ADAPTIVE USE OF *TRIPS* (TRANSPORTATION RESOURCE INTEGRATED PLANNING SYSTEM) TO MODELING TRANSPORT PLANNING AND MANAGEMENT IN A MANUFACTURING FIRM

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ABSTRACT

The need for secured shipping operations in sub-saharan africa calls for great concern and need for urgent action. Efforts at combating this challenge left decision makers and takers with no option but to wait endlessly for solution one day or resort to the use of intuition in determinig issue of such a magnitude. Although, the adapted model TRIPS was originally designed to guarantee protection for materials in transits as well as in storage,but its inherent fall out as benefits supported budget request and incorporation of transportation planning and management in any projects affecting movement of materials (cargoes, trailers etc.) that need protection or thus have security concern.The paper among other things describe the adaptive use of TRIPS model to aid effective and efficient transportation planning and management and also recommend the need for further research effort geared at enhancing overall development of transportation integrated system (TIS) for better decision making.

Key Words: Adaptive, TRIPS, Modeling, Planning ,Management & Manufacturing Firm

INTRODUCTION

Decision-making is said to be psychological construct. Every decision-making process produces a final choice or opinion. It begins when we need to do something but we do not know what. Therefore, decision-making is a reasoning process, which can be rational or irrational, and can be based on explicit assumptions or tacit assumptions. This means that although we can never "see" a decision, we can only infer from observable behaviour that a decision has been made. Therefore, we conclude that a psychological event that we call "decision making" has occured. It is a construction that imputes commitment to effect the action. The model is called TRIPS – for Transportation Resource Integrated Planning System. TRIPS combines rules on TSS operations with workload projections and a detailed description of all the resources constraining transportation of these materials. The resource constraints include shipper and receiver site capabilities and the availability of federal agents, transporters, and certified packages to support the work. The manager is forever beset by the necessity to choose among alternatives the outcome of which is definitely unknown. Strategic decisions take place at three different levels in an organisation. These levels are functional, businesses and corporate. The corporate strategic manager seeks to maximize the attainment of long-term organisation priorities such as maximizing shareholders wealth and developing managerial ability. The economic downturn in many African countries, particularly Nigeria, has been having serious effect on some organisations in the maunfacturing sector to the extent that a number of such organizations have had to close shop due to escalating cost of production and distribution. However, the distribution cost outweighs the production cost. We investigated to what extent a transportation model like TRIPS could help in solving the problem and which type of model will be most suitable for use in order to:

- Achieve the attainment of corporate objectives
- Optimize the profitability level
- Aiding bugetary decisions

MATERIALS AND METHODS

A good deal of research work has been devoted to the investigation of issues similar to ours, and it is interesting to compare different approaches in order to draw lessons for our problem. As will be shown in the following sections, the proposed methodology relies on a variety of research fields. In what immediately follows, we take a brief look at the past work of various authors in the area being investigated.

Freight Distribution Systems

One of the related fields that can provide useful insights for our problem is the abundance literature on the modeling of freight distribution systems. Bearwood et al. (1959), Eilon et al. (1971) estimate the length of a TSP tour for a fleet of vehicles through simulation. In distribution problems it is usually possible to divide the service area into several zones each of which is served with one vehicle and each path is estimated using the formulas for the TSP tour. This very popular technique, called "cluster-first, route second", has been successively used in many papers modeling distribution problems. Larson and Odoni (1981) provide useful insights for the multi-route problem, while a generalization of the TSP formula for zones of different shapes is provided in Daganzo (1984a). Some authors [for example Adebisi and Hurdle (1982); Aldaihani et al. (2004); Quadrifoglio, Hall and Dessouky (2005)] adapt a model for fixed lines bus systems to flexibles services (that is, services in which the buses can deviate from their pre-defined path to serve requests off the route). In those cases, the decision variable usually considered is the headway between two successive vehicles or the slack in the schedule. This kind of service is different from our DRT system, since in our case there are no predefined paths and so headways cannot be defined. For this reason, a model for conventional transit system cannot be used in our case. In the 1970's due to the diffusion of Para transit services, some researchers proposed different methodologies to model simplified variants of a DRT system in order to compare them with conventional bus line networks (Ward, 1975). The issue of the design of an integrated urban public transportation system was investigated by Batchelder and Kullman (1977). However in this case the model for the dial-a-ride system was based on computer simulations calibrated on real datasets. Wilson and Hendrickson (1980) focus on performance models, where the decision variable is related to the quality of the service, and provide an excellent comparative analysis on the different methodologies that have been proposed. They also report from previous unpublished research empirical models for the determination of the number of vehicles that were calibrated on real data. It is well known that empirical models are difficult to use in a context that is different from the one upon which they have been calibrated.

Agent-Based Model Simulation (ABMS)

An attempt at aiding the understanding of this study will necessitate a little excursion into the explanation of Modeling Technique, as explained through the understanding of Agent-Based Simulation. Agent-based simulation is establishing itself as a serious, useful area of study. The essential idea of agent-based modeling and simulation (ABMS) is that many phenomena, even very complex ones, can best be understood as systems of autonomous agents that are relatively simple and follow relatively simple rules for interaction. Applications range from modeling agent behavoiur in the stock market (Arthur et al. 1997) and supply chains (Macal 2003, 2004) and modeling bacterial cell behaviour (Emonet et al. 2005). Agent-based modeling and simulation is also an experimental technique, a frame work for developing electronic laboratories in which the most detailed assumptions about individual agents, their behaviours and interactions can be varied and explored.

ABMS and Traditional M&S Techniques

Agent-based modeling can provide an overarching framework for model based on other modeling techniques. For example, models may be composed of agents whose decision-making behaviors are represented by formal optimization problems or by informal decision heuristics. Another example is agent behaviors represented as statistical models deriving agent behaviors from the agents' input information. Agent-based modeling can also be used as a complement to other modeling techniques: for example, an agent model that builds system behavior from the behaviors of the individual agents can be "docked" (used in conjunction) with a more aggregate Systems Dynamics model of the system, to see whether the two approaches yield similar results over a range of test cases. The goal of this study is to model a many-to-many demand responsive transit service without predefined itineraries and schedules. In this case, the fleet has to be dispatched exclusively on the basis of the list of requests, like in taxicab systems, the difference being the possibility of serving customers with some detours in order to share the ride. We believe that this kind of service is of particular interest for the possibility of offering a high quality service with an efficient allocation of the resources. To achieve this, we have modeled a service in which time windows are associated with each pickup and delivery point. The definition of time window is different from the notion of “time deadline” that can be found in previous works, for example concerning hauling services (Hall, 1996). Although Daganzo (1987) modeled a distribution problem considering time windows associated with each delivery point, the suggested methodology is not suitable when temporal constraints are tight as in the case we are considering. Thus, we need a procedure that is not easily derivable from existing methodologies. For example, comparing our problem to the previously discussed ones, it can be observed that in our case, it is impossible to model it as a fixed-line service since we cannot define a “path” or a “headway” between the vehicles. On the other hand, the joint need of avoiding transfers for any pair of pickup and delivery points and of limiting the maximum ride time for every customer prevents us from dividing the area into several service zones served by a single vehicle, hence, a “cluster-first, route-second” model is not appropriate.

Model Formulation

The TRIPS model is a large-scale linear programming formulation. The baseline formulation determines the maximum workload that can be accomplished within constraints imposed by limited resources. However, the model can also be used in a “resources requirements” mode, in which it computes the set of resources that would be required to service a specified workload. The model formulation relies on definition of several core terms. Most basic among these is definition of time periods considered in the model. Many of the variables in the model are defined over a set of discrete periods indexed by $t = 1,2,\ldots,T$. In the analyses performed to date, these periods are months, and the model planning horizon extends out ten years. A *campaign* is the movement of a specific type of material in a specific type of package, from an origin point to a destination point. The model allows a shipment “window” to be defined for each campaign. This window represents the degree of scheduling flexibility that exists regarding when to move a particular shipment in that campaign. Because the basic time period in the model is one month, the minimum degree of flexibility assumed is that movements can occur any time within a single month. However, if greater flexibility is available for a specific campaign, the window can be expanded. If a shipment is not moved within its specified window, the packages not moved on time are said to be *deferred*. The model attempts to avoid deferral of shipments, but if resources are too constrained, deferrals can occur and are reported in the model output. A third important concept in the model is that of a truck *fleet*. Each fleet is a particular physical trailer type. Material shipments are assigned by the model to truck movements by specific fleets, and we can restrict specific campaigns to move only in certain trailer types. The model assigns packages and resources to *convoy deployments*. A convoy deployment involves the dispatch of TSS agents and transporters to move the contents for one or more campaigns. One convoy may move contents between a series of shipping and receiving sites before returning to its home base. The campaigns establish the workload, the convoy deployments determine how efficiently the workload is accomplished. The goals are to minimize deadhead miles, maximize the quantity of packages transported in each convoy, and minimize the overall resource requirements to support all of the requested work scope. All of these goals have to be met within the requirements of the missions being supported.

To describe the baseline model formulation, we can begin by defining a set of input parameters, as follows:

$Q_c(t)$: quantity (number of packages) of cargo for campaign c first available to move in time period t

$D_c(t)$: time period by which cargo for campaign c made available in period t must be moved

$V_k(t)$: trucks available in fleet k in time period t

$H(t)$: available agent-hours in time period t

v_c: packages for campaign c that can be shipped in one truck

π_k: vehicle-miles of productive use for a truck in fleet k per time period

d_{ij}: distance from node i to node j (miles)

g_c : distance from origination node to destination node for campaign c

ψ_c: relative priority of shipping a package from campaign c

γ_c: penalty cost for not moving a package of material for campaign c

The number of packages of material assembled into a single shipment varies across campaigns, and the proportion of a truck's capacity required for a single shipment also varies across campaigns. Because a whole truck must sometimes be used to carry a partial load, we transform the raw workload input, $Q_c(t)$, which is measured in number of packages, into workload demands measured in number of trucks, which we can denote $W_c(t)$. The transformation is:

$$W_c(t) = [Q_c(t)/v_c] \quad \text{(Eq. 1)}$$

That is, the number of trucks demanded is the smallest integer number that is sufficient to carry the desired number of packages.

From the set of $W_c(t)$ and $D_c(t)$ values specifλied, we can compute two other sets of parameters:

$$A_c(t) = \sum_{\tau=1}^{t} W_c(\tau) \quad \text{(Eq. 2)}$$

$$R_c(t) = \sum_{\tau=1}^{t} \{W_c(\tau) \mid D_c(\tau) \le t\} \quad \text{(Eq. 3)}$$

$A_c(t)$ defines the cumulative number of truckloads for campaign c available for movement through the end of period t, and $R_c(t)$ represents the minimum requirement for movement of truckloads in campaign c through period t (i.e., in order to move packages within their allowable “time windows”). These values are used in the model to bound the actual movements. Material cannot be moved until it is available, and it should be moved by its deadline period. The values of $A_c(t)$ and $R_c(t)$ are used in the model as inputs, but they are computed from the actual data ($W_c(t)$ and $D_c(t)$).

The following decision variables are determined by the model:

$q_{ck}(t)$: units of cargo (packages) of campaign c that are actually moved using fleet k in period t

$x_{ck}(t)$: trucks from fleet k moved carrying cargo of campaign c in period t

$y_{ijk}(t)$: number of trucks of fleet k that move empty from i to j in time period t

$N_c(t)$: truckloads of cargo for campaign c that are deferred (i.e., not carried within the allowable time window) at time t

The objective of the model is to maximize total system completed workload. In addition, the actual objective function implemented contains penalty terms for deferred workload and empty truck-miles, so the actual objective is:

$$\text{Max} \sum_{c,k,t} \psi_c g_c e^{-\lambda t} x_{ck}(t) - \sum_{c,t} \gamma_c g_c N_c(t) - \theta \sum_{k,i,j,t} d_{ij}\, y_{ijk}(t) \quad \text{(Eq. 4)}$$

The ψ_c coefficient in the first term provides a relative weighting based on the priority level of the campaign. The γ_c term in the second term reflects the relative penalty for deferring workload from campaign *c*. The $e^{-\lambda t}$ term creates a small time preference (e.g., using a small value of λ = 0.01), so that it is advantageous to carry shipments early in their allowable time window, rather than later. The penalty term on empty truck-miles is present to prevent solutions that move vehicles for no real purpose, and in implementation the value of θ is very small (0.001). Two sets of constraints in the model are used to bound the workload and define deferred workload. The cummulative amount of cargo (in truckloads) for campaign *c* that is moved by the end of period *t* is

$$\sum_{\tau=1}^{t} \sum_{k} x_{ck}(\tau).$$

We use that value, plus $R_c(t)$ and $A_c(t)$ defined by (2) and (3), to define deferred workload, $N_c(t)$. These constraints are as follows:

$$\sum_{\tau=1}^{t} \sum_{k} x_{ck}(t) + \mathrm{Nc(t)} \geq \mathrm{R}_c(t) \qquad \forall c,t \qquad \text{(Eq. 5)}$$

$$\sum_{\tau=1}^{t} \sum_{k} x_{ck}(t) \geq \mathrm{A}_c(t) \qquad \forall c,t \qquad \text{(Eq. 6)}$$

Restrictions that certain campaigns must use specified types of trucks are implemented by constraining some of the flows to be zero:

$$x_{ck}(t) = 0 \text{ for } ck \text{ combinations that are not acceptable} \qquad \text{(Eq. 7)}$$

Conservation-of-flow equations force the flow of trucks in each fleet *k* to balance at each network node, *i*, in each time period, *t*:

$$\sum_{j} y_{jik}(t) + \sum_{c\in\Delta_i} x_{ck}(t) = \sum_{j} y_{ijk}(t) + \sum_{c\in\Omega_i} x_{ck}(t) \qquad \forall i, k, t \qquad \text{(Eq. 8)}$$

The left-hand-side of (6) is the total flow of trucks (empty plus loaded) in fleet *k* into node *i* in time period *t*, using the notation that Δ_i represents the set of campaigns whose destination is node *i*. The right-hand-side of (6) represents the total flow of fleet *k* trucks out of node *i* in time period *t*, where Ω_i is the set of campaigns whose origin is node *i*.

The total resources available, represented as truck-miles and agent-hours, constrain the operations in each period:

$$\sum_{c} g_c x_{ck}(t) + \sum_{i,j} d_{ij}\, y_{ijk}(t) \;\leq\; \pi_k V_k(t) \quad \forall k, t \qquad \text{(Eq. 9)}$$

$$\xi_0 + \xi_1 \Big[\sum_{c} g_c x_{ck}(t) + \sum_{i,j} d_{ij}\, y_{ijk}(t)\Big] \;\leq\; H(t) \quad \forall t \qquad \text{(Eq. 10)}$$

The left-hand-side of (9) is the total truck-miles operated (including both loaded and empty miles) for fleet k in period t, and the right-hand-side is the available truck-miles from a fleet of size $V_k(t)$. The vehicle productivity parameter, π_k, is a critical input to the model, because it determines how much work an average vehicle can perform. Constraint (10) expresses agent-hours required as a linear function of total truck-miles operated, using the parameters ξ_0 and ξ_1. For a variety of operational reasons, the relationship between truck-miles and agent-hours is not exactly linear in practice, but for long-range planning this is sufficiently accurate. The parameters ξ_0 and ξ_1 are estimated statistically from historical data and knowledge of the detailed operational rules in effect. Constraint (10) then limits operations to those that can be staffed with available agents. In any given time period, either available truck resources or available agents to staff operations may be the limiting resource. Oyatoye & Magbagbeola (2010), the model allows investigation of both capital expenditure plans for acquiring more trucks over time, and training plans for increasing the agent pool, as means of relaxing resource constraints.

Equations (4)-(10) define a linear programming (LP) problem. For the purposes of long-term (i.e., multiple years of monthly periods) planning, we solve this problem as an LP even though the solution can generate non-integer flows of trucks. As long as we interpret the solution as a forecast of the general character of operations in future months, and do not try to infer from it that a specific truck is carrying a specific load at a specific time, this is an acceptable solution strategy. The model has been implemented in a PC environment, using a commercial linear programming software package such as CPLEX and GAMS.

RESULT AND DISCUSSION

Supporting The Model With Valid Data

The modeling effort requires four main types of data:

- Workload information, in the form of projected number of packages to be shipped, by package type, campaign and month, over the planning horizon (currently ten years)
- Resource availability (trucks and agents), by month, over the planning horizon
- Network data (locations, mileage, etc.)
- Operational data (loading limits for packages on trucks, vehicle productivity, parameter estimates for agent-hours calculation, etc.).

This data represented a large increase in the amount of planning information sites and program office were asked to provide. New data calls are not favorably received, so getting support for accurate and timely data inputs was challenging. Changes to resource allocation and operating rules have then affected inputs to the model.

Uses And Impacts Of The Modeling Effort

The algorithms used by the model are of little direct use in guiding material disposition decisions. To support management analysis, a significant effort was invested in developing graphical output from the model that accurately summarized the analytical results. Graphical presentations highlight disconnects between workload and resource capacity. Good graphics also clarify the impacts of changing various parameters involved in managing these materials through disposition. Figure 1 shows one solution set created from the model for management review.

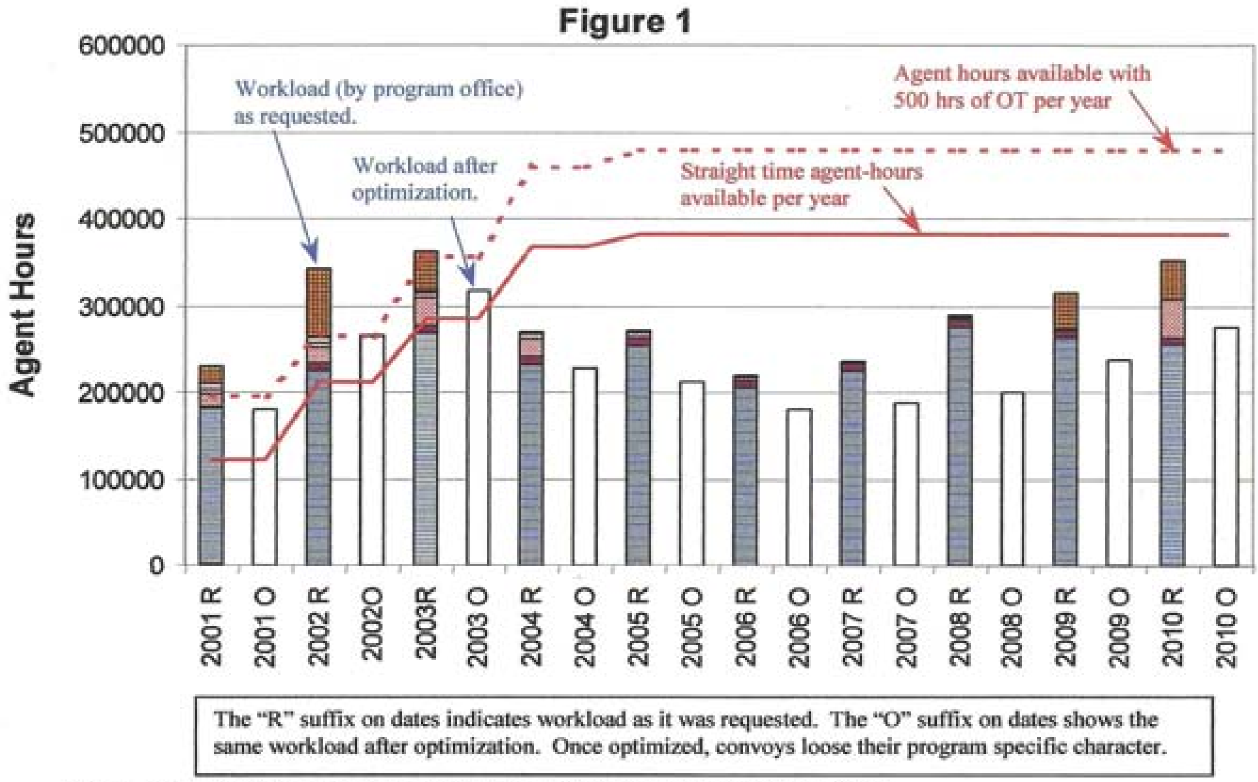

Fig. 1. One solution set created from the model for management review.

Source: Gary L et al (2002), WM '02 Conference, February 24-26, 2002 Tucson, AZ pp.6

Our modeling effort has produced these benefits:

1. The planning for secure shipments now supports more efficient operations.
2. The planning data is now better aligned with the actual shipments than it was in the past. This increases confidence in modeling results and allows management to make effective decisions based on recommendations coming from the model.
3. The modeling data has supported budget requests to provide increased resource capacity
4. The effort has highlighted the importance of including transportation planning in any projects affecting the movement of DOE's cargoes that can affect national security.

CONCLUSION AND RECOMMENDATIONS

The Transportation Safeguards System is a vital aspect of the Department's protection for materials of national security interest, but there are resource constraints. With the end of the cold war, many of the materials preserved for national defense activities are being declared surplus to production operations.
Managing these materials through disposition is a complex endeavor. Transportation management is one of the complicated support functions in this process. Prior to creating this model, there was no way to assess the capacity of TSS resources to supported the integrated secure transportation workload under a variety of scenarios being considered. We now have a tool that can provide this information.
Managers responsible for making disposition decisions for special nuclear materials can now review the costs and benefits of a variety of disposition scenarios. Transportation planning can be incorporated into that decision making process. Perhaps the greatest result is that the cost of collecting the data and running the model has been less than the opportunities for cost avoidance the model has presented to the Department. It is an elegant analytical tool that makes good business sense.

The interest in using an approximation model lies in the possibility of the planner to perform sensitivity analysis through the construction of several different scenarios. In this way, the choice of the best compromise between quality of service and financial resources is much more effective. Another useful generalization of the present work might be the inclusion of the proposed methodology in a demand-supply equilibrium model for a general DRT system, similar to what was proposed by Chang and Schonfeld (1991) and Chang and Lee (1993) for the specific case of a deviation service. This is a research field that deserves more attention and that may be a key issue in developing DRT services that are more cost-effective but still satisfying for the customers, hence, it is highly recommended for further study to serve as antidote to reducing to the barest minimum (or non-existing) fleet operations problems when noticed or envisaged to occur (a proactive-approach) especially in manufacturing firms that has big supply-chain of customers to satisfy with their products or services as applicable.

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