65	117	372	ð	C	ა	Ŭ	Û	υ	Э	0	a	้อ	3
	Ù	<u>Ľ</u>	Q	0	Ú	C	0	0	ა	ა	Ö	Ō	ວັ	ů	5
	い	C	U	U U	>	C	0	0	C	Ů	a	ð	ð	ม้	ő
ù	έć	ωŪ	72	73	110	116	122	123	C	C	ð	Ű	õ	ů	ō
	ι. G	Q	J	J	)	G	0	0	ð	0	U	Ü	J	ŭ	Ď
	3	U	с J	υ	3	C`	J	υ	0	0	ა	Ń	ð	õ	ē
2	25	101	ŋ	0	0	C	0	Ũ	ð	υ	ა	υ	Ŭ	Ō	٥ ٥
	υ	0	U	Ú	0	C	0	0	0	0	Ĵ	Ű	Ĵ	Ĵ	ō
	ů	ß	0	Ü	9	ζ.	0	0	0	0	2	Ũ	Ú	Û	Ū

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f. <u>Port Distance Table</u>: This table consists of 6 pairs of numbers per line. The first number in each pair is the number of the Siglum to which the pair corresponds. The second is the distance (in units of latitudinal degrees) between the pair of canonical ports corresponding to that siglum. There are 4 Port Distance Tables, one for each season. Below is a partial listing of the Port Distance Table for the fall.

# Table 7-7 Sample Data from Port Distance Table Fall

1	15.00	2	78.30	3	51.29	4	26.23	5	15.00	ట	20.94
7	27.44	8	35.46	9	86.35	10	57.07	11	42.08	12	17.03
13	20.94	14	27.02	15	101.93	10	17.20	17	27.44	19	27.02
19	8.02	20	22.03	21	37.69	22	47.79	23	43.21	24	98.10
25	175.82	26	94.96	27	34.51	28	65.94	29	10.42	30	55.45
31	12.65	32	29.73	33	26.49	34	41.73	35	39.23	30	86.27
37	86.66	38	73.96	39	29.73	40	50.32	41	25.34	42	80.15
43	105.91	44	22.00	45	26.49	44	50.32	47	18.70	43	29.74

g. Estimated Travel Time Table: This table is a 69 x 69 matrix where each entry corresponds to every possible canonical port pair, whether linked by a direct route or not. These entries are arranged in 69 groups of 69 entries spanning 4 lines. The entries represent the expected travel time in integral days betweeen the two ports. If the entry is negative, the absolute value of this number is an index to the Multiple Travel Time Table, which follows immediately. This table consists of a pair of numbers, giving the estimated travel time for both super-tankers and non-super-tankers. This table is also seasonally dependent, one for each of the four seasons. Table 7-f is a sample of the Estimated Travel Time Table for the spring.

Table 7-8 Sample of Estimated Travel Time Table (Spring) 29 31 35 31 38 42 35 41 . 39 40 34 33 32 15 28 27 8 18 17 25 20 2 ñ.

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n alama ya wa kanala ali ili una kanala kwa ukita ukitaka kutaka kuta kata kanala ka kata kata kata kata kata Nata

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14	10	8	18	28	27	17	25	29	0	2	З	6	8	2	9	23	5
8	12	13	-8	38	28	15	13	15	2	10	21	45	46	8	9	9	10
7	9	10	13	12	12	11	12	12	12	13	14	13	10	9	-		
21	23	27	29	53	33	33 -	36	40	39	37	38	32	31	30	27	15	17
15	11	8	16	26	25	15	23	27	2	0	1	- 4	6	З	7	21	7
10	10	11	-9	37	26	17	15	15	20	8	19	43	44	6	7	7	8
5	7	8	11	10	10	Э	10	10	1.0	11	11	11	8	7			
21	22	27	59	28	35	33	36	40	38	36	38	31	31	29	26	15	16
14	10	9	15	25	24	15	17	21	З	1	Ŭ	3	6	3	7	20	6
9	10	10	-10	36	26	16	14	16	4	8	18	43	44	5	6	6	7
4	6	- 7	11	9	9	9	9	9	9	11	11	11	8	ô			
17	19	23	25	25	29	29	32	36	35	33	34	31	31	29	26	14	16
14	11	15	15	25	22	11	19	23	6	4	З	0	2	6	з	18	10
13	6	7	-11	36	23	20	18	21	7	5	18	39	40	5	з	З	4
1	3	4	2	6	6	5	6	6	6	7	8	7	4	3			

h. Proto-Routing Table: This table consists of three 69 x 69 arrays; the first for merchants, the second for tankers less tahn 70,000 gt, and the third for tankers greater than 70,000 gt. The first line indicates which month is being processed, for example in Table 7-9 we are processing Week 48 i.e., month December. The second line indicates the ship type; for example; Tau = 1 for merchants. The 69 x 69 elements spans 5 lines. The entries represent the number of ship days traveled between any pair of canonical ports of a given ship type in a given month. There exists 12 Proto Routing Tables, one per month. Table 7-9 is a sample of Proto 48.

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Table 7+9 Sample Data from Proto 48

WEFK=43 TAU=L Ü Û V ΰ ð θ Э υ ΰ  $\cdot \cdot \mathbf{)}$ Û ŋ ÿ Э Ó J Ú ù ე C ð ΰ Э 5+ υ C υ Э .) з Û ð Э С C J Û Э ΰ .) i) Ĵ 5 C 168 1510 Ĵ 5 L С Э С υ C Û Э Ü С Э Э Э ΰ Ü · 0 С · 0 ð Ũ 

> i. <u>Ship Days Table</u>: The format is similar to that of The Proto Routing Table; namely, that it consists of three tables each having 501 entries. These are again three different ship types, TAU = 1, TAU = 2, TAU = 3. The elements are listed according to sigla; i.e., canonical ports linked by a direct route, which represent the total number of ship days for the sigla; i.e., between the pairs of canonical ports. Following it lies the Residual Table, again by ship type. The Residual Table stores the number of ship days to be distributed for local traffic and 'nonroute' traffic about the canonical ports. Table 7-10 is a sample of the ship days table for month 48; i.e., December

Table 7-10 Sample Ship Days Table

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			TB	= 1			
450 0	144 0	265.4	310.0	280.8	481.3	493.9	68.9
400.2	144.0	078 4	4 9	265.1	334.0	191.9	8.0
191.7	607.0	213-1	44400	1000 2	3485.5	198.3	332.6
435.3	245.6	145.6	1162.7	1000.0	42 5	402.9	318.3
269.0	1180.9	3800.8	1569.1	202.3		040 A	964 . 1
164.1	203.2	28.6	55.8	139.(	191.0	E07.7	1128.3
703 1	42.0	1694.9	1106.2	36.0	674.0	331.V	754 0
172.1	722 0	0.0	0.0	294.0	36.0	515.0	304.0
81.0	(00.0	220.0	222 0	281.9	0.0	169.3	43.0
532.9	108.1	200.0	1154 4	292 1	699.0	763.2	1725.1
0.0	0.0	2619.6	1134.4	070 E 0	975 é	Ð.0	55.5
2236.0	1115.0	90.2	0.0	3.0	2,0.0	70 0	794.3
995 7	42.6	110.1	289.6	8.1	0.0	16.0	243 2
074.0	202 6	358.2	45.0	875.1	75.0	18.7	210.2
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#### CHAPTER VIII

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#### Conclusions

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This report provides shipping distribution by 1° square throughout all the ocean areas in the world. The distributions are temporally divided by month, season, and annual average. The ships are broken down into 5 classes: merchants, tankers, super tankers, fishers, and oil rigs.

The temporal variation is clearly area dependent. Some areas, such as the North Pacific are very seasonal dependent; other areas, such as the Indian Ocean are almost seasonal independent.

Fishing vessels are distributed for only winter and summer. These distributions are based on nutrient distribution and area catch tonnage. There is no raw data describing at-sea positions which allowed a refinement for densities.

The merchant and tanker distributions are heavily based upon Lloyd's Shipping Index for 1972, with growth factors applied to update the port traffic to 1978. The 1972 data base was rather spotty in inherent quality. Considerable care was taken in polishing and editing the individual data entries. A new data base of better quality would provide better absolute numbers; however, the basic shipping patterns would almost assuredly remain unchanged.

Multiple sources were used for trend and growth analysis of the 1972 data base. The growth is definitely geographically dependent. The merchant vessel population increased rather slowly; tanker population increased by 60 percent from 1972 to 1978. Both populations changed in character; i.e., ship type, size, tonnage, speed, power plant, and construction technique.

117

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The predicted data base was verified by comparison with results of naval exercises. Agreement within a rather large area of the North Pacific is within one standard deviation of the measured result. Additional comparisons should be made as more statistically reliable data becomes available. Until that time it is believed that the results are easily correct within a factor of two (2) and can be used with confidence for a number of analyses. 

#### APPENDIX

# Program Documentation

A. <u>PROGRAM</u>: ALPHA (RTNGMRGE) REFERENCE PARAMETERS - PROGRAMS; DSNAME = CN5054.PS1.ALPHA VOL = SER = PUBL03 UNIT = 3330 DCB = (BLKSIZE = 3120, LRECL = 80, RECFM = FB) Sequenced 73/80. (Wylbur line numbers) REFERENCE PARAMETERS - JCL and CONTROL DATA SET: DSNAME = CN5054.PS1.JCL(ALPHA) VOL = SER = PUBL03 UNIT = 3330 WYLBUR EDIT format

FUNCTION: Merges the original Routing Table and the Mediterranean Routing Table to form the final routing table. It determines the correspondence between the Mediterranean route and port numbers and those used in the final routing table. The program is written in a generalized form to allow use for other, similar applications with different numbers of points, routes, and multiple routing tables, and also difference function points between the original and additional routing tables. Similar routes and ports from additional and original routing tables are overlayed.

INPUT DATA SETS:

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FILENAME	DSNAME	CONTENTS
ORG	RTNGTBL.ORG	Routing Table (original version)
	· •	including Muliple Routing Table.
ADD	RTNGTBL. ADD	Routing Table (Mediterranean
		additions), including Multiple

Routing Table (if any).

# FILENAME ADD

DSNAME RTNGTBL.ADD

# CONTENTS

(Both ORG and ADD may contain any number of entries per line, provided that the LRECL specified by JCL or Volume Table-of-Contents is exactly equal to the line length with no extra padding blanks at the end. Each run of the routing table must start on a new line; in that case only the preceding line may be truncated. The format is otherwise under control of the Control Data Set parameters, (discussed below). The multiple Routing Tables should immediately follow the main routing tables, with one pair per line and no spaces between them, with the same number of digits as specified for the main routing table. Control Data Set Parameters: ORG#NO#PORTS (Number of ports in the original routing table) ORG#NO#ROUTES (Number of routes in the original routing table) ORG#NO#MRTS (Number of multiple routing tables in the original routing table) ORG#NO#DIGITS (Number of digits in the routing table used for recording ports, routes, and multiple-routingtable numbers) ADD#NO#PORTS (Number of ports in the additional routing table)

SYSIN

FILENAME SYSIN

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DSNAME

#### CONTENTS

ADD#NO#ROUTES (Number of routes in the additional routing table) ADD#NO#MRTS (Number of multiple routing tables in the additional routing table) ADD#NO#DIGITS (Number of digits in the additional routing table used for recording ports, routes, and multiple-routing table numbers). NEW#NO#PORTS<sup>1</sup> (Number of port for which space should be allocated in the new routing table). NEW#NO#DIGITS (Number of digits to be used in the new routing table for recording ports, routes, and multiple routing table numbers)

These parameters are read in Data-directed format. This is followed by a list giving the port in the original routing table which is closest to the port in the additional routing table. There is one line for each port in the additional routing table, and two entries per line. The first giving the number of the closest port in the original routing table, the second a code (enclosed in single quote) which is 'IDENT' if ports are identical, and 'ADJCN' if they are merely adjacent. Otherwise, this list may be in free format.

This is followed by a list of number pairs specifying which routes from the additional routing table are to be overlayed on routes, from the original routing table. The first element of each pair gives the additional route number, and the second the original number. The list is terminated by two '0's. At least one space or a comma must be inserted between entries, otherwise, this list may be in free-form format.

<sup>1</sup>May be omitted if equal to 2.

OUTPUT DATA SETS:

FILENAME	AME DSNAME CONTENTS					
NEW	RTNGTBL.NEW	New routing table, along with the multiple routing table.				
Sysprint	SYLIB (PORTNO)	Error messages, along with the table of correspondence between addi- tional and new port numbers, and the multiple routing table numbers (original numbers are carried over unchanged).				

-----

JCL USAGE: Assumes that a load module has been placed by the linkage editor specifying the NCAL option in LINKLIB (ALPHA) and is now to be reprocessed by the loader.

MAJOR VARIABLES:	CONTENTS
Port#INDX. NEW#Port#NO	An array referenced by an additional port
	number containing corresponding new
	port numbers.
PORT#INDX. ADD#PORT#NO	Array referenced by new port number
	containing corresponding additional
	port number, or '0' if none.
ROUTE# INDX . NEW# ROUTE #NO	Array referenced by additional route
	number, giving number of corresponding
	route in new routing table.
Port#Map	Array referenced by additional port
	numbers containing port number of
	closest original port, and code
	(either "IDENT" or 'ADJCN')
ORG#RING#TBL, ADD#RING#TEL,	Two dimensional arrays referenced by
NEW#RTNG#TBL	criginal, additional, and new port
	numbers, respectively, containing
	routing tables.

MAJOR VARIABLES:	CONTENTS
MRT#TBL	Array used to hold multiple routing
	tables, referenced by new multiple
	routing table number.
(RTNG#ELEMENT, RTNG#ELMNT#1 (#2,#3) MRT#ELMNT)	Various temporaries, used while
	building tables.

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PROGRAM STRUCTURE

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#### LINES

# FUNCTION

5/35 Reads in control parameter, checks for consistency 38/141 Reads in list of original ports closest to additional ports, and determines the correspondence between additional ports, routes, and multiple routing table numbers and those used in the new routing table. Builds PORT#INDEX and ROUTE#INDEX for later use. 145/368 Reads in original and additional routing tables, builds new routing table, and writes it out. (More details are provided by comments in the program.)

PROGRAM MESSAGES: (apart from new/additional routing table correspondence list)

'SEVERAL ADDITIONAL PORTS HAVE BEEN IDENTIFIED WITH THE ORIGINAL PORT NO XXX INDICATING ERROR IN PORT MAPPING SECTOR. EXECUTION TERMINATING.'

Response: Correct control data set 'INVALID LINKAGE CODE IN PORT MAPPING VECTOR, ADD PORT NO XXX EXECUTION TERMINATING.'

Response: Correct control data set SYSTEM MESSAGES: (Probable meaning) 'CONVERSION' CONDITION RAISED, 'CNFILE' = (ADD

> Response: Nake sure that the control data set parameters correspond to the actual format of the input routing tables. Nake sure LRECL of input routing tables allows for no blanks at end of each line (except for truncated lines at end of the row). Checks the numeric fields for invalid character in the input routing tables.

# COMPLETION CODE SZZZ TIME LIMIT EXCEEDED Response: Checks for infinite recurive loop in additional routing table that are triggered in lines 257/351.

в. PROGRAM: BETA1 REFERENCE PARAMETERS (SOURCE PROGRAM) DSNAME = CN5054.PS1.BETA1 VOL = SER = PUBL03DCB = (RECFM = FB, BLKSIZE = 3120 LRECL = 80) Sequenced 73/80 WYLBUR line numbers. REFERENCE PARAMETERS (LOAD MODULE): DSNAME = CN5054.PS1.LINKLIB(BETA1) VOL = SER = PUBL03UNIT = 3330Load module may be invoked by // EXEC PGM = BETAL REFERENCE PARAMETERS (JCL), (For load module invocation) DSNAME = CN5054:PS1.JCL(BETA1), VOL = SER = PUBL03UNIT = 3330Wylbur EDIT format Builds Siglum Table and Siglum Indices (Siglum Map

FUNCTION: Builds Siglum Table and Siglum Indices (Siglum Map and Inverse Siglum Table) from Routing Table, except for moving the Multiple Routing Table from the Routing Table to end of the Siglum Table, which must be done by hand.

INPUT FILES:

DDNAME	DSNAME	CONTENTS
RTNGTBL	CN5054.PS1.RTNGTBL.NEW	Final version of Routing
· .		Tables, must be precisely in format specified in
		table descriptions
OUTDUT FT	1.85 •	

SGLMNDX	CN5054.PS1.SGLMNDX	Inverse Siglum Table and
		Siglum Map
SGLNTBL	CN5054.PS1.SGLMTBL	Siglum Table

MAJOR VARIABLES: INV#SGLM#TBL SGLM#MAP SGLM#TBL,RTNG#TBL

Inverse Siglum Table Siglum Map Routing Table, on input, converted to Siglum Table in place.

#### PROGRAM PARAMETERS:

The following parameters are set implicitly by the program structure and will necessitate program modification if changed.

PARAMETER Number of Canonical Ports (69)

Number of Canonical Routes (85)

Maximum Number of Sigla (600)

Maximum Number of Sigla per Route (45) REFERENCES (LINE NUMBERS) 24,27 Dimension 52,74 I/O Format 54, DO loop limit 19 Dimension 20,21 Repetition factor in INITIAL attribute 75,4 I/O Format 72,22 DO Loop Limit

16 Dimension

21 Dimension 21 Repetition factor in INITIAL attribute 75.4,75.5 I/O Format (Note: overflow of this number may be easily detected by examining the Siglum Map. The first entry per route is the <u>actual</u> number of the Sigla for that route. If this is greater than 45, this parameter must be increased.)

8-A

PROGRAM STRUCTURE:LINESFUNCTION50/52Reads in the Routing Table.54/60.6Converts all entries flagged as<br/>representing direct routes to<br/>Sigla, building simultaneously the<br/>Inverse Siglum Table and Siglum<br/>Map.601/endWrites out Siglum Table, Inverse<br/>Siglum Table, Siglum Map

PROGRAM MESSAGES:

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None

SYSTEM MESSAGES (WITH PROBABLE CAUSE):
'CONVERSION' CONDITION RAISED, 'ONFILE' = RTNGTBL
 Response: Check the Routing Table for invalid code. Make
 sure that the format corresponds to that given
 in table descriptions.

с. PROGRAM: BETA

REFERENCE PARAMETERS - SOURCE PROGRAM; DSNAME = CN5054.PS1.BETA VOL = SER = PUBL03UNIT = 3330DCB = (RECFM = FB, BLKSIZE=3120, LRECL=80)sequenced 73/80 with WYLBUR line numbers.

REFERNECE PARAMETERS - LOAD MODULE;

DSNAME = CN5054.PS1.LINKLIB (BETAF) Note Suffix VOL = SER = PUBL03UNIT = 3330Load module read for execution via PGM parameter of EXEC card; no link-editing necessary.

**REFERENCE PARAMETERS - JCL** 

DSNAME = CN5054.PS1. JCL(BETA)VOL = SER = PUBL03UNIT = 3330Wylbur EDIT format

FUNCTION: Converts the original form of the route envelope trees to the final form by converting degrees/minutes to decimal degrees, calculating edge length, inserting back pointers, and collecting leaf and route identifiers into two indices, the Index to Envelope by Route and the Index to Envelope by Siglum. A separate output tree is generated for each season. As a secondary by-product, it effectively compares all direct-route linkages in the routing table through the intermediary of the Siglum Map and Inverse Siglum Table to the associated route envelope trees. It prints an error message if a branch of a route tree is never referenced by the route table. Inspection of the Index to Envelope by Siglum will also reveal any direct-route linkage for which no associated branch

in the route Envelope Tree exists, as the indicated

A-10

line number, will be '999.99'.

A '999.99' for latitude or longitude in the output route envelope trees means that a vertex has been omitted for some season in input.

#### INPUT DATA SETS:

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DDNAME	DSNAME	CONTENTS
SGLMNDX	CN5054.PS1.SGLMNDX	Inverse Siglum Table and Siglum Map
INENV	CN5054.PS1.ENVELOPE	Original Version of Route Trees

#### OUTPUT DATA SETS:

ENVINDX	CN5054.PS1.ENVINDX	Index to Envelope by Route and Index to Envelope by Siglum
OUTENVP	CN5054.PS1.OUTENV. SPRING	Final version of Route Envelope, one per season.
outenvs	CN5054.PS1.OUTENV. SUMMER	
OUTENVF	CN5054.PS1.OUTENV. FALL	
OUTENVW	CN5054.PS1.OUTENV. WINTER	

JCL USAGE: Assumes that the load module has been placed in CN5054.PS1. PROGRAM PARAMETERS:

> The values of the following parameters, are set implicitly via program structure. The program must be revised and recompiled if they are changed:

# PARAMETERS

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# REFERENCES (POSSIBLY NOT COMPLETE) BY LINE

Maximum # of routes (85)

# 13,48 Dimension

14 Repetition factor in INITIAL attribute 78,245 Repetition factor in FORMAT

PARAMETERS	REFERENCES (POSSIBLY NOT COMPLETE) BY LINE
Maximum # of Siglum (506)	15,46 Dimension
	16 Repetition factor in INITIAL attribute (2X number of Sigla)
	77,246 Repetition factor in FORMAT
Maximum # of Sigla per	50 Dimension
route (45)	78 Number of lines read by FORMAT from
	Siglum Map (3)
Maximum # of Output	16.3,17 Dimension
Vertices per Route (75)	16.5,16.6 Repetition factor in INITIAL attribute

PROGRAM MESSAGES: 'PORT W ROUTE ENVELOPE DOES NOT OCCUR IN ROUTING TABLE, ROUTE NO = XXX YYYYY' XXX is Route number YYYY is print out of leaf, as taken from original form of Route

Tree.

Message may be printed twice for the same leaf, if it is marked in the input Route Trees as being used for both entrance and egress and is used in Routing Table for neither purpose.

Response: Correct Route Trees by eliminating unused branch of the route, or correct the Routing Table by finding some use for the route, or ignore it if certain that the error is harmless, (Note: Route 21 and and one branch of route 12 are currently unused).

#### IBM 5371 DATA EXCEPTION

(Program uses decimal arithmetic in many calculations.)

Response: Check for illegal code in the alphanumeric field in the input route tree envelopes. Also make sure input matches picture specifications in lines 27/37, 43/45.2.

?'TRANSMIT' CONDITION RAISED, 'ONFILE' = {INENV

(DCB parameters are specified within program and <u>cannot</u> be modified by JCL or volume table of contents)

Response: Check that INENV or SGLMNDX are associated with data sets with LRECL = 72, BLKSIZE = 3096. If not, reformat data set (it may have been accidently stored in WYLBUR EDIT format) by using it and saving it with LRECL=72.

'CONVERSION' CONDITION RAISED, 'ONFILE' = SGLMNDX

Response: Make sure Inverse Siglum Table contains no more than the maximum number of Sigla (currently 506) expected by program BETA. If it contains less, pad with extra blanks or blank lines to simulate 506. (Note: If a terminal error occurs in processing a route, the envelope output file will contain all previously processed routes.)

# MAJOR VARIABLES:

T

INDX\_ENVLP\_BY\_ROUTE, INDX\_ENVLP\_BY\_SGLM INV\_SGLM\_TBL, SGL\_MAP

IN\_VERTEX, IN\_ENVELOPE Contain Envelope Indices

Contain Siglum Indices

Alternative dummy variables describing record from the input route envelope trees, overlayed upon input buffer, depending upon whether record is vertex descriptor or route header.

A-13

#### OUT ENVELOPE

Array used for storing the final forms of the route envelope trees. It holds the verticies corresponding to all four seasons, but one route only (it is written out after processing each route) Array used to reinitialize OUT-ENVELOPE at the start of processing each route, setting latitudes and longitudes to the impossible '999.99' Dummy variable overlayed on OUT - ENVELOPE

OUT\_VERTEX\_BUF

OUT ENVELOPE INIT

#### PROGRAM STRUCTURE

LINES 75/78

101/108

109/144

144/172

Establishes ENDFILE on-unit to terminate processing after all input trees have been read. If this is the beginning of processing a

to facilitate output.

Reads in Siglum Indices

FUNCTION

new route, write out envelope tree for preceeding route, Record vertex number in INDEX - TO ENVELOPE - BY - ROUTE and re-initialize

Check if this vertex is a leaf corresponding to a canonical port, and if so, update INDEX TO ENVELOPE BY SIGLUM.

Convert degrees - minutes to decimal degrees, and moves the fields which do not need to be changed to the output variables.

173/184.7 Locates predecessor node and sets back the 185/206 pointer. If the same vertex is used for all four seasons, copy it to all four copies of OUT ENVELOPE. Calculate edge length, and if latitude/longitude of both main vertex and its predecessors are the same for each season copy it. 206.5/229 If the vertex differs for the various seasons, search the seasons previously calculated to see if both main vertex and its predecessors have same latitude/longitude, in which case copy edge length, otherwise, calculate it over. Go back to 100 for next vertex.

# 232/end

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Write out last route.

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D. PROGRAM: BETA2

REFERENCE PARAMETERS (SOURCE PROGRAM)

DSNAME = CN5054.PS1.BETA2 VOL = SER = PUBL03 UNIT = 3330 DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 3120) Sequenced 73/80 WYLBUR line numbers

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REFERENCE PARAMETERS (OBJECT MODULE)

DSNAME = CN5054.PS1.LINKLIB(BETA2) VOL = SER = PUBL03 UNIT = 3330

Objective Module must be reprocessed by Linkage Editor/Loader specifying entry point PLISTART

REFERENCE PARAMETERS (JCL) (For object module execution) DSNAME = CN5054.PS1.JCL(BETA2) VOL = SER = PUBL03 UNIT = 3330 WYLBUR EDIT format

#### FUNCTION:

Sums the edge lengths from the Route Envelope Trees (final form) to build the Port Distance Table, determining the total path length for each Siglum. It must be run once for each season.

### INPUT FILES

DDNAME	DSNAME	CONTENTS
ENV	CN5054.PS1.OUTENV.SPRING SUMMER FALL WINTER	Route Envelope Trees, for appropriate season

ENVINDX

CN5054.PS1.ENVINDX

Index to Envelop by Siglum

**OUTPUT FILES:** 

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ALC: NO

PRTDIST CN5054.PS1.PRDIST.SPRING

SPRING Port Distance Table, for the SUMMER FALL appropriate seasons WINTER

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MAJOR VARIABLES: ENVELOPE

INDEX#ENVLP#BY#SGLM LENGTH Array holding needed subfields of the Route Envelope Trees Array holding the index to Envelope by Siglum used for summing up the edge lengths

### **PROGRAM PARAMETERS:**

The following parameters are built into the logical structure of the program and if changed will necessitate program modifications:

#### PARAMETER

Number of routes (84) Maximum number of Sigla (506)

#### REFERENCE (LINE NUMBER)

56.2 I/O Format (skipped over) 12 Dimension 56.3 I/O Format 100 DO loop limit

Maximum Number of Vertices 8 Dimension in Route Envelope Tree (900)

#### PROGRAM MESSAGES

'ERROR, SGLM = XXXX'

Response: The Index to Envelope by Siglum containes an '0' instead of a line number in the Route Envelope Trees. Correct the Routing Table or the Route Envelope Trees (original form) as necessary and re-run everything.

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#### **PROGRAM STRUCTURE:**

LINES	FUNCTION
51/56.3	Read in Tables
100/112	Sum lengths
108.4/111.6	Write out length

#### E. PROGRAM: GAMMAL

```
REFERENCE PARAMETERS (SOURCE PROGRAM)
DSNAME = CN5054.PS1.GAMMA1
VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)
Sequenced 73/80 WYLBUR line numbers
```

```
REFERENCE PARAMETERS (OBJECT MODULE)
DSNAME = CN5054.PS1.LINKLIB(GAMMA1)
VOL = SER = PUBL03
UNIT = 3330
Object Module - must be reprocessed by Linkage Editor/ Loader
specifying entry point PLISTART
```

```
REFERENCE PARAMETERS (JCL)
DSNAME = CN5054.PS1.JCL(GAMMA1)
VOL = SER = PUBL03
UNIT = 3330
Wylbur EDIT format
```

FUNCTION: Constructs the Port Hash Table from the Port Table. The Port Name Abbreviation is converted  $\cos a$  Hash Index by taking its S/370 numeric value, dividing it by 2999, and using the remainder.

REVISION STATUS: Make certain JCL specifies most recent revision of PORTTBL before running.

INPUT FILES:

DDNAME PRTTBL DSNAME CN5054.PS1.PORTTBL

# CONTENTS

Port Table

OUTPUT FILES:

PRTHSH

CN5054.PS1.PRTHASH

Nachine-readable Hash table

HASHOUT

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# CN5054.PS1.HASHOUT

Human-readable Hash Table

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MAJOR VARIABLES:

PORT#HASH#TBL

PORT#HASH#TBL#BUF

PORT#DSCRPTN

PORT#NAME#A, PORT#NAME#B PORT#NAME#C

NEXT#AVL#SPACE

PROGRAM STRUCTURE: Line

40/47

50

51/68

52/55

56/66

67/68

Port Hash Table

Dummy variable overlayed on PORT#HASH#TBL during output.

Array storing the needed fields from the Port Table

Various formats of the temporary variables used during conversion of the port name abbreviation to the Hash Index

Cursor used to manage loading of overflow area in the Hash Table

Format

On-unit to enable an error causing Port to be printed out. On-unit to end the program after all records from Port Table are read.

Loop for each sucessive port

Render Port name, and convert to Hash Index

If another Port already has that Hash Index determine the proper bin to use in the overflow indices.

Store the port name and number in the. Port Hash Table.

# Write out Fort Hash Table

# 75/83

# PROGRAM MESSAGES:

Following any system error message is a print-out of Port Table entry being processed when the error occurred, the Hash Index calculated (if any), and NEXT#AVL#SPACE cursor.

F. PROGRAM: GAMMA2 REFERENCE PARAMETERS (SOURCE PROGRAM) DSNAME = CN5054.PS1.GAMMA2VOL = SER = PUBL03UNIT = 3330DCB = (RECFM = FB, BLKSIZE = 3096 LRECL=72)Sequenced 73/80 WILBUR line numbers. REFERENCE PARAMETERS (OBJECT MODULE) DSNAME = CN5054.PS1.LINKLIB(GAMMA2) VOL = SER = PUBL03UNIT = 3330(Object module must be reprocessed by the linkage editor/ loader specifying entry point PLISTART). REFERENCE PARAMETERS (JCL for Object Module execution) DSNAME = CN5054.PS1.JCL(GAMMA2)VOL = SER = PUBL03UNIT = 3330Wylbur EDIT Format

#### FUNCTION:

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Builds the Estimated Travel Times Table by tracing the Siglum Table and totaling the port distances from the Port Distance Table. It assumes a speed of 12 knots. For ships traveling from one canonical port to itself, it assumes a travel time of 0 days (which may later be modified by Wylbur EDIT commands). It must be run 4 times, once for each season. Also it constructs the Multiple Travel Time Tables and places the additive inverse of a pointer to them in the proper place in the Estimated Travel Time Table.

FILES:

INPUT:

DDNAME

SGLMTBL

PORTOST

<u>DSNAME</u> DL CN5054.PS1.SGLWTBL

#### CONTENTS

Siglum and Multiple Routing Twoles P at Distance Tables, as appropriate for season.

SUMMER

FALL WINTER

CN5054.PS1.PRTDIST.SPRING

OUTPUT:

TRAVTME

Travel Time Tables

#### SUMMER FALL WINTER

SYSPRINT Intermediate checks.

CN5054.PS1.TRAVTME.SPRING

UPDATE STATUS: '(CHECK)' prefixes and line 75.5 used during the checkout may be removed, but are harmless except for producing lots of output. Otherwise, the program is finished.

#### **PROGRAM PARAMETERS:**

Changes in the following parameters will require program modification.

PARAMETER	REFERENCE (LINE NUMBER)	
Number of Cononical	15,20 Dimension	
Ports (69)	52,100 I/O Format	
	58 LO Loop limit	
Maximum number of	21.5 Dimension	
Sigla (506)	56 I/O Format	
Maximum number of Multiple	21 Dimension	
generated (100)	100 I/U Format	
Estimated Inverse Speed (Days/Degree Latitude)	64,68,80,85,91 Multiplier	

#### MAJOR VARIABLES:

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SGLM#TBL	Sig
MULT#RTNG#TBL	Mult
TRAV#TME#TBL	Trav
Mult#Trav#Tme#TBL	Mult
PORT#DIST	Port
PORT#1,PORT#2	Orig
PORT, PORTM	Inte
TIME, TIMEM	Accu
BRANCH	Mult

Siglum Table Multiple Routing Table Travel Time Table Multiple Travel Time Table Port Distance Table Origin and Dest. Ports numbers Intermediate Port numbers Accumulators for travel time Multiple Routing Table branch

Second Bridge & State State

PROGRAM STRUCTURE FUNCTION LINE Reads in the Table 50/56 58/97.5 Loops through the Siglum Table using all possible port combinations 59/60 Initializes for each origin and destination port pair Traces the Siglum Table recursively 61/73 until the Multiple Routing Table is encountered 76/78.5 Initializes the Multiple Routing Table, trace for each of the two branches Traces the Siglum Table recursively, 79/96 choosing the proper multiple routing table, branch for each time through.

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PROGRAM: DELTA1 G. **REFERENCE PARAMETERS - SOURCE PROGRAM;** DSNAME = CN5054.PS2.DELTA1 VOL = SER = PUBL03UNIT = 3330-1DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)REFERENCE PARAMETERS - JCL DSNAME = CN5054.PS2.DELTA1.JCL VOL = SER = PUBL03UNIT = 3330 - 1WYLBUR EDIT format FUNCTION: Provides a visual check on the Route Trees to catch transcription errors. It plots each vertex of the given route and designates canonical ports by a C and a non canonical port by a V. The great circle path is generated and displayed between each pair of vertices. A 5° allowance is allotted on either ends of the route for clarity. The program was used for each of the four seasons on all 85 routes. INPUT DATA SETS: DSNAME CONTENTS World in terms of periods and blanks CN5034.PS2.LANDSEA CN5054.PS1.SGLMNDX Inverse Siglum Table and Siglum Map CN5054.PS1.ENVINDX Index to Envelope by Route and

Index to Envelope by Siglum CN5054.PS1.OUTENV.SPRING Final version of Route CN5054.PS1.OUTENV.Fall Envelope, one per season CN5054.PS1.OUTENV.WINTER CN5054.PS1.OUTENV.SUMMER <u>MAJOR VAPIABLES:</u> LSEA4. WORLD1 Contains Landsea table

SIGM22	Contains	Siglum	indice	98
INSIG	Index Env	velope	by Sigl	.um

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PROGRAM STRUCTURE	
Lines	Function
1/17	Dimensions various arrays, i.e.,
	Route Trees, Landsea, Siglum Map,
	Index Envelope by Siglum
18/37	Reads in all the necessary files.
	A factor of 90.5 is added to the
	latitudes and 181 to the longitudes
38/70	Checks if we are beginning a new route,
	and if so, writes out the previous route.
	Determines the minimum and maximum longi-
	tudes
71/115	Determines the great circle path between
	pairs of vertices according to the vertex
	widths.
115.1/281	Stores the corresponding code for
	canonical ports, non canonical ports, and
	great circle paths.

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H. <u>PROGRAM</u>: DELTA2 REFERENCE PARAMETERS - (SOURCE PROGRAM) DSNAME = CN5054.PS2.DELTA2 VOL = SER = PUBL03 UNIT = 3330 DCB = (RECFM = FB,LRECL = 80,BLKSIZE = 3120)

REFERENCE PARAMETERS - JCL

DSNAME = CN5054.PS2.DELTA2.JCL

VOL = SER = PUBL03

UNIT = 3330

INPUT FILES:

DSNAME

WYLBUR EDIT FORMAT

FUNCTION: Checks the canonical port mapping. The noncanonical ports are plotted using symbols to denote the various associated canonical ports. This provides a quick checking procedure to determine if in a given area there are more than one canonical port associated to it. It also spots typegraphical error occurring in the Port Table. An example of this is the occurrence of a port in the middle of a large landmass. The program is run in two parts, once for canonical ports 1-34 and is repeated for canonical ports 35-69.

#### CONTENTS

CN5034.PS2.LANDSEA	The world stored in terms of periods
	and blanks
CN5054.PS4.PORTTBL	Table of all the ports and the corres-
	ponding latitude, longitude and
	associated canonical port.
MAJOR VALUABLES:	
SUMTAB	Vector containing the code for the
	canonical ports.
WORLD	Array containing the landsea table.

LINES	FUNCTION
1/14	Dimensioning various arrays
15/20	Read in the port table with the correspon-
	ding latitude, longitude and associated canonical port.
21/32	Determines if the assoicated canonical port lies in the range of this run. Then
	it deals with the North, South, East, West by adding or subtracting the appro- priate value.
23/53	Checks if two different canonical port codes lie in the same 1° x 1° square, and if so, designates it on the output by an asterick. It also displays the full world.

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I. PROGRAM: DELTA3 **REFERENCE PARAMETERS:** SOURCE PROGRAM; DSNAME = CN5034.PS2.DELTA4VOL = SER = VOL = PUBL03UNIT = 3330DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)**REFERENCE PARAMETERS - JCL** DSNAME = CN5034.PS2.DETLA4.JCL VOL = SER = VOL = PUBL03UNIT = 3330DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)FUNCTION: Checks the routing table. Prevents the occurrence of infinite loops, and does various checks on nondirect routes. In the case of a multiple routes the check was done manually. When an error is spotted a corresponding message is written. INPUT DATA SETS: DSNAME CONTENTS CN5054.PS1.RTNGTBL.FINAL 69x69 array called Routing Table. MAJOR VARIABLES ROUTEM Alphanumeric array containing the code ' ' for direct route, 'P' for intermediate port and 'B' for multiple route ROUTEM Array containing the various routes between 2 ports PROGRAM STRUCTURE FUNCTION LINE 1/10 Dimensions various arrays 11/19 Reads in the Routing Table and declares some logical variables 20/endReads a pair of canonical ports. It traces through the path and undergoes various checks along the way. If there are inconsistancies an error message is written.

J. PROGRAM: GAMMA

REFERENCE PARAMETERS: (Source Programs) DSNAME=CN5054.PS1.GAMMA

VOL=SER=PUBL03

UNIT=3330-1

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DCB=(RECEM=FB,LRECL=80, BLKSIZE=3120)

Sequenced 1/834 WYLBUR line numbers

MACROS INVOKED:

DEFINE#MONTH#TBL

DEFINE#PORT#HASH#TBL

TEST

SET#INVALID#FIELD#LIMIT

COMPARE

SEARCH#PORT#HASH#TBL

SEARCH#MONTH#TBL

GET#DATE

SHPDYS

MAJOR VARIABLE(other than those limited to use in macros)NEW#INPT#SHPOverlayed on each record from

INPT#SHP

VAL#FLGS, NEW#VAL#FLGS

## TRNS#SHP

(OBJECT MODULE)

DSNAME=CN5054.PS1.LINKLIB(GAMMA) ACAS VOL=SER=PUBL03 V UNIT=3330-1 3

Must be reprocessed by loader

SHPINPT in buffer Contains data moved from NEW#INPT #SHP (both variables are needed to maintain synchronization since 2 sequential input records must be compared to check for duplicated records).

Validity flags to ID fields in NEW#INPT#SHP, INPT#SHP respectively. Contains data obtained by translating INPT#SHP by converting port name abbreviations to port numbers and month abbreviations/day of month to day of year.

SHP (J)	J=1 to 20
	Search table contains 15 to 20
	ships from OLDSDT.
BETA	Index of first ship in search table
W	Index of last ship in search table
P	Points at last ship in search table
CANNA (T)	Points to ship preceding SHP(J) in
GANINA (G)	$e_{\text{restrict}} = 0$
	Boints to ship succeeding SHP(I) in
PHI (J)	Formes to ship successing bit (0) and $(0)$
- ( - )	Search table. Fil(w)-33,
F (J)	0 Indicates position 5 empty in search
	table.
	1 not empty
C (J)	0 indicates SHP(J) unmatched
	1 SHP(J) matched
RHO	Counts inserts to the search table.
SUM	Counts comparisons.
PROGRAM STRUCTURE:	
LINES:	FUNCTION
238/261	Initialization for the first processed
	week or the 13th week of the season,
262/293	Initialization for each week of process-
	ing.
294/330	Move previous NEW#INPT#SHP, NEW#VAL#FLGS,
	and NEW#ERR#INT, respectively. Read new
	NEW#INPT#SHP, check ID fields for validity
	via TEST macro and simultaneously set
	NEW#VAL#FLGS. Invoke COMPARE macro to
	test NEW#INPT#SHP and INPT#SHP for
,	duplication, Maintain COUNTER.INPT#SHP.
	and synchronize TRANSMIT and ENDFILE
	conditions with INPT#SHP processing.
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A-30

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Branch to ERR#WPT#SHP if too many errors, or TRANSMIT condition raised, and to FINISH on ENDFILE condition. Translate PEE (Port Entrance/Egress Data) from INPT#SHP to internal form and store in TRNS#SHP, simultanteously setting validity flags. Translate origin port data. Translate port of last call data. If port name is missing, but other data given, then ship has arrived at its final destination, so use port of destination name and flag this field in TRNS#SHP as being the final destination. Use Last Call Code ('AR', 'IN', 'PD', 'SD') to determine whether LCALL date should be interpreted as arrival or departure date. Translate port of destination name, if it has not been moved to LCALL field. Port name abbreviations must be translated to DOT port number (modified), and month/day-of-month pairs to day-of-year. Sets up the search tables for all the weeks. Searches and matches the ships. Calls MACRO SHPDYS which actually calculates the days between ports and increments PRTRT. Minor bookkeeping to make the two parts of the program more compatible and programming somewhat easier as values are transferred from one variable to

A-31

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331/413

332/352

353/399

400/413

415/680

415/426

426/431 432/464 465/507 508/532 533/597 598/656

657/662

663/680

a second variable that will be used in this part of the program. Test for week 13, that is the 13th week of the season. Two functions: sets up the initial search file for the 13th week of the season, does the initial calculations for any ship that makes its first appearance after the 13th week of the season. Loads the search file at the beginning of each week. Reloads the search file as comparisons are made. Compares, takes a TRNS#SHP and searches the file for a match. If a match occurs, goes to calculations. Inserts new ships into search file. Determines if the data on a ship fits into one of six categories available. Then sets the data up in a form compatible with MACRO SHPDYS. SHPDYS is called and actual days calculated and the proto-routing table incremented. Once the calculations are done, test on SUM. If SUM is still less than 10 control is sent back to GET#INPT#SHP If SUM is greater than 10, test to see if the pointer is within 5 of the last ship on the list. If pointer is not, send control to GET#INPT#SHP. If pointer is within 5 then send control to WRITEBOUT.

Writes out the top of the search file.

A~32

Resets the chain and various pointers and sends control back to LOAD where the search file is again filled with new ships. ERR#INPT#SHP program segment for 681/733 processing the errors not correctable by program logic. ENDFILE. Closes ship input file, writes 734/767 out error messages, on file ERRMSG and SYSPRINT. Writes out the last of the search file, 768/781 makes sure all ships have been taken off of the input file and written out on the new file for next week. 782/798 If INDX is equal to 1, sends control back to INITIALIZE, closes the appropriate file. If INDX does not equal 1, dumps proto-routing table for that week onto a temporary file. If also MOD(INDX, 4) = 1, sends control to DUMP #PRTRT. 799/834 Dumps proto-routing table onto a file for the appropriate week. Sends control back to initialize it, unless it is the first week of the season, i.e., the last week processed and then closes down all the files, writes out a message saying 'normal' and ends the program. INTERNAL TABLES **PORT HASH TBL** Used for translating port name abbreviation to DOT port number. Documentation elsewhere. MAPS DOT PORT number to canonical port CANSPORT number.

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Contains travel time table for the season. Documentation elsewhere. Contains multiple travel time table for the season. Documentation elsewhere. The proto-routing table. A 3x69x69

table containing the cummulative days spent by each of the three ship types traveling between any two canonical ports.

CONTROL VARIABLES VAL#FLGS.TO#ID OCCURENCES: <u>NAME</u> VAL#FLGS.TO#ID NEW#VAL#FLGS.TO#ID

HOW SET By TEST macro By TEST macro By LOAD#TBL#SHP macro using VAL#FLGS.TO#ID <u>APPLIED TO</u> INPT#SHP.ID NEW#INPT#SHP.I ł

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FUNCTION:

DAYS

IDAYS

PRTRT

BIT 1	Name Field	'l'B - Valid; 'O'B - invalid
BIT 2	Not used - reserve	d for TYPE field
BIT 3	Flag Field	'l'B - valid; 'O'B - invalid
BIT 4	Year built field	'l'B - valid; '0'B - invalid
BIT 5	Type and weight fields	'l'B - both valid; '0'B - at least one invalid
SPECIA	AL FUNCTIONS (VAL#FLGS.	TO#ID, NEW#VAL#FLGS)
	'0000000'B	ENDFILE Condition
	'0000000'B	TRANSMIT Condition
	a'00000000'B	First Record (void)

CONTROL VARIABLES

#### VAL&FLGS.TO&PEE

FORNAT: BIT(8) OCCURENCES:

NAME		HOW SE	T		APPLIED TO
rrns#shp.v	AL#FLGS.	By Sea	irch	*Month*TBL.	TRNS\$SHP.PEE PRT\$OR
rrns#shp.v To#pee.por	AL#FLGS. T‡CALL	get‡da Search	te, I#Poi	and T#HASH#TBL	TRNS <b>#SHP.PE</b> E PRT <b>#CALL</b>
TRNS#SHP.V TO#PEE.PRT	AL#FLGS. #DST	SEARCH macros code	l‡POI and	RT#HASH#TBL l surrounding	trns‡shp.pze prt‡dst
FUNCTION:					
BITS 1&2	Port number f	ield	'11' '10' corn flag the '00'	B - fully val B - valid, bu responds to a ged as a gene port table - invalid or	id t port number port name ric term in blank
BITS 3&4	Arrival data	field	'11'	- fully vali	đ
	Departure dat field	e	'10' by c or h - wh or a fiel code	- upper limi correlation on by use of day- nen month name actual data in d of PRT#LCAL was invalid.	t, obtained month name of-report, invalid, arrival L if LCALL
			'01' usir day date PRT inva	- lower limi ng first day of of month inva in Departure LCALL if LCAL alid	t, obtained by f month when lid, or actual field of L field was
			'00' inva fiel PRT ship	- filed miss lid, when in d or Arrival DST probably of has not yet	ing or totally Departure field at means that left or arrived.
BIT 7			'l' was port	indicates tha designated as : in input data	t this port a destination a
			,0, qøs:	indicates that Inated	t it was not so
CONTROL VA	RIABLES				
name Gate		TESTED By SEC to con the se	OND OND trol arch	PART loading of table	VALUES '0' - have first TRNS\$SHP of week Need to load the search table for the first time
		A-3	15		•

NAME

#### TESTED ON

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INDX

By SECOND#PART WEEK#13 to transfer control after initial calculations on ship

By SECOND#PART to indicate if we are searching forward or backward through the search table

By SECOND#PART Transfer of control during loading of search table

By SECOND#PART WRAP#UP '1' - refilling the
table
Counts no. of weeks
processed this season.
Sends control to DUMP
#PRTRT at INDX ≠ 1

but MOD (INDX,4)=1

'0'- filling the tables

for the first time

VALUES

started

table

'l' - have a TRNS#SHP initial loading. Has

'-l' - need to get a TRNS#SHP after refill-

ing of the search

'0' - we are in week

'l'- we are in OTHER

13 of the season

week than 13 '0' - forward

this week

'l' - backward

INPUT DATA SETS:

FILENAME = SHPINPT

DDNAME = DOTINP52, DOTINP51, etc. Determined dynamically during execution by concatenating WK#OF#RPRT to "DOTINP'. CONTENTS: DOT Marine Traffic Generator Input Tape for appropriate week. ENVIRONMENT Specification: F RECSIZE (84) TOTAL BUFFERS (10) DCB Specifications (on DD card): TRTCH = ET, OPTCD = C FILENAME, DDNAME = PRTHSH CONTENTS: Port Hash Table Referenced by DEFINE#PORT#HASH#TBL macro FILENAME, DDNAME = NEWPRT CONTENTS: Canonical Port Numbers ENVIRONMENT Specification: FE RECSIZE (200) BLKSIZE (5000)

and the second s FILENAME = TRAV DDNAME = TRAVTME, FALL TRAVTME. WINTER treest TRAVTME.SPRING TRAVTME, SUMMER CONTENTS: Number of shipdays between any two canonical ports. Also multiple route table for voyages that pass through the canals ENVIRONMENT Specification: FB RECSIZE (80) BLKSIZE (3120) OUTPUT DATA SETS: FILENAME, DDNAME = ERRMSG -----Print file (SYSOUT=A) containing all error messages generated. FITENAME, DDNAME = SYSPRINT CONTENTS: System error messages, copies of certain important error L., messages from ERRMSG, system debugging output. Print File (SYSOUT=A) 1. FILENAME=PROTO DDNAME = PROTO48PROTO44 PROTO40 CONTENTS: The Proto-Routing table for each month. ENVIRONMENT Specification: FB ١.... RECSIZE (72) BLKSIZE (3120) FILENAME = PRO#TEMDDNAME = PRO.TEMPCONTENTS: Temporary proto-routing table to be used in case a restart is necessary. At the end of normal execution contains the cumulative list for ports of origin. ENVIRONMENT Specification: FB RECSIZE (80) BLKSIZE (3120) MACRO FUNCTIONS: TEST TEST Checks ID field of input record and sets corresponding validity flags. COMPARE COMPARE Compares ID fields of two records and checks for identity. SIFL SET#INVALID#FIELD#LIMIT

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		Used with TEST, DPHT, SMT, AND GD
		macros to limit total number of
		invalid fields to be allowed before
		branching to error routine.
dpht	Define#port#hash#tBL	Reads in Port Hash Table and contains
		declarations for associated variables.
SPHT	SEARCH#PORT#HASH#TBL	Searches Port Hash Table for a given
		port name abbreviation.
DMT	DEFINE#MONTH#TBL	Initializes Month Table to optimum
		sequence for linear searching.
SMT	SEARCH#MONTH#TBL	Obtains starting day of given month
		from the Month Table.
GD	GET#DATE	Adds day of month to starting day of
		month to obtain day of year.

SHPDYS

Calculates ship days between canonical ports. If canonical ports are identical assigns max. value of 2. Increments Proto-Routing table.

### SYSTEM OPERATIONS

MACRO DEFINITIONS:

REFERENCE PARAMETERS: DSN = CN5054.PS1.PLI.MACLIB VOL = SER = PUBL03 UNIT = 3330-1 DCB = (DSOPG=PO\_PECEM=FB\_BL)

DCB = (DSORG=PO, RECEM=FB, BLKSIZE=3120, LRECL=80) Sequenced 73/80 WYLBUR line numbers

ACCESS METHOD:

1. Include

//PL1.SYSLIB DD DSN = CN5054.PS1.PL.MACLIB
// VOL = SER=PUBL03,UNIT=3330-1,DISP=SHR
card among complier DD cards.

%INCLUDE (BNTS), (DST),...(GTS); card specifying short form of all macro names to be used in the source text for each external procedure.

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I. If Gamma is to be modified.

- 1. Make changes in source code. DSN = CN5054.PS1.GAMMA VOL = SER=PUBL03
- 2. RECOMPILE and Linkedit. Gamma, JCL to accomplish this is located in Data set: DSN = CN5054.PS1.GAMMA.COMPLIN
  - VOL = SER=PUBL03
- 3. The load module is placed in a library. DSN = CN5054.PS1.LINKLIB(GAMMA) VOL = SER=PUBL03
- 4. To execute the load module Gamma the JCL is located in GAMMA.JCL.EXEC.
  - DSN = CN5054.PS1.GAMMA.JCL.EXEC
  - VOL = SER=PUBL03

The JCL for the data set name GAMMA.COMPLIN is as follows:

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#### The JCL for GAMMA.JCL.EXEC

з. //JOBLIB DD DSN=CN5054.PS1.LINKLIB.UNIT=3330-1, з. ZZ VOL=SER=PUBL03, DISP=SHR 4. //GB\_EXEC\_PGM=GAMMA,PARM=\*ISA(102K)/D\* //SYSPRINT DD SYSDUT=A 5. //EVEN DD DSN=CN5054.PS1.TEMP.PORT.SHP.FILE1,UNIT=3330-1, 6. 7. VOL=SER=PUBL03,DISP=(OLD,KEEP),DCB=(RECFM=FB,LRECL=38) //ODDS DD DSN=CN5054.PS1.TEMP.FORT.SHP.FILE2,UNIT=3330-1, 8. 9. 11 VOL=SER=PUBL03,DISP=(OLD,KEEP),DCB=(RECFM=FB,LRECL=38) 1Ŭ. //NEWPPT DD DSN=CN5054.PS1.NEWPRT, 11. VOL=SER=PUBL03, DISP=(SHR, KEEP), UNIT=3330-1, 1. 12. DCB=(RECFM=FB+LRECL=200+BLKSIZE=5000) 11 //ERRMSG DD SYSDUT=A.DCB=(BLKSIZE=2640,LRECL=132, 13. 14. // RECFM=FB> 15. //PRTHASH DD DSN=CN5054.PS1.PPTHSH, VOL=SER=PUBL03, 16. 1.1 DISP=SHR; UNIT=3330-1 17. //TRAV DD DGN=CN5054.PS1.TRAVIME.WINTER,VOL=SER=PUBL03, 18. UNIT=3330-1, DISP= (DLD+KEEP) 11 19. //DOTINP01 DD VOL=SER=PS1001,UNIT=3330,DSN=CN5054.PS1.COPY01, DCB=(RECFM=FB+LRECL=84+BLKSIZE=3108)+DISP=SHR 20. 11 21. //DBTINP02 DD V8L=SER=PS1001,UNIT=3330,DSN=CN5054.PS1.CDPY02, DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR 22. 11 //DOTINPOS DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY03, 23. DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR 24. 11 25. ZZDOTINP04 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY04, DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR 26. 11 27. //DOTINP05 DD VOL=SER=P\$1001.UNIT=3330.DSN=CN5054.PS1.COPY05. 28. // DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR 29. //DOTINP06 DD VOL=SER=PSI001.UNIT=3330.DSN=CN5054.FS1.COPY06. 30. DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR 11 31. ZZDOTINP07 DD VOL=SEP=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY07. DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108).DISP=SHR 32. 11 33. //BOTINP08 BD VOL=SER=PSI001,UNIT=3330,DSN=CH5054.PS1.COPY09, 34. // DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR 35. //DOTINP09 DD VOL=SER=PS1001,UNIT=3330,DSN=CN5054.PS1.COPY09, // DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR 36. 37. //DOTINP10 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY10, 38. DCB=(RECFM=FB+LRECL=94+BLKS12E=3108)+DISP=SHR 39. //DOTINP11 DD VOL=SER=PS1001,UNIT=3330,DSN=CN5054.PS1.COPY11, 40. // DCB=(RECFM=FB+LRECL=84+BLKSIZE=3108)+DISP=SHR 41. //DOTINP12 DD VOL=SER=PSI001.UNIT=3330.DSN=CN5054.PS1.COPY12. 42. // DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR //DOTINP13 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY13, 43. 44. DCB=(RECFM=FB+LRECL=84+BLKSIZE=3108)+DISP=SHR AND AND //PRBT001 DD DSN=CN5054.PS1.PRBT001,UNIT=3330-1; 15. 46. DISP=(NEW, KEEP), DCB=(RECFM=FB, LRECL=80, 47. 1.00 BLKSIZE=3520), VOL=SEP=PUBL03, SPACE=(TRK, (10, 5)) //PRETE05 DD DSN=CN5054.PS1.PR0TE05,UNIT=3330-1, 48. DISP=(NEW, KEEP), DCB=(RECFM=FB, LPECL=80, 49. 11 BLKSIZE=3520),VOL=SER=PU&L03,SPACE=(TRK,(10,5)) 11 50. 51. //PROTO09 DD DSN=CN5054.PS1.PROT009,UNIT=3330-1, DISP=(NEW, KEEP), DOB=(PEOFM=FB, LRECL=80, 52. 11 BLKSIZE=3520), VOL=SER=PUBL00, SPACE= (TRK, (10, 5)) 53. //PRO#TEM DD VOL=SER=PUBL03,UNIT=3330-1, 54. DSN=CN5054.PS1.PR0.TEMP,DISP=(DLD,KEEP), 55. 545. 1.1 DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120)

An execution time parameter is passed to Gamma on the PARM card. Code is as follows:

A → Fall; sets WK#OF#RPRT=53 Fudge=365 B → Summer; sets WK#OF#RPRT=40 Fudge=286

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- → Spring; sets WK#OF#RPRT=27 Fudge=195
- D --- Winter; sets WK#OF#RPRT=14 Fudge=104
- E ---- Test case;WK#OF#RPRT=53

RTEST=1



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K. PROGRAM: EPSILON

REFERENCE PARAMETERS (SOURCE PROGRAM)

DSNAME = CN5054.PS1.EPSILON VOL = SER = PUBL03

UNIT = 3330 - 1

DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 3120)

FUNCTION: EPSILON reads a monthly Proto-Routing Table and from

it generates a SHP.DAYS Table. The Proto-Routing Table is indexed by ship type, egress port, and entrance port. EPSILON examines each element of the Proto-Routing Table. If for each ship type, t, the (t,A,B)-th element of the table is zero, then no action is taken. If for some t the (t,A,B)-th element is non-zero, then the (A,B)-th element of the Routing Table is examined.

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- i. If the (A,B)-th element is a blank followed by an integer, n then the route from A to B is a canonical route and the contents of the (t,A,B)-th position in the Proto-Routing Table are added to the (t,n)-th element of the SHP.DAYS Table where n is the (A,B)-th element of the Siglum Table. This is done for each t where the (t,A,B)-th elements of the Proto-Routing Table is non-zero.
- ii. If the (A,B)-th element of the Routing Table is N followed by a zero then A=B and the contents of the (t,A,B)-th element of the Proto-Routing Table are moved into the (t,A)-th element of the RESIDUAL TABLE for random distribution in the vicinity of port A.
- iii. If the (A,B)-th element of the Routing Table is a P followed by an integer, M, then the RECURSIVE INDEX LIST is started. P indicates that the voyage from A to B is a compound route. That is, the route is not direct. M is the canonical port number of the end of the first segment of the route. The (A,M)-th element of the Siglum Table

stored in the RECURSIVE INDEX LIST. Then the (M,B)-th element of the Routing Table is examined. If it is a canonical route number, that is blank followed by an integer, then the (M,B)-th element of the Siglum Table is stored in the RECURSIVE INDEX LIST, and the list is terminated. If the (M,B)-th element of the Routing Table is a B followed by an integer K, then the MULTIPLE ROUTING TABLE is used to determine which of the two pointers is correct. If the (M,B)-th element of the ROUTING TABLE is a P followed by an integer J, then this step is repeated with the (M,J)-th element of the Siglum Table being added to the RECURSIVE INDEX LIST, and the recursion continues until the list is terminated. When termination occurs, then the RECURSIVE INDEX LIST is used to extract distances from the PORT DISTANCE TABLE. The extracted distances are used to proportion the ship days among the various component routes. That is one assumes the number of days spent going from point A to point M is that same fraction of the total days spent going from A to B as the distance from A to M is to the total distance from A to B.

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iv. If the (A,B)-th element of the ROUTING TABLE is a B followed by an integer L, then the various ship types influence the choice of routes. One examines the L-th row of the MULTIPLE ROUTING TABLE if t=3, i.e., ship type is large tanker, the first entry of row L indicates the next canonical port for the route. If t<3 then the second entry of the L-th row indicates the next canonical port.

After processing the entire PROTO-ROUTING TABLE, the program writes out the SHP.DAYS TABLE, zeroes it, and proceeds to the table for the next month.

# INPUT DATA SETS

Filename	=	FT33F001
DSNAME	=	CN5054.PS1.RTNGTBL.NEW
CONTENTS:		Routing Table
Filename	=	FT34F001
DSNAME	=	CN5054.PS1.SGLMTBL
CONTENTS:		Siglum Table
Filename	=	FT36F001
DSNAME	=	CN5054.PS1.PRTDIST.FALL (SUMMER, SPRING, WINTER)
CONTENTS:		Port Distance Table
Filename	H	FT08F001
DSNAME	#	CN5054.PS1.PROTO48,35,22,09
CONTENTS:		First Proto-Routing Table of the Season
Filename	=	FT09F001
DSNAME	=	CN5054.PS1.PROTO44,31,18,05
CONTENTS:		Second Proto-Routing Table of the Season
Filename	8	FT10F001
DSNAME	=	CN5054.PSI.PROTO40.27.14.01
CONTENTS	8	Third Proto-Routing Table of the Season
OUTPUT DAT	ra :	SETS
Filename	=	FT20F001
DSNAME	=	SHP. DAYS 48, 35, 22, 09
CONTENTS:		Ship Days Table for the first month of the season
Filename	-	FT21FC01
DSNAME	*	SHP.DAYS44,31,18,05
CONTENTS:		Ship Days Table for the second month of the season
Filename	13	FT22F001
DSNAME	۵	SHP.DAYS 40, 27, 14, 01
CONTENTS:		Ship Days Table for the third month of the season

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	MAJOR VARIABLES					
	RTA(69,69)	Alphabetic information from the Kouting Table				
kyw.d.	RTN(69,69)	Numeric information from the Routing Table				
<b>[</b> ]	PRT(3,69,69)	Proto-Routing Table				
hand	MRT(69,69)	Multiple Routing Table				
	PDT (500)	Port Distance Table				
	SIG(69,69)	Siglum Table				
	RESID(3,69)	Residual Table for random distribution in the vicinity of ports				
	RESINL(20)	The RECURSIVE INDEX LIST, to temporarily hold Siglum values for compound routes.				
	SDT(3,500)	SHP.DAYS Table indexed by ship type and Siglum				
í	PROGRAM STRU	CTURE FUNCTION				
<i>\</i> .	29/42	Reads in the Routing Table, the Multiple				
j.		Routing Tables, the Siglum Table, the				
L		Port Distance Table for the appropriate				
(		season ·				
1	43/44	Reads in the Proto-Routing Table for each				
1		month of the season .				
	46/92	Performs the function of EPSILON .				
	49/51	Checks if Proto-Routing Table is zero for				
		these two ports.				
1	53/91	Performs the correct calculation based on				
<b>1</b> . 2		the alphabetic value of the Routing Table •				
( i	57/58	Pouting Table has a blank in the alpha-				
	21/00	betic position .				
<b>f</b> ]						
	60/61	Routing Table has an N in the alphabetic				
<b>1</b>		position.				
U						
4*1						
<b>F</b> *3						
U	· .					

63/65	Routing Table has B in the alphabetic position.
66	Routing Table has a P in the alphabetic position
67/83	Accumulates Siglum in the RECURSIVE INDEX LIST for cases P and B.
87/90	Calculates Ship Days Table for cases P and B.
93/95	Writes the Ship Days Table and the Residual Table onto the disk pack.
96/102	Zeros the SHIP.DAYS and Residual Tables for the next month.
103/105	Increments counters for controlling the number of months processed and the logical devices for I/O.
106	Tests on the number of months processed.

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SYSTEM OPERATIONS The JCL is located in the data sets JCL.EPSILON. Below is a copy of the JCL. г. // EXEC FTG1CG //FORT.SYSIN DD DSN=CN5054.PS1.EPSILDN+UNIT=3330-1+ 3. 11 4 VEL=SER=PUBL03+DISP=(SHP+KEEP) 5. ZZGD.FT33F001 DD DSN=CH5054.PS1.RTNGTBL.NEW+ 6. 11 UNIT=3330-1.VOL=SER=PUBL03.DISP=(SHR:KEEP) 7. //GD.FT34F001 DD DSN=CN5054.PS1.SGLMTBL+UNIT=3330-1; 8. VOL=SEP=PUBL03+DISP=(SHR+KEEP) 11 //GD.FT36F001 DD DSN=CN5054.PS1.PRTDIST.FALL.UNIT=3330-1. 9. 10. VEL=SEP=PUBL03.DISP=(SHP.KEEP) 11 //GD.FT08F001 DD DSN=CN5054.PS1.PPDTD\$;UNIT=3330-1; 12. VOL=SEP=PUBL03.DISP=(OLD.KEEP).DCB=(PECFM=FB. 13. 11 LPECL=80.PLKSIZE=3520) 14. 11 14.1 //G0.FT09F001 DD DSN=CN5054.PS1.PRDTD\$+UNIT=3330-1+ 14.2 VOL=SEP=PUBL03,DISP=(OLD,KEEP),DCB=(PECFM=FP, 11 14.3 11 LPECL=80.PLKSIZE=3520> 14.4 //GD.FT10F001 DD DSN=CN5054.PS1.PRDTD\$;UNIT=3330-1; 14.5 VOL=SER=PUBL03.DISP=(DLD.KEEP).DCB=(PECFM=FP. 11 14.6 11 LRECL=80.BLKSIZE=3520) 15. ZZGD.FT20F001 DD DSN=CN5054.PS1.SHP.DPYS48+UNIT=3330-1+ 16. 11 VOL=SEP=PUBL03:DISP=(OLD:FEEP):DCB=(PECFM=FB:LRECL=72: 17. FLKSIZE=3120) +SPACE=(TPK+(10+5)) 11 18. //ED.FT21F001 DD DSN=CN5054.PS1.SHP.DAYS44.UNIT=3330-1: 19. 11 VOL=SEP=PUBL03+DISP=(OLD+YEEP)+DCB=(PECFN=FB+LPECL=72+ 20. 11 PLKSIZE=3120) +SPACE=(TPK + (10,5)) 21. \*/GD.FT22F001 DD DSM#CM5054.PS1.SHP.DAYS40+UNIT#3330-1+ 22. VOL=SEP=PUPL03+DISP=(OLD+KEEP)+DCP=(RECFM=FP+LPECL=72+ 11 23. 11 BLKSIZE=3120) + SPACE=(TPK + (10,5))

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L. PROGRAM: THETA1 **REFERENCE PARAMETERS - SOURCE PROGRAM** DSNAME = CN5054.PS2.SPLINE2 VOL = SER = PUBL03Unit = 3330DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)**REFERENCE PARAMETERS - JCL** DSNAME = CN5054.PS2.SPLINE.JCL VOL = SER = PUBL03Unit = 3330WYLBUR Edit Format FUNCTION: Generates a set of X values to be used in Theta for the distribution. It takes a set of data points and determines the Type I' Cubic Spline in which it interpolates. Then it uses two iterations of Newton's method to determine intermediate values between any two successive sextile points. Thus producing a set of 13 X values. This is done for each season.

INPUT FILES:

DSNAME

#### CONTENTS

CN5054.PS2.SEXTILE.SP A table of sextile points CN5054.PS2.SEXTILE.SU

CN5054.PS2.SEXTILE.FALL

CN5054.PS2.SEXTILE.WINTER

OUTPUT FILES

#### DSNAME

CN5054.PS2.X13SP CN5054.PS2.X13SU CN5054.PS2.X13FALL CN5054.PS2.X13FALL Table containing 13 X values correspond-

CONTENTS

ing to each route.

MAJOR VARIABLES	
M(J)	Coefficients of such spline
XTEMP	X value genera fter one iteration
	of the Newton's method
X(13)	The 13 X values, six of which are the
	original sextile points normalized
	between [-1,1]
PROGRAM STRUCTURE	
LINES	FUNCTION
1/5	Dimensions various vectors and reads in
	a set of sextile points
5/15	Normalizes the sextile points and checks
	if they are monotonic.
16/34	Determines the coefficient of the cubic
	spline from the sextile points, i.e., the
	mj'a.
35/last	Performs two iterations of the Newton
	method and routes the generated values
	plus the original ones on a file.

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M. PROGRAM: X13 TABLE

**REFERENCE PARAMETERS:** 

DSNAME = CN5054.PS2.X135U,CN5054.PS2.X13SP

CN5054.PS2.X13FALL,CN5054.PS2.X13WINTER

VOL = SER = PUBL03

UNIT = 3330

DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 3120)

SOURCE: Generated by THETAL

USAGE: Used by THETA for distribution of shipping data by one degree square.

- FORMAT: Matrix 30x13 or 29x13 according to the season. Each group spans two lines 7 entries are on the first line in (7F10.5) and six entries on the subsequent line. For each route there is a corresponding set of 13x values.
- FUNCTION: Used by F from THETA in the distribution of the density across the route.

N. <u>PROGRAM</u>: SEXTILE TABLE REFERENCE PARAMETERS:

DSNAME = CN5054.PS2.SEXTILE.SU,

CN5054.PS2.SEXTILE.SP,CN5054.PS2.SEXTILE.FALL,

CN5054.SP2.SEXTILE.WINTER

VOL = SER = PUBL03

UNIT = 3330

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DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 3120)

SOURCE: Ocean Routes Envelope Report

USAGE: Used by program THETA1 to build 13 X values for each set of sextile points

FORMAT: SEXTILE table 7x29 matrix or 7x30. Varies according to seasons. Each group spans 1 line with 7 entries in format (7F10.5).

FUNCTION: Used by THETAl to generate the 13 X values.
O. PROGRAM: THETA

REFERENCE PARAMETERS - SOURCE ?ROGRAM;

DSNAME = CN5054.PS2.THETAWVOL = SER = PUBL03UNIT = 33330 $DCB = (RECFM \approx FB, BLKSIZE = 3120, LRECL = 80)$ REFERENCE PARAMETERS - JCL DSNAME = CN5054.PS2.THETA.JCLW VOL = SER = PUBL03UNIT = 33330DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)FUNCTION: Takes the Ship-Days ~ Table, created by Epsilon, applies the growth factor to the ship populations and converts the data from ship-days per route to ships per one degree square. The distributions are done between canonical ports, for the various types of vessels for each month. INPUT DATA SETS: CONTENTS DSNAME CN5054.PS1.SGLMNDX Inverse Siglum Table & Siglum Map CN5054, PS1. ENVINDX Index Envelope by Route and Index Envelope by Siglum CN5054.PS2.X13SP The 13 X values generated by sextilepoints per season CN5054.PS].SHP.DAYS 48 Ship days table, per month

CN5054.PS2.POINTR.SP Pointer to the 13 X values by route, per season CN5054.PS1.PRTDIST.SPRING Port Distance Table, one for each season

OUTPUT DATA SETS

DSNAME

CONTENTS

CN5054.MERCH.COUNTS.ARRAY.SPRING Distribution by 1° square

FALL

WINTER

SUMMER

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enter e	PROGRAM STRUCTURE	
No.	LINES	FUNCTION
-	1/11	Dimensions various arrays. That is SHIPDS
		for the ship days table, PRTDST the port dis-
		tance table, SPLINE the Spline Table, SIGMP2
n Na Na		the Siglum-map, INSIG the Index Envelope by
<b>X</b> :		Siglum, IEBR the Index Envelope by Route.
1		The Route Trees are read route at a time and
· .'		each component is stored in a vector. They
		consist of LENGTH, the edge length, LAT, the
		latitude of the vertice, LONG, longitude of
		the vertice, BPOINT, the backpointer, IDENTS,
ί.		the identifier of the vertices, WIDTH, the
}		vertex width, EDWITH, the edge width of the
•-		segment, DEN, an array that has the 1° square
í		distribution.
	11/17	Initializes the distribution matrix DEN to zero,
	18/49	Reads in all the input data sets.
	50/55	Applies the growth factor to the ship days
		table
Į	56/62	Begin to process the routes one at a time.
<b>.</b> .	63/67	Checks the line number of the present route
1		by use of a counter called ISTART to that of
		the Index Envelope by Route.
	68/87	Checks to make sure that a route does not
		exceed 41 lines. It then proceeds to read in
r :		the designated number of line of the route.
	88/91	Sets Flag2 to False if the route crosses the
		date line.
	92/99	Accesses the appropriate set of 13 X values
×.¥		for the given route.
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A-53

100/108 Looks at the first number of the Siglum Map for the given route. This indicates the number of Siglia assigned to that route. It checks to make sure that it is not zero and if it is it processes the next route.

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- 109/110 It refers to the Index Envelope by Siglum for the given Siglia. This tells us the line numbers in the Route Trees for the two canonical ports.
- 111/119 Next it computes the density, i.e., the number of ship days per month. Also it determines the distance for the given Siglia.
- 120/145 Next it determines the peak or the common branch in the trees by doing a comparison on the identifiers.
- 146/155 Calls the subroutine to actually distribute the number of ships across the segment of the route.
  - 156/164 Writes out the 180x360 matrix on a data set.
    165 The subroutine that distributes the number of ship days across the route.

166/171 Dimensions and declares various variables.

- 172/183 Checks if this route crosses the date lines and sets a flag. If it does another flag is set up to determine which segment actually crosses the date line.
- 184/408 Processes the first segment according to the various cases. If the vertex widths of the 2 vertices are zero, one set of calculations are performed. If one vertex is zero and one is non-zero, one will be sent to another part of the program for various calculations. Still another set of equations are used when both vertices have a non-zero vertex width. All of these equations can be obtained from Chapter 4.

A-54

P. DATA FILES

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1. TABLE: Routing Table (Alpha) (Final Version)
REFERENCE PARAMETERS:
DSNAME = CN5054.PS1.RTNGTBL.NEW

VOL = SER = PUBL03 UNIT = 3330 DCB = (RECFM=FB,LRECL=72,BLKSIZE=3096)

SOURCE: Generated by Program Alpha from the Original Routing Table and the Mediterranean additions, with later corrections made simultaneously to the original.

USAGE: Used by program Betal to generate the Siglum Table.

FORMAT: 1. 69x69 matrix entered in 69 groups of 69 elements. Each group spans 3 lines with 24 elements each on lines 1 and 2, and 21 elements on line 3. Each entry contains:

(a) A 1-letter code; specifying meanings of the following number:

P Canonical Port

Blank Canonical Route

B Multiple Routing Table Index

N Null Entry

(b) A 2-digit number, with meaning as specified by (a).

Multiple Routing Table 15x2 matrix, entered in
 15 lines of 2 entries each. Each entry contains a
 2-digit code, denoting a canonical port.

FUNCTION:

Let  $\alpha$ ,  $\beta$  denote two canonical ports with  $1 \le \alpha$ ,  $\beta \le 69$ . Then the  $(\alpha, \beta)$  element of the Routing Table determines the route from port  $\alpha$  to port  $\beta$  by specifying either an intermediate port (denoted by P), a canonical route linking  $\alpha$  to  $\beta$  (denoted by a blank), a multiple routing table to be checked (denoted by a B), or identity of ports  $\alpha$  and  $\beta$ 

A-55

(denoted by an N). If a multiple routing table is specified, let  $\gamma$  be the numerical code given. Then the ( $\gamma$ ,1) and ( $\gamma$ ,2) entries in the multiple routing table gives the intermediate port for each of the two options, supertanker and non-supertanker.

### CORRECTION PROCEDURE:

<u>Either</u> enter changes simultaneously in the final version, original version, and Mediterranean supplement of Routing Table, <u>or</u> enter changes in the original version and Mediterranean supplement, then rerun program ALPHA. After <u>any</u> changes, the following programs must be rerun: GAMMAL. After changes affecting ports linked by direct routes, the following programs must be rerun: BETAL, BETA, BETA2, GAMMA2. If these modifications cause the number of Sigla to exceed 506, programs BETA and BETA2 will need to be modified internally as well. 2. TABLE: Routing Table (Alpha) (Original Version) REFERENCE PARAMETERS:

> DSNAME = CN5054.PS1.RTNGTBL.ORG VOL = SER = PUBL03 UNIT = 3330 DCB = (RECFM=FB,LRECL=60,BLKSIZE=3120)

SOURCE: Entered from the Ocean Routes Envelopes Report, with corrections (attached).

USAGE: Used by program Alpha to build the final version of the Routing Table.

FORMAT: 1. Routing Table 50x50 matrix, entered in 50 groups of 50 entries each. Each group spans 3 lines with 20 entries each on lines 1 and 2 and 10 entries on line 3. Otherwise, like Routing Table (final version).

> 2. Multiple Routing Table 4x2 matrix, arranged as . in the Routing Table (final version).

FUNCTION: As in the Routing Table (final version), except that the Mediterranean canonical ports are excluded.

CORRECTION STATUS PROCEDURE:

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See Routing Table (final version).

A-57

3. TABLE: Routing Table (Alpha) (Mediterranean Additions)

### **REFERENCE PARAMETERS:**

DSNAME = CN5054.PS1.RTNGTBL.ADD VOL = SER = PUBL03 UNIT = 3330 DCB = (RECFM=FB,LRECL=72,BLKSIZE=3096)

SOURCE: Entered from the Ocean Routes Envelopes report, with corrections (attached).

USAGE: Used by program Alpha to build the Routing Table (final version).

FORMAT: 1. Routing table 24x24 matrix, entered in 24 lines of 24 entries each.

FUNCTION: It is like the Routing Table (final version), but it includes only Mediterranean canonical ports. Indexing of the port numbers differs from that of final version, and is related to it by the Mediterranean port/ route renumbering table.

CORRECTION STATUS PROCEDURE:

See Routing Table (final version).

4. TABLE: Mediterranean Port/Route Renumbering Table REFERENCE PARAMETERS:

> DSNAME = CN5054.PS1.WYLIB (PORTNO) VOL = SER = WYLIB 1

Wylbur Edit Format

SOURCE: Generated by program Alpha while building the final Routing Table.

USAGE:

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port numbers assigned to the Mediterranean's additional ports and routes.

FORMAT: Lists of new canonical port, route number and the corresponding Mediterranean additional port numbers and routes, as used in the ORE report. 5. TABLE: Route Trees (Original Form)

### **REFERENCE PARAMETERS:**

DSNAME = CN5054.PS1.ENVELOPE VOL = SER = PUBL03 UNIT = 33% DCB = (REC<sup>MAREFB</sup>,LRECL=80,BLKSIZE=3120) Sequenced in columns 73 through 80.

SOURCE: Entered from the ORE report, with subsequent corrections. USAGE: Used by program Beta to generate the final form of Route Trees and various indices. ι,

FORMAT: 84 groups containing a variable number of lines, corresponding to each of the 84 canonical routes. Each group is headed by a marker card with an'R' in column 1 and the 2-digit route number in columns 3/4. Each line within the group represents a separate vertex, except when alternate data must be entered for the various seasons. In this case, a group of four lines represents a vertex, with the season code ('P' for spring, 'S' for summer, 'F' for fall, 'W' for winter) punched in column 1. Data fields on each line and formats are as follows:

# Columns

1	Route Heade	er or	season	marker	
2/5	Edge width	(F4.2	2)		

- 6/10 Latitude (2-digit degree, 2-digit minute, 1-letter hemisphere code (N or S)
- 17/20 Vertex width (F4.2)

21 Always blank

22/23 If the vertex is identical with a canonical port, the canonical port number was inserted, otherwise it remained blank

Columns 24 Always Blank 25/48 Binary identifier 49 If the vertex is identical with a canonical port, a direction code, as follows: Blank Entrance and Egress point 1 Entrance point only 2 Egress point only FUNCTION: It provides the basic tree structure, which was obtained from the ORE Report. It is used to create the final form of the Route Trees by program Beta. CORRECTION STATUS Errors detected by BETA program corrected. Errors detected by examining output from BETA2 and DELTAl have been corrected.

CORRECTION PROCEDURE:

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Enter corrections, then rerun programs BETA, BETA2 and GAMMA2.

6. TABLE: Route Trees (Final Form)

VERSIONS: 4 (one for each season)

**REFERENCE PARAMETERS:** 

DSNAME = CN5054.PS1.OUTENV.SPRING, CN5054.PS1 OUTENV.SUMMER, CN5054.PS1.OUTENV.FALL, CN5054.PS1.OUTENV.WINTER

VOL = SER = PUBL03UNIT = 3330

DCB = (RECFM=FB, LRECL=55, BLKSIZE=3135)

SOURCE: Generated by program Beta from Route Trees (original version)

USAGE: Used by program BETA2 to build the PORT DISTANCE TABLE, and also in Theta to distribute the ships across the routes.

FORMAT: Approximately 800 lines, each containing data for a single vertex as follows:

Columns

1/24 Vertex Identifier (Binary)

- 25/30 Vertex Latitude (F6.2) (Decimal Degrees) (Negative - Southern Hemisphere, Positive - Northern Hemisphere)

38/41 Vertex Width (F4.2)

42/47 Edge Length (F6.2) (In Latitudinal Degrees)

- 42/51 Edge Width (F4.2)
- 52/55 Back Pointer (I4)
- FUNCTION: Determine the Siglum assigned to a given pair of canonical ports from the Siglum Table. Look up this Siglum on the INDEX TO ENVELOPE BY SIGLUM. The two line numbers contained in this table point to the verticies in the ROUTE TREE ENVELOPES corresponding to these ports. From each of these vertices, trace the Route Trees backwards using the back pointer

until the first common parent node is encountered. This may be most easily determined by comparing the identifiers. Alternatively, use the INDEX TO ENVELOPE BY ROUTE to locate the root node of the tree structure for any given route. Look up the Siglum Map as well, using the route number. The list of sigla given here for that route may now be used to determine the terminal leaves of the Route Tree by looking them up in the INDEX TO ENVELOPE BY SIGLUM.

### CORRECTION STATUS:

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As for Route Trees (original version).

### CORRECTION PROCEDURE:

Make all changes to the original version of the Route Trees (or to Routing Table), then rerun BETA to update indices as well. The following programs must then be rerun: BETA2, GANNA2. 7. TABLE: Siglum Table

## **REFERENCE PARAMETERS:**

DSNAME = CN5054.PS1.SGLMTBL
VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM=FB, BLKSIZE=3096, LRECL=72)

SOURCE: 1. Siglum Table: constructed by program BETAL from final version of RTNGTBL.

2. Multiple Routing Table: carried from Routing Table, final version.

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USAGE: Will be used in EPSILON

FORMAT: 1. Siglum Table: 69x69 matrix, corresponding to each possible pairing of world canonical ports, entered in 69 groups of 65 entries each. Each group spans 4 lines, with 18 entries in each of the first 3 lines and 15 in the last. Each entry consists of: a. A 1-letter-code, determining meaning of the

accompanying number:

P Canonical Port

Blank Siglum

B Multiple Routing Table Index

N Null entry

b. A 3-digit number, with meaning as specified by (a).

2. Multiple Routing Table: See Routing Table, final version.

FUNCTION: Like the Routing Table, except that route numbers have been replaced by sigla. To every ordered pair of canonical ports linked by a canonical route a different siglum is assigned. This siglum may be used later to retrieve the route trees, and ship table.

CORRECTION STATUS:

As for Routing Table.

A-64

# CORRECTION PROCEDURE:

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Make all corrections to routing table, then rerun BETAL to update indices as well. The following procedures must also be rerun: BETA, BETA2, GAMMA2.

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### 8. TABLES: Siglum Indices

# **REFERENCE PARAMETERS:**

DSNAME = CN5054.PS1.SGLMNDX VOL = SER = PUBL03 UNIT = 3330, DCB = (RECFM=FB, LRECL=72, BLKSIZE=3096)

SOURCE: Built by program BETAl while constructing the Siglum Table .

USAGE: Used by program BETA while constructing route envelope tree indices, and by GAMMA while checking them.

Inverse Siglum Table: Headed by word 'INV# FORMAT: 1. SGLM#TBL', followed by a list of number pairs, with 12 pairs per line and 2 spaces between pairs. Each pair corresponds to a successive siglum, and contains two 2-digit numbers specifying the pair of canonical ports (origin and destination, in order) associated to that siglum. (WARNING: The current version of BETA expects up to 506 entries in the INV#SGLM#TBL, corresponding to a maximum of 506 sigla. If this limit is exceeded, BETA must be modified. If less than 506 sigla exist, INV# SGLM#TBL may need to be padded with blank lines to simulate this number.) 2. Siglum Map: Headed by word 'SGLN#MAP'. Con-

tains 85 canonical routes, each requiring three lines. Each group contains a header entry plus 45 entries (15 per line) in I4 format beginning in Column 3. The header entry is in I2 format and begins in Column 1 of the first line of each group. The header entry specifies the number of port pairs linked by that canonical route (or equivalently, the number of sigla assigned to each route). These sigla themselves follow as a list in the regular entries, with excess entry positions set to 0.

FUNCTION:

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Let x be a given siglum number. Then the x-th entry in the Inverse Siglum Table gives the port pair associated with that siglum. (If this port pair were looked up in the Siglum Table, the corresponding entry there would be x). Let y be a canonical route number. Then the y-th group of entries in the Siglum Map gives all sigla corresponding to that route.

CORRECTION STATUS:

As for Routing Table.

# CORRECTION PROCEDURE:

Make all changes to Routing Table, then rerun BETAL, to update Siglum Table as well. Following programs must then also be rerun: BETA, BETA2, GAMMAL.

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9. TABLE: Envelope

**REFERENCE PARAMETERS:** 

DSNAME = CN5054.PS1.ENVINDX VOL = SER = PUBL03 UNIT = 3330 DCB = (RECFM=FB, LRECL=72, BLKSIZE=3096)

SOURCE:

Built by program BETA from Route Envelope Trees and Siglum Indices.

USAGE: Used by program BETA2 when building Port Distance Table, and by GAMMA and THETA whenever referencing Route Trees Table. Also for debugging Route Trees and Routing Table.

FORMAT: 1. Index to Envelope by Route headed by word 'INDX#ENVLP#BY#ROUTE', followed by 84 numbers in (I4,2X) format with 12 numbers per line, forming 7 lines.

> 2. Index to Envelope by Siglum immediately follows index to envelope by route. Headed by word 'INDX# ENVLP#BY#SGLM' followed by one pair of numbers for each siglum in (14, I4, 4X) format with 6 pairs per line. (There are currently 501 sigla, hence 501 such pairs).

FUNCTION: See Route Trees (final version). A '0' anywhere except at the end of the Index to Envelope by Siglum indicates that a leaf was missing or not correctly identified as a canonical port in the tree structures (original version), or that an incorrect route was specified in the routing table. (A 0 at the end occurs if the number of sigla < 506).

CORRECTION STATUS:

As for Route Trees and Routing Table.

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# CORRECTION PROCEDURE:

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Make all changes in original version of tree structure or in routing table. Then rerun BETAl (for changes in routing table) and BETA (always). Before re-running BETA, pad the siglum index with blank lines, if necessary to simulate 506 sigla. Following programs must then also be rerun: BETA2, GAMMA2.

10. TABLE: Port Distance Table

VERSIONS: 4 (one for each season)

**REFERENCE PARAMETERS:** 

DSNAME = CN5054.PS1.PRTDIST.SPRING VOL = SER = PUBL03 UNIT = 3330 DCB = (LRECL=72, BLKSIZE=3096, RECFM=FB)

SOURCE: Generated by BETA 2 program from route trees (final version, copy appropriate to given season) and Index to Envelope by Siglum.

USAGE: Used by GAMMA2 to construct estimated travel time table, and also in Epsilon to build the Ship Days Table.

FORMAT: One pair of numbers in (1X,14,1X,F6.2) format for each siglum (currently approximately 500 in all), with 6 pairs in a line. The first number in each pair is the number of the siglum to which the pair corresponds, the second, the distance (in units of latitudinal degrees) between the pair of canonical ports corresponding to that siglum.

CORRECTION STATUS:

As for Routing Table.

CORRECTION PROCEDURE:

Nake all changes in Routing Table or Route Trees then re-run BETA1, BETA, and BETA2. Program GANNA2 must then also be rerun to construct new Estimated Travel Time Table.

FUNCTION: Determine siglum corresponding to port pair linked by direct route, look up in Port Distance Table to determine distance between them. Unreasonable distances indicate poor routings by Routing Table or route trees. 11. TABLE: Estimated Travel Time Table
VERSIONS: 4 (one for each season)

**REFERENCE PARAMETERS:** 

DSNAME = CN5054.PS1.TRAVTME.SPRING VOL = SER = PUBL03 UNIT = 3330 DCB = (RECFM=FB, BLKSIZE=3096, LRECL=72)

SOURCE: Built by Program GAMMA2 from Siglum Table and Port Distance Table.

USAGE: To be used by GAMMA when needed to reconstruct arrival/departure dates.

FORMAT:

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69x69 matrix each entry corresponding to every possible corresponding port pair, whether linked by direct route or not. These entries are arranged in 69 groups of 69 entries each, with each group spanning 4 lines with 18 entries each in lines 1-3 and 15 entries in line 4. (The Siglum Table is laid out similarly). Each entry is in I4 format and gives either (if positive) the expected travel time in integral days between the two ports or else (if negative) an index to the Multiple Travel Time Table. This is followed immediately by the Multiple Travel Time Table, consisting of pairs of numbers in (I4, I4) format, one pair per line, giving the estimated travel times for each of the 2 type classes (super-tanker, non-super tanker).

PUNCTION:

Let (x, y) denote a pair of canonical ports. Then the (x, y) entry gives the estimated travel time between these to ports, unless it is negative. In that case, let its absolute value be 2, then the 2th pair in the Multiple Travel Time Table gives the estimated travel time between those two ports for each of the type classes. Unreasonable travel times indicate poor Routing Table or Route Trees. Travel time estimates assume velocity of 12 knots.

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CORRECTION STATUS:

As for Routing Table and Route Trees.

CORRECTION PROCEDURE:

Make changes in Routing Table and Route Trees. Then rerun programs BETA, BETA1, BETA2, and GAMMA2. 12. TABLE: Port Table

### **REFERENCE PARAMETERS:**

DSNAME = CN5054.PS1.NEWPORT.VOL = SER = PUBL03UNIT = 3330DCB = (RECFM=FB, BLKSIZE=3120, LRECL=80)Sequenced 73/80 (Old version: DSNAME = CN5054.PS1.PORTTBL.)

SOURCE:

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Hand corrections to output from the ORE report program, which used DOT port table.

Used by GAMMA1 to build Port Hash Table, and by USAGE: GAMMA to assign ports to proper canonical ports.

FORMAT: The line number of each entry in the Port Table is the port number used by DOT. The first field contains a new port number, which is usually the same but differs in the following cases:

1. Port abbreviation occurs with several spellings port numbers reset to assign the same port number to all variants.

2. Port name is a generic term (such as East Coast U.S.) - port number is flagged with a negative sign. The other fields give latitude, longitude of port and assigned canonical port.

CORRECTION STATUS:

Mediterranean canonical port assignments, enter variant spellings and generic names flagged. Errors discovered by DELTA2 are corrected in NEWPORT, with generic names not flagged in PORTTBL.

**CORRECTION PROCEDURE:** 

Enter corrections directly, then rerun GANNAL.

13. TABLE: Port Hash Table (Machine Readable Form)

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.PRTHASH, VOL = SER = PUBL03 UNIT = 3330 DCB = (RECFM=F , LRECL=10000)

SOURCE: Built by program GAMMA1 from port table.

USAGE: Used by program GAMMA to determine the port number assigned to each port abbreviation.

FORMAT:Machine readable only. Each bin consists of 10<br/>bytes, as follows:ByteContents1/6Port Abbreviation (character)7/8Port number (fixed binary (15) )9/10Overflow pointer (fixed binary (15) )

The prime area currently contains 2999 bins, and the overflow area contains 2001 bins.

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CORRECTION STATUS:

Does reflect flagging of variant spellings and generic names in the port table.

CORRECTION PROCEDURE:

Nake changes (if any) in Port Table, then rerun program GAMMAL.

FUNCTION: Take character string value of the port abbreviation, treat it as a number, then divide it by 2999 (or other prime number, if this is changed), use this as bin index. Compare port abbreviations, if they are the same, then the port number is as given in that bin. Otherwise, use overflow pointer as the new bin index (to overflow area) and repeat this until either port abbreviation is found, or overflow printer = 0, in which case port abbreviation is not in port table.

X-74

(CONT)13. TABLE: Port Hash Table (People - readable form). REFERENCE PARAMETER:

> DSNAME = CN5054.PS1.HASHOUT VOL = SER= PUBL03

UNIT = 3330

DCB = (RECFM = FB, LRECL = 18, BLKSIZE = 1900) SOURCE: Built by program GAMMA 1 from PORT TABLE. USAGE = People - readable form of PORT-HASH TABLE -

no other function.

FORMAT:

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Antwine and the second on

Standard Local Mark and a Statistical State

[]

Columns	Field
1/6	Port Abbreviation (Character)
7/8	Blank
9/12	Port Number (14)
13/14	Blank
15/16	Overflow Index (I4)

First 2999 records belong to prime region, remainder to overflow.

FUNCTION: Same as PORT HASH TABLE (machine-readable form). CORRECTION STATUS, PROCEDURE: Same as PORT HASH TABLE (machinereadable form). 14. TABLE: Sextile Array REFERENCE PARAMETERS:

> DSNAME = CN5054.PS2.X13FALL,CN5054.PS2.X13W, CN5054.PS2.X13SP,CN5054.PS2.X13SU

VOL = SER = PUBL 03

DCN = (RECFM = FB, LRECL = 80, BLKSIZE = 3120)

SOURCE: A supplementary program entitled Newton which processed the sextile points created by the ORE.

USAGE: Used by program Theta to help produce the Merchant Counts Array

- FORMAT: An array which varies in sizes from 29x13 to 31x31 according to seasons. The first group of thirteen elements spans two lines. The first line has 7 entries in F10.5 format and the second line has 6 elements in the same format.
- FUNCTION: It takes the Type I' Cubic Splines consisting of seven sextile points from the ORE work. These points are then normalized to the interval [-1,1], and the five intermediate sextile points which were determined by Newtons method will describe the distribution. This data is stored in the Sextile Array and is accessed via the Cubic Spline Pointer Table. The last set of points is the general default spline.

] [

15. TABLE: Cubic Spline Pointer Table

**REFERENCE PARAMETERS:** 

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DSNAME = CN5054.PS2.POINTR.SP,CN5054.PS2.POINTR. SUMMER CN5054.PS2.POINTR.FALL,CN5054.PS2.POINTR. WINTER

34

VOL = SER = FUBL 03

DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 3120) SOURCE: Hand generated according to given route USAGE: Used by program THETA as one of the inputs to help create the Marchants Count Array FORMAT: There are 7 lines with 12 numbers on each line in I3,3X format FUNCTION: This table contains the pointers to the Sextile Array. This table contains 85 entries, one for

each route, one per season.

A-77

16. TABLE: Proto Routing Table REFERENCE PARAMETERS:

> DSNAME = CN5054.PS1.PROTO48,CN5054.PS1.PROTO44, CN5054.PS1.PROTO40,CN5054.PS1.PROTO35, CN5054.PS1.PROTO31,CN5054.PS1.PROTO27, CN5054.PS1.PROTO22,CN5054.PS1.PROTO18, CN5054.PS1.PROTO14,CN5054.PS1.PROTO09, CN5054.PS1.PROTO05,CN5054.PS1.PROTO01

VOL = SER = PUBL03

DCB = (REFM = FB, LRECL = 80, BLKSIZE = 3520)

SOURCE: Built by program GAMMA while processing the Lloyds data base.

USAGE: Used by program EPSILON to produce the Ships Days Table by month.

There are three 69x69 arrays one for merchants, FORMAT: tankers less than 70,000gt, and tankers greater than 70,000gt. The first line of each array indicates which month is being processed for example WEEK = 35. The second line indicates the shiptype for example, TAU = 1. The 69x69 array signifies the number of canonical ports, of a given shiptype in a given month. The format is as follows: line 1 contains message WEEK = , line 2 has TAU = . The 69 groups of 69 entries each spans five lines with 16 entries each in lines 1-4 and 5 entries in line 5. Each entry is in. 15 format. Therefore the format is as follows: 4(1615/),515. The code for the ship types and months are as follows:

TAU = 1 signifies that the following table consists
 of the number of ship days for merchant vessels
 between pairs of canonical ports

A-78

TAU = 2: signifies that the following table consists of the number of ship days for tankers under 70,000 gt. between pairs of canonical ports TAU = 3: signifies that the following table consists of the number of ship days for tankers over 70,000 gt. between pairs of canonical ports WEEK = 1 represents the month of January WEEK = 5 represents the month of February WEEK = 9 represents the month of March WEEK = 14 represents the month of April WEEK = 18 represents the month of May WEEK = 22 represents the month of June WEEK = 27 represents the month of July WEEK = 31 represents the month of August WEEK = 35 represents the month of September WEEK = 40 represents the month of October WEEK = 44 represents the month of November WEEK = 48 represents the month of December Let (x, y) denote a pair of canonical ports.

FUPCTION:

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Let (x,y) denote a pair of canonical ports. Then the (x,y) entry gives the total number of days that ships have been enroute between ports x and y. 17. TABLE: Ship Days Table

**REFERENCE** PARAMETERS:

DSNAME = CN5054.PS1.SHP.DAYS48,CN5054.PS1.SHP.DAYS44, CN5054.PS1.SHP.DAYS40,CN5054.PS1.SHP.DAYS35, CN5054.PS1.SHP.DAYS31,CN5054.PS1.SHP.DAYS27, CN5054.PS1.SHP.DAYS22,CN5054.PS1.SHP.DAYS18, CN5054.PS1.SHP.DAYS14,CN5054.PS1.SHP.DAYS09, CN5054.PS1.SHP.DAYS05,CN5054.PS1.SHP.DAYS01

VOL = SER = PUBL03

DCB = (RECFM = FB, LRECL = 72, BLKSIZE = 3096)

- SOURCE: Built by program EPSILON from the Proto Routing Table, Siglum Table and Routing Table.
- USAGE: Used by program Theta to produce the Merchants Count Array
- FORMAT: The format of the Ship Days Table is similar to that of the Proto-Routing Table. There are again three different ship types; TAU = 1, TAU = 2, TAU = Each class is composed of 501 elements and is 3. listed according to siglia i.e., canonical ports that are linked by a direct route. Following this lies the Residual Table, again for each ship type. Heading the table is the specified TAU, Then the 500 element vector spans 63 lines where the first 62 lines contain eight elements in F9.1 format and line 63 has five entires in the same format. Then there is a header entitled RESIDUAL TABLE. The following 69 entries, corresponding to the canonical ports, which span six lines. The first five lines contain 12 entires in 16 format and the sixth line has nine entries in 16 format.

17. TABLE: Ship Days Table REFERENCE PARAMETERS:

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DSNAME = CN5054.PS1.SHP.DAYS48,CN5054.PS1.SHP.DAYS44, CN5054.PS1.SHP.DAYS40,CN5054.PS1.SHP.DAYS35, CN5054.PS1.SHP.DAYS31,CN5054.PS1.SHP.DAYS27, CN5054.PS1.SHP.DAYS22,CN5054.PS1.SHP.DAYS18, CN5054.PS1.SHP.DAYS14,CN5054.PS1.SHP.DAYS09, CN5054.PS1.SHP.DAYS05,CN5054.PS1.SHP.DAYS01

VOL = SER = PUBL03

DCB = (RECFM = FB, LRECL = 72, BLKSIZE = 3096)

SOURCE: Built by program EPSILON from the Proto Routing Table, Siglum Table and Routing Table.

USAGE: Used by program Theta to produce the Merchants Count Array

The format of the Ship Days Table is similar to FORMAT: that of the Proto-Routing Table. There are again three different ship types; TAU = 1, TAU = 2, TAU = 3. Each class is composed of 501 elements and is listed according to siglia i.e., canonical ports that are linked by a direct route. Following this lies the Residual Table, again for each ship type. Heading the table is the specified TAU. Then the 500 element vector spans 63 lines where the first 62 lines contain eight elements in F9.1 format and line 63 has five entires in the same format. Then there is a header entitled RESIDUAL TABLE. The following 69 entries, corresponding to the canonical ports, which span six lines. The first five lines contain 12 entires in 16 format and the sixth line has nine entries in 16 format.

A-81

. . FUNCTION: The 500 element vector represents the total number of ship days for the given siglia. The Residual Table stores the number of ships to be distributed for local traffic and 'non-route' traffic about the canonical ports. A-82

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