An Algorithm For Generating Ship Streams For A Computer Simulation Program Of A Coal Export Terminal

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Abstract: In an ever changing world, the size distribution of ships visiting a port changes as the port exports to different markets. Data analysis has shown that some countries use ships that have characteristics which require more time to load proportionally than others. Small capacity ships with derricks have proportionally longer berth commitment times than large capacity ships without derricks. The total tonnage that can be shipped through a port can be greatly influenced by the type and size of ships that visit the port. The program used to generate the ship streams for the simulation program uses the historical data of ships that have visited the port and generates a ship stream that takes into account the forecast shipments to various markets. Some markets may increase the tonnages shipped through the port while others may reduce their usage of the terminal. On the other hand, some markets may not change their usage, but proportionally reduce their usage of the port as the total throughput of the port increases. In the case of a first time user of the ports facilities the user is questioned as to the type of ships that will be used to transport the coal so that the appropriate type of ships can be specified in the ship generation program. For each market, the generation program randomly chooses ships from a list of appropriate ships until all that markets needs for ships has been fulfilled. As each ship is placed in the final list, it is tagged with a pseudo random number between zero and one. Whence all the markets have been serviced by the program the list of generated ships is sorted on the basis of the tagged number.

1. INTRODUCTION

1.1 Generating Arrivals

In most simulation models, the generation of arrivals is undertaken by a random variate generator; according to a predetermined probability distribution. This distribution is based on historical data, which may be used with or without the estimation of parameters of the distribution. In such cases, it is assumed that arrival patterns in the future will continue to be similar to the past, but that is not always the case.

1.2 Coal Export Scene

However it has been observed that great variations exist in the type and size of the ships that visit the bulk coal terminal over the years. This is due to numerous factors such as the changing market penetration of the various exporters, new mines being opened up, and new markets being captured. This is further complicated because of the use of different size and types of ships by various importers who are responsible for dispatching the ships. As coal is sold well in advance of delivery date, the exporters can forecast their shipping requirements reasonably accurately up to a year in advance. This makes it possible to have a ship generation routine that can produce a ship arrival stream that is closer to reality than using pure historical data.

1.3 Ship Characteristics

Data for 1098 ships, for the period 1 July 1992 to 30 June 1996, were made available by the bulk export terminal. This data was statistically analysed and it was found that ships serving various markets varied greatly in their characteristics. The characteristics that were studied are listed below.

- Summer DWT
- Vessel Type
- Summer Draft
- Tonnes/cm Immersion
- Min. De-ballasting Time
- Number of Hatches
- Number of Loaded Hatches
- Nominal Hatch Capacity Tonnes
- Draft Survey Tonnage
- Market
- Number of Products Loaded
- Tonnage of Each Product Loaded

From these characteristics, certain other factors were derived, such as single or multi product shipments and whether the ship was partial or fully loaded.

1.4 Objectives

The primary objective of this study was to produce a ship stream generation routine that could be used with the computer models of the terminal's operations. Another objective was to ascertain the markets that were relatively more expensive to ship to in a quantitative manner. In view of the varying characteristics of ships going to various markets and the differences in ships carrying steaming and coking coals to the same market, it is imperative that a flexible ship stream generation routine be used. The generation routine can produce appropriate ship streams in response to the changes in market penetration of the various exporters using the terminal.

2. MARKETS, TONNAGES AND SHIPS

2.1 Ship Characteristics

Ship characteristics and size distributions vary greatly from market to market.

Table 1:
Type and Number of Ships Separated by Markets

Country	GBC		BC	
	Number	%	Number	%
Algeria	0	0	14	100
Australia	4	57	3	43
Belgium	0	0	22	100
Brazil	1	2	61	98
Chile	18	62	11	38
China	9	45	11	55
Denmark	0	0	24	100
Egypt	0	0	1	100
Germany	0	0	1	100
Holland	0	0	5	100
Hongkong	4	7	54	93
India	138	83	28	17
Iran	19	83	4	17
Israel	0	0	1	100
Italy	0	0	5	100
Japan	36	8	424	92
Korea	0	0	75	100
Malaysia	0	0	25	100
New Cal	1	100	0	0
Pakistan	0	0	1	100
Portugal	0	0	2	100
Romania	0	0	2	100
Spain	0	0	7	100
Sweden	0	0	3	100
Taiwan	2	4	48	96
Thailand	1	25	3	75
Turkey	2	15	11	85
U. K.	0	0	18	100

One of the major reasons that some markets use small ships rather than the more economical larger ships is the draft restrictions at the ports of discharge. This is evident when looking at data of ships that sail into the Bay of Bengal where ports are relatively shallow. Some discharge ports do not have unloading facilities and therefore must be served by ships that have the capability to unload their cargo. These ships are geared bulk carriers. However, they have the disadvantage in loading as the time required for the shiploader to change from one hatch to another is about twice of that required for a non-geared ship. From Table 1 it can be seen that 16 markets are served exclusively by non-geared ships, one is served exclusively by a geared ship, and eleven markets are served by both. In the markets serviced by both geared and non-geared ships, one type usually dominates. Non-geared bulk carriers are predominant in six markets and geared bulk carriers dominate in two. In the other three markets the numbers are too close to say that one type dominates.

2.2 Tonnages to Various Markets

The bulk loading terminal exported to 28 different markets over the four years period for which data is presented in Table 2.

Table 2:
Tonnages and Number of Ships Separated by Markets

Market	Number of Ships	Total Tonnage Shipped	Average Draft Survey Tonnage
Algeria	14	801,584	57,256
Australia	7	252,690	36,099
Belgium	22	1,450,429	65,929
Brazil	62	2,833,185	45,697
Chile	29	1,336,913	46,100
China	20	810,625	40,531
Denmark	24	3,519,607	146,650
Egypt	1	48,110	48,110
Germany	1	120,017	120,017
Holland	5	676,159	135,232
Hongkong	58	5,200,429	89,663
India	166	7,620,421	45,906
Iran	23	927,402	40,322
Israel	1	58,203	58,203
Italy	5	346,985	69,397
Japan	460	37,923,659	82,443
Korea	75	7,745,487	103,273
Malaysia	25	1,606,230	64,249
New Cal	1	20,442	20,442
Pakistan	1	40,027	40,027
Portugal	2	125,362	62,681
Romania	2	232,625	116,313
Spain	7	765,360	109,337
Sweden	3	198,970	66,323
Taiwan	50	4,349,601	86,992
Thailand	4	260,875	65,219
Turkey	13	823,150	63,319
U. K.	18	1,265,792	70,322
Total	1099	81,360,339	74,031

Six major markets account for nearly 80% of all tonnage. From Table 2, it can be clearly seen that the average draft survey tonnage of ships varies greatly from market to market. The range is from 146,650 tonnes for ships going to Denmark to a 20,442 tonne ship going to New Caledonia. The tonnage shipped to various markets does not closely reflect the numbers of ships going to the corresponding market. From Table 2, it can be clearly seen that Japan is the major destination market for coal shipped through the terminal accounting for 46.6% of the total coal throughput and 41.9% of all ships for the four year period. In the same period, India imported a similar quantity of coal to Korea, but India accounted for 15.1% of the ships whilst Korea only accounted for 6.8% of ships. This is of great importance to operations of the terminal due to the relative increase in hatch change delays when loading small ships. In view of the great variations in average shipment size from market to market, any shift in the proportion of coal going to various markets will greatly effect the size distribution of ships visiting the terminal and thus effect the potential throughput of the bulk loading terminal.

Another notable characteristic is that almost half the markets took less than 2 ships per year. From Tables 3a and 3b, it can be seen that ships carrying steaming coal and coking coal to the same market also have different characteristics. For example, ship carrying steaming coal to Japan have an average DWT of 76,507 tonnes whereas ships carrying coking coal to the same market average 116,191 tonnes. Ships transporting steaming coal to Korea average 68,810 tonnes whist ships carrying coking coal to this market have an average DWT of 173,811. Their DWT range for coking coal is six fold whereas for steaming coal the minimum DWT is only 75% of the maximum. Due to the different characteristics in shipments of coking and steaming coal, ship streams for steaming and coking coals were generating with separate progams.

Table 3a:
DWT and Number of Ships Loading Steaming Coal Separated by Markets

Country	Number of Ships	Max DWT	Min DWT	Mean DWT
Chile	25	70,402	34,219	50,241
China	11	127,050	37,871	52,608
Denmark	24	214,263	138,655	160,305
Holland	3	169,381	151,014	157,565
Hongkong	58	145,370	45,345	93,940
India	4	43,656	22,549	32,088
Israel	1	146,019	146,019	146,019
Japan	303	149,505	33,024	76,507
Korea	21	81,783	61,451	68,810
Malaysia	25	76,384	64,871	65,358
Taiwan	20	149,500	62,703	87,075
Thailand	4	70,424	59,460	66,648

Table 3b:
DWT and Number of Ships Loading Coking Coal Separated by Markets

Country	Number of Ships	Max DWT	Min DWT	Mean DWT
Algeria	14	72,017	64,657	67,291
Australia	7	61,972	21,735	41,463
Belgium	22	129,882	62,267	78,327
Brazil	62	194,941	60,740	109,364
Chile	4	43,682	36,241	38,831
China	9	41,378	30,868	37,934
Egypt	1	69,497	69,497	69,497
Germany	1	184,349	184,349	184,349
Holland	2	187,011	68,676	127,844
India	162	73,350	34,554	50,516
Iran	23	70,424	35,110	44,565
Italy	5	157,650	71,363	107,013
Japan	166	182,711	21,340	116,191
Korea	54	231,851	37,878	173,811
New Cal	1	21,259	21,259	21,259
Pakistan	1	52,630	52,630	52,630
Portugal	2	76,650	69,734	73,192
Romania	2	184,349	150,940	167,645
Spain	7	179,618	61,539	143,860
Sweden	3	73,505	65,362	68,527
Taiwan	30	149,647	65,085	123,811
Turkey	13	146,859	39,728	73,281
U. K.	18	179,618	63,195	81,070

Table 3c:
Dead Weight Tonnages and Number of Ships Loading Both Coking and Steaming Coal Separated by Markets

	COKING COAL			STEAMING COAL		
Country	No	Max DWT	Min DWT	No	Max DWT	Min DWT
Chile	4	43,682	36,241	25	70,402	34,219
China	9	41,378	30,868	11	127,050	37,871
Holland	2	187,011	68,676	3	169,381	151,014
India	162	73,350	34,554	4	43,656	22,549
Japan	166	182,711	21,340	303	149,505	33,024
Korea	54	231,851	37,878	21	81,783	61,451
Taiwan	30	149,647	65,085	20	149,500	62,703

Another important consideration in the time required to load a ship is the number of products that the ship is carrying. Product changes during loading often require relocating yard machinery from one coal stockpile to another. Relocation can sometimes cause longer than normal hatch change delays.

2.3 Steaming and Coking Coal

It can be seen from Tables 3a, 3b and 3c that most markets take either steaming or coking coal and only 7 of the 28 markets take both. It can also be seen that size of ships carrying the two types of coal within the same market varies greatly. Therefore, the steaming coal and coking coal ship streams were generated separately and later combined into one stream.

2.4 Multi Product Loaded Ships

Longer hatch change delays can occur on ships carrying more than one product. Machinery relocation form stockpile to stockpile can be very time consuming, thus the time required for hatch/product change can be significantly longer that for a simple hatch change. For this reason the number of different products that a ship carries can greatly influence the throughput of the terminal and must be considered in the ship generation program. Table 4 shows the variations in multi-to single product loadings from country to country.

Table 4:
Product Analysis of Ships Separated by Markets

Country	Single Product		Multi Product	
	Number	%	Number	%
Algeria	4	29	10	71
Australia	6	86	1	14
Belgium	6	27	16	73
Brazil	33	53	29	47
Chile	29	100	0	0
China	20	100	0	0
Denmark	24	100	0	0
Egypt	0	0	1	100
Germany	0	0	1	100
Holland	4	80	1	20
Hongkong	58	100	0	0
India	161	97	5	3
Iran	23	100	0	0
Israel	1	100	0	0
Italy	3	60	2	40
Japan	316	69	144	31
Korea	44	59	31	41
Malaysia	25	100	0	0
New Cal	1	100	0	0
Pakistan	1	100	0	0
Portugal	2	100	0	0
Romania	1	50	1	50
Spain	3	43	4	57
Sweden	0	0	3	100
Taiwan	34	68	16	32
Thailand	4	100	0	0
Turkey	13	100	0	0
U. K.	15	83	3	17

2.5 Possible Future Changes

The world coal market operates in a very dynamic environment and it is expected that the quantities of coal shipped through the terminal are not likely to remain constant. In the past few years the market penetration of the various exporters has been quite volatile. There is a potential for existing importers to either increase or decrease the number of coal shipments passing through terminal. Some of the importers may no longer use the terminal, and there is the potential for the exporters to find new markets. There may even be new exporters

Another possibility is that a coal buyer may modernise its fleet or discharge port and thereby have an effect on the distribution pattern of ships visiting the terminal.

3. SHIP STREAM GENERATION PROCEDURE

The historical data was separated into two "*EXCEL*" worksheets, one for ships carrying steaming coal only and the other for ships carrying coking coal. The data on each worksheet was grouped by market. For each of these worksheets, an associate "*Visual Basic*" macro was written to generate a new list of ships. Both of the macros follow the same basic algorithm and perform a similar task. The input required for these two macros are a list of total tonnages of each product for each market Table 5 is such a list for steaming coal and list of ships that visited the terminal. This has been sorted by market. Table 6 is a sample of the input list of ships loading steaming coal that serviced one of the markets.

It should be noted that coal types B and D are new types of coal that have not been exported through the terminal as yet. Provision for them was made in the program, as it is anticipated that the export of these coal types will commence in the foreseeable future.

Figure 1 is a flow chart of the basic algorithm that is used for ship stream generation. The tolerance and reject counter ensure that the algorithm terminates. It was found that for some of the markets, the tolerance had to be much greater than others especially if there were not many ships to choose from or that all the ships were of similar size. The number of attempts at finding a ship to take the remaining coal at a certain tolerance was set at 20 after some trial and error, and was a compromise of execution speed and a more exhaustive trail of the ships available to carry the coal.

Table 5:
A Sample Input List For Generating a 10 Year Ship List of Steaming Coal at a Throughput of 37 MTPA

Market	Coal A	Coal B	Coal C	Coal D
Chile	0	0	5,232,031	0
China	0	0	12,133,952	0
Denmark	0	0	34,020,304	0
Hongkong	0	0	52,739,543	0
India	0	0	1,194,513	0
Israel	0	0	590,259	0
Japan	0	0	212,396,494	0
Korea	0	0	16,289,394	0
Malaysia	0	0	4,391,401	0
Holland	0	0	13,760,143	0
Taiwan	635,855	0	14,624,899	0
Thailand	0	0	2,645,633	0

Table 6:
Sample Input List of Ships that Carried Steaming Coal to China.

Ship No	DWT	Vessel Type	Draft Metres	Immersion Tonnes/ Centimetre	Min. De-ballast Time	No Hatches	No of Loaded Hatches	Hatch Capacity Tonnes	DS Tonnes
93-001	37871	GBC	10.764	45.5	15	5	5	9450	35694
93-115	56233	GBC	13.200	55.3	10	7	7	11448	40560
94-162	56233	GBC	13.200	55.3	10	7	7	11448	38494
94-217	39839	BC	10.000	45.0	8	6	6	8185	38470
94-231	38460	BC	10.246	50.0	24	7	7	8697	36463
94-232	39035	GBC	11.000	55.3	15	6	6	8179	38402
95-114	127050	BC	17.089	105.0	18	9	9	11785	116508
95-176	61902	BC	12.348	60.0	20	7	7	11072	58725
95-271	38460	BC	10.246	50.0	21	7	7	8697	37485
95-302	38460	BC	10.246	50.0	21	7	7	8697	36635
96-067	45149	GBC	11.240	52.6	15	5	5	12259	38473

3.1 Generating Ships For a New Market

For accommodating a new market, the program requires the tonnages of each coal type to be shipped and the key characteristics of ships (ie, size, type) that will be used to carry the coal. Other data required is whether the products will be shipped on their own or in combination with other exporters and whether the ships will be fully or partially loaded. From this information, a ship input list can be assembled from data of similar ship that serve other markets.

3.2 Generating Ships For a New Exporter

An exporter joining shipping operations at the terminal would need to forecast its total shipments to each market to which it would be exporting. There would also be a need for that exporter to advise if any of the markets would be loading with an exiting user, ie, if some single product shipping would become multi product. The user would also have to advise if it were shipping to a port in a country which requires or can handle different ships used by other exporters. This could mean that a country's ship list be broken into to subgroups. Some exporters may export to a shallow river port in a country and others may export to a deep water port in the same country on ships with completely different characteristics.

3.3 Inter-Arrival Times

Inter-arrival times for ships were found to follow a negative exponential distribution as was expected Pegden et al.[1995]. To reproduce a similar distribution of inter-arrival times the mean is required by *"ARENA"*. This can easily be calculated once the ship stream is generated as the number of ships required to carry the product is then known. It is just a matter of dividing the hours to be simulated by the number of ships. Once the mean inter-arrival time is known it can be used as an input into the *"ARENA"* port model. The CREATE module of *"ARENA"* then uses this time to generate the ship arrival times.

3.4 Characteristics of generated Ships

All relevant ship details are read from the list of ships generated by the "*Visual Basic*" macros. Each time a ship is scheduled to arrive by the *"ARENA"* CREATE module, all ship details are read from the next record in the text file where list of ships is stored.

4. CONCLUSION

The algorithm described in this paper gives us a means of generating a ship stream that can be tailored to the changing requirements of the terminal being studied. The same basic algorithm could be used to generate streams of transport vehicles wherever the product to be transported is to be carried vehicles that are not all the same.

5. REFERENCES

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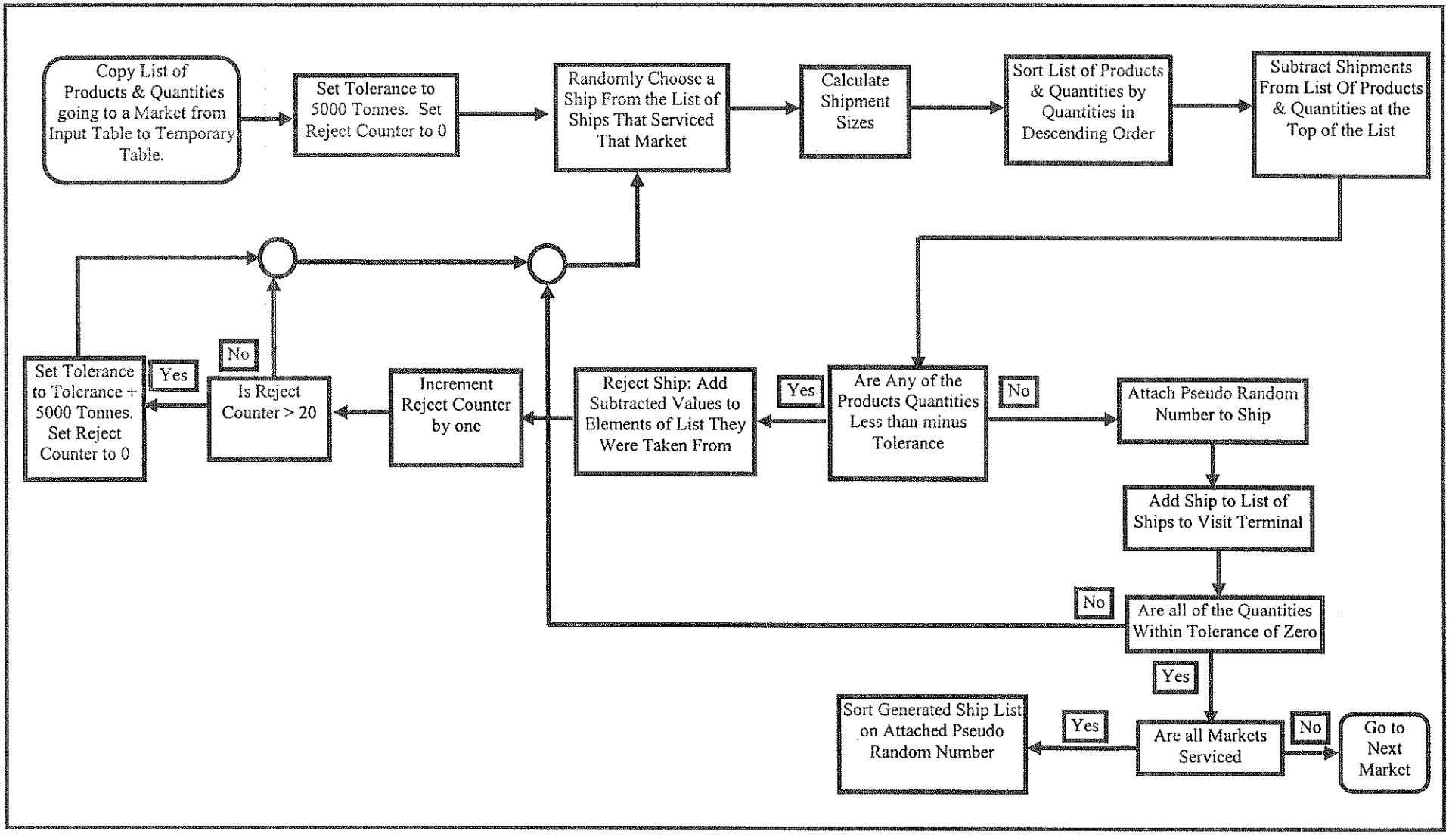

Figure 1
Flow Chart Of The Ship Stream Generation Routine