CANADIAN TRANSPORTATION RESEARCH FORUM
LE GROUPE DE RECHERCHES SUR LES TRANSPORTS AU CANADA

21st ANNUAL MEETING

PROCEEDINGS

VANCOUVER, B.C.
MAY 1986

ON THE OPERATING ASPECTS OF MATERIEL DISTRIBUTION ACTIVITY WITHIN THE CANADIAN FORCES

by

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1.0 Introduction

In support of the National Materiel Distribution System (NMDS) study, the Operational Research and Analysis Establishment within the Department of National Defence was requested to examine the operating aspects of the materiel traffic activity in the Canadian Forces (CF). The intent was to ascertain whether the system met the approved system objectives, namely, "to deliver materiel safely, on time, and at least cost to its destination".

The NMDS study was to consider CF materiel distribution in its full national context. However, due to the lack of a management information system for materiel traffic activities, the task of accomplishing the study on a CF-wide basis would have been too costly in terms of resources, time and money. A random sample of the traffic activity in the Western Region of Canada was chosen as the basis for a special data collection survey and the collected data were analyzed to establish the effectiveness and efficiency of the traffic movement. The performance of the entire materiel traffic system (MTS) was then statistically inferred. Due to the lack of an appropriate data base on historical materiel traffic movements, there was no baseline for comparison purposes and the standard or classical performance measures for this one time snapshot of the MTS in the Western Region did not provide a basis whereby the performance of CF transportation operations could be evaluated. Other evaluation techniques had to be used to establish the levels of effectiveness and efficiency of the MTS.

The organization of the paper is as follows. The principles and policy that apply to materiel traffic activity within the CF is outlined in the next section. This is followed by a discussion of

the data sample. Finally, the evaluation methodology for the effectiveness and efficiency of the materiel distribution within the CF is explained.

1.1 The Materiel Traffic System

The basic principle of materiel traffic management within the CF is to effect delivery of the required materiel in serviceable condition, at the place and on the date designated by the consignee, in a safe and cost effective manner. In addition to the liaison, coordination, planning and programming functions, materiel traffic activity embraces receiving, shipping and customs clearance tasks. It is a policy of the Canadian Forces that materiel should be moved by the most practical and efficient means, including military and non-military transport, consistent with urgency and economy. This implies that where adequate and economical CF facilities and equipment are available, they will be utilized to the fullest extent possible. Thus, small lot shipments should be considered for consolidation along the CF transportation system whenever possible in order to economize on transportation and documentation costs.

Within the Canadian Forces Supply System, supply materiel requested by a consignee is assigned a priority code to reflect the urgency of requirement for the materiel. The codes are defined as OX for Immediate Operational Requirement; 01 and 02 for Urgent Requirements (with the former having a shorter available delivery time from the demand date than the latter); and 03 and 04 for Routine Requirements (where the former is mainly for a specific project and may have a shorter available delivery time than that for Code 04). The essence of the performance evaluation for the materiel traffic system is to determine the degree of satisfaction of assigned due-dates for each materiel priority code. Here, it should be emphasized that there is no obvious advantage in delivering the low priority CF supplies (Codes 02, 03, 04) earlier than the assigned due-dates. Interest will also be directed towards investigating the output per unit cost of delivering supplies from the originating traffic agent (TA) to the consignee.

Presently, the movement of CF materiel is a series of sequential actions which occur over a period of time in different locations. It involves a planned set of Canadian Forces transportation and/or common carrier operations. In brief, the operations are as follows: the traffic agent attempts to consolidate consignments where possible into shipments, marshalls shipments and completes a movement plan; a carrier transports the shipments to the specific destinations and a destination traffic agent receives and inspects incoming shipments for loss or damage. A diagramatic illustration of the sequential actions of the materiel movement through the CF transportation operations can be found in Fig. 1.

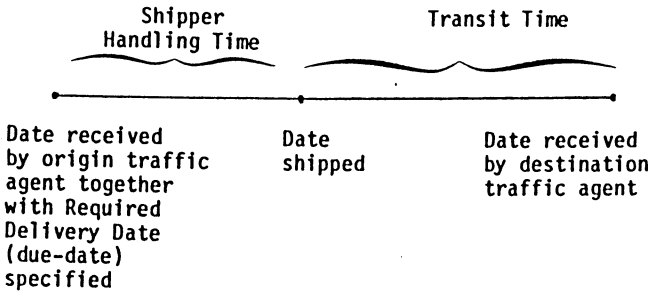

Fig. 1 - Diagram Showing the Various Time Factors Involved in the Transportation Problem

The transportation of CF materiel can be accomplished either by means of CF resources (e.g. Mobile Support Equipment, Air Transport) or commercial means (e.g. Rail, Road, Road Express, Bus, Parcel Post, Commercial Air Freight, Air Express). The Required Delivery Date or due-date is the overriding consideration in selection of the mode of transportation. The mode providing the fastest means of transportation necessary to satisfy the Required Delivery Date should normally be used. Premium transportation, such as Air express, Air freight, etc., should be used only when urgency or characteristics of a particular shipment dictate.

1.2 Materiel Traffic System Sample Data

To collect data, shipping information forms for inbound and outbound shipments were designed and forwarded to various CF bases/stations in the Western Region. The inbound shipment form identified the transportation control number (TCN), the origin and destination base/station, the date received by the consignee, and the weight, volume, mode and materiel priority codes of the shipment. The outbound shipment form collected information on the TCN, the origin and destination base/station, the Required Delivery Date (RDD), the date received from the consignor, the date shipped, the cost, the mode, the materiel priority codes, the weight and volume.

The data sample was collected during time periods, 1 Nov - 15 Dec 1983, and 15 Jan - 29 Feb 1984. A total of 117,083 inbound and outbound shipments (records) were collected. With this sample, 35,669 records were rejected as invalid (e.g. incomplete TCNs) or absence of information on a shipment's final destination. There were a total of 38,345 valid inbound and 43,024 valid outbound records in the sample. The number of shipments where both the

shipper and receiver could be identified through common TCN was 10,298 shipped by CF resources and 1,655 shipped by commercial means. Of the latter, 1141 records or 68.94% contained no indication of cost. This seriously reduced the accuracy of the calculated cost efficiency measure for commercial carriers.

2.0 Measuring MTS Effectiveness and Efficiency

2.1 Effectiveness

Many measures of effectiveness and efficiency might have been selected for the purpose of studying MTS performance [1,2,3]. However, to those operating the CF transportation system, the performance measure of greatest interest is the degree to which a consignee's requirements are met. Since materiels that miss their due dates will directly or indirectly affect the military readiness of the CF, failure to meet the Required Delivery Date (RDD) is taken as the performance measure. The effectiveness of the operating aspects of the CF materiel traffic system is assessed using the following performance measure:

$$\%\ \text{RDD violations} = \frac{\text{Number of shipments not meeting RDD}}{\text{Total number of shipments shipped to meet RDD as specified}} \times 100\%$$

From the collected data, this effectiveness measure has been calculated for each materiel priority code (MPC) and plotted in Fig. 2. Assuming that the data sample is unbiased and random, 95% confidence intervals [4] for the effectiveness of the entire MTS are included in Table I.

Table I

MTS Levels of Effectiveness

MPC	Total number of shipments less pre-shipment violations*	% RDD Violations For The Sample Data	95% Confidence Interval For The % RDD Violations For The Entire MTS
0X	492	33.9%	29.9% - 38.2%
01	866	24.9%	22.1% - 27.9%
02	2071	15.7%	14.2% - 17.3%
03	2641	9.4%	8.3% - 10.6%
04	2402	6.1%	5.2% - 7.1%

* Pre-shipment violations occur when the RDD has already been passed before receipt by originating TA. There were a total of 3481 pre-shipment violations out of 11,953 shipments.

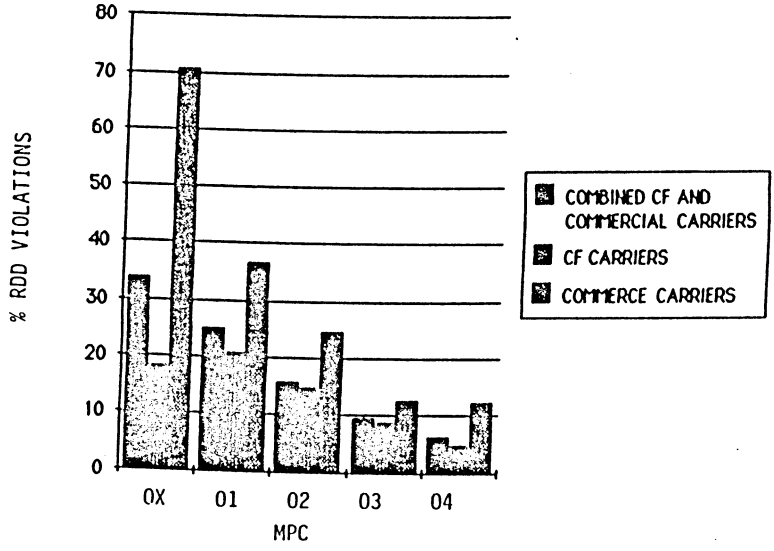

Fig. 2 - Levels of Effectiveness For Sample Materiel Traffic Data

2.2 Efficiency

By definition efficiency defines the relationship between resource input and resulting output. Within the CF we must concern ourselves with two measures: one relating to commercial carriers based upon cost; and the other based upon CF vehicle fleet utilization. The efficiency measure for commercial transport is:

$$\text{COST EFFICIENCY} = \frac{\text{WEIGHT X DISTANCE}}{\text{COST}}$$

(This cost efficiency measure is just the inverse of the cost per output, e.g. cost per ton-mile.) In Fig. 3, the cost efficiency measures calculated from the data for the different modes of transportation are presented. These results correspond to our expectation that cost efficiency for Air Express would be lowest, and Rail would be highest. It is interesting to note that the 'bus' has a remarkably low output to cost ratio, even less so than 'air'. The 95% confidence intervals for the efficiency of the entire MTS are presented in Table II.

Table II

National Materiel Distribution Study

Transportation Efficiency By Commercial Mode

Mode	95% Conf. Interval For Cost Efficiency For Entire MTS
Air Express	0.148 - 0.263
Bus	0.111 - 0.364
Air	0.322 - 0.438
Post	0.486 - 0.626
Road Express	0.259 - 0.993
Road	0.599 - 1.086
Rail	1.604 - 2.243

N.B. The small sample size of the bus shipments required that the Student's t-distribution be used for the evaluation of this confidence interval.

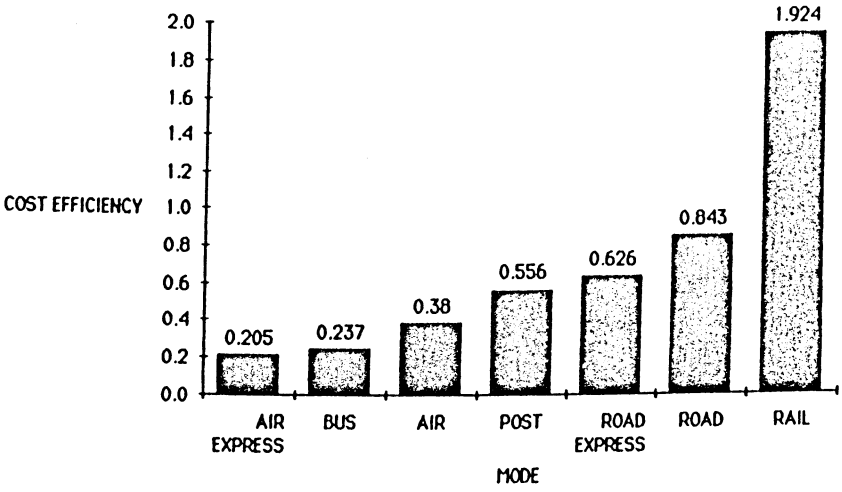

Fig. 3 - Levels of Efficiency For Sample Materiel Traffic Data

The assessment of vehicle efficiency or utilization is difficult because the operation of CF carriers (vehicles or aircraft) is a policy decision, not totally related to cost. There are also varying capacities of different types of vehicles used along different routes. Vehicle utilization assessment is further confounded by the use of both scheduled and unscheduled freight services. This aspect of the study is still under investigation and will not be dealt with in this paper.

2.3. Mean Early Time Evaluation

The % RDD violations in Table I and the cost efficiency measures in Table II, although accurate measures on their own, have no baseline for comparison purposes. Are the resulting values, therefore, good or bad? What is the trend? With the lack of a management information system for CF materiel traffic operations, historical performance cannot be studied and such questions cannot be directly answered. Comparison of the results with those of other such military systems is not possible due to the unique situation of the Canadian Forces in this regard. Given these constraints, a 'mean early time' evaluation scheme is used to quantify MTS performance. This technique in analyzing performance is novel in the literature. It depends mainly on the inherent nature of our problem, namely, there is no obvious advantage in delivering low priority items (Codes 02, 03, 04) earlier than the assigned due-dates. The mean early time scheme illustrates the extent of the potential for more fully utilizing early time to consolidate shipments at the originating traffic agency and also the possibility of transporting materiel on a higher cost-efficient mode of transport.

Table III presents the mean early time for Code 02, 03 and 04 items shipped via commercial means. (Codes 0X, 01 items are omitted in the Table because, by definition, they are urgent requirements and immediate delivery for these supplies is necessary.) Also included in the Table are the calculated 95% confidence intervals for the mean early times of the entire MTS.

Table III

MTS Mean Early Times

Materiel Priority Codes	Total Shipments Less Pre-Shipment Violations	Shipments Delivered To Consignee On Or Prior To Due-Date	Mean Early Time (In Days)	95% Confidence Intervals For Mean Early Times For Entire MTS (In Days)
02	226	170	6.27	5.27 - 7.28
03	388	339	11.65	10.85 - 12.45
04	376	330	15.49	14.68 - 16.30

Fig. 4 illustrates the commercial modes of transportation used for the shipments in Table III delivered on or prior to the assigned due-dates.

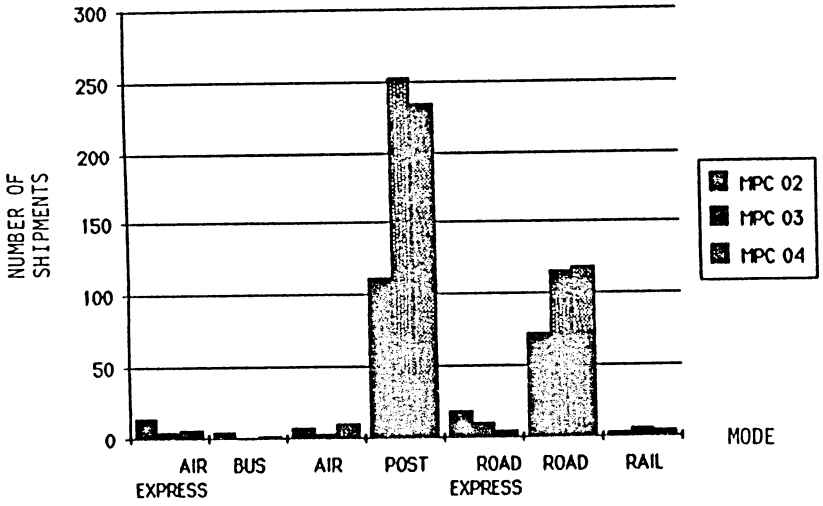

Fig. 4 - MTS Utilization of Commercial Mode Of Transport For Shipments Delivered On Or Prior To Due-Dates

By combining the information from Table II and Fig. 4, the percentages of shipments that use low and high cost efficient modes of transportation are calculated and presented in Table IV.

Table IV

MTS Utilization Of Low And High Cost Efficient Commercial Modes Of Transportation

MPC	Low Cost-Efficiency (Air Express, Air, Bus, Post, Road Express)	
	% of Sample Employing This Means Of Transport	95% Confidence Interval For Entire MTS
02	67.26%	61.14% - 73.37%
03	69.07%	64.47% - 73.67%
04	67.29%	62.55% - 72.03%

MPC	High Cost-Efficiency (Road, Rail)	
	% of Sample Employing This Means Of Transport	95% Confidence Interval For Entire MTS
02	32.74%	26.62% - 38.86%
03	30.93%	26.33% - 35.53%
04	32.71%	27.97% - 37.45%

Approximately 2/3 of the low priority commercial shipments of the MTS are shipped via low cost-efficient means of transport (Table IV). This situation is further worsened by the fact that shipments arrive at destination a lot earlier than the assigned due-dates, as depicted in Table III. Thus there exists some scope for improving the cost- efficiency of commercial shipments without reducing current levels of effectiveness. Areas in which the MTS might be improved are suggested by the above analysis of early shipment arrival times. However, there are within the MTS limited opportunities for improvement that are imposed by geographical and physical factors. For example, for some CF bases/stations, there might not exist the space or facilities whereby the shipments can be held for consolidation.

3.0 Concluding Remarks

This study of the operating aspects of the departmental National Materiel Distribution System (NMDS) required the collection and analysis of large amounts of data. This information on materiel and traffic movement is not available to NMDS managers as there is no automated data collection system currently operating in support of this function. All data have been collected on hand-written forms listing 117,083 materiel movements during a total three months period in the Western Region. Its subsequent transcription to computer tape records has required over a year and a half and a tremendous effort from full and part-time professional and clerical staff to bring it to its present state. However, the information upon which the results of this report is based is both limited in scope (confined to the Western Region) and by now, relatively old. It represents only a one-time reading of NMDS operation, and deficiencies in the data collection, such as the absence of cost data in many of the records submitted, cannot, without an unreasonable amount of further time and expense, be corrected.

The lack of an automated management information system for NMDS managers within the Department of National Defence is much more serious, however, than the difficulties it has imposed upon the conduct of this study. Those responsible for managing the system and achieving the highest levels of operational efficiency and effectiveness lack the essential information necessary for system planning and control. The data gathering and reduction processes used for this study are totally inadequate for management purposes. It is obvious that a nation wide information system network is required to bring together the large number of locations where transportation management decisions must either be made or acted upon. While it is clearly beyond the scope of this study to attempt to specify such a system, it does identify many of the major issues that would have to be addressed and highlights their relative importance and interdependence.

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