JOURNAL OF MARITIME RESEARCH

Vol XI. No. III (2014) pp 51–57

ISSN: 1697-4040, www.jmr.unican.es

Classification of Indian Seaports Using Hierarchical Grouping Method

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ARTICLE INFO

Article history:
Received 01 November 2014;
in revised form 03 November 2014;
accepted 01 December 2014.

Keywords:
Seaport Classification, Indian Seaports, Hierarchical Grouping Method, Cargo, Error

ABSTRACT

India is a major maritime nation with a long coastline, spanning about 7516.6 kilometers, constituting 200 ports in east coast and west coast. East coast and the west coast have 54 and 146 seaports, respectively. Indian ports are classified as Major, Intermediate and, Minor ports; this classification has an administrative significance. Nevertheless, the words: major, intermediate, and minor do not have any relation with the cargo volume throughput. This paper suggests a new approach based on temporal cargo variation to classify a port system. The reason to classify port system based on temporal cargo flow is mainly due to its relevance for cargo operation service, making decisions on freight rate, and service quality performance benchmarking. The key issue faced while attempting for evaluating these measures over a large number of ports is the trouble in comparable data collection from all the port locations and defining the criteria for such evaluations, which will be applicable to all ports. Also, individual port evaluation may not be easy while considering a region's port system with heterogeneous number of ports. However, this problem can be cut down by classifying ports into certain homogeneous groups. The proposed classification scheme is applied to classify Indian port system. Due to unavailability of data, the application of the proposed method is restricted to 12 Indian ports only. Based on the analysis we propose to classify the 12 Indian seaports into four groups. This classification scheme can be applied to any port system elsewhere.

1. Introduction

India is a major maritime nation with a long coastline, spanning about 7516.6 kilometers, constituting 200 ports. These ports are strategically located along the two coast lines: East coast and West coast to facilitate international trade and seamless multimodal transportation. The east coast and the west coast have 54 and 146 seaports, respectively (Department of Businees and Innovatioon, 2009; Ministry of Shipping, 2011). The Indian ports are classified as major, intermediate and minor ports. This classification scheme is not representative of the cargo volume handled by the ports. For example, a newly developed Mundra Port classified as minor port handled about 83 million tons of cargo during fiscal year 2012-13; this volume is higher than that at most of the major ports. Literature review on port classification suggested that though there are a number of frameworks for seaport classification, however, no single frame work or terminology is generalized. This study examines some of the earlier studies on seaport classification and proposes a new approach for classifying the seaports. The new classification scheme is based on temporal variations in cargo volume at port locations. In this study, we applied the proposed classification scheme to classify Indian ports. This methodology may also be applied to any port system elsewhere. The reason to classify port system based on temporal cargo flow is mainly due to its relevance for cargo operation service, making decisions on freight rate, and service quality performance benchmarking. The key issue faced while attempting for evalu-

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ating these measures over a large number of ports is the trouble in comparable data collection from all the port locations and defining the criteria for such evaluations, which will be applicable to all ports. Also, individual port evaluation may not be easy while considering a region's port system with heterogeneous number of ports. However, this problem can be cut down by classifying ports into certain homogeneous groups. A classification scheme of ports may give an insight into their operating advantages or disadvantages of the similar ports. The operation level of service gets affected with the variations in cargo volume. Therefore, this paper uses an alternate approach to classify ports based on their volume variations pattern.

To summarize, the purpose of this study is to classify the seaports in India to understand the traffic behavior patterns among the classified ports. The focus is to cluster the ports into an optimum number of groups of ports with reference to the historical monthly tonnage value.

The rest of the paper is organized as follows: Literature review is discussed in the next section. The section following literature review briefly reports about the data used for this study. The subsequent section presents the methodology used for port classification. The classification results are discussed in the next section. The conclusion, discussion, and further scope of this study are presented in the final section.

2. Literature Review

Seaports are often dissimilar from each other, where various cargo operations are carried out by different organizations. Because of dissimilarities in port systems, various operational, organizational and strategic management approaches are used for efficient movement of cargo traffic. Classification of ports may give an insight into their operating advantages and/or disadvantages.

Alderton (Alderton, 2008) classified ports into two large groups: 1) by functions and 2) by geography. By functions, ports are classified based on cargo interface, such as transit port, feeder port, hub port, and domestic port; maritime industrial development area; and specific ship/shore interface such as fishing port, naval port, and specific commodity port; and specific ship/shore interface such as fishing port, naval port, and specific commodity port. The functional classification of ports focuses on 1) regionalization of a port system (Notteboom & Rodrigue, 2005), and 2) integration of shipping and surface based logistics networks (Robinson, 2002). By geography, ports are classified as coastal submergence, tidal, artificial harbors, and river ports. Bichou and Gray (Bichou & Gray, 2005) classified ports as a combined channel system of trade, supply, and logistics. This interpretation relates port services to loading and unloading of cargo. In addition, this explains that a port can supply shippers with value-added logistics services along with services like trade, financial, leisure, and property development. The United Nations Conference on Trade and Development (United Nations Conference on Trade and Development, 1990) suggested another concept for port classification i.e. hub and feeder port system. Ports have also been classified according to their linear development which is known as generation classification. The generation classification defines the port's linear development through its functional and evolutionary change. For example, a global logistics center developed from a regional transport facility from a fishing village. This classification is widely accepted in the maritime industry, which identifies ports on the basis of generation development or evolutionary stage (Fujita & Mori, 1996; Lee, et al., 2008; United Nations Conference on Trade and Development, 1990). The evolutionary stage of a port may be referred to the development of spatial and functional relationship between a port and its corresponding city. Ports can also be divided by different functions. For example, ports integrate their functions as transshipment hubs or regional load centers to improve their competitiveness with respect to globalization or regionalization (Tongzon & Heng, 2005). Ports are also classified according to their size or scope of influence and may be generally identified in the perspective of 1) trade-relation: non-sea borne trade versus sea borne (Sanchez, et al., 2003); 2) section-relation: industrial clusters versus maritime clusters (De Langen, 2002) space-relation: national versus international, feeder versus hub, hinterland versus foreland. Although, there are a number of classification schemes for ports, there is no single classification scheme which is established. All these classification schemes have not much association with the cargo volume throughput; whereas, cargo throughput is a key input for various planning, design, and operational activities relating to different types of ports. The review of the available sample of literature and the foregoing discussion suggested for further investigations on port classification. We have proposed a new classification scheme in the first part of this paper, which is based on temporal variation of cargo volume at different port locations. This methodology is applied to Indian ports and may be applied for classifying any port system elsewhere. The focus of the proposed classification scheme is to develop a systematic approach for port classification based on temporal cargo traffic variation.

3. Study Data

According to the federal structure of Indian constitution, maritime transport is administered by both the central and the state Governments. The federal Ministry of Shipping and the coastal states administer the 200 ports. Our study is restricted to 12 ports only due to the unavailability of data for the remaining ports. Figure 1 shows a map of India with the locations of 12 study ports. Monthly cargo inbound and outbound data from 2002 to 2012 for the 12 ports are collected from Center for Monitoring Indian Economy (CMIE). Table 1 shows the average tonnage share and recent year tonnage values for all the ports under study. The ports are coded with a number for the ease of classification procedure.

4. Methodology

Cargo volume at a given port varies from day to day, and month to month throughout the year. This temporal variation of cargo flow is the basis of the proposed classification scheme.

Table 1: Annual average cargo share for major Ports

Sl. No.	Port Name	Port Code	Annual Average Cargo Share (%)	Cargo Volume (million tons)			
				2012 – 2013	2011 – 2012	2010 – 2011	2009 – 2010
1	Kolkata	1001	8	39.88	43.25	47.55	46.42
2	Paradip	1002	10	56.55	54.25	56.03	57.01
3	Visakhapatnam	1003	12	58.96	67.42	68.04	65.50
4	Chennai	1004	10	53.40	55.71	61.46	61.06
5	Tuticorin	1005	5	28.26	28/11/15	25.73	23.79
6	Cochin	1006	3	19.85	20/09/15	17.87	17.43
7	New Mangalore	1007	6	37.04	32.94	31.55	35.53
8	Mormugao	1008	7	17.69	39.00	50.02	48.85
9	Mumbai	1009	10	58.04	56.19	54.59	54.54
10	JNPT	1010	11	64.50	65.75	64.31	60.76
11	Ennore	1011	2	17.89	14.96	11/01/15	01/10/70
12	Kandla	1012	16	93.62	82.50	81.88	79.50

Figure 1: Thematic diagram of port and airport locations in India

Source: www.mapsofindia.com

The basic presumption made in this analysis to classify ports is that the differences in temporal flow patterns observed at different ports in India. The available samples of literature did not report the port classification based on temporal variation of freight traffic, whereas the temporal variation of cargo has relevance towards port operation, service quality benchmarking, and making decisions on freight rates etc. Therefore, a methodology for port classification based on traffic volume factor is presented in the following subsection.

4.1. Hierarchical Grouping Method for Port Classification

This method of classification is based on the differences in temporal flow patterns at different port locations. It has two approaches (Timm, 2002) Agglomerative (bottom up) and Divisive (top down), and these approaches are commonly used in behavioral research. This method compares a set of 'M' objects (e.g., 12 ports); measured on 'N' variables (e.g., 12 mean monthly cargo volume factors), and clusters them into optimum number of homogenous groups i.e. a group of ports with similar traffic variation pattern. The analysis of cargo volume pattern is defined by 12 monthly average volume factors. The average volume factors are the ratios of the mean monthly daily cargo volume (MMDCV) to annual average daily cargo volume (AADCV) for a given port. In order to compute the average monthly factors the monthly factor for each month in each year is calculated first. This is given in Eq.1. In Eq.1 the average annual daily cargo volume is considered to take care of annual cargo volume variation. The average monthly factors (Avg. MF) are calculated as per the Eq.2.

$$MCVF = \frac{\text{Mean Monthly Daily Cargo Volume}}{AnnualAverageDailyCargoVolume} \quad (1)$$

Where, $MCVF$ =Monthly Daily Cargo Factor.

Exhibit (a)– Cargo volume ($\times 10^3$ tons)

Port	April	May	June
P_1	238	311	410
P_2	237	312	408
P_3	242	315	412
P_4	243	317	410

Exhibit (b)

Port	P_1	P_2	P_3	P_4
P_1	0.0	3.0	18.0	30.5
P_2		0	25.0	32.5
P_3			0	4.5
P_4				0

$$Avg \cdot MF_i = \frac{\sum_{j=1}^{1=R}(MCVF_i)}{R}, \quad \forall i \& j \tag{2}$$

Where, i denotes a particular month, j denotes a year, and R denotes the number of study years.

Although the hierarchical grouping method is not explained here in detail; the basic concept and the criteria to classify the ports into an optimum number of classes are briefly described. The readers are suggested to refer Ward's method (Joseph, et al., 2008; Timm, 2002) for hierarchical grouping procedure in detail. The following paragraphs describe the port grouping process to understand the use of the proposed method in port classification context, which is based on cargo traffic.

The agglomerative or 'bottom-up' approach is used in this classification scheme. This approach is based on the postulation that the most information is available when ports are ungrouped. Using this approach, the grouping process initially defines each port as a group: M groups. At the first step, the method reduces the number of groups by one resulting with M-1 groups, while clustering two ports with least error into a single group. The method uses a weighted mean average error function (Timm, 2002) to combine another port to the existing cluster from the previous stage. We have used the squared Euclidean distance to measure the within group error. At each step the remaining groups are reduced systematically by one number until all the ports are clustered to a single group. The Euclidean distance or the error sum of squares is defined as follows (Eq. 3).

$$\delta_{(A,B)} = \frac{\mu_A \mu_B}{\mu_A + \mu_b} \sum_{k=1}^{k=N} \{\chi_{k,A} - \chi_{k,B}\}^2 \tag{3}$$

Where, $\delta_{(A,B)}$ = Potential error associated wiwith the group A and B. $\chi_{k,A}$ = k^{th} monthly cargo volume factor value for port group A. $\chi_{k,B}$ = k^{th} monthly cargo volume factor value for port group B. N = Total number of cargo volume factors considered for analysis. μ_A = Number of ports in group A. μ_B = Number of ports in group B.

The application of this procedure for port grouping may be easily explained by considering a simple example as follows.

4.1.1. *Illustration of hierarchical grouping method for port classification*

Let us consider 4 ports P1, P2, P3 and P4 with average monthly cargo volume (in 000 tons) for a quarter as given below in in Exhibit (a).

Step 0 Let us assume we have four groups and each group consists of just one port. Therefore, the error within each group can be treated as zero.

Step 1 Compute the potential error matrix by using the Eq.3 to find the error between any two ports. The error matrix is given as below in Exhibit (b) for this case.

Step 3 It may be observed the error between ports P1 and P2 is minimum. Therefore, P_1 and P_2 can be grouped in one class or group. Let a class/group called as C constitutes the two ports P_1 and P_2. The class/group C retains the within group error i.e. $\delta_{(P_1,P_2)} = 3.0$

Step 4 Let us compute the new potential error matrix for the 3 new groups i.e. C, P_3 and P_4. For example, the weighted mean average error associated between C and P_3 to combine C and P_3 as per the following Equation.

$$\delta_{(C,P_3)} = \frac{\delta_{(P_1,P_2)}(\mu_{P_1} + \mu_{P_2}) + \delta_{(P_2,P_3)}(\mu_{P_1} + \mu_{P_3})}{\mu_{P_1} + \mu_{P_2} + \mu_{P_3}} + \frac{\delta_{(P_2,P_3)}(\mu_{P_2} + \mu_{P_3}) - \delta_{(P_1,P_1)}(\mu_{P_1})}{\mu_{P_1} + \mu_{P_2} + \mu_{P_3}} + \frac{-\delta_{(P_2,P_2)}(\mu_{P_2}) - \delta_{(P_3,P_3)}(\mu_{P_3})}{\mu_{P_1} + \mu_{P_2} + \mu_{P_3}}$$

Where, δ represents the error between two ports and μ represents the number of ports present in a group. Using the above equation for C and P_3, we will get:

$$\delta_{(C,P_3)} = \frac{3.0 * 2 + 18.0 * 2 + 25.0 * 2}{1 + 1 + 1} + \frac{-0 * 1 - 0 * 1 - 0 * 1}{1 + 1 + 1} = 30.67$$

The potential error matrix can be computed using Eq.3 for all remaining ungrouped ports after pairing P1 and P2 as explained above. The potential error matrix is given as follows in the Exhibit (c) for this case.

Step 5 It may be noted that the incremental error is taken into consideration while choosing which two groups should be combined. For example, if P_3 will be added to group C, then the incremental error in group C will be:

$$\delta_{(C,P_3)} - \delta_{(C,C)} - \delta_{(P_3,P_3)} = 30.67 - 3.0 - 0.0 = 27.67$$

Exhibit (c)

Port	C	P_3	P_4
C	3.0	30.67	44.0
P_3		0	4.5
P_3			0

Exhibit (d)

Port	C	D
C	3.0	56.75
D		4.5

If we consider ports P_3 and P_4, the incremental error will be $4.5-0.0-0.0 = 4.5$. The incremental error is minimal at this stage for P_3 and P_4. Therefore, P_3 and P_4 can be grouped in another class. Let us say this class is D.

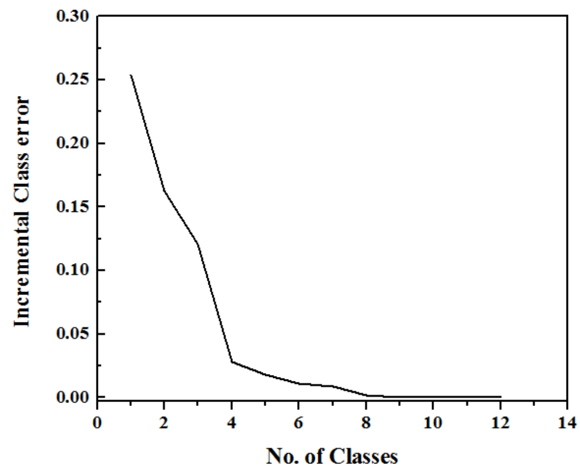
Step 6 Because of the new group or class, the error matrix will be computed again and is given below in Exhibit (d). This is the final error matrix in this example.

The incremental error is $56.75-3.0-4.5 = 49.25$, if C and D will be put together in a single group or class. In other words the error increases by 49.25, if all the ports will be put in a single class. In this example, only four ports with cargo volume variation for 3 months are considered. We developed a computer program using Microsoft Studio for this classification scheme, which used the average monthly factors to classify the Indian port system. The results obtained from the agglomerative hierarchical classification method are discussed in the subsequent section.

5. Classification Results

The classification results from the computer program are obtained and the incremental errors are plotted against the number of classes. Figure 2 shows the incremental error associated with the number of classes. Perhaps the most confounding issue for any researcher conducting either a hierarchical or non-hierarchical grouping analysis is the determination of the number of groups to represent the similar objects within a group (Joseph, et al. 2008). This decision is critical for hierarchical techniques because, a natural increase in heterogeneity comes from the reduction in number of clusters. Unfortunately, "no standard objective selection procedure exists" (Joseph, et al. 2008); since no statistical significance test is available to determine the optimum number of groups. Thus, the researcher must look at the trend in the values of heterogeneity to identify the optimum number of groups in such way that the incremental error is as minimal as possible, whereas there should be a clear distinction between the groups. Considering all these limitations for choosing optimum number of classes, we chose the optimum number of port classes with subjective analysis. This is discussed below.

Figure 2: Class error association with no. of classes



It may be observed from Figure 2, that the optimum number of port classes remains in between 4 to 7 because a considerable increase in error is noticed in this range and the error substantially increases as we decrease the number of classes. Also, it is clear that the number of classes should not be less than 4 because any reduction in number of classes beyond this point results in high error (see Figure 2). Thus, we decided to choose the 4-class port classification in this case and analyzed the monthly cargo flow pattern for this classification. The result from the computer program for 4-class classification is tabulated in Table 2.

5.1. Analysis of Monthly Variations in Cargo Flow

The ports in a class are additionally analyzed for statistical comparisons of mean monthly traffic factors. The ports assigned to a particular class in Figure 3(a-d) show consistent patterns of monthly variations in cargo flow. This justifies the temporal cargo variation patterns could be systematically related to Indian port system. This is discussed in detail in the subsequent paragraphs.

Figure 3 (a-d) shows the average monthly cargo flow patterns for the 12 study ports in 4 different classes. From all the plots in Figure 3, it is clear that the ports present within a class follow the similar temporal flow pattern except Mormugao. The following points are noteworthy for the four classes.

1. Class I represents mainly low volume ports. The cargo share of class I ports varies between 2 - 5% of the total traffic throughput at all the study ports. The annual average daily cargo volume (AADCV) variation is about 35 to 75 thousand tons for this port class. These ports experience higher freight flow towards the end of financial year (Feb-March).
2. The class II type ports receive almost uniform freight flow throughout the year. The AADCV value for this class is about 90 -120 thousand tons. However, flow pattern for Mormugao is different. It receives highest volume during January to May each year. But, there is significant amount of reduction in freight volume occurs

Table 2: 4-class port classification

Class	Port Code	Port Name	Annual Average Cargo Share (%)	AADCV ('000 tons)
I	1005,1006,1011	Tuticorin, Cochin, Ennore	2 – 5	35 – 75
II	1001,1007, 1008	Kolkata, New Mangalore, Mormugao	6 – 8	90 – 120
III	1002,1004,1009	Paradip, Chennai, Mumbai	10	150 – 160
IV	1003,1010,1012	Visakhapatnam, JNPT, Kandla	11 – 16	170 – 250

during June to September and these months are rainy season months in India. This seasonal variation may possibly happen due to (1) lower maintenance of road network connecting to the port terminals during rainy season and (2) shut down of available six transshippers for 59 days during monsoon period. The transshippers only operate between 183 to 194 days during the whole year. These transshippers handle almost 25% of total ore cargo handled by the Mormugao port. The non-operational period of transshippers needs to be further investigated to find out the issues and challenges involved in operating the transshippers during the monsoon period. However, this issue is not addressed in this paper. Nevertheless, the Mormugao port is included in this class since the MCVF considers the entire yearly cargo flow variation.

3. The class III ports constitute the ports like Paradip, Chennai and Mumbai port. The AADCV values at all these ports are approximately 150 - 160 thousand tons. All these ports receive little reduction in cargo throughput during May. In class IV the AADCV value lies between 170 - 250 thousand tons and the cargo throughput is almost uniform throughout the year.
The above analysis and observation may be used as an input for port operation planning, adopting efficient maintenance program for the road network connecting the port facilities, port facility planning, making decisions of freight rates, etc.

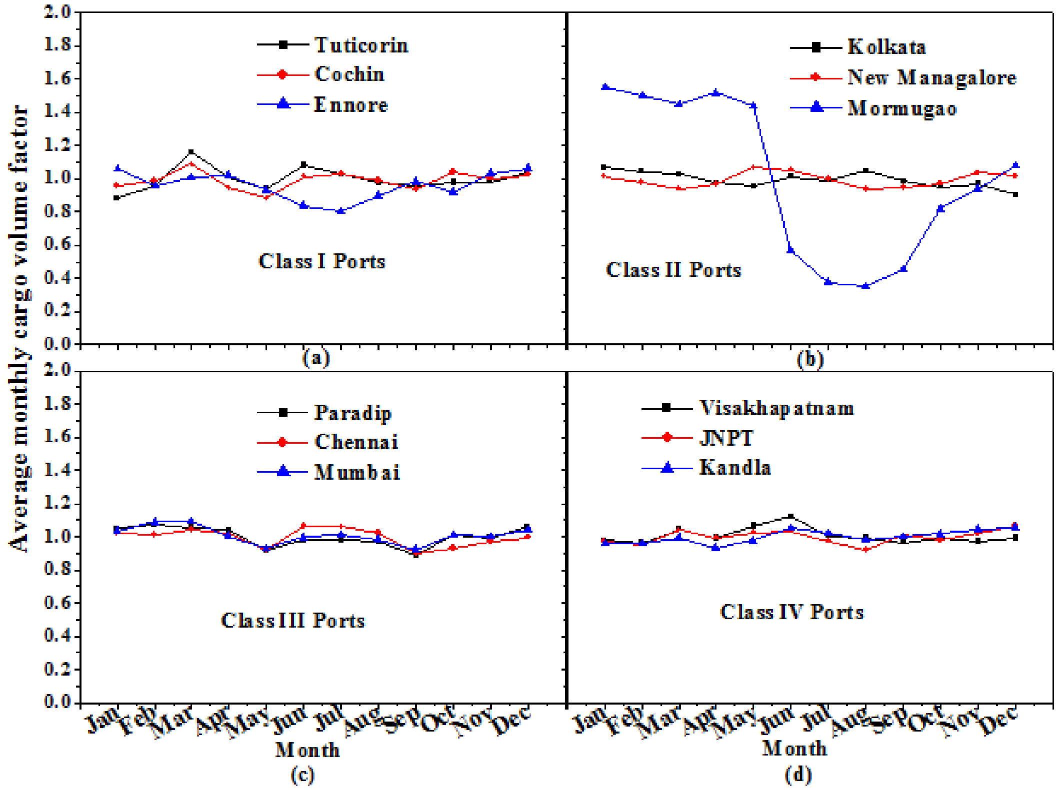
6. Conclusions and Future Research

Ports are not similar in their operation, functions and institutional organization. In addition, the different services or activities executed in a single port have dissimilarities in scope and nature. Although a number of port classification frameworks are available in literature, none has been generalized. None of the past studies considered temporal variation of cargo volume for classifying ports. This paper has illustrated a methodology for developing a classification for port systems with comparable temporal variation of cargo volume. The key issue faced while attempting for evaluating these measures over a large number of ports is the trouble in comparable data collection from all the port locations and defining the criteria for such evaluations, which will be applicable to all ports. Also, individual port evaluation may not be easy while considering a region's port system with heterogeneous number of ports. However, this problem can be cut down by classifying ports into certain homogeneous groups. The proposed classification scheme is applied to classify Indian port system. Due to unavailability of data, the application of the proposed method is restricted to 12 Indian ports only. Based on the analysis we propose to classify the 12 Indian seaports into four groups. This classification scheme can be applied to any port system elsewhere.

Average monthly cargo volume factor was used as classification variable. Cargo volume data can be easily accessed from various port authorities. It would be a matter of compiling them in a single database that will enable the development of a classification applicable for a wider region. This paper contributes the literature by proposing a new method for classifying the Indian ports based on temporal variation in cargo flow. The method adopts the agglomerative hierarchical grouping and applied the same to classify the Indian port system.

The existing classification methods for ports have multiplicity in definitions and are subjective in nature. This leaves a chance to include considerable subjective decisions while planning and designing for various activities at different ports. The proposed method of classifying ports on the basis of temporal cargo volume variations is more objective than the conventional methods. The new method has proposition towards a standard classification of seaports according to cargo volume share and temporal flow pattern. This classification scheme may lead to establish some standardized basis for several transportation functions, such as collection of port traffic data, planning, design, and operation of port facilities etc. Another use of this method may be for the purpose of monitoring and reviewing port classification with respect to time. If a specific port is assumed to have gone through a considerable change in cargo flow characteristics (e.g. commodity characteristics) over a period of time, the type of analysis described here can help to reassign the port to a proper class. Although Indian port system is investigated in this study, it is hoped that many other port systems may adopt this approach from this research, since majority of the port systems have the cargo traffic information available to them which is required for the proposed classification. We considered only 12 ports for applying the new classification scheme due to the difficulty in collecting data for all the 200 ports. The proposed classification methodology may be applied for all the 200 ports to classify them, which would be

Figure 3: Average monthly cargo volume factor for 4 port classes



considered as an extension of this research.

7. Acknowledgement

The authors wish to thank the Mumbai Port Trust authority, Paradip Port Trust Authority and CMIE for the collection of the port freight data used in this study.

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