ABSTRACT

Computer-Aided Truck Fleet Management for Goods Distribution in Metro-Manila[1]

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This paper describes the author's experience in applying a computer-based vehicle routing and scheduling decision-support system (DSS) to the planning, operations, and management of a truck fleet for goods distribution in Metro-Manila. The paper will focus on the process of implementing the DSS within the Metro-Manila setting, and on the results of the various applications of the system. The system was implemented for a local firm[2] which provides logistics, transportation, and physical distribution services in Metro-Manila.

The system utilizes a transportation network model on which a heuristic algorithm for solving the multi-objective vehicle routing and scheduling problem with multiple constraints is implemented with a very user-friendly and highly interactive graphical user-interface.

Various physical distribution strategies were analyzed such as all-night-delivery, segregation of goods, varying fleet composition, etc. Also, the impacts of new service locations, varying time-windows, fluctuations in demand for goods movement, road traffic congestion, truck bans, and other traffic regulations on route operations and performance were analyzed. The results indicate that reductions in route distance, route time, and route costs in the range of 10% to 25% can be realized with the use of the model. These cost reductions translate to huge savings in transportation and physical distribution costs of firms particularly those with large truck fleet sizes. Another important benefit from the system is in terms of providing transportation managers with greater ability to monitor and control truck fleet operations and undertake strategic truck fleet planning and management.

Keywords: *Routing and Scheduling, Truck Fleet Management, Networks, Computer Modelling, Decision Support System*

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[1] This paper was prepared for presentation at the **2nd Annual Conference of the Transportation Science Society of the Philippines**, U.P. National Center for Transportation Studies, Diliman, Quezon City, July 29-30, 1994.

[2] The local firm is Prodigy Distributors, Inc. which is a member of the HAVI Far East, L.P. group of companies.

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BACKGROUND

The goods or *physical distribution function* of business firms has over the years evolved from a narrow and distinctly separate functional area of management into a broader *supply chain or logistics management* concern which views goods distribution from a more holistic perspective.

Logistics management integrates all processes and information related to the flow and storage of goods in the entire supply chain consisting of the following movements: (a) raw materials from extraction sites to processing plants; (b) intermediate goods from processing plants to manufacturing sites; (c) wholesale goods from manufacturing sites to warehouse or distribution centers; and, (d) consumer goods from distribution centers to retail stores. For each of these movements, transportation plays a crucial role. Furthermore, given the different characteristics of goods at each stage of the supply chain, the requirements for transport, handling, and storage significantly vary.

In terms of cost, Anderson and LaLonde (1989) showed that transportation is typically a major cost component of total logistics costs. It can be gleaned from Figure 1 that transportation cost dominates all other elements of total logistics cost by at least a factor of 2 to 1. Therefore, productivity improvements in the transportation of materials and goods can significantly impact the bottom line of business firms and ultimately consumer prices and customer service. This paper describes the author's experience in applying a computer-based vehicle routing and scheduling model to reduce transportation cost and improve distribution productivity of a Metro-Manila firm[2] engaged in goods distribution.

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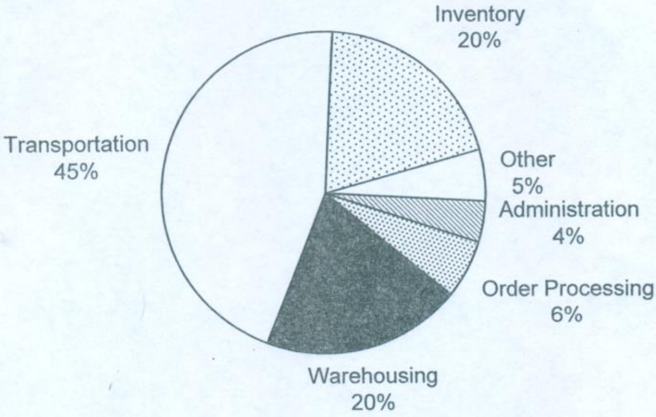
Figure 1. Major Elements of Logistics Costs



Source: Anderson, D.L. and B.J. LaLonde (1989)

In managing transportation in a business logistics setting, it is important to view three major logistical decision areas which are related to each other in the sense that each of the strategic, tactical, and operational decisions within each decision area would have an impact on other decision areas. These three areas are facility location, transportation, and inventory. A more specific listing of various key logistical decisions is shown in Table 1 next page. J. Perl and S. Sirisoponsilp (1988) classify these decisions according to scope, investment requirement, time horizon, and frequency of decisions made. In this paper we specifically focus on the operational decisions related to: (a) assignment of loads to vehicles; and (b) routing and scheduling.

Table 1. **Classification of Facility Location, Transportation and Inventory Decisions into Three Hierarchical Levels**

LOGISTICS DECISIONS	STRATEGIC	TACTICAL	OPERATIONAL
Facility Location	Number of DCs Location of DCs Assignment of DCs to Supply Sources Allocation of Demand to DCs	Material Handling Equipment	
Transportation	Mode Type of Carriage	Carrier Shipment Size	Assignment of Loads to Vehicles Routing & Scheduling Crew Assignment
Inventory	Total System Inventory Location of Inventories	Size of Inventories at Various Locations Levels of Safety Stock at Various Locations	Control Discipline at Various Locations

Source: *J. Perl and Sirisoponsilp (1988)*

THE VEHICLE ROUTING AND SCHEDULING PROBLEM

Problem Description

The vehicle routing and scheduling problem basically involves the determination of an optimal sequence of stops and the corresponding schedule of arrival time and service time at each stop for a given vehicle. L. Bodin et al (1983) provides an excellent state-of-the-art review of the research area dealing with this problem in the Operations Research field of study. There are numerous variations in the formulation of vehicle routing and scheduling problems depending on a number of characteristics as presented in Table 2 next page.

Table 2. **Characteristics of Routing and Scheduling Problems**

Characteristic	Possible Options
(a) Size of Available Fleet	one vehcile multiple vehicles
(b) Type of Available Fleet	homogenous (only one vehicle type) heterogenous (multiple vehicle types) special vehicle type (compartmentalized, etc.)
(c) Housing of Vehicles	single depot (domicile) multiple depots
(d) Nature of Demands	deterministic (known) demands stochastic demand requirements partial satisfaction of demand allowed
(e) Location of Demands	at nodes (not necessarily all) on arcs (not necessarily all) mixed
(f) Underlying Network	undirected directed mixed euclidean
(g) Vehicle Capacity Restrictions	imposed (all the same) imposed (different for different routes) not imposed
(h) Maximum Route Times	impsoed (same for all roads) imposed (different for different roads) not imposed
(i) Operations	pickups only drop-offs (deliveries) only mixed (pick-ups and drop-offs) split deliveries (allowed or disallowed)
(j) Costs	variable or routing costs fixed operating or vehicle acquisition costs common carrier costs (for unserviced demands)
(k) Objectives	minimize total routing costs minimize sum of fixed and variable costs minimize number of vehicles required maximize utility function based on service or convenience maximize utility function based on customer priorities

Source: L. Bodin, et al (1983)

With reference to Table 2, this paper deals with the vehicle routing and scheduling problem with the following characteristics:

(a) multiple vehicles
(b) homogeneous and special vehicle types
(c) single depot
(d) deterministic demand
(e) demands located at nodes
(f) directed network
(g) imposed (different vehicle capacities)
(h) not imposed route times
(i) mixed and split deliveries
(j) total costs
(k) multi-objective

Solution Approaches

The two most common approaches to solving routing and scheduling problems are through set covering or partitioning (which are special classes of zero-one integer programming models), and heuristics. The former is based on a good theoretical framework but can efficiently deal with rather small problems only. This approach would not be able to handle most real-world applications.

Since most routing and scheduling problems of interest are considered *NP-hard* (i.e., no polynomially-bound algorithm has yet been found), only heuristic approaches can deal with practical problems for now. The effort required to solve *NP-hard* problems increases exponentially with problem size in the worst case, Bodin, et al (1983) describe a number of heuristic approaches that have been developed in the past.

THE COMPUTER-BASED DECISION SUPPORT SYSTEM SOLUTION APPROACH

General Description

Due to the complexity of the vehicle routing and scheduling problem faced by transportation planners and managers in real-world situations, the most common solution technique employed, particularly for large applications, is the computer-aided heuristic approach using a digitized transportation network model. There are many proprietary vehicle routing and scheduling software available in the market today, one of which is called TRUCKS, which is the subject of this paper . TRUCKS is a routing and scheduling software developed by Manugistics, Inc. based in Maryland, USA.

TRUCKS is a decision-support system that provides a very versatile and systematic approach to the vehicle fleet planning and management for goods distribution. It employs a heuristic algorithm to solve complex combined vehicle routing and scheduling problems.

The **objective function is multi-dimensional** and may include minimization of number of routes, route distance, and route time. All these objectives may translate to a minimization of some cost function.

The allowable **constraints or system parameters are numerous** and user-definable, making the system very powerful and versatile in addressing various transportation planning and management issues, evaluating alternative strategies, and dealing with different operating environment scenarios. These constraints/parameters include:

(a) levels and fluctuations in the demand for goods movement (in terms of number of cases, volume, or weight);

(b) less-than-truckload (LTL) splitting by service location;

(c) service location time-windows ("hard" and "soft");

(d) fixed and variable loading and unloading rates by location (in cases per hour);

(e) vehicle capacities (in terms of weight, cube, or pallet positions of space available for goods carried);

(f) fleet size (i.e., number of vehicles);

(g) dispatch limits by warehouse;

(h) equipment restrictions by service locations;

(i) limits on route lengths (in terms of total route hours, continuous drive time, distance, and number of locations served);

(j) geographical zoning of routes;

(k) routes balancing by distance, time, or number of locations served;

(l) traffic regulations (e.g., one-way streets, truck bans, parking restrictions, etc.),

(m) time-of-day variation in driving times between service locations (to handle road traffic congestion effects on the vehicle routes and schedules);

(n) labor-related regulations such as required break-times and layovers; and,

(o) other constraints under development such as vehicle travel restriction by link, turning movement restrictions, etc.

Routing & Scheduling Methods

The system can be used to handle three (3) different methods of routing commonly used by transportation practitioners, namely:

(a) Preset Routing

This is the most basic method in which the stops are preset and static. Routes are manually manipulated as necessary. This method provides the least efficiency in routing.

(b) Input Route Group Routing

For this method, key stops are fixed on each route and all other stops are added to the route by executing the routing algorithm. It gives some level of flexibility in handling day-to-day fluctuations in the demand for goods movement. This method provides better routing efficiency than Preset Routing.

(c) Dynamic Routing

This method yields the most efficient routes because it allows the algorithm to optimize the routes for all the stops. In other words, there are no predefined limits on route sequences. It is the most flexible method in dealing with highly-variable operating environments and demand conditions.

System Hardware Requirements and Software Features

TRUCKS is written in C language and designed to run on personal computers under DOS. The required configuration is at least a 386-based, 16 Megahertz, PC with 4 Megabyte RAM. The software alone would require approximately 6 Megabytes of fixed disk space. Required fixed disk space for data depends on the size of your application and it can range from 2 to 200 Megabytes depending on whether or not electronic maps would be used. Three hundred megabytes is recommended if a Tiger Map or similar Geographical Information System (GIS) data is to be used. A Video Graphic Array (VGA) color monitor and Three-button Microsoft compatible serial mouse are also needed. The user interface is graphical and highly-interactive. The software requires the use of a digitized road network model which can be graphically displayed and edited. The road network model is composed of link, node, and service location records organized as a relational database management system.

SYSTEM IMPLEMENTATION

Background

Successful implementation of any transportation model, or any quantitative model for that matter, depends on how well the model was calibrated or validated to sufficiently replicate the particular real-world environment for which the model is being developed. While the TRUCKS software has an efficient heuristic algorithm which produces some optimal set of vehicle routes and schedules, the result of this algorithm is only as good as the input data and parameters. The most critical inputs to the algorithm are as follows:

(a) calibrated road network model

(b) accurate service location data

(c) appropriate routing parameters

In developing this particular TRUCKS model for Metro-Manila, the major characteristics of the operating environment that the model should be able to address sufficiently were identified as follows:

(a) Tight time-windows

(b) Severe traffic congestion

(c) Truck Ban

(d) Vehicle physical restrictions

(e) Variations in transport demand

(f) Rapidly expanding market

Since the primary benefit from applying the TRUCKS Model is in terms of potential cost reductions, historical information on transportation costs were summarized and the findings indicate that:

(a) fuel cost accounts for only 10% of total transportation cost; and,

(b) the greatest potential cost reduction can be obtained by reducing manpower and non-fuel operating expenses.

The latter expenses can be reduced by minimizing the number of routes and maximizing vehicle utilization. These objectives were given greater weights during model execution.

Road Network Digitizing and Validation

A digitizer was used to develop a road network model that served as a major input to TRUCKS. While most applications of the model were in Metro-Manila, the network model itself cover as far north as Baguio City and as far south as Los Banos, Laguna because of the existence of a few service locations in said areas and along the way from Metro-Manila. Annex I shows the coverage of the entire digitized network while Annex II shows a zoomed-in image of the network along a segment of Quezon Avenue in Quezon City. The actual digitizing work was very easy and quick to accomplish, but data entry of link and node labels was rather tedious.

The validation of link speeds took much longer than network digitizing because of the need to achieve a high degree of accuracy on the resulting travel times between service locations. The basis for validating the link speeds were historical data on actual travel times observed over a period of time. For each service location pair, the observed travel times varied over a certain range. The travel time between a pair of service locations estimated using the TRUCKS network model was considered acceptable if it fell within the observed minimum travel time and observed maximum plus a reasonable buffer travel time. A buffer of up to thirty (30) minutes was considered reasonable depending on the distance between service locations. Out of a total of 140 pairs of service locations for which there were historical information on observed travel times, approximately 121 of TRUCKS-estimated travel times fell within the acceptable range, yielding a **network model accuracy level of 86%.**

TRUCKS Model Calibration

While accurate link speeds and path travel times between service locations are crucial inputs to any vehicle routing and scheduling algorithm, there are also other service location data and routing parameters which affect the route and schedule optimization process.

Service location data that need to be estimated from historical records or defined appropriately include the following:

(a) Loading and unloading rates

(b) Waiting time

(c) Truck fleet capacities

(d) Traffic congestion penalties

(e) Unit costs

(f) Goods movement demand

The routing parameters generally define the desired operational characteristics of the resulting routes and schedule; and, control the heuristic algorithm's execution. These are shown in Table 3 below.

Table 3. TRUCKS Routing Parameters

```
TRUCKS 8.00                        ROUTER PARAMETERS
>
ROUTING SWITCHES                                ROUTING SETTINGS
Build SLM in Memory (Y/N)?.......... N          Max Bypasses per Route.......   150
Delete Stops without Orders (Y/N)?.. Y          Max Orders per Route.........   100
Insert Stops in Skeleton Seq. (Y/N)? N          Max Routes Generated.........   100
Min Distance/Time - Router (D/T)?... D          Max Stops per Route..........    70
Off-Duty Time within Strings (Y/N)?. N          Min Travel Time between Stops
One-Way Streets (Y/N)?.............. N          Order Wander Limit (%).......    10
Order Windows Override Loc (Y/N)?... N          Route Wander Limit (%).......    50
Post-Router Shifting (Y/N)?.........            Router Iterations............     1
Product Class Sequencing (Y/N)?.....            Service Time within Windows..
Router Log to File or Printer (F/P)? F          Zone Class...................     1
Violate Location Windows (Y/N)?..... Y

ITERATION EVALUATION FACTORS
Distance  1.0  Wait/Layover Time       Drive Time       Soft Window

HARD/SOFT WINDOWS                           BALANCING
                          A B C D E           Wgt     Vol     Pal     Stops
Active Soft Windows       N Y N N N         * Route Time   Include Wait (Y/N)? N
Hard/Soft Window Setting (1-5)   5            Target Routes
```

The calibration process basically involves the iterative adjustment of service location data and routing parameters until the TRUCKS Model yields a set of routing schedule that closely simulates actual routing operations and schedule. For the case applications presented in the next section, calibration work for the baseline condition was iteratively undertaken until the transportation manager achieved a level of personal comfort on the accuracy of the TRUCKS Model.

TRUCK Model Outputs

The basic output of the model is a set of optimal vehicle routes and schedules stored in database form. A particular example is presented in Table 4 next page. This output can also be displayed graphically and the users can interactively revise the routes and schedules as they please. The other standard reports include the Load Manifest, Driver Manifest, Trip Directions, Route Cost Summary, Route Variance, Route Comparison, Tractor Schedule, Trailer Utilization, and Planners Spreadsheet. Interface modules for ASCII file upload and download of data are also available.

Table 4. Example Output of the TRUCKS Model

```
TRUCKS 7.00                          PRODIGY DISTRIBUTORS, INC.                    PAGE 21
11/06/92 17:38                       ROUTE DATA SUMMARY
                                     ROUTE GROUP:P2-WED

ROUTE:W-11   CLASS:1  TYPE:L  DRIVER 1:          DRIVER 2:          TRACTOR:        TRAILER:*1
```

SN	IDENTIFIER	ARRIVE	DEPART	TZ	DRIVE	OD	WAIT	SVC	DIST	WEIGHT	VOL	PCS	PAL
DI	000 PRODIGY DISTRIBUTORS	10/14/92 07:45	08:00					:15			308	326	
01	045 JULIA VARGAS	10/14/92 H08:30	08:41		:30			:11	10.6		1	1	
02	041 SM MEGAMALL	10/14/92 H08:46	09:20		:05			:34	0.5		1	1	
03	003 GREENHILLS	10/14/92 H09:28	09:38		:08			:10	2.7		3	3	
04	031 GALLERIA	10/14/92 H09:45	09:55		:07			:10	2.2		1	1	
05	018 MAKATI CINEMA SQUARE	10/14/92 H10:14	10:24		:19			:10	8.2		4	5	
06	009 GREENBELT	10/14/92 H10:29	10:45		:05			:16	0.7		4	4	
07	025 TAFT	10/14/92 H11:01	12:26		:16			1:25	4.4		294	311	
RE	000 PRODIGY DISTRIBUTORS	10/14/92 13:23	13:38		:57			:15	21.7				
					2:27			3:26	51.0		308	326	

CASE APPLICATIONS

This section describes the various potential applications of this decision support system and demonstrates some of the results obtained by applying the system to improve transportation operations and management for a distribution company in Metro-Manila. Route distance, route time, route cost, and number of routes reductions or increases presented below are with reference to a baseline condition defined as the actual operations and prevailing conditions just prior to the implementation of the model.

Improvement of Current Master Routes

Improving current master routes is the most frequent application of this model. As the demand for goods movement changes periodically and the number of service locations increase or decrease, master routes need to be revised to gain potential improvements in distribution productivity. Other factors which necessitate the generation of revised master routes include changes in traffic regulations such as the truck ban hours, and seasonal variations in weather conditions which may affect travel times between service locations.

The initial implementation of the model was to improve the then manually-generated master route. The model was able to produce a much-improved master route which resulted in a **25% reduction in route distance, 24% reduction in route time**, and **32% reduction in route cost**. The magnitude of these reductions is very significant during initial implementations. Lower reductions can be expected for succeeding implementations as long as the operating environment remains relatively unchanged.

Impacts of New Service Locations

Service locations are any origin or destination sites where vehicles stop to perform various activities such as loading goods, unloading goods, break-time or layover of drivers, drop-off or pick-up of trailers, fuel refilling, etc. Goods loading and unloading activities may either be at customer or supplier sites. Usually the number of supplier and customers would grow over time as business expands. This means that new service locations are added to the network and there would be a need to determine whether the existing truck fleet can still handle the increase in service locations; and if not, how many and when additional trucks would be needed.

The model was used to determine the expected impact to truck fleet requirements given the projected number of new service locations in a future year. The results are illustrated in Table 5 below.

Table 5. Impacts of New Service Locations

Quarter	1st	2nd	3rd	4th
Additional Service Locations (Cummulative)	2	7	10	11
Route Distance	+0.2%	+0.5%	+3%	+3.5%
Route Time	+4.4%	+12%	+14%	+14.5%
Number of Routes	+5.3%	+8%	+13.2%	+13.2%

Determining Optimal Time-Windows

Time window is defined as the specific interval time-of-day during which activities such as goods loading and unloading are undertaken at particular service locations. Time windows are usually limited due to a number of operational constraints such as availability of personnel to do goods receiving or dispatch, opening and closing time of certain storage facilities, etc. Generally, clients at service locations prefer that these time-windows be as narrow as possible. However, such requirement imposes a severe constraint on the ability of transportation managers to maximize truck fleet productivity.

For example, two service locations may be located right next to each other such that it would only make sense to assign them together in the same route. However, if their time-windows are far apart, say, one-hour windows but one starts at 8 A.M. while the other at 8 P.M., this situation would require two truck trips instead of just one, assuming of course that there is enough truck capacity to carry the goods to or from both service locations.

The approach followed in determining optimal time-windows was to first execute the model without time-window constraints at each of the service locations, except for cases in which it would be extremely difficult, if not physically impossible, to service a location. Then, the resulting scheduled arrival and departure times at each service location should then define the appropriate time-windows. This exercise was undertaken and the results indicate that the expected reductions are **24% in route distance, 24% in route time, and 17% in number of routes.**

Fleet Composition Analysis

Determining the appropriate fleet composition is also important in making decisions related to vehicle acquisition. This problem becomes much more complex in environments where there are physical restrictions in terms of vehicle size, traffic regulations to follow, characteristics of the goods to be carried in terms of handling and transporting requirements, etc. The model can only handle this problem by conducting carefully structured what-if analyses designed to address specific issues faced by transportation managers.

An example of this analysis was undertaken with the objective of comparing the effectiveness of homogenous fleets of trucks in which the fleets differ in truck type. Five (5) types of trucks were compared and the results for a particular route group are shown in Table 6 below.

Table 6 Homogenous Truck Fleets Using Different Truck Types

	Route Distance (kms)	Route Time (hours)	Number of Trucks	Truck Loading (%)
Base Condition (Mixed Fleet)	548	46	4	49
18ft-6ton Truck (500 ft^3 truck capacity)	418	37	3	82
21ft-9ton Truck (620 ft^3 truck capacity)	391	35	3	83
26ft-14ton Truck (750 ft^3 truck capacity)	375	34	3	91
32ft Tractor -Trailer (1200 ft^3 truck capacity)	369	33	2	57
40ft Tractor-Trailer (1500 ft^3 truck capacity)	368	33	2	46

The total route volume (i.e., a total of 2,571 cases of goods to be carried occupying a total space of 2,571 ft^3) were held fixed for each of the homogenous truck fleets analyzed above. Under this demand condition, it appears that the 26ft-14ton truck type may be the best choice given that for larger truck types, truck utilization in terms of loading percentage drops significantly compared with the correspondingly almost negligible decrease in route distance and route time.

Simulation of Manually-Generated Routes

Under certain situations, transportation managers may have to manually generate routes and their only need would be to assess whether the resulting estimated arrival times and travel times are reasonable enough. Since the model makes use of a validated transportation network, then by inputing the sequence of stops and the dispatch time from the distribution center, simulated arrival times and travel times can be derived. These simulated times can then be used to refine the manually-generated schedule.

This route simulation is also particularly useful if the transportation manager needs to make preliminary estimates of route distances and route times to new service locations for which there are no historical travel time data available. For new locations, a route travel time survey is typically conducted prior to actual route implementation. However, for planning purposes, the accuracy of simulated times may be sufficient depending of course on the accuracy of the transportation network parameters.

The model had been used in a number of route simulation analyses and the transportation manager has already gained a sufficient level of confidence on the accuracy of the transportation network. There had been cases where the simulated schedule came extremely close to the actual schedule.

Evaluating Transportation Operation Strategies

Given that the model can be used to simulate route schedules, and allows the transportation manager with great flexibility to control a lot of routing parameters, various transportation strategies can be easily evaluated. Some of the strategies that have been tested include the following: (a) all-night delivery; and, (b) integrating the delivery and pick-up of soft-drink syrup tanks.

All-night delivery is a strategy where the routes are scheduled during the wee hours of the night when there is least traffic on the roads and the procedures at the service location are set such that there is no need for a receiving crew. Using this strategy, the expected reductions are **24% in route distance, 24% in route time, and 17% in number of routes.**

Alternative ways of scheduling the delivery and pick-up of syrup tanks also analyzed such as: (a) fully integrate with all goods; (b) combine with selected goods and segregate from the rest of the goods; and, (c) completely segregate from all goods. The results of the analysis suggest that full integration with all goods is the best strategy.

Other Applications

The model can also be used to assist the transportation manager in monitoring the performance of the drivers. It can generate a route variance analysis report which basically compares the route schedule against the actual run as recorded in a load manifest. Data about the actual run can be obtained by having the driver manually fill-in actual arrival and departure times at each stop, or through the use of an in-cab computer for data capture. For both cases, an interface module is available to facilitate the inputing of data into the system.

Another application of the model was on fleet planning and budgeting. Since the model is capable of estimating route costs, it became possible to estimate transportation budgets given forecasted market demand scenarios and correspondingly, planned fleet acquisition and operational strategies. This feature of the model has been very instrumental in assisting transportation managers in their strategic planning and budgeting functions.

CONCLUSION

In this paper, it was demonstrated that there are significant benefits and productivity gains that can be obtained from using a computer-aided heuristic approach to solving complex vehicle routing scheduling problems . Furthermore, it was shown that the TRUCKS Model developed for Metro-Manila was a very versatile tool that can assist decision-makers not only in dealing with operational transportation problems, but also with strategic planning and management issues in logistics, transportation, and physical distribution. Experiences with using the model indicate that reductions in route distance, route time, and route costs in the range of 10% to 25% are attainable. These cost reductions translate to huge savings in transportation and physical distribution costs of firms particularly those with large truck fleet sizes. Another important benefit from the system is in terms of providing transportation managers with greater ability to monitor and control truck fleet operations and undertake strategic truck fleet planning and management

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ANNEX I: Coverage of the TRUCKS Network Model

ANNEX II: Example Zoomed-In Image of the TRUCKS Network Model