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DISPATCHING CONTINUOUS MOVES

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ABSTRACT

Continuous Moves (CM) is a term coined by the trucking industry. This paper defines CM's, classifies them and discusses their economies. A unifying mathematical optimization model for dispatching orders is then presented. The model selects the best way to dispatch each and every order, whether as a part of a CM or not. However, the model does consider all the feasible types of CM's. Practical aspects associated with implementing CM's are also discussed.

The term ***continuous move*** has emerged from the trucking industry during the last decade. A truck is productive (i.e., generates revenue) only when it moves loaded. From the truck operator(s perspective loading and unloading are necessary facilitating activities that rob truck time, whereas waiting and driving an empty truck are counter productive and should be minimized. Thus, the basic concept behind the term *continuous move* is that a truck should be kept moving with revenue generating loads. However, the term *continuous moves* has a variety of meanings depending on the type of operation with which it is associated. It usually refers to long-haul trucking operations where a truck is assigned several days of work and does not necessarily return to its starting location. In order to keep their trucks moving loaded, truck operators give a variety of economic incentives to shippers (or to third party providers) who provide *continuous moves* for their trucks.

This paper reviews continuous moves (CM) in the context of a variety of operational environments. It introduces a classification of continuous moves, discusses the economic incentives offered by truck operators for continuous moves, presents a mathematical model that is used to construct and select an efficient set of continuous moves while simultaneously considering other feasible alternatives for dispatching the orders, and discusses practical considerations for implementing continuous moves. For the sake of clarity the next section provides definitions of commonly used terms, and defines and classifies CM's. It is followed by a brief literature review of dispatching CM's. Then, the orders dispatching environment is presented with a unifying mathematical optimization model that is used to dispatch orders. A discussion of practical considerations in dispatching CM's follows, closing with a brief summary.

CLASSIFICATION OF CONTINUOUS MOVES

In order to facilitate clear classification of continuous moves (CM's), definitions of some basic common terms are required:

Origin– A single location (a stop).

Destination– A single location (a stop).

Order– A shipment from a single origin to a single destination with a size that does not exceed a truck(s capacity. If an order requires more than a truck(s capacity, it must be split into several orders.

Load– The cargo on a truck at any given moment.

Truckload (TL) order– An order that requires a full truck capacity or an order that is shipped separately on a truck (such an order may be a combined order consisting of several orders with a common origin and a common destination).

Inbound TL– A load on a truck consisting of several orders that have more than one origin, but a single destination. The intermediate origins are usually referred to as pick up locations.

Outbound TL– A load on a truck consisting of several orders that have a single origin and multiple destinations. The intermediate destinations are often referred to as stop-offs.

Less-than-Truckload (LTL) order– An order that requires less than a full truck capacity. Multiple such orders may be on a truck simultaneously.

Truck mode– A set of trucks that have the same operating rules and the same cost structure.

Truck type– A set of trucks of the same mode that have the same physical characteristics (e.g., capacity, compartments).

The terms TL and LTL above correspond to a large extent to carriers' mode of operation and their freight rates.

Generally, a continuous move (CM) is a sequence of shipments (orders) assigned to a truck. However, not every sequence of shipments is a continuous move. For the purpose at hand, a CM is defined as a truck route spanning more than one day and consists of a sequence of legs during which the truck is loaded (fully or partially) more than once, unloaded (fully or partially) more than once, and these activities are interwoven (all the loading activities do not precede all the unloading activities). Although multiple local delivery (and/or pick up) routes during a truck shift (or a route with a backhaul) can also be considered a CM, such is not the case here. CM refers only to long haul operations with open (one-way) routes.

The objective of a CM is to improve the truck's utilization and profitability. Therefore, the truck's operator offers economic incentives to the shipper to assemble CM's. The definition of a CM and the corresponding discounts are subject to negotiations between the shipper and the truck operator. Usually a CM limits the time the truck has to wait for a second (or subsequent) order of the CM (the dwell time), or limits the deadhead distance that the truck has to go to pick up the second (or subsequent) order of the CM (or it may limit both time and distance). There may be other limitations on a CM, such as minimal distance of a loaded leg, or maximal time of a CM. The discount given to the shipper for a CM may be a fixed dollar amount for each order following the first one, a percentage discount on the freight rate for all the orders in the CM (or only on the orders following the first one), or a combination thereof. The actual discount may also depend on the CM characteristics.

Using the definitions above, several types of CM's can be identified:

Pure TL-CM– The continuous move consists of a sequence of TL orders (see Figure 1).

Combined TL-CM– The continuous move consists of a sequence of orders that is a combination of TL orders, Inbound TL loads, or Outbound TL loads (see Figure 2).

LTL-CM– The continuous move consists of multiple LTL orders with different origins and different destinations. Some orders may share an origin, and some orders may share a destination. This is actually a sequence of interwoven pick-ups and deliveries where the truck may not be empty till the end of its route (see Figure 3).

The hypothetical examples in Figures 1 through 3 are intentionally simple ones in order to demonstrate the concepts. An example of an actual LTL-CM is provided in Table 1. The truck loads three orders in the initial source in Detroit (MI), one to OH, one to NY, and one to CT. It delivers first the OH order, and, at the same location, loads two additional orders, one to NY, and one to MA. Then it delivers the two NY orders (at two different locations), the CT order, and, finally the MA order.

FIGURE 1
PURE TL CONTINUOUS MOVE

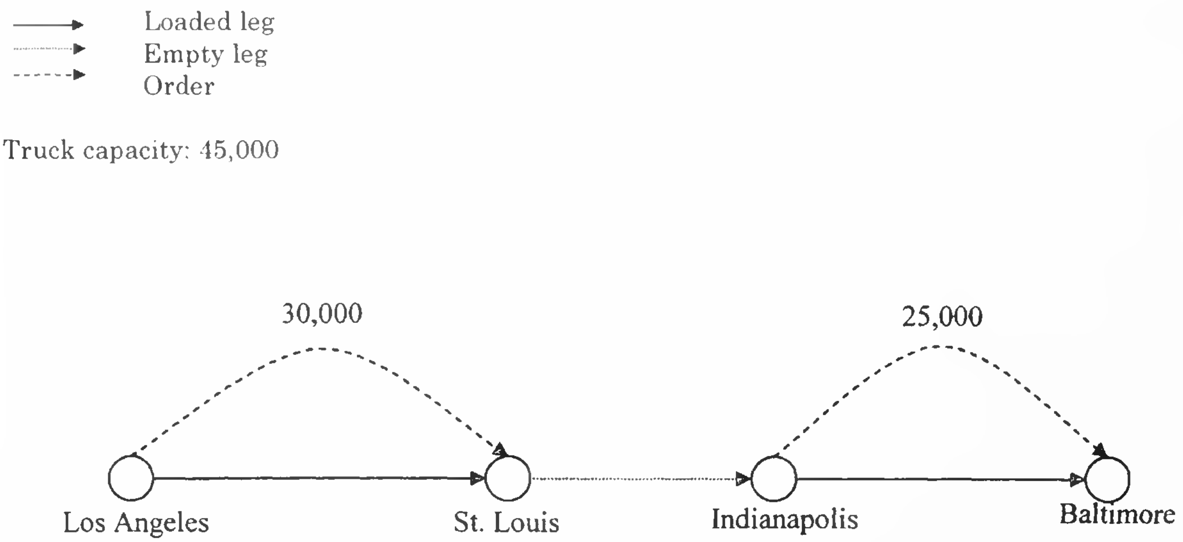

FIGURE 2
COMBINED TL CONTINUOUS MOVE

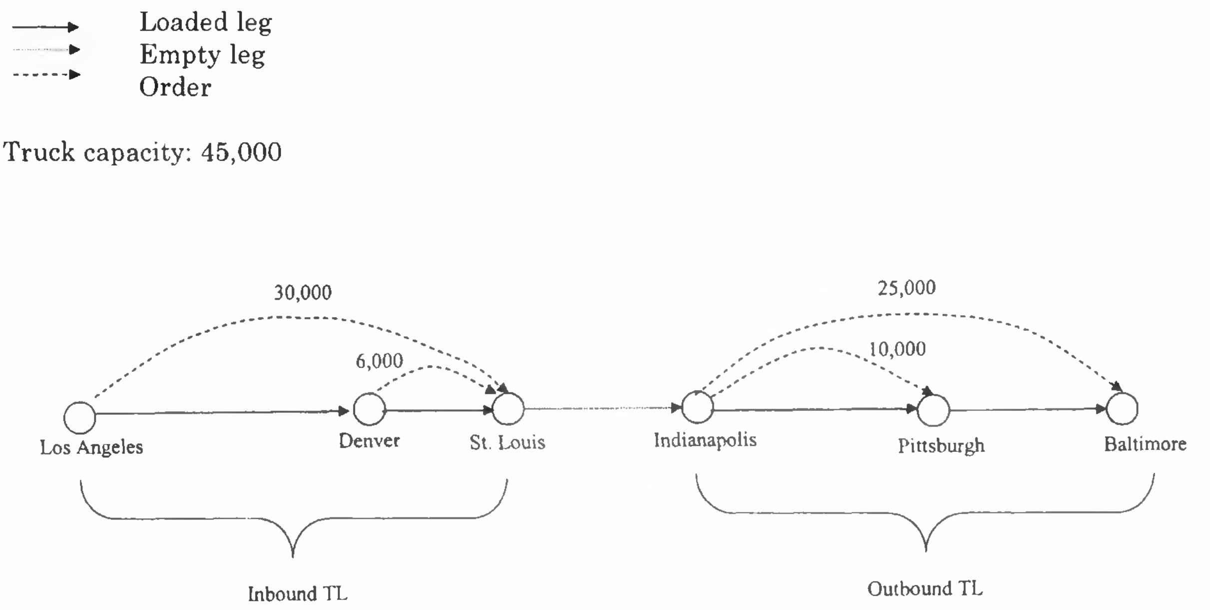

FIGURE 3
LTL CONTINUOUS MOVE

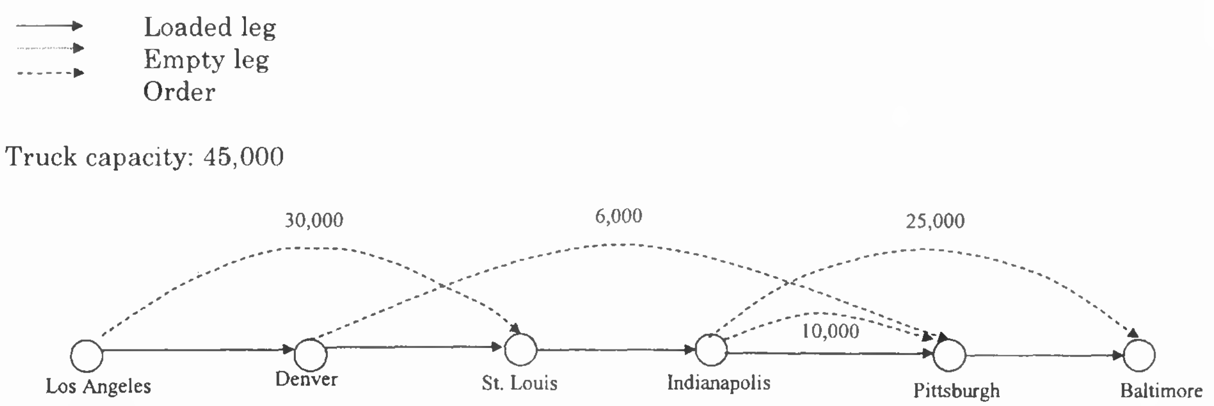

TABLE 1
EXAMPLE OF LTL-CM ROUTE

Order No.	Location		Weight (Lbs.)*	Load on Truck (Lbs.)
	No.	State		
141	13	MI	16,542	
64	13	MI	10,012	
99	13	MI	6,944	33,498
-141	18	OH	-16,542	
135	18	OH	11,074	
151	18	OH	2,719	30,749
-99	63	NY	-6,944	23,805
-151	109	NY	-2,719	21,086
-64	49	CT	-10,012	11,074
-135	101	MA	-11,074	0

*A negative number indicates delivery

LITERATURE REVIEW

The term *continuous moves* (CM) does not seem to appear in the academic literature, but different types of CM's have been addressed to some extent. Continuous moves fall in the domain of the vehicle routing literature, which is vast (for a recent review see Toth and Vigo, 2002). However, very few papers deal with vehicle routing problems that include CM's, and usually not in the context of the wider perspective of dispatching orders, where CM's are only one alternative out of several options for how to dispatch an order. Moreover, a uniform fleet is usually assumed, which allows mini-mizing miles rather than costs. Skitt and Levary (1985) and later Desrosiers et al. (1988) dealt with a Pure TL-CM problem where the fleet is uniform and, therefore, they minimize truck miles. A more complicated TL-CM problem that involves multiple products and non-uniform fleet was addressed by Brown et al. (1987).

Goetschalckx (1988) described a decision support system for dynamic truck dispatching. It is used for assigning orders to a uniform fleet of contract carrier trucks. When a new order comes in, the system evaluates incrementally, adding it to existing routes or establishing a new route for it. Route alternatives for the order are ranked and presented to the dispatcher for selection. This system is for LTL-CM but dispatches one order at a time using a uniform fleet. In a review paper, Savelsbergh and Sol (1995) present "the general pickup and delivery problem," which covers a large variety of vehicle routing problems, including some types of continuous moves. Their "static full truck load pickup and delivery problem" is the TL-CM move used here. They discuss the various types of problems and corresponding solution algorithms. However, each type of problem corresponds to a single mode of truck. When an order can be assigned to different (alternate) modes of trucks, separating the orders by truck mode before solving the dispatching problem may be far from optimal. Later, Savelsbergh and Sol (1998) presented a system for dynamic dispatching of Outbound TL loads using a heterogeneous fleet of a single mode of trucks. Multi-day routes that are a sequence of Outbound TL loads are assigned to each truck. These are one type of the Combined TL-CM move used in the current research.

More recently, a proposed system for solving a diverse variety of vehicle routing problems was outlined by Desrochers et al. (1999). The perceived system first identifies the type of problem through a dialog with the user. Then the system selects or constructs a suitable algorithm to solve the problem based on what was learned in the previous step. The authors did some initial exploratory work using expert system tools. However, it is not clear how such a system would deal with multiple different overlapping vehicle routing problems.

A unifying approach to dispatching orders that considers simultaneously all feasible truck modes and route types for each order is presented here. An outline of a LTL-CM route generator, a route type that, to the best of the authors' knowledge, has not been published before in the literature is also presented here. To solve the orders dispatching problem that includes (optional) CM's, a variant of the familiar set partitioning model is used. Set partitioning models have been used also to solve other complex resource scheduling problems, such as crew scheduling (see, for example, Butchers et al., 2001).

DISPATCHING ORDERS

Shipping an order as a part of a CM is only one option faced by a dispatcher. At any given time, the dispatcher has to assign a set of orders to the available trucks at minimal cost while meeting the service requirements. Usually different modes of trucking services can be used to ship an order. Even when there is no choice of mode of truck for a specific order, there still may be alternate possibilities to consolidate that order with other orders into truck routes. Generally, the following modes of trucks may be available to the dispatcher:

- Private fleet–paid by miles and hours and usually kept close to its origin (i.e., assigned closed routes)
- Dedicated carrier–similar to private fleet but requires minimum charges
- Contract carrier–paid either by miles (where the mileage rate may depend on the final destination) or on a point-to-point basis (based on origin and destination), with additional charges for stop-offs. Usually assigned open routes.
- LTL common carrier–paid by class, order size, origin and destination. Each order is charged separately (no economies in consolidation of orders).
- TL common carrier–paid by origin and destination on a point-to-point basis. Each order is charged separately (no economies in consolidation of orders).

Private fleets and dedicated carrier trucks are usually kept close to their origin and assigned one- or two-day closed routes. Some of these routes may be viewed as short CM's. However, because they charge by miles and hours and their routes are closed, a different procedure (generator) is required to create their routes. Due to the way contract carriers charge for their trucks, they are the primary candidates for CM's. Properly implemented CM's have the potential to save cost both to the shipper and the carrier involved.

When one tries to dispatch a set of orders at minimal cost while meeting service requirements using various modes of trucks, it is necessary to take a comprehensive view of the dispatching alternatives. Except for special situations, it is difficult to know in advance what is the best way to ship a specific order without considering the other orders that are being dispatched at the same time. An order with a given size, origin and destination may one day be best shipped by one mode of truck and the next day by another mode of truck, depending on availability of other orders with which it could be consolidated on a truck. Most models found in the literature deal with each truck mode separately. Such an approach requires assigning (in advance) each order to a truck mode. The approach used here is to consider all truck modes and all orders simultaneously, and assign each order to a truck mode and route in a manner that minimizes the cost of shipping all the orders while meeting all service requirements.

A variant of the familiar set partitioning model to select a set of routes that provides the least-cost way to ship the given set of orders using the available fleet of trucks is used in this research. Set Partitioning (SP) is a mathematical model that has been very useful for transportation routing and scheduling (see Ronen, 1995). It accommodates discrete and nonlinear costs that are common in transportation of goods, allows incorporation of a large variety of operational considerations, and provides a minimal cost dispatch. For a given set of orders and trucks, a large number of feasible candidate routes is generated in an SP model. A given order may be included in multiple (alternate) routes. A candidate route consists of a specific truck and a specific subset of the considered orders with a detailed schedule of their pick up and delivery. Only feasible routes that satisfy all the operational requirements are considered. The cost of each route is calculated, and the SP model selects the subset of routes that minimizes the total cost of shipping the considered set of orders while assuring that each order is shipped exactly once, and each truck is used exactly once.

The author prefers to use a variant of the SP model, an Elastic Set Partitioning (ESP) model. In ESP, violation of the SP constraints is allowed at a cost that is included in the objective function (see Appendix C). ESP is a more compact and flexible model where shipping each order by a common carrier is not considered explicitly, but rather through the constraint violation penalties, and not all trucks must be used, as explained in Appendix C. The elastic model assures mathematically feasible solutions even when there is insufficient truck capacity to dispatch all orders (in that case the excess orders are assigned to common carriers). A detailed numerical example of an ESP model was provided in Bausch et al. (1994).

The problem with the SP (and ESP) approach is that when a very large number of alternate routes are considered it may take a significant amount of time to find the minimal cost dispatch. However, with the rapid development of computing power this is becoming less of a concern. The key to achieving good results is in the generation of the candidate routes. The time window of each order (earliest time available and latest delivery time) introduces a natural sequence of the orders and reduces the number of potential routes. Tighter time windows that result from the shift to just-in-time requirements further improves the route generation process.

An Elastic Set Partitioning (ESP) model can be used as a unifying approach for dispatching orders from multiple origins to multiple destinations. In addition to other types of routes, it can consider all the types of CM's and select the most efficient way to dispatch each order in a given set of orders. Several different route generators are necessary to implement this approach: (a) Private/dedicated trucks, (b) Inbound TL, (c) Outbound TL, (d) LTL-CM (see Appendix A), and (e) routes chaining. The first generator (a) creates routes for private or dedicated fleet trucks. These are closed routes that may implicitly include CM's. The last generator (e) chains TL orders with routes generated by (b) and (c) to create additional CM routes. This approach is outlined in Appendix B.

In order to assemble CM's, some basic data are necessary for each order: origin, destination, size, earliest available time, latest delivery time, and special requirements (equipment, handling). In addition, distance and driving time among locations must be known, as well as loading and unloading time and delays, operating hours of the various locations involved and driver work restrictions. In order to determine the economies of CM's, the basic freight rates and the relevant discounts must be known. In addition, the characteristics of the various available trucks must be known, such as: location, capacity, equipment, operating rules, cost structure and specific costs.

In order to use CM's, one first has to create a set of potential CM's, and evaluate their operational feasibility and economic viability. Creating Pure TL-CM's is relatively easy, especially when one uses a fast computer. Since each order is shipped separately, the issue is how to chain the TL orders into an efficient set of CM's, and which orders to ship without CM's. A large number of potential CM's can be generated and the best subset can be selected. This type of problem has been addressed by multiple authors without mentioning the term CM (for a recent example see Ronen, 2000).

Creating Combined TL-CM's is more complicated because they may also include Inbound TL loads and Outbound TL loads (for Inbound and Outbound TL loads see Bausch et al., 1995, and Brown and Ronen, 1997). Once a set of potential Inbound TL loads and potential Outbound TL loads is generated, one can chain them together (while also considering pure TL orders) into potential Combined TL-CM's.

Creating good LTL-CM's is much more challenging due to the enormous number of order combinations possible. Logically, an LTL-CM starts with an Outbound TL load and then additional orders are added to it. The Outbound TL load usually starts at a major (primary) origin. Some simple rules may be used to focus the search for orders to be added: minimal size of an order to be considered for addition to the CM, maximal additional driving time (or distance) to load (or unload) an order, maximal number of orders on the truck at any time (the more orders on a truck the more chance of delays on the route), maximal allowed utilization of truck capacity (to allow access to orders at the nose of the truck), only orders moving in the same general direction. When an order is added to a CM one must also make sure that the addition will not cause a delay in delivery of another order that is already in the CM beyond its latest delivery time. The generator that generates LTL-CM's must perform a detailed deterministic simulation of the route in order to assure feasibility of the generated CM's. It must assure that every order on the route is picked-up and delivered on time, while the operating rules of the truck are not violated. Only routes that are deemed feasible are considered by the optimization model. Such a generator is outlined in Appendix A.

After the candidate set of routes is generated, each route must be priced before the set is submitted to the optimization model. Carriers may charge differently for different types of CM's. A Pure TL-CM will usually be charged at a TL rate with the agreed upon discounts for the CM. A Combined TL-CM will usually be charged at the TL rate with stop-offs, with the CM discount. However, a LTL-CM may be charged at the TL rate with stop-offs or at a mileage rate, with or without a CM discount.

Creation of CM's may be easier or harder, but one should not lose perspective. Using CM's to ship orders is not the objective, it is just a means to reduce shipping costs (while meeting service requirements). When one has to ship a given set of orders, the objective is to ship that set at minimal cost while satisfying customer service requirements. Thus, each order should not be considered separately, but rather the shipping of the whole set of orders should be optimized. Usually there is a large variety of ways to ship a given order. An order may be shipped by a private-fleet truck, a dedicated truck, a contract carrier, or a common carrier. It may be shipped alone, or as a part of a consolidated load which may, or may not, be included in a CM. Each one of these possibilities has a different cost. Due to economies of scale in shipping that are reflected in rate structures, the cheapest way to ship a given order usually depends on which other orders are shipped with it.

An ESP-based dispatching system that considers various types of CM's has been implemented in a commercial dispatching system. It selects the optimal set of routes out of hundreds of thousands of considered routes. The cost savings that result from considering CM's depend to a large extent on the specific mix of orders, the carrier freight rates, and the associated CM discounts.

PRACTICAL ASPECTS

There are economies of scale in assembling CM's. The denser the set of orders that is considered for CM's, both geographically and temporally, the higher the likelihood to match orders and assemble CM's. Due to these economies of scale, third party providers are in a better position (than shippers) to assemble CM's by combining orders from different shippers. However, combining orders from different shippers in a CM can pose some complications, such as: equitable distribution of the carrier(s discount for the CM among the participating shippers, objection from one shipper to ship his orders with a competitor's orders on the same truck, or objections from competing destinations to receiving their orders on the same truck. In addition, it must be assured that all the orders that end up on the same truck can be shipped together (don't ship packaged lube oil with packaged food). Further complications in CM's may be posed by requirements for loading or unloading appointments. One missed appointment may disrupt the remainder of the CM.

Economies of scale call for centralized dispatching, and possibly releasing the orders that are not combined into CM's to regional dispatching centers. Some final destinations are preferred by certain carriers (they may have loads originating in the same area) whereas other destinations may be deemed undesirable. These preferences are usually reflected either in the rates or in the discounts given for CM's ending in such destinations.

Another major issue is availability and reliability of data concerning future shipments. CM routes usually span several days and require commitment of future shipments that may not be ready at the time the CM commitment is made. Information regarding order timing, size, and even origin or destination may change till the truck shows up to load the order. The farther into the future one ventures, the less reliable the data are.

From an operational perspective, CM's can be divided into two categories:

"Give me another load"–an inbound truck is available for an outbound load. Due to carrier requirement to return a driver home by a certain time, a CM may have to head in a certain direction and end by a specified time.

"Use the truck for X days"–a specified period commitment with defined start and end locations will usually result in a lower mileage rate, but will require a minimal charge. Both of these categories can be incorporated into the ESP model.

The dynamic aspects of dispatching must also be taken into account. At any given time trucks are moving with assigned loads and changes in their schedules may happen for numerous reasons. The approach outlined above can be used in a dynamic mode if one knows what orders are on each truck, where each truck is heading, and other relevant data. However, when creating a dynamically updated dispatch one should take into account the time it takes to communicate the revised instructions to the field.

SUMMARY

Continuous moves represent an effort to increase the utilization (and revenue generation) of trucks. Economies of scale in assembling CM's call for centralized dispatching. The various varieties of TL continuous moves are much easier to assemble than LTL continuous moves. However, in the current competitive business environment with pressures to reduce inventory and to ship just-in-time, few shippers have the luxury of shipping exclusively full TL loads to their customers. Thus, LTL continuous moves, although much harder to assemble, may represent a significant opportunity.

An order usually can be shipped by a variety of truck modes, and the cost of shipping the order on a given day usually depend on other orders that are shipped with it. Therefore, if one wishes to minimize shipping costs, CM's must be considered in the context of the total dispatching picture. ESP is an optimization approach that facilitates minimizing the total shipping costs of all orders every day.

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APPENDIX A
OUTLINE OF LTL-CM GENERATOR

1. Start and read data
2. Create seed CM's:
   - 2.1 Take the next primary source. If none left go to 3
   - 2.2 Sort originating orders by earliest available time
   - 2.3 Create Outbound TL loads going in the same direction following all CM rules. Put each one of them in the candidate CM list
   - 2.4 Take each originating order that is not included in any of the Outbound TL loads and make it a candidate CM
   - 2.5 Go to 2.1
3. Append an order to a candidate CM:
   - 3.1 Take the next CM from the candidate CM list. If none left go to 4
   - 3.2 Take each order that is not included in the candidate CM and try to add it to the CM. If an order can be added to the candidate CM write the new candidate CM (the one with the additional order) at the end of the list of candidate CM's.
   - 3.3 Go to 3.1
4. Cost the candidate CM's:
   - 4.1 Take the next CM from the candidate CM list and cost it. If none left go to 5.
   - 4.2 If the cost of the candidate CM is larger than the cost of shipping each order included in it separately, eliminate this candidate CM.
   - 4.3 Go to 4.1
5. Stop.

APPENDIX B
OUTLINE OF ROUTES GENERATOR

1. Start and read data
2. Generate routes for private and dedicated fleet trucks
3. Generate non-CM routes for contract carrier trucks (some of these routes may be Inbound TL or Outbound TL loads)
4. Create candidate TL-CM's (pure and combined) for contract carrier trucks:
   - 4.1 Sort TL orders, Inbound TL loads, and Outbound TL loads by earliest start
   - 4.2 Chain the entities in 4.1 to create new candidate TL-CM's.
   - 4.3 Cost each new candidate TL-CM. Delete the TL-CM if it(s cost is higher than the cost of shipping each order separately
5. Create candidate LTL-CM's (see Appendix A)
6. Submit all remaining routes (CM and non-CM) to the ESP model.

APPENDIX C
ELASTIC SET PARTITIONING MODEL

The author cast the orders dispatching problem into the following Elastic Set Partitioning (ESP) model.

Indices:

o= 1,..., orders
r = 1,..., routes
t = 1,..., truck types
R(t) routes for truck type t
R(o) routes delivering order o.

Data:

$Cost_r$–cost of route r (a function of the truck type and the set of orders in the route).
$CCost_o$–cost of shipping order o by common carriers.
$ICost_t$–cost of keeping a truck of type t idle.
N_t–Number of trucks of type t.

Binary Decision Variables:

$ROUTE_r$ = 1 if route r is selected.
$COMMON_o$ = 1 if order o is shipped by common carrier.

Integer Decision Variable:

$IDLE_t$ = Number of trucks of type t that are not assigned a route.

ESP Formulation:

$$Min\left\{\sum_r Cost_r ROUTE_r + \sum_0 CCost_0 COMMON_0 + \sum_t ICost_t IDLE_t\right\} \quad (1)$$

Subject to:

for every order: $$\sum_{r \in R(o)} ROUTE_r + COMMON_o = 1 \quad (2)$$

for every truck type: $$\sum_{r \in R(t)} ROUTE_r + IDLE_t = N_t \quad (3)$$

Constraints (2) assure that every order will be shipped, either as a part of a truck route or separately by a common carrier. If the order is not included in a selected route the variable COMMON must equal 1, and the cost associated with shipping the order by a common carrier is paid. Constraints (3) assure that every truck is either assigned a route or is paid the cost of keeping it idle (the cost of keeping a truck idle may be zero if there is no commitment to use it or pay for it). The objective function minimizes (the cost of performing the selected routes + the cost of common carrier shipments + the cost of not using the trucks).

A truck type is a set of trucks that have identical physical, economic and operational characteristics. Clustering trucks into types may reduce very significantly the size of the problem, depending on the specific operation. Instead of generating routes for each truck separately one can generate routes for each truck type, and the number of routes assigned to a truck type is limited to the number of trucks of that type.

The routes are those generated by the routes generator (see Appendix B) and may include continuous moves.

AUTHOR BIOGRAPHY

David Ronen is professor of logistics and operations management at the University of Missouri– St. Louis (UMSL). For eight years, he served as area coordinator for management science and information systems at UMSL. Dr. Ronen holds a Ph.D. in business logistics and operations management from the Ohio State University (1980), an M.S. in operations research (1972) and a B.S. in industrial engineering and management (1970), both from the Technion–Israel Institute of Technology. Prior to his arrival at Ohio State, Dr. Ronen worked for five years in research and commercial organizations involved in international shipping, trade, and manufacturing. His primary interests lie in the application of quantitative tools and information technology to solving practical business logistics problems. Since 1980, Dr. Ronen has been involved in the development of logistics management tools for major corporations. His work has been published in *Operations Research, Management Science, Naval Research Logistics Quarterly, Interfaces, Journal of the Operational Research Society, European Journal of Operational Research, Journal of Business Logistics, Maritime Policy & Management, OMEGA, Computers & Operations Research, Information & Management*, and other journals.