The Application of a Dynamic Methodology to assess the Benefit of a Logistics Information System in Defence

by

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INTRODUCTION

This paper describes the application of a system dynamics based three-stage methodology (Wolstenholme, 1990) for the assessment of computerised information systems (CIS), to a proposed military logistics information system.

The system in question was nearing the end of the Requirements Definition phase of the System Life Cycle process. A Benefit Assessment had been carried out by the consultants responsible for the design of the system. The tools used by them had, however, encouraged the conclusion that any improvement in the information system must have a positive effect on organisational effectiveness directly proportional to that level of improvement, and that the overall level of improvement is the sum of individual gains. No study of the interaction of the physical operation and the information system had been carried out.

SUMMARY OF METHODOLOGY

The three stages of the methodology are:

Stage 1 - the development of a model representing the physical and associated information flows of the essential activities of the organisation, in its current operational mode.

Stage 2 - the modification of the stage 1 model to incorporate representation of the proposed computerised information system.

Stage 3 - using the Stage 2 model as a test-bed, the identification and assessment of the opportunities enabled by the CIS and the likely detrimental effects arising from its installation.

STAGE 1

Knowledge capture

At the outset of the project, an overview of the structure and the organisational setting of the Logistics operation was provided by senior officers within the research establishment responsible for the CIS project.

In order to acquire the in-depth knowledge of the Logistics operation necessary for model development, the cooperation of Logistics personnel was vital. The approach adopted to achieve this objective was to develop a simple model of a logistics operation, which contained some of the features of the military operation to be modelled (Wolstenholme, 1988). This model was used to demonstrate the application mode and the potential of the proposed methodology, and to illustrate the nature of the information required for development of the project model.

The success of this approach owed much to the ease of interpretation of the influence diagram presentation format and to the ability of System Dynamics models to represent the real-world in real-world terms. A direct result, was the assignment of a senior officer to coordinate requests for information.

Both written material and verbal presentations by Logistics personnel followed, enabling initial model formulation. Follow-up sessions were preceded by a list of queries to be resolved which ensured the attendance of knowledgeable personnel and minimised the time commitment of the clients. Consultation continued until it was agreed that the model adequately represented the real-world object system.

Organisation - overview

The army organisation is hierarchical, consisting of a number of Corps each of which have three Divisions. A Division usually has three Brigades, which are further divided into a number of Units. Each Division has its own Squadron Transport Unit.

It is an extremely complex operation, encompassing a number of identifiably distinct functions - Operations and Logistics Coordination, Resupply and Replenishment, Transport Management, Route Management, Equipment support, Manpower Management, Manpower Support, Real Estate Management, Non-combatant Evacuation Organisation Management and Prisoner -of-War Management - each with its own command structure and further sub-functions.

Representation of the organisation

The modeller is always faced with the dilemma of the level of detail required for validation of the model. The degree to which clients will accept the model as credible is influence by the amount of detail included. However, the requirement for too much detail can present the modeller with technical difficulties which force unacceptable compromises and can obscure the strategic implications of policy implementations. To represent the Logistics Function in all its detail would entail a lengthy model development phase and a resulting model whose size and complexity would mitigate against ease of analysis.

Our approach, therefore, was to model in detail only the core activity of the logistics function and to represent all other functions in terms of their impact on, or interaction with, this core activity. The core activity was defined, by reference to the objectives of the operation, as the planning and implementation of movement and storage of men and materials throughout the Corps.

In a military context, this core activity involves the movement and storage of hundreds of commodities over many routes and varying distances and is, therefore, in itself, too complex to model in detail. A "representative activity" - Ammunition Supply - was selected, the contention being that the impact of the proposed CIS on the whole operation could be inferred by analysis of its impact on this representative activity.

The Model

The model represents the flow of ammunition in a single Corps during the outloading (Transition to War) stage and the following period of hostilities. Ammunition movement in only one Division is shown in detail. This flow of ammunition is illustrated in Figure 1 and the corresponding flow of Divisional transport in Figure 2.

Figure 1: AMMUNITION MOVEMENT

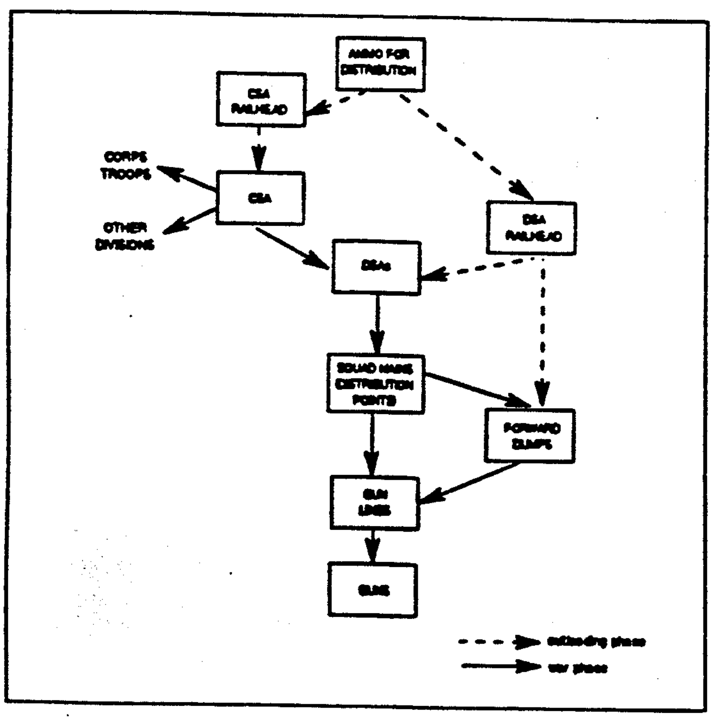
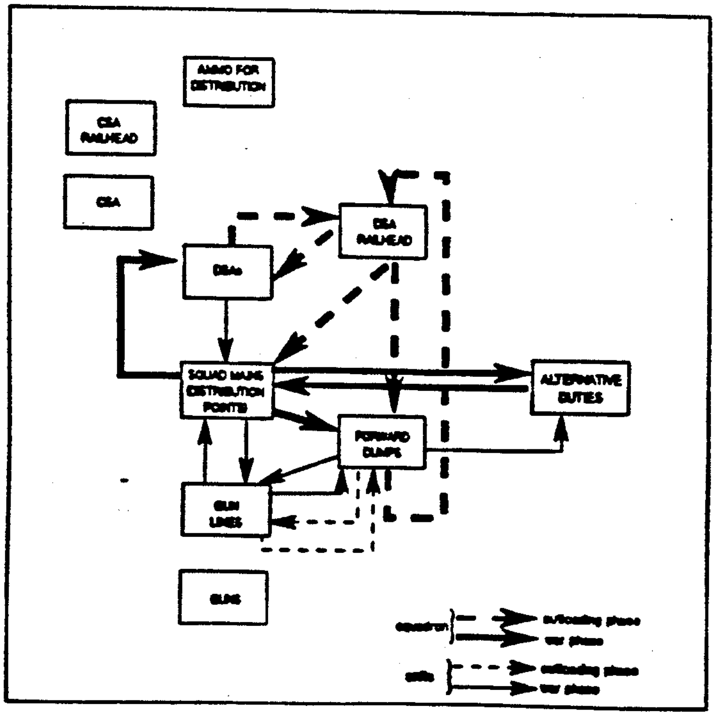


Figure 2 : DIVISION TRANSPORT



The following are represented in aggregated form: Ammunition levels at DSAs, Squadron holdings, Brigade/unit holdings and requirements, actual and required firing rate, Squadron transport capacity and movement, and Unit transport capacity and movement.

During outloading, the planned levels of ammunition are moved by rail to stock the Corps Supply Area (CSA) and the Divisions. Squadron transport moves the ammunition from the Division railhead to the Divisional Supply Areas (DSA) for storage, and forward to Dumps for collection by Units. At the end of the outloading period, guns should be loaded to capacity and units should hold their designated Unit Mobile Stocks (UMS).

Once hostilities commence, Guns are reloaded either directly from accompanying unit vehicles or from stocks grounded at gun positions. Empty Unit vehicles are directed back to replenish either by direct transfer from squadron transport at Distribution Points, or from Forward Dumps, whichever is perceived to be closest. Ammunition is supplied to Unit transport on demand. When supplies at the Dumps are depleted, unit vehicles are redirected to the nearest DP to top up.

Loaded Squadron vehicles dump their ammunition holdings at Forward Dumps only when they are required for duties other than ammunition supply. All squadron vehicles not on other duties are engaged in ammunition replenishment. Ammunition is available on demand at the DSAs for collection by squadron vehicles.

Stock states through the Division are monitored by Division HQ, who receive regular reports from DSAs, Transport HQ and Brigade HQs. There is no link to Forward Dumps. Daily reports to Corps request replenishment of the DSA tocorrect any discrepancy between the perceived Divisional holdings and level of stock desired for that stage of hostilities. The true level of holdings is always assumed to be lower than that reported. At the CSA, priority is given to Divisional requests over that of the Corps troops who are supplied directly from the CSA.

In addition to the losses of both ammunition and transport on route between locations, losses are assumed to take place at both Squadron Mains and Forward Dumps due to enemy action and at the Dumps due to overrun. Loss rates are dependent on the intensity of hostilities and on the distance from the front line.

The quantitative model was developed using DYSMAP2/386 on a Compaq 386/20 computer.

STAGE 2

A sophisticated distributed database system serving Corps, Division and Brigade levels, accessible at all HQs, storage areas and Control Points monitoring forward grounded stocks, and providing support to all the Logistics functions was proposed.

At this stage, however, only support for four functions - Operations and Logistics Coordination, Resupply and Replenishment, Transport Management and Route Management - was being assessed.

Representation of the CIS

The expected effects of the CIS on the ammunition supply function are defined below:

1. From improved Route Management:-
    - Reduction of losses due to choice of safer routes.
    - Reduction in average distance travelled due to increased timeliness and accuracy of route information.

2. From improved Transport Management
    - shorter turnaround time on alternative duties.

3. From improved monitoring of ground-dumped stock
    - Reduction in unit transport unable to locate dumps.
    - Reduction in ammunition losses from dumps due to overrun.
    - Reduction in distances travelled by unit transport to dumps.
    - Improved orders to units.

4. From installation of on-line Communications and Database
    - Improved timeliness of stock states.
    - Availability of information from forward dumps.
    - Availability of information on deliveries expected.
    - More accurate information at HQs.
    - More accurate and timely information on transport.

Where effects were expressed in terms of changes in variables already represented in the Stage 1 model, the representation of the CIS simply involved adjustment of parameter values.

Representation of information flow attributes - timeliness, comprehensibility, relevance, availability and accuracy - posed a greater challenge. The following strategy was adopted for their representation in the model:

- Timeliness changes would be represented by alterations in the values of the delays associated with information transmission.

- Comprehensibility changes would be represented in terms of the effects on the time taken to assimilate and incorporate the information into the associated decisions.

- Relevance is related to the effect of the incorporation of a piece of information into a decision and would be judged in terms of the effect on performance.

- Availability would be represented by an information link between the source of the information and any additionally enabled destination.

- Accuracy could be quantified in terms of the difference between the perceived and true values of a variable and modelled by a random number function representing a distribution of values about the true value of the variable in question. Due to current limitations of the software, this proved problematical and has not been implemented in the model. Its exclusion, however, was not felt to invalidate the findings.

Performance Measures

The high level objective of any Commander is "to achieve the mission". In support of this, the logistics function is required both "to maintain operational flexibility" and "to sustain operational capability". Performance measures were defined to assess the extent to which these sometime opposing organisational objectives were supported.

Tentative measures were formulated at the outset, but the choice of the final format and range of the measures as defined below, was greatly aided by comparison of the Stage 1 and Stage 2 models.

Ammunition Profile: The "ammunition profile" represents the distribution of ammunition between storage sites at a point in time. It provides a measure of "operational flexibility", in that the degree of flexibility available to a Commander depends on the resources at his disposal. It is also a measurement of "operational capability" which depends on the accessibility of resources.

Ammunition Losses: The "minimisation of ammunition losses" whether due to enemy action, overrun (i.e. stocks not picked up) or transport loss is related to the ability to sustain operational capability. The total loss level is monitored, and broken down into total losses at Distribution Points, losses at Forward Dumps attributed both to enemy action and overrun, and, and total losses during movement.

Ammunition Usage: The "achievement of mission" objective can be expressed in terms of the ability to maintain the required firing rates throughout the mission. The "total ammunition fired by front-line units" and the "ammunition allocated to Corps troops" are monitored and compared with the levels required or requested.

Transport Capacity Requirement: This quantity is defined as "the squadron transport capacity required at the outset, which will enable the required firing rates to be achieved throughout the mission". It is an expression of the level of resources required to achieve the high level objectives

If desired and/or acceptable values for each of the above concepts are defined, the contribution of the CIS can be measured in terms of its capacity to enhance the organisation's ability to achieve and maintain these values

Scenario Representation

The battle conditions are represented by the required firing rate, which is defined as the firing rate required to achieve the mission and is the primary driving force for the model. In addition, the demand for transport for duties other than ammunition supply is represented as an exogenous force in the form of a Table function, which can be varied.

MODEL ANALYSIS

Experimental conditions

Due to the sensitive nature of the data required for quantitative representation of the real-world situation, the model reported was formulated with dummy values as used in training establishments.

The simulation period was 9 days - 3 days outloading and 6 days of hostilities. The performance of the model in response to a stepped increase in the required firingrate at the commencement of hostilities is reported. No replenishment of the ammunition held at the CSA or squadron and unit transport was modelled.

Comparison of Stage 1 and Stage 2 models

The stage of the operation at the end of the projected period of hostilities is illustrated (Figure 3). Being indicative of the ability to react to further hostilities, this snapshot provides a useful comparison of the Stage 1 and Stage 2 models.

For the first three measures, the initial squadron transport capacity was held at 2300 pallets for both models.

The distribution of remaining stocks shows distinct differences in the stage 2 model, stock has been pushed forward to a much greater extent. This has the effect of increasing the flexibility and short-term capability of Unit and Brigade commanders but reduces that of Division and Corps commanders.

Counter-intuitively, the total ammunition losses show an increase in the Stage 2 model - 2.5 as opposed to 2.25 days supply - reducing the capacity of the Division to maintain operational capability.

Squadron transport capacity lost over the 9 day period is reduced from 63% of total capacity to 45%. This supports the intuitive interpretation. However, with an expectation of a 50% reduction in the fractions lost "programmed" into the model, the expected Stage 2 figure is 36%.

In the Stage 1 model, required firing rates are not achieved at all times, despite adequate stocks in the DSA. The discrepancy follows a time of high commitment of squadron transport to other duties. The CIS increases the ability of the operation to maintain required firing rates but at the cost of reduced ability to meet the demands of the Corps troops.

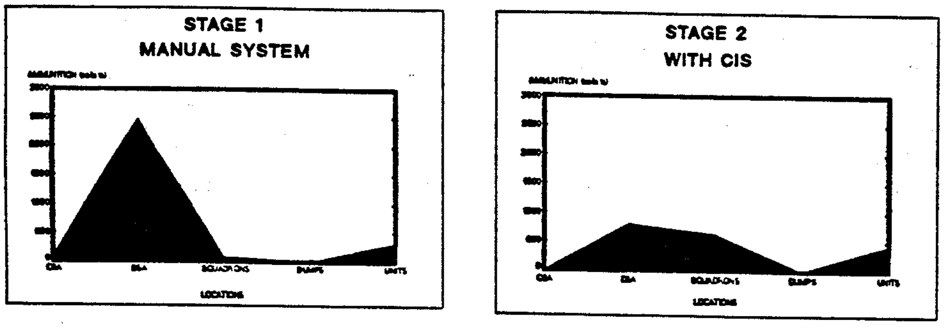
The CIS has no presence forward of Brigade level. Intuitively, therefore, the only effect expected in this area would be a positive one arising from the improved quality of unit directives relating to dump location and monitoring. This is borne out by the increase in the ability of the system to achieve required firing rates but an unanticipated effect is the increase in the loss of unit transport from 78% to 83% of initial capacity.

In the Stage 2 model, required firing rates can be achieved with an initial 1850 pallet capacity whereas the Stage 1 model requires an initial capacity of 2500 pallets to achieve these rates.

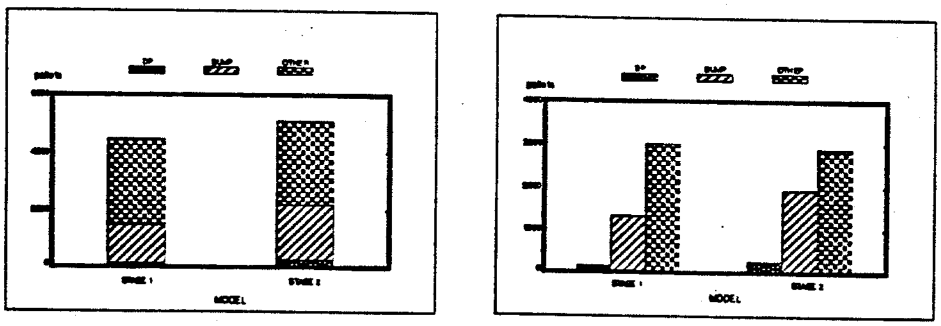
FIGURE 3

PERFORMANCE OF STAGE 1 AND STAGE 2 MODELS
SNAPSHOT AFTER 6 DAYS

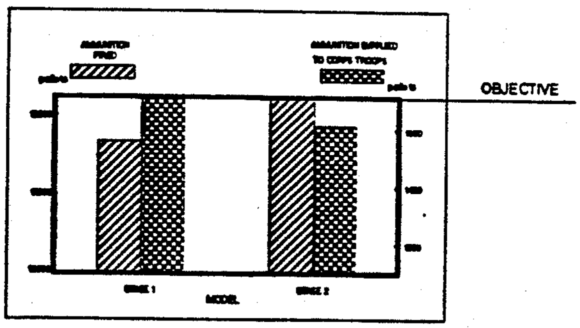
Ammunition Profiles



Ammunition Losses



Ammunition Usage



Minimum Transport Capacity Required

MODEL	
STAGE 1 MANUAL	STAGE 2 WITH CIS
2500 PALLETS	1850 PALLETS

Further comparison of the performance of the models resulted in the following observations.

Counter-intuitively, the greatest ammunition losses occur if only the route and/or transport management functions are implemented. The additional losses are nearly totally due to an increase in the losses at the Dumps and Distribution Points.

The incorporation of the added information supplied from the terminals at the ACP's leads, on its own, to the greatest reduction in ammunition losses. This is the result that one would intuitively expect. However, the savings are completely overshadowed by the increased losses resulting from the implementation of the route and transport management functions.

The installation of the database and the associated on-line communications contributes little to the overall performance under the prevailing policies. This is easily explained by the realisation that although the availability and quality of information is increased, no changes have been implemented to take advantage of the facility.

STAGE 3

Stage 3 of the methodology supports the view that a proposed CIS must be evaluated in terms not only of its immediate impact but also in terms of its potential to support more efficient policies. The changes which may be necessitated or enabled by the introduction of the CIS and the limitations of the prevailing policies and structure are examined.

In the case of the Logistics system, the objectives which the CIS and management policies wish to enable can be expressed relative to the performance measures as follows:

(a) To enable "required firing rates" to be met at all times.
(b) To minimise "ammunition losses".
(c) To improve "operational flexibility", by maintaining the optimum distribution of ammunition.
(d) To minimise the resources/capacity required, particularly that of transport.

Of these, objective (a) is accepted as the primary objective.

The changes reported below were formulated as a result of the analysis of the Stage 2 model performance. They by no means exhaust the possible options which could be studied.

1. Reduction of Transport Capacity

It was realised that the increases losses resulting from the implementation of the Route and Transport Management options, were due to the increased opportunity of the system to move ammunition forward at a rate which was greater than the forward units could consume. The resultant build-up of stocks at Dumps and DPs increased the probability of loss due to either enemy action or overrun. A simple solution would be to reduce the transport capacity available for ammunition resupply by an amount equivalent to the anticipated transport loss reduction.

2. Exclusion of the Divisional replenishment safety margin

The prevailing policy at Division HQ is to assume that their perception of stock states is always higher than the true values, due to the inaccuracies introduced by reporting delays and errors. A fudge factor is thus added to their calculations. The introduction of the CIS with its accompanying increase in information quality, should make this compensation element redundant

3. "All units to Dump"

The increased availability of information about stock held at Forward Dumps offers the potential to reduce losses at these locations. The vulnerability of grounded stocks to loss could be reduced by directing all Units to collect from the Dumps whenever stock had to be grounded. This would increase the average distance travelled by the Unit transport but its implementation was felt worthy of study.

4. "Desired Profile"

The argument behind the introduction of the "desired profile" concept is that only Corps command have a holistic view of the progress of action and are in a position to determine the optimum distribution of ammunition, but that the Commanders in situ have the best view of their own situation. The responsibility for maintaining the designated stock level at a particular location should lie with the commander at that level. The determination of the appropriate stock levels, however, should be the responsibility of Corps command and aim to prevent over-stocking in vulnerable locations.

Under present policies, which have been moulded by the inefficiencies of the information network, ammunition is moved forward whenever transport is available. Only Unit commanders try to maintain desired stock levels at the Front, but their success is highly dependent on the mode of operation of squadron transport. The introduction of an effective communication system should enable a higher level of control.

Ideally, of course, stock would be moved forward only when it can be taken up. However, in a military context, the probability of disruption of supply lines is high and a balance has to be achieved between the minimisation of losses and the capacity to meet required firing rates. We report here on the first stages in the determination of the "Desired Profile", where desired stock levels for the DSA and Brigade holdings are introduced.

Model Performance under new policies

All policies described above increased the capacity of the operation to meet the required firing rate and to meet the demands of the Corps troops.

Only the "Reduction in Transport Capacity" and "Desired Profile" policies succeed in reducing ammunition losses below that of the "manual" system.

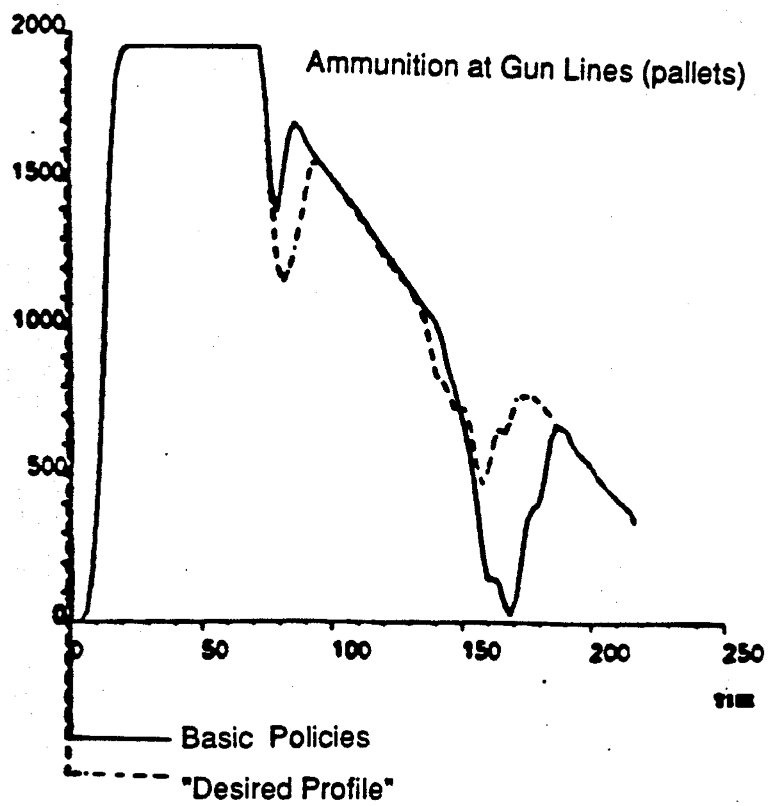
Both the "No over-ordering" and the "All to dump" policies increase the flexibility of the Corps commander by allowing stock to be retained longer at the CSA.

The "All to Dump" policy decreases the capability to meet required firing rates if the average distance from the Front to Dumps increases above about 10%. Alternative approaches to improved Dump management may offer greater opportunities.

The "Reduction in Transport Capacity" has obvious attractions in resource savings. In addition, the reduction in losses resulting from the slowing of stock distribution to more vulnerable positions, increases the flexibility of Corps command. However, flexibility within Divisions is reduced. Stocks held at the DSA cannot always be moved forward and the capacity of the system to react to shocks is severely limited.

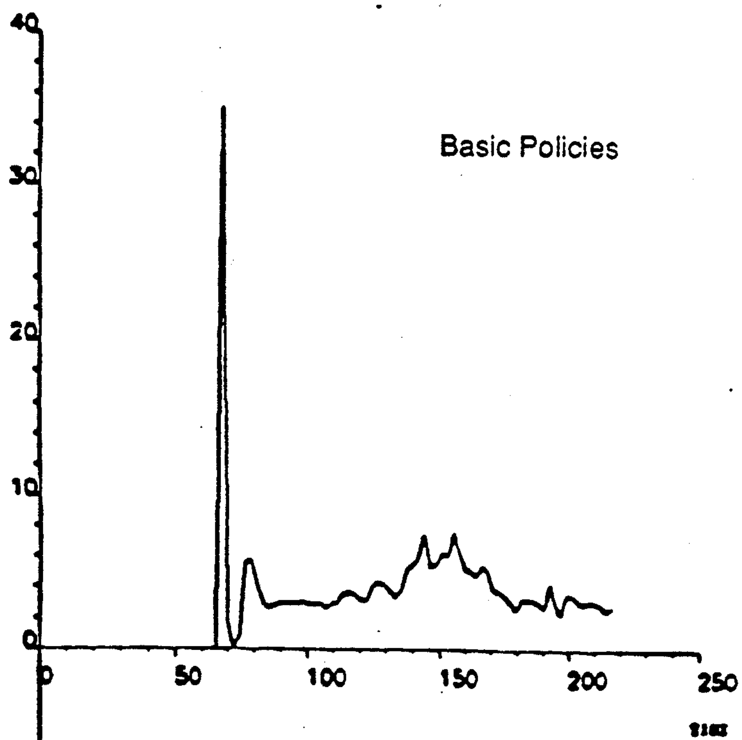
The "Desired Profile" concept shows the most promise. The control imposed by this policy has a greater potential to cushion the system against shocks (Fig. 4).

Figure 4



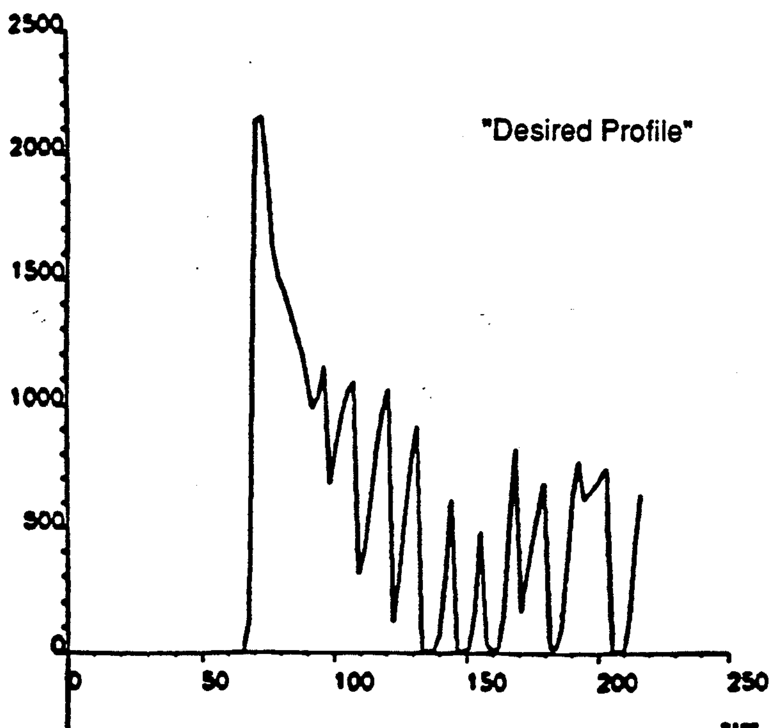
In addition, the availability of squadron transport is increased (Cf. Figs. 5 and 6), offering the opportunity for this resource to be managed more efficiently. This better management may itself enable reduction of capacity.

Figure 5



Transport Capacity (pallets)

Figure 6



Transport Capacity (pallets)

CONCLUSIONS

An evaluation of the contribution of the above approach to the assessment of computerised information systems in general, is presented by Gavine and Wolstenholme (Gavine, 1990).

In relation to the assessment of the Logistics system, the model was felt to contribute to the understanding of its impact on the Ammunition Supply function. However, the extent to which the model contributes to the assessment of the impact of the CIS on the whole organisation has still to be resolved. Within the Supply function itself, only "combat" supplies are available on demand. Bids have to be submitted for all other commodities, a facet not represented in the current model and this may affect the generality of the observations from the ammunition model.

There is a need to establish whether the logistics activities, designated as "support" activities in the present model, need to be modelled in more detail. It would be possible to apply the approach in modular fashion to each of the functions in turn, and combine the results in a higher level model.

Given the above reservations, the indications at this point in the analysis are that, whilst the proposed logistics system has the potential to improve performance, its implementation must be accompanied by changes to the mode of operation. It has to be recognised that the deficiencies of the present manual system have enforced poor control procedures, the continuation of which, after the implementation of the CIS, could result in a more costly, and eventually less effective operation.

References

Gavine A., Wolstenholme E.F. 1990 "An Appraisal of System Dynamics in Assessing the Impact of Computer Information Systems", International System Dynamics Conference, Boston, Mass., USA.

Wolstenholme E.F., Watts, K.M., 1988 "A Methodology for the Assessment of Management Information Systems", International System Dynamics Conference, San Diego, California, USA.

Wolstenholme E.F., Gavine A, Watts, K.M., Henderson S., 1990 "The Design of a Dynamic Methodology for the Assessment of Computerised Information systems", International System Dynamics Conference, Boston, Mass., USA.