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Interactive Optimization Improves Service and Performance for Yellow Freight System

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Yellow Freight System has evolved from a regional motor carrier to one of the largest less-than-truckload motor carriers, handling over 15 million shipments annually over a network of 630 terminals. As the company grew, terminal managers in the field lacked the information that would allow them to coordinate their activities around the network. We developed a large-scale interactive optimization system called SYSNET to optimize the routing of shipments and design of the network. SYSNET has allowed Yellow to evaluate and implement basic operating strategies that run counter to decades of standard practice. In addition to substantial cost savings, SYSNET has improved Yellow's overall planning responsiveness in a changing business environment. But the far more important statistic to Yellow's 300,000 regular shipping customers has been the significant improvement in both transit times and service reliability.

Yellow Freight System, Inc., was founded in 1926 as a regional motor carrier serving the Midwest. By 1980, it had grown to 248 terminals, handling 5.4 million shipments per year. In 1980, after

years of debate, Congress passed the Motor Carrier Act, which effectively removed a blanket of government controls that restricted market entry and controlled prices. Using this freedom, Yellow has grown to

the point that today, it is one of the largest motor carriers in the country, handling over 15.4 million shipments annually distributed between 630 terminals and some 35,000 communities. Yellow serves over 300,000 domestic and international customers and reported revenues in 1990 exceeding 2.3 billion dollars.

From a mixed operation in the '70s, Yellow now predominantly serves the *less-than-truckload* portion of the freight market. LTL trucking is characterized by shipments that are under 10,000 pounds, with the large majority falling under 1,000 pounds. Since a tractor-trailer combination can pull approximately 45,000 pounds (depending on whether the tractor is pulling a single 48-foot *van* or two 28-foot *pups*), it is necessary to consolidate these shipments in order to form economical loads and provide quality service. An LTL carrier handles the consolidation function using *break-bulk* terminals. By contrast, *truckload* motor carriers focus on shipments that fill an individual truck. This avoids the consolidation function, which eliminates the need for a network of terminals. Under the prior regulatory environment, motor carriers were essentially required to handle both truckload and less-than-truckload freight as a result of the market entry restrictions. Under deregulation, Yellow Freight has specialized in the LTL segment of the market and truckload freight now constitutes less than two percent of its total shipments.

The '80s were a difficult decade for the motor carrier industry. Deregulation created tremendous opportunities for growth but also presented management with new and difficult challenges to manage these

larger operations more efficiently than before. In addition to removing market entry restrictions, deregulation also removed a system of pricing guidelines that had controlled prices in a manner that generally guaranteed a healthy return on investment. After 1980, motor carriers were forced to compete on price, creating tremendous pressure to cut costs. Additional pressure to reduce costs came from the manufacturing community, which was facing intensive international competition.

The Motor Carrier Act effectively removed a blanket of government controls.

The result was a substantial reduction in transportation rates. Between 1980 and 1990, transportation rates for Yellow Freight rose only 3.9 percent, translating to a drop in real terms of 29 percent.

In addition to real rate reductions, the shipping community, in response to intense international competition, began to raise their expectations on service. For many shippers, Yellow Freight is a full partner in their total quality management programs. The timely delivery of freight, whether it be parts or raw materials to a manufacturing plant or finished goods to a retailer, is an important component of the logistics system. Furthermore, while fast delivery is important, service reliability is critical. Both late and early deliveries create sloppiness in the process that in the '70s was easily absorbed by large inventories, but today is unacceptable. This heightened emphasis on service clashed with some long-standing operating practices used by

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the national LTL carriers. In the past, published service standards (the time a carrier is allowed before delivering the freight) provided a fairly large margin for error, encouraging some loose operating practices that emphasized reduced costs over service.

The effect of these pressures can be seen in the tremendous attrition the industry suffered. Out of the top 20 revenue-producing LTL carriers in 1979, only six remain today. Over this same period, Yellow grew from 248 terminals to 630 terminals. The incentive to grow came from two sources: first, larger LTL carriers can consolidate shipments more easily and economically than smaller ones, creating a cost efficiency that translates to lower prices; second, many shippers prefer to work with a single carrier that can handle a major portion of their business. A smaller carrier must routinely interline, or transfer, freight with another carrier to cover some markets. A single, large carrier simplifies tracing and billing, with fewer opportunities for errors.

This growth has had the effect of creating an extremely large and complex operation. With a fleet of 45,000 tractors and trailers, Yellow picks up more than 60,000 shipments daily, with approximately 10,000 trucks dispatched each day (excluding local pickup and delivery). Furthermore, the larger network requires a greater degree of coordination than a small system, arising from the need to consolidate flows to build economical loads. In a smaller network, there are simply not that many options, allowing most of the operational decisions to take place in the field governed by a few simple rules. As a net-

work becomes larger, the number of options for routing a trailer grows significantly, and the problem of coordinating a decentralized system becomes a major management challenge. In a network spread across the United States, many decisions are made in the field based on local information, with limited coordination among different parts of the system. Terminal managers tend to focus on specific productivity measures, such as the number of trailers they are able to load direct, over which they have the most control.

In 1986, Yellow initiated a project to improve its ability to manage a complex system. An in-house network simulation tool was reaching its limits, and Yellow was interested in using modern network methods to both simulate and optimize a large network. The project had one primary goal: improved service and service reliability through better management control of the

Yellow Freight has specialized in the LTL segment of the market.

network. This goal was supplemented by broader management objectives: to improve the accuracy of the planning process through more accurate cost and service models; to improve the speed and responsiveness of planning and analysis; and to develop a process for managing and coordinating a large network of activities. There was also an expectation that improved planning would result in better productivity and lower costs.

A project team was formed with members of the operations planning depart-

ment at Yellow and an outside consultant (the last author). The development effort started with an existing model that had been developed as part of a similar project with another carrier (see Powell and Sheffi [1989]). Using this model as a base, a major programming effort was undertaken to meet the planning needs at Yellow. These modifications, which almost doubled the length of the code, included changes in logic used to model operations and in the level of detail used in costing and reporting. Particularly important were interfaces developed that allowed the model to communicate with existing data bases in use at Yellow. This ability allowed the recommendations made by the model to be sent to the field. Additional systems were developed at Yellow to facilitate the maintenance of the cost and operating parameters that define Yellow's network.

The result of this effort was SYSNET®. At its core, SYSNET is over 80,000 lines of FORTRAN code for performing sophisticated optimizations using modern network tools. We developed an innovative, interactive optimization methodology that places human beings in the loop, putting advanced, state-of-the-art optimization methods in their hands. These methods were essential in the development of a system that would handle the entire network without resorting to heuristic methods to reduce the size of the problem. As a result, the user is able to analyze the impacts of changes on the entire network in a simple, interactive fashion. Projects that would require weeks can now be completed in a few hours (or, in some cases, a few minutes) with a much higher degree of precision. Shipment consolidation decisions that

used to be simulated are now optimized, taking into account the system effect of each decision.

Yellow uses SYSNET for two sets of applications. The primary use is tactical *load planning*, which involves monthly planning and revision of the set of instructions that govern handling and consolidation of shipments through the network. The load plan is static, with contingency provisions to handle daily fluctuations in the freight. Each month, the load plan undergoes minor revisions to handle forecasted changes in freight volumes. The second set of applications involves longer-range planning of the network itself. These problems cover

Out of the top 20 revenue-producing LTL carriers in 1979, only six remain today.

the location and sizing of new facilities, and long-range decisions that govern the flow of freight between the terminals. SYSNET allows the user to optimize the load plan using powerful interactive tools. It assists with strategic planning by allowing the user to propose network configurations and then optimizing the operation of the network before calculating total costs.

At Yellow, SYSNET has come to mean much more than a single piece of FORTRAN code. Instead, it embodies an entire planning methodology that has been adopted by all levels of the company. From strategic planning studies that are communicated to senior management, to network routing instructions sent right to the field, SYSNET has become a comprehensive planning process that has allowed

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management to maintain control of a large, complex operation. Better network management and improved coordination have produced annual savings to the company estimated at over \$7.3 million. In addition, Yellow uses SYSNET as the central tool in the design and evaluation of projects worth over \$10 million in annual savings. But the far more important statistic, to Yellow's 300,000 regular shipping customers, has been the significant improvement in both transit times and service reliability, with potential savings to the shipping community estimated at millions of dollars annually.

Basic Operations

It is important to understand the basics of less-than-truckload operations to appreciate both the complexity of the problem and the contribution of SYSNET. LTL networks are characterized by a set of terminals that handle consolidation. We treat the beginning of the journey of an LTL shipment as starting at an *end-of-line* terminal, which might be located in a city such as Boston. However, the journey actually begins at a shipper's loading dock, where a city-pickup-and-delivery truck operated by Yellow Freight picks up the shipment. Each day, these city trucks bring the shipments into the Boston end-of-line terminal to begin the process of moving through the network. At the end-of-line, the shipments might be unloaded from the city trailer and then reloaded onto *line-haul* trailers that will take the shipments out of Boston. A typical line-haul trailer will carry 30 to 40 shipments that might be destined for anywhere on the network. This trailer, however, will take the shipments only as far as Maybrook, New York,

where Yellow maintains a large consolidation or *breakbulk* facility. Boston is considered a *satellite* of Maybrook, which serves as the initial consolidation terminal for 40 other end-of-line terminals in the northeast.

Having arrived at Maybrook, the trailer is unloaded, and the shipments are sorted onto other trailers, many of which are destined for other breakbulks. One trailer might be dedicated to shipments heading to the Chicago breakbulk, with final destinations at the various end-of-line satellites of Chicago. Shipments from Boston and from other satellites of Maybrook headed to the Chicago region will be combined on the Chicago trailer. This trailer will depart, ultimately arriving in Chicago where it is again unloaded. Then shipments with a common final destination, such as Milwaukee, will be combined on the trailer destined for Milwaukee.

An LTL network, then, uses a set of breakbulk terminals to serve as collection points for freight originating and terminating at terminals in that region. The satellites around a breakbulk form a hub-and-spoke network to perform the primary consolidation function, feeding high density lanes that join each pair of breakbulks. Figure 1 illustrates the network for selected terminals served by Yellow. From the perspective of network planning, shipments are treated as originating and terminating at the end-of-lines. Trailers always move directly between end-of-line and breakbulk terminals, and normally do not make stops at other end-of-lines to fill up a trailer (they may stop at other end-of-lines for other operational reasons, but once the doors of a trailer are closed, they are nor-

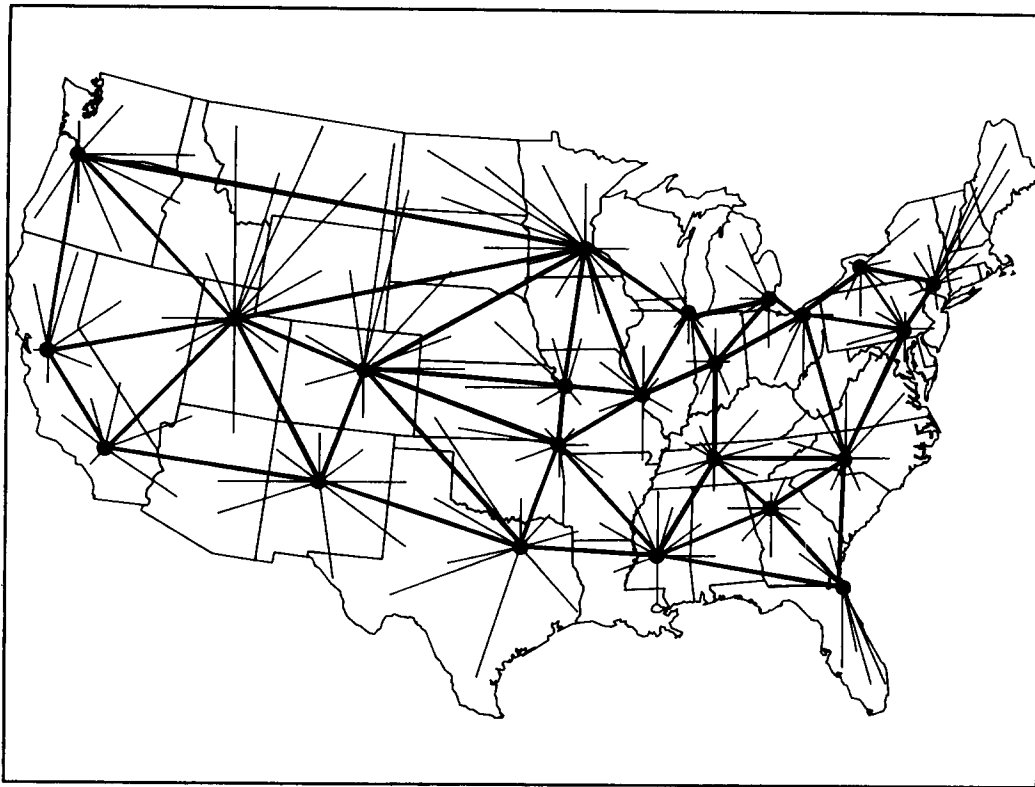


Figure 1: Yellow's line-haul network uses a hub-and-spoke pattern to perform freight consolidation.

mally not reopened until the trailer has reached its next unloading destination).

The path of a trailer from one breakbulk to another will often move over a sequence of intermediate *relays*. In most instances, a relay will be another breakbulk, and the distance from one breakbulk to a neighboring one is typically the distance a driver can cover in a single shift. Once a trailer arrives at an intermediate relay point, a different driver will take it over the next leg. The set of individual driver legs is referred to as the *line operations network*, which often looks like an abstraction of the highway network. Since shipments are never loaded or unloaded at intermediate relays, the path of the shipment is

identified by the sequence of points where the shipment is *handled* (or sorted). The shipment from Boston to Milwaukee is said to follow the Boston-Maybrook-Chicago-Milwaukee path.

This pattern of moving from end-of-line to breakbulk to breakbulk to end-of-line is often referred to as the standard routing for national LTL carriers. In many instances, however, it is possible to use a more efficient path. For example, assume that the terminal manager in Boston notices that he has enough freight bills to fill a trailer going directly to Chicago. As a large terminal, he may normally send 20 trailers each day to his *primary break* in Maybrook, and by loading a Chicago

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trailer, he may be able to reduce the number of trailers that need to be sorted at Maybrook. Eliminating the need to handle a trailer of freight not only saves handling costs but can eliminate up to a day in the total transit time for a shipment.

The process of bypassing a breakbulk is referred to as *loading direct*. The Boston terminal manager who sends a truck direct to Chicago is said to be bypassing the *origin breakbulk*. On the other hand, the terminal manager at Maybrook may identify a set of shipments all heading to Milwaukee and load a trailer that bypasses the *destination breakbulk* at Chicago (it is extremely rare for a trailer to be loaded direct from one origin end-of-line to another). In

some cases, directs are identified on an ad hoc basis by taking advantage of groups of shipments that happen to be moving through the system at one time and place. More often, however, the freight patterns are such that directs can be identified and run on a regular basis. Directs that are run on a regular basis, in addition to the normal running of trailers between breakbulks and between a break and its satellites, can be viewed as making up the *service network* (Figure 2). The service network is an abstraction of the actual flows of trailers, which must generally follow a network similar to that shown in Figure 1.

Separate from the problem of determining where to run directs is specifying

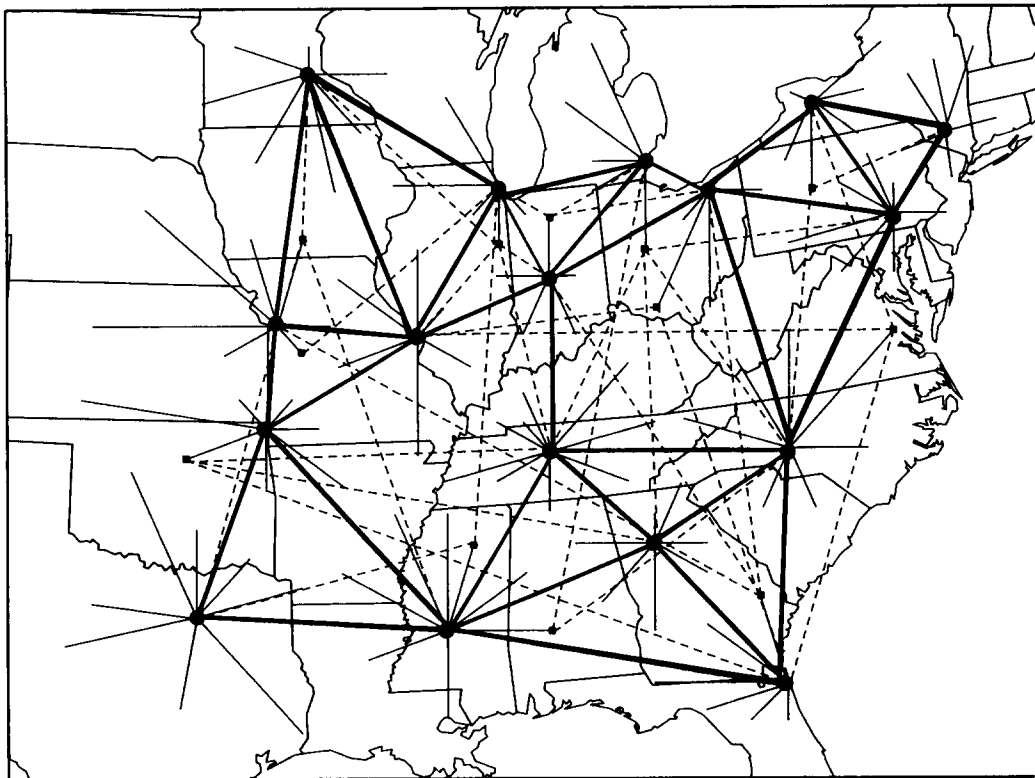


Figure 2: The service network allows trailers to bypass consolidation facilities to improve service and reduce costs.

which shipments should go on a trailer. For a large carrier, there is often more than one path from origin to destination over the service network. The routing of a shipment over a network of services is referred to as the *load plan* (or load pattern, or freight movement plan). The load plan is a set of instructions that, in its simplest form, can be stated as a shipment being handled at terminal A (independent of its origin), with destination C, should be put on a trailer headed to B.

A routing such as this from A to C implies that the carrier offers direct service from A to B. It is possible that A is the origin terminal in Boston, and B may simply be the first breakbulk in Maybrook. However, assume that a shipment from Boston to Milwaukee has two routing options: the first runs from Boston to Maybrook and then direct from Maybrook to Milwaukee, and the second goes direct from Boston to Chicago, and then from Chicago to Milwaukee. In the past, the standard solution to this would always be to put the shipment on the trailer going to Chicago, under the philosophy that it is always better to load a shipment to the terminal closest to its final destination. Determining the best routing of the shipment, which includes the problem of determining where to run directs, is called the load-planning problem.

Determining when and where to run directs and what shipments to put on a direct is the central problem addressed by SYSNET, and it is one of the largest and most challenging problems faced by large LTL carriers. A small regional carrier typically will use only three to five breakbulks. It has few opportunities to run

directs, since the large majority of its shipments run through a single break. If an opportunity to run a direct arises, then the cost and service advantages make it imperative to do so. For these carriers, the basic operating strategy is to run a trailer direct whenever and wherever possible. Furthermore, since shipments rarely run through two breakbulks, the only place to run a direct is from the origin end-of-line to the destination end-of-line. Such a strategy requires no central coordination or planning, so all decisions are made in the field.

Like most carriers, Yellow started as a regional carrier with much the same strategy. As it grew, the policy of running directs whenever possible remained in place, and the management of directs also remained a largely decentralized process. Efforts to control the routing of shipments

SYSNET specifically tracks "the cost of moving air."

were easily overridden in the field. As the company grew into a national carrier, making the transition to the standard two-breakbulk routing, the number of possible routings of shipments mushroomed. Particularly problematic is the effect that the behavior of one terminal manager can have on the performance of another. For example, when Maybrook loads a trailer direct to Milwaukee (Figure 3a) part of this trailer is filled with freight arriving from Boston. Boston may decide that it wants to start loading a trailer direct to Chicago, using the freight to Milwaukee to help fill the trailer (Figure 3b). This change in strategy affects the flow of shipments into May-

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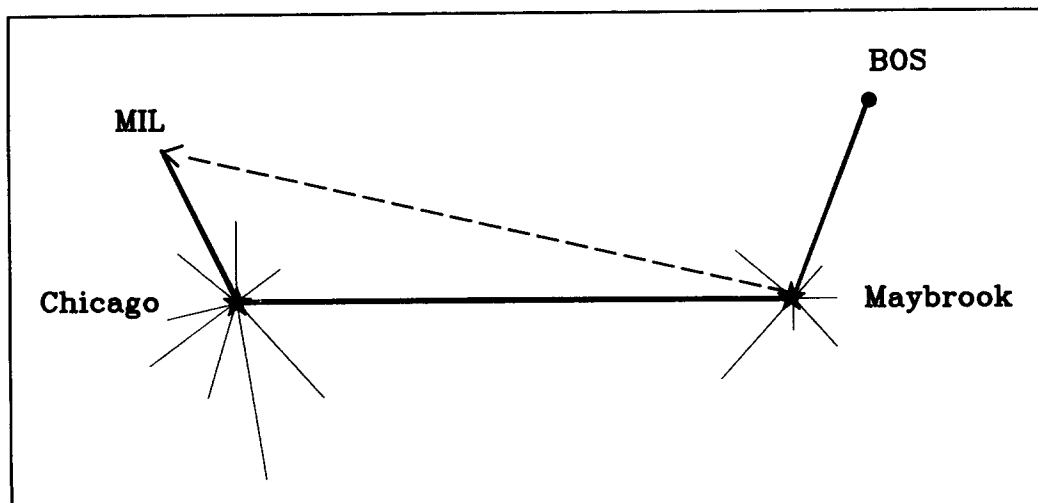


Figure 3a: A direct service from the Maybrook breakbulk to the Milwaukee end-of-line allows trailers to bypass the sorting process at the Chicago break bulk.

brook, which may have the effect of forcing Maybrook to eliminate the Milwaukee direct, routing all the freight through Chicago. The resulting service network may be more expensive for several reasons. First, the cost of handling freight at Chicago may be higher than at Maybrook, implying that the savings in handling at Maybrook may be more than offset by higher handling costs at Chicago. Second, Chicago may be close to capacity, creating additional congestion problems. Third, it is possible that the change in routing actually increases the overall distance a trailer must cover.

A fourth issue addresses a systematic problem with directs run out of end-of-lines. As a rule, the pounds per trailer, or *load average*, for direct trailers departing from end-of-line terminals is lower than for direct trailers departing from breakbulks. Breakbulks have both a greater volume and a broader mix of freight (small and large, light and heavy shipments), that allows people to pack more pounds in a

trailer. The practice of allowing the Boston end-of-line the option of loading a trailer direct to Chicago creates a pattern of favoring directs out of end-of-lines over directs loaded out of breakbulks.

Despite these issues, the basic policy used not only at Yellow but at most of the national carriers was to run direct, whenever possible, wherever possible. Running directs to bypass a breakbulk was considered so beneficial that extraordinary strategies were designed to increase the number of directs that were run. For example, the rule of thumb was that avoiding a breakbulk was equivalent to saving a day in transit time. As a result, if the Boston terminal did not have enough freight on Wednesday to fill a trailer to Chicago, the trailer could typically be held until Thursday or Friday (taking advantage of the industry pattern of not counting weekends as service days). The single biggest effect of this practice was to introduce tremendous variability in the service a shipment received. From an operational perspective,

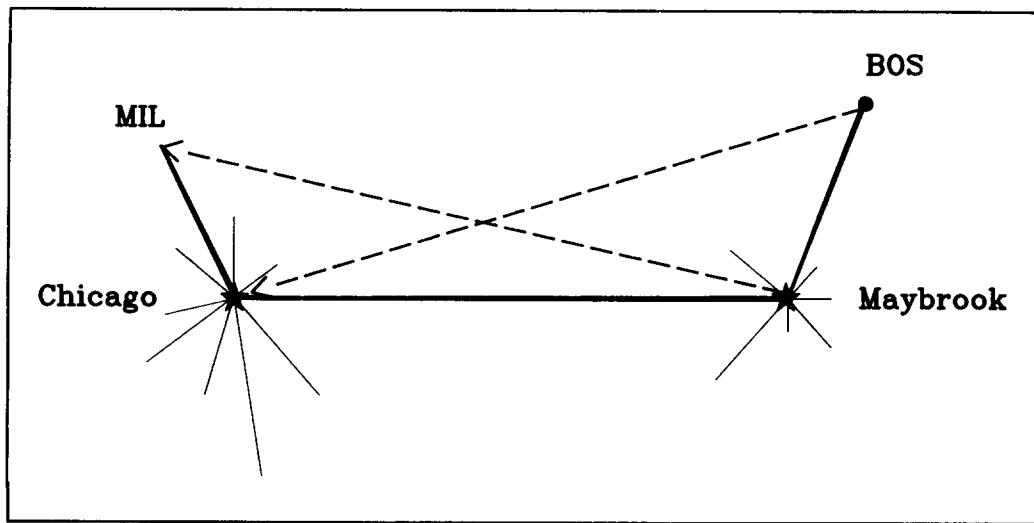


Figure 3b: An additional direct service from Boston to the Chicago breakbulk eliminates the sorting at breakbulk, but diverts flow from the Maybrook to Milwaukee direct.

this strategy also tended to disrupt the natural flow of trailers, since the ability to hold freight on Wednesday would often create an artificial wave of trailers moving out on Friday.

The terminal manager faced a strong financial incentive to load directs but lacked the information needed to make effective decisions. It was not unusual for a terminal manager to try to load a trailer direct and 36 hours later find that the trailer still was not full (terminal managers were also evaluated on the average number of pounds they put on trailers). At this time the manager would be forced to make a judgment about whether to hold the trailer a third day or simply to run it into the primary break. Conversely, freight that could have been run direct often was not, simply because the terminal manager sometimes did not realize that there was that much freight going to a common destination.

This operating strategy had four principal limitations:

- (1) Lack of direction and information in the field created uncertainty and variability in operations, with a significant impact on service reliability;
- (2) The rule to run a direct was based on flow (the ability to fill a trailer) rather than cost;
- (3) Decisions made by one terminal manager were not coordinated with the rest of the system; and
- (4) Decentralized decision making restricted management control over the operation of the network.

The challenge of the SYSNET project was to overcome these limitations.

The Planning Process

We developed SYSNET to address two sets of problems. The first covers the operational task of managing the load plan that controls network flows. The second covers a broader set of tactical and strategic planning problems that arise routinely when managing a large network. These include —Breakbulk capacity planning; Using five-

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year forecasts of demand, we simulated flows through breakbulks to estimate future capacity needs, which determine corporate capital requirements, needed for financial planning.

—Breakbulk location: As growth requires new consolidation facilities, we needed to plan the location of these terminals and their integration with the rest of the network.

—Capacity management: Because seasonal shifts in freight can create capacity problems at individual breaks, Yellow wants to route flow to divert freight around problem, congested breakbulks.

—Satellite alignment: Although most of the freight out of an end-of-line passes through its primary breakbulk, when there is more than one logical choice for the primary breakbulk, Yellow may want to determine the optimal choice(s) based on the overall directionality of the freight.

—Opening new end-of-lines: Yellow may open new end-of-lines to enter a new market or to better serve an existing one. Since the number of end-of-line terminals in an area affects their ability to load directs, the trade-off between one large terminal or several smaller ones must be analyzed. At the heart of these strategic-planning problems remains the load-planning problem, since each question must be evaluated in part based on its effect on the routing of shipments and the ability of terminals to load directs.

In developing a new planning process, we had the following specific goals:

- (1) To develop an accurate, company-wide cost model;
- (2) To use optimization methods for certain sets of decisions;

- (3) To improve the overall responsiveness of the planning process through enhanced speed and ease of use; and
- (4) To handle the entire network simultaneously, allowing individual changes to be evaluated in terms of their impact on the entire system.

The SYSNET planning process at Yellow Freight encompasses demand forecasting, data-base management, simulation, optimization, and monitoring and control. A summary of SYSNET can be divided between a description of the mathematical model; the solution strategy; and the systems support required to develop and maintain the input data files and to communicate results to the field. Powell and Sheffi [1989] provide a detailed discussion of the mathematical model and solution strategy. Elements that were particularly important to this project included the way the system handled service and the role of interactive optimization.

Modeling Service

Yellow Freight has always made service its highest priority, an emphasis we felt throughout the project. The time to deliver a shipment consists of driving time, trailer unloading time, and the schedule delay that occurs while waiting for an outbound trailer to fill up prior to dispatch. Since it can take anywhere from six to 24 hours to load and dispatch a trailer, schedule delay is not only an important source of total travel time, it is one of the major sources of travel time variability. Schedule delay, however, can be reduced through effective planning. If Maybrook is currently loading five trailers per week to Chicago, shipments will wait on average half a day for the trailer to fill and leave. If more Chicago

freight can be routed through Maybrook, trailers will fill faster and the schedule delay will decrease.

The second issue in service is reliability. For a shipper, it actually can be more important to reduce the variability of transit times than to reduce the average transit time. Under the old strategy, which allowed terminal managers considerable latitude as to when to load directs, service could fluctuate widely, reflecting the availability of opportunities to load direct and the ability of the terminal managers to recognize and act on these opportunities. Perhaps more important than the effect a manager might have on the terminal's freight is the impact the actions of one terminal can have on other parts of the network. Each time the Boston terminal decides to load the Chicago freight direct, the arrival of freight to Maybrook headed to Milwaukee is affected. Thus changes in the routing of the freight out of the origin terminal create higher variability in the flow of shipments on other legs in the network. In fact, the high volume of relatively small LTL shipments originating at a terminal tends to be surprisingly stable. The variability arising from changes in how the freight is routed can be much larger than the day-to-day variations in the shipments.

These issues argue in favor of operating a network of direct services that is stable and reliable. Directs should be identified that can be efficiently run on a regular, daily basis. Of course, opportunities to load directs will arise due to random fluctuations in the freight. However, these opportunities must be controlled since directs can work against the system.

SYSNET employs a model that addresses

the combined concerns of speed, reliability, and economic efficiency by using a simple set of rules. If direct service is offered between two terminals, it is assumed to do so on a regular basis with a minimum frequency of, say, eight trailers weekly. Freight is assumed to follow a single path from origin to destination over the course of the week. If a direct is offered that does not have eight trailers per week of freight, then the model still assumes that eight trailers are sent each week. If more freight is available, then the number of trailers needed is assumed to rise linearly. Of course, if the direct service is not offered (implying zero flow) then the cost is zero.

If we plot the flow of trailers as a function of the flow of freight (measured in units of trailers per week) the result is the plot shown in Figure 4. The implication of this function is that the decision to offer a direct service means that Yellow must be willing to pay the cost of at least eight trailers per week. The imposition of a high minimum frequency implies that service will be both fast and reliable. Freight will be able to follow this pattern every day with a minimum of schedule delay. It is now up to the cost model to determine if this new service is cost effective. If there are only five or six trailers of freight (or less), then it is likely that the service will not be offered. The important feature is that the direct is all or nothing; a service is not offered unless it makes sense for all the freight moving in that traffic lane. If the direct is cost effective, we are assured that we are offering quality service at a reasonable cost.

The Model

The essential features of the model are

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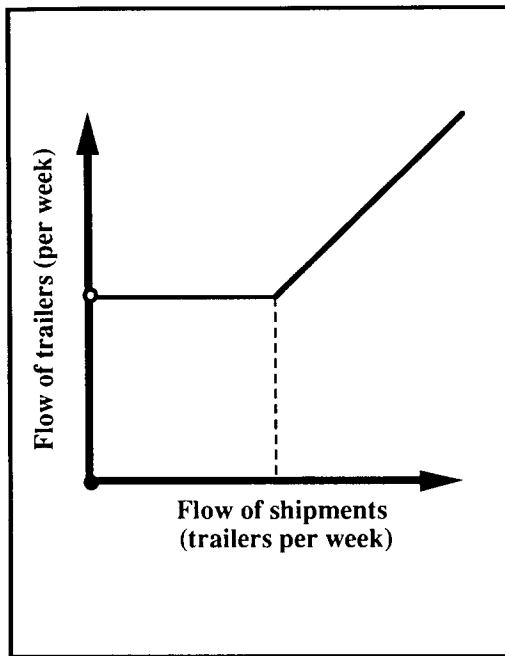


Figure 4: SYSNET maintains a high level of service by requiring a minimum number of trailers to depart each week on a direct, regardless of the amount of freight moving.

the cost elements and the decision variables. The major decision variables include

- The size and location of breakbulks and end-of-lines and the alignment of end-of-lines with breakbulks,
- The routing of loaded trailers over the network,
- Where to offer direct service in the network,
- The routing of LTL shipments through the network, and
- The flows of empty trailers required to balance loaded flows.

The important cost categories used are

- Transportation costs for LTL freight,
- Transportation costs for truckload freight,
- Empty transportation costs,
- Handling costs at end-of-lines,

- Handling costs at breakbulks,
- Relay costs, and
- Pickup and delivery costs within the city.

We calculated all flows and costs on an average weekly basis, using forecasts of freight flows. Included in the loaded transportation costs are trailers moving partially full as a result of service constraints. SYSNET specifically tracks what came to be known as “the cost of moving air,” which represents a measure of the degree to which trucks are running only partially full as a result of the minimum service frequency constraint (known as running for service). If a particular change to the network produced a sudden increase in the cost of moving air, then this was a flag that trailers were now running partially full suggesting further investigation. Pickup and delivery costs were included for model calibration purposes but did not change as a function of the load plan.

Solution Approach

This optimization formulation can be characterized as a nonlinear, multicommodity network design problem. The challenge of solving this problem arises from recognizing its large size. Ignoring the possibility that direct service can join end-of-line terminals, there are approximately 30,000 different opportunities to potentially offer direct service between end-of-lines and breakbulks. Heuristic pruning rules can further reduce this to about 7,000 elements. There are over 400,000 integer routing variables governing the path followed by each shipment over the service network. Added to these numbers are 1.2 million network flow variables for tracking flows of shipments and 50,000 empty flow

variables.

A separate set of concerns further complicates the issue. Despite the tremendous effort put forth in building and tuning an accurate cost model, ultimately it is still an approximation, with simplifications introduced either in recognition of basic limitations of the data or to maintain a semblance of tractability in an otherwise large and complex model. These limitations of the model ranged from the use of steady state flows to the inability to explicitly model special service constraints on individual lanes.

We devised a solution approach that recognized the inherent hierarchy in the decisions that are being made. Decisions about the location of terminals and breakbulks are made at the highest level. Second is routing loaded trailers over the line-haul network, which must take into account the balance of driver flows into and out of terminals. Next is determining where to offer direct service. This is followed by routing shipments over the network, which determines the flows of loaded trailers. Finally there is the optimal routing of empty trailers to balance the flows of loaded trailers.

We adopted an interactive optimization approach to take advantage of the skills of a knowledgeable user in two specific areas. First, while some of the decisions can be optimized by the computer with some confidence, others, such as locating terminals or designing a network of direct services, are mathematically very complex. Human beings are very effective at recognizing certain special patterns and guiding the computer toward good solutions. Second, the user can monitor the progress of the search and identify areas where limitations of the model may create problems.

We designed the system to allow different degrees of user involvement at each level in the hierarchy (Table 1). At the highest level, suggestions for the location of terminals and breakbulks are completely controlled by the user. The issues here are very complex, and there are generally very few options to consider. The second level consists of how the trailers are routed once they have been loaded with shipments. This is a high level decision, because it affects the allocation of work and driver domiciles around the network. The third level consists of where direct ser-

Decision	Level of User	
	Interaction	User Control
Terminal size, location, and alignment	High	User initiated "what if"
Routing loaded LTL trailers		User initiated "what if" with least-cost path suggestion
Add/drop directs		Computer generated suggestions; user reviews and accepts/rejects suggestions.
Routing LTL freight (the load plan)		Computer generated changes; user review and override
Routing empties	Low	User review, but no control.

Table 1: SYSNET provides different levels of user and computer involvement for different types of decisions.

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vice should be offered. Here, it is not possible for the user to initiate suggestions since there are far too many possibilities. Also, the decision to add or drop a direct service is considered too important to be left entirely up to the user. The fourth level governs the detailed routing of shipments over the network. This problem is extremely large, but also relatively simple. We built a sophisticated set of rules into a specialized shortest path algorithm to give the computer the ability to make (as opposed to suggest) routing changes. However, the user can review and override this logic. Finally, the routing of empties was left entirely up to the computer with no direct user control.

The key area of user involvement is the interaction with the computer over where to add or drop direct service. In a typical session, the user will guide the search for improvements by working on specific parts of the network. For example, the user might ask for suggestions for adding directs from the satellites of Maybrook to all the other breaks in the system. SYSNET simplifies this process by providing symbols to represent groups of terminals. For example, BRK represents all the breakbulks, EOL represents all the end of lines, and "*" represents all terminals. SYSNET will then compile a list of all the potential directs that could be run between these two groups of terminals. The user could even ask for suggestions for adding (or dropping) directs between all end-of-lines and all the breakbulks. Since this list can get quite long, SYSNET first prunes the list using simple rules and then sequences the list using a subgradient-based search procedure. Finally, SYSNET works down the

list, evaluating each potential change in terms of its actual impact on the entire network.

The last step is computationally the most intensive part of the process. Each potential direct is successively added to (or dropped from) the network. In response to each change, the flows of shipments are rerouted, loaded movements are recalculated, and empty balancing is reoptimized. The change in costs over the entire system is then found, after which the network must be restored to its original status so that the next candidate can be evaluated. On an IBM 3090, this complete evaluation of a single direct can be completed in under one second. This speed was critical to the use of the system in an interactive fashion. Optimization theory was central in helping us to accurately prune the list of candidate directs, and extensive engineering of network optimization algorithms was needed to produce the high speed attained in performing exact evaluations of each addition or deletion.

Finally, the user is presented with a ranked list of suggested changes to the network. This list contains the impact of each change, broken down into different cost categories. Table 2 shows a typical menu of suggestions. For each suggestion, the menu shows if it is an add or a drop; the origin and destination of the direct; the gain or loss of flow in trailers per week; and the changes in costs around the system. Cost changes are divided among line-haul transportation costs; line-haul variance (a measure of the partially full trucks moving for service); handling costs at breakbulks and end of lines; and changes in the movement of empty trail-

CHANGE IN COSTS

No.	Chg	From	To	Flow	Line	Var	H-BB	H-eol	Mpty	Total
#1	ADD	KCM	BOS	12.55	-409	85	-890	0	-61	-1275
#2	ADD	KCM	CVE	8.48	-345	121	-747	0	-72	-1043
#3	ADD	ATL	MIL	9.21	-280	-53	-587	0	128	-792
#4	DROP	BOS	STL	-3.45	57	-915	248	0	-161	-771
#5	ADD	CVE	HOU	6.20	37	220	-705	0	-54	-502
#6	ADD	MBK	ELK	6.87	45	186	-439	0	-181	-389
#7	ADD	JMI	WOU	7.02	188	65	-519	0	-54	-320
#8	DROP	BAL	CGB	3.90	-102	-287	405	-125	-11	-120
#9	DROP	BAL	HOU	4.20	-78	-394	489	-125	18	-90

ENTER: C (CONTINUE) T (TOP) I (IMPLEMENT) F (FORCE) D (DETAILED ANAL) P (PRIMARY BRK) E (ERASE) R (REFRESH)

Table 2: SYSNET suggests directs that can be added to or dropped from the network and provides summary information to help the user make decisions.

ers. The user may decide to accept or reject each recommendation or to perform further detailed analyses using a submenu. Of course, the impact of each change is calculated in isolation, and it is important to consider potential interactions. If the user accepts a change, the system recalculates its cost impact to ensure that savings are still realized even though they may be somewhat different from those originally estimated. The user may also request that the system "refresh" the cost calculations by rescanning the entire list of suggestions. A knowledgeable user can usually identify strong interactions and guide the process accordingly.

The interactive aspects of the code proved important in two respects. First, the user was needed to guide the search for changes in the network. The user might know, for example, that freight levels are increasing in the midwest or that a particular breakbulk is experiencing capacity problems. In other cases, the user might

know that the current solution is a local minimum and that a significant change in the network is required to achieve an overall improvement. For example, adding a new breakbulk requires a substantial amount of freight to be forced through it before it has the volumes to start loading economical directs. A human being can easily identify these spatial patterns and test out promising configurations.

The second use of the interactive feature, which proved critical to the adoption of the system, was the user's ability to accept and reject suggestions made by the computer. In contrast to a black-box approach, SYSNET displays suggested changes and allows the user to evaluate each one in terms of difficult-to-quantify factors. For example, Yellow provides special services for individual customers that may require freight routings that run counter to SYSNET's suggestions. Also, local considerations, such as work rules or special operating practices that are not incor-

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porated into the model, can be accounted for by a knowledgeable user.

We devoted considerable research to developing and tuning these algorithms [Powell 1986; and Powell and Sheffi 1983]. For example, we studied the solution of the shipment-routing subproblem extensively [Powell and Koskosidis forthcoming]. We tested and compared several different primal and primal-dual algorithms. The primary contribution of this research was a set of primal heuristics which could be shown to provide very accurate solutions. We also researched exact algorithms for network design problems [Lamar, Sheffi, and Powell 1990] to help evaluate the effectiveness of the local search heuristics. Research into exact solutions of the network design problem for less-than-truckload applications [Balakrishnan, Magnanti, and Wong 1989; Balakrishnan and Graves 1989; Magnanti and Wong 1981] has been limited to networks that are considerably smaller than the problem presented by Yellow Freight. Reflecting this limitation of optimal approaches, other researchers have developed heuristics for solving the service network design problem, most commonly using a black-box search technique [Crainic and Roy 1987; Leung, Magnanti, and Sanghal 1990].

Systems Support

A major part of the project was to integrate SYSNET into the corporate MIS system. SYSNET requires extensive information about freight flows and forecasts, transportation and handling costs, and a variety of productivity and performance measures. To remain current, this data must be periodically updated, which requires access to a broad range of files. We

developed a set of production programs that can be used to scan all the raw data files and compile the necessary statistics, which range from a count of the number of doors in a breakbulk to an estimate of the average density of freight originating in Boston to a calculation of the average cost per mile for trailers moving from Maybrook to Cleveland.

For strategic planning, the outputs from SYSNET are a set of reports used to prepare management summaries on different options. However, SYSNET is also used on an operational basis to perform load planning. In this role, SYSNET is used to maintain a file that determines the actual routing of shipments through the service network. This file, which contains the load plan, is accessed directly by systems that are used by virtually every terminal manager in the field. SYSNET's control of the load plan and its ability to communicate these instructions to the field is the single most significant accomplishment of the project. Over the course of the project, numerous requests were forwarded through information services, which is responsible for all production programming on the mainframe. These requests were given priority over a two-year backlog of data requests from other departments.

Implementation

The primary objective of SYSNET was to take over and manage the flow of shipments through the network. Several members of the operations planning department became proficient in the use of SYSNET. In their hands, SYSNET became the principal tool for managing the controlled direct program. The implementation of this program represents one of the single larg-

est changes in the basic operating strategy implemented since Yellow's emergence as a national LTL carrier. At the heart of the program was the transition from a policy that encouraged terminal managers at origin end-of-lines to load directs past the origin breakbulk. The controlled direct program required terminal managers to make the transition from managing based on a set of (outdated) operating strategies (load whenever possible) to managing according to a computerized load plan. This plan would specify which directs should be run on a daily basis and which should not. The computer would also specify directions controlling where directs could be run if on a given day there was sufficient freight to fill a trailer. Furthermore, the load plan even specifies which shipments are to be loaded on each trailer. Thus, the load plan might instruct the Boston terminal manager to load a Chicago direct but to put the shipments to Milwaukee on the trailer to Maybrook (allowing the Maybrook terminal manager to fill a trailer to Milwaukee). The load plan must be followed rigorously on a daily basis, thereby providing even, predictable flows through the network. Exceptions are allowed but only under tightly controlled circumstances that are explicitly handled within the load plan.

There are four key elements to the implementation process: (1) selling the concept to upper management; (2) developing an implementation strategy; (3) implementing the system in the field (which included selling it to people in operations); and (4) providing management incentives and enforcement.

Adoption by Upper Management

Implementing this major change in oper-

ation required the involvement and support of all levels of the company. This process began with the acceptance of the system within the operations planning department. Operations planning was responsible for guiding the project and managing, with close cooperation from the information services department, all aspects of the implementation. The system's acceptance was largely due to the use of interactive optimization, which gave users the support required to optimize such a large network while also keeping them in close control of the entire process. Users could analyze suggested changes to the network based on changes in flows and costs, which could be compared against actual field totals. They could validate each number that came to the screen using sup-

In 1990, Yellow used SYSNET to identify over \$10 million in annual savings from projects such as these.

porting reports. Two principles had guided our development of the model: first, it must be believable, which is to say that it must be accurate; and second, it must be verifiable, which limits the basic complexity of the system.

The next step was to validate the cost model. SYSNET produces a system summary report that breaks down all the major cost categories, including transportation costs, handling costs, pickup and delivery costs, and corporate overhead. It further summarizes transportation costs according to whether they are loaded or empty, truckload or LTL, truck or rail, and by dif-

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ferent trailer types. We were able to compare both total system costs and the different subcategories against actual cost summaries for these categories. The individual cost categories within SYSNET consistently match corporate statistics within a few percent, and total costs often match within one or two percent.

The validation of the cost model, both in aggregate and in the different components, played a major role in gaining upper management's acceptance. This step was particularly significant considering that the chief executive officer of Yellow Freight, George Powell III, had been the original manager of the line-haul simulation package developed at Yellow in the late '70s. The interactive reports and features that convinced operations planning also played an important role in gaining top management support. We ran interactive sessions for upper management to demonstrate how SYSNET made suggestions and generated supporting reports to back up the numbers. We demonstrated how standard operating practices could be detrimental and why coordinating the entire network was important. By doing this we gained the confidence from upper management that we needed to support a field implementation.

Developing an Implementation Strategy

With the support of upper management, we were able to develop an implementation strategy. This step involved much more than simply convincing field operations that the new concept would improve operations. The controlled direct program changed operating philosophy so drastically that a single, corporate-wide transition was viewed as simply too dangerous.

Managing 10,000 dispatches and 60,000 shipments efficiently each day depends on a basic predictability in the freight flows. The allocation of drivers around the network is closely controlled by union contracts that can seriously penalize the company if flows are shifted from one part of the network to another. Breakbulk managers need to plan their dock schedules for loading and unloading trailers.

In implementing SYSNET, Yellow made a systematic change in the way it loaded directs. Specifically, SYSNET encourages a greater proportion of directs to be loaded out of breakbulks than out of end-of-lines compared to Yellow's standard method of operation. It was impossible to change this method of operation over the entire network simultaneously. However, it was also difficult to do it in a piecemeal fashion. For example, implementing the new strategy at the Maybrook breakbulk and its satellites would increase the amount of freight coming into Maybrook from its satellites. Maybrook would then do its utmost to load directs past the other breakbulks in the system to reduce their handling costs. However, Maybrook would not have the capacity to handle this additional freight if the other breakbulks in the system did not simultaneously try to load directs past Maybrook.

To deal with this problem, we developed a phased implementation strategy that began with the smallest breakbulks in the system and worked up to the larger ones. Careful planning insured that no breakbulk would be over capacity during the intermediate stages of the process. Yellow implemented SYSNET between November 1988 and May 1989, with the summer of

1989 representing the first major transition period. We planned the entire implementation to ensure that no breakbulk would find itself over capacity during the transition period.

Field Implementation

Once we had developed the complete strategy, we had to communicate the new concept to terminal managers in the field. This stage involved three steps: (1) designing new support tools so that the SYSNET routing instructions were easy to follow; (2) training terminal managers and dock personnel to use these new systems; and most important (3) convincing terminal managers that the new approach was a good idea.

We developed two new support tools to assist field operations. The first was a set of reports that managers or dock supervisors could access from their local computer terminals, giving them immediate access to the SYSNET load pattern. The second tool was a revised shipment movement bill. (A movement bill is a document that accompanies each shipment.) The new document includes the SYSNET routing instructions for that shipment, telling the dock worker exactly what trailer to load the shipment into along its entire path from origin to destination. This movement bill provides a very high level of control over the routing of individual shipments. Since the bill is used by thousands of employees, its modification represented a major implementation challenge.

The operations planning department handled training by organizing a series of visits to all 25 breakbulks. Each week, a team from operations planning visited a new breakbulk to handle the transition for

that terminal. In some weeks, the team converted several breakbulks at once. During each visit, staff members explained the principles behind the controlled direct program, the new reports, and the use of the new routing instructions. Furthermore, this training continued long after the initial visit. A member of operations planning with extensive experience in line operations made countless phone calls to terminal managers to review their use of the system, discuss problems, suggest alternatives, and generally help them through the process.

Our most important task was to convince terminal managers of the logic behind the new operating strategy. Ten years of incentives to load directs at will are not easily replaced. Especially difficult to change was their intuition that they should put shipments on trailers going the longest possible distance. The idea that a shipment should be loaded on a trailer going to the nearest breakbulk, when it could be put on a trailer going to the destination break, contradicts a paradigm in the industry. Terminal managers needed to understand that they had to follow the load plan because it was designed to coordinate different parts of the system. We used examples to illustrate the effect their decisions could have on other terminals. Generally, people in the field accepted the principle that their decisions should be coordinated with those in the rest of the system.

Management Incentives and Enforcement

Prior to SYSNET, Yellow evaluated terminal managers in part based on the number of trailers they were able to load direct. Immediately following the implementation

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of SYSNET, we developed a target that represented the anticipated number of directs that they should be loading based on the SYSNET plan. Yellow then measured terminal managers' performance based on how closely they met this target. After a period of time, it deemed compliance with the plan so good that today it does not formally measure terminal managers' performance on the basis of the directs they load. They are measured on other activities and Yellow continues to monitor compliance with the load plan informally. It then contacts terminals that appear to be out of compliance to determine the reason. In short, SYSNET has changed load planning from a decentralized process that depended on local management incentives to a centralized process that relies on monitoring and enforcement.

The Tactical Planning Room

Our need to communicate the logic behind SYSNET has proved to be ongoing, even beyond the problem of obtaining initial acceptance. For everything from direct loading decisions to changes in the alignment of satellites to breakbulks, operations planning must explain and justify each recommendation. To assist with this process, Yellow uses a special room equipped with graphical display tools that allow meetings to be conducted around SYSNET. In one common use of the facility, Yellow brings regional managers in from the field to run through a series of what-if scenarios, allowing them to pose their own questions. During such meetings, an operator runs SYSNET from a computer terminal, displaying the results on a large screen. The operator can show different reports, along with detailed analysis summa-

ries, allowing participants to appreciate the issues and trade-offs that arise during an analysis. If an idea does not work, the participants can propose and test alternative scenarios. The tactical planning room has proved invaluable in involving a much larger part of the organization in the planning process than was possible before, producing a high level of acceptance for the system that extends down to field operations.

Ongoing Planning Applications

Without question, the major visible application of SYSNET was the implementation and management of the controlled-direct program. In addition, SYSNET continues to play a major role in a range of other tactical and strategic planning areas. One example is the original application of Yellow's old line-haul simulator, breakbulk capacity planning. With SYSNET, Yellow can forecast flows five years into the future, but instead of simply simulating activities, it can use SYSNET to optimize the load plan with these new flows. Thus, a 20-percent increase in average volumes does not necessarily mean a 20-percent increase in flows moving through the breakbulk. Yellow can use SYSNET to identify new directs that can be run with the higher flow levels, thereby reducing the demands placed on the handling facilities. The result is a much more accurate simulation of what will actually happen in five years.

Other applications range from far-reaching studies of the fundamental structure of Yellow's network to such operational questions as the alignment of satellites to breakbulks. The LTL industry tends to be dominated by different "philosophies": di-

rects should be loaded out of origin end-of-lines; large breakbulks are better than small breakbulks (these facilities can range from 60 or 80 doors to over 400 doors, with clear implications with regard to network consolidation); regions should be served by a lot of small end-of-lines or by a few large ones. Due primarily to the sheer size of the networks, these philosophies can be difficult or impossible to analyze in a formal, quantitative manner. Existing operating practices tend to persist because of the difficulty in proving that a different strategy is better. SYSNET allowed Yellow to replace philosophy, intuition, and gut feel with formal analytical tools.

The Impacts of the System

SYSNET's impact can be seen in four areas: in the quality of planning practices and management culture; in the cost savings resulting directly from improvements in load planning; in analyzing projects; and in improved service to customers from more reliable transportation.

Qualitative changes include the following:

Management gained greater control over network operations. SYSNET allowed Yellow to convert from being a carrier that relied on operating policies to manage trailer loading and dispatching to one that has direct management control. The new load pattern closely controls the loading of directs, and management can quickly change the load pattern in response to changing needs. Yellow felt this new level of control was an important tool for managing future growth of the company.

It could set realistic performance standards. Prior to SYSNET, Yellow evaluated

terminal managers on how many trailers they could load direct, relative to goals based on past performance. SYSNET allowed Yellow to set direct-loading standards based on anticipated freight levels, creating more realistic performance expectations.

Planners can better understand the total system. Yellow can now evaluate new projects and ideas based on their impact on the entire system. Prior to SYSNET, it was difficult or impossible to calculate system impacts. Now, staff at all levels appreciate the need to coordinate the entire system.

Managers can base decisions on analysis. Managers found it difficult to analyze complex new options in the past, often doing nothing or managing by philosophy. SYSNET allows them to analyze many of these projects formally.

Managers plan and respond more quickly. With SYSNET managers can analyze new options quickly in response to changing situations. The departure of a competitor (which happened frequently during the last decade) can create sudden new business that may be difficult to handle in the short run. A sharp economic recession can leave trucks waiting for freight. Yellow can now analyze such new scenarios and quickly send new instructions to the field.

Analysts are better able to try new ideas. They can test new operating strategies quickly and easily. They try new ideas on the computer, which ultimately leads to new ideas in the field.

Yellow is introducing new technologies. Because of SYSNET, Yellow is more open to the use of new information technologies. Originally a mainframe application,

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SYSNET is now installed on a network of Sun work stations, and Yellow plans to increase the use of work stations in other areas of the company.

The new system has reduced claims. The reduction in shipments handled produced a reduction in shipments damaged, since most damage occurs at the breakbulks when shipments are handled. Although the cost savings are small, management felt that the claims reduction represented an important dimension of customer service. In short, SYSNET has had a substantial impact on management culture at Yellow.

Performance Improvements Due to Better Load Planning

We undertook a study to estimate the savings that could be directly attributed to the use of SYSNET in the load-planning process. Total cost savings for the system were estimated at over \$7.3 million annually, based on productivity improvements in four areas: increased percentage of shipments moving direct, thereby saving handling costs; reduction in fixed facilities costs due to reduced demands placed on the breakbulks; reduced line-haul costs from more efficient routing of trailers; and reduced transportation costs, resulting from trailers traveling fewer miles.

We estimated the savings in breakbulk handling costs by calculating the total freight moving direct immediately before and after the project. After adjusting for the overall growth in tonnage between 1988 and 1989, we found that 11.6 percent more freight moved direct after the project compared to before. On an annual basis, this translates to 390 million pounds of freight that avoided the consolidation pro-

cess, with total savings of \$4.7 million annually.

In addition to these direct savings, reducing shipments handled in the long run reduces investment in fixed facilities. Typically, a breakbulk facility handles approximately 6,000 shipments per door per year. Thus, the savings can be viewed as eliminating the need for 51 doors throughout the system, at a cost savings of over \$185,000 annually in depreciation expense.

SYSNET also reduced the cost of routing trailers, in part by identifying directs with lower transportation costs. Conventional wisdom in the industry calls for loading directs that cover the longest distance. SYSNET identifies directs that should be added because of their total cost impact on the system, as opposed to simply choosing directs based on flow. In some instances, it is better to load a short direct that reduces the total miles traveled. The savings due to better routing of trailers alone were estimated to be \$1 million annually.

Finally, SYSNET reduced overall transportation costs by helping to increase the number of pounds loaded onto a trailer. It is common knowledge that the average weight on a trailer loaded direct out of an end-of-line is substantially lower than a trailer loaded direct out of a breakbulk, with differences of as much as 10 percent. Breakbulks have both a higher volume and broader mix of freight to work with, which gives them greater opportunities to choose freight that will maximize the utilization of a trailer. In 1988, only 32 percent of all directs were originated at breakbulks; in 1990, 44 percent of the directs originated at breakbulks, a shift that is completely attributable to the implementation of SYS-

NET. The result is an increase in the average number of pounds on trailers moving direct by approximately 380 pounds. This shift in the load average alone produced savings in transportation costs of approximately \$1.42 million per year.

Ongoing Projects

Operations planning uses SYSNET principally to analyze a variety of projects ranging from relocating breakbulks to re-aligning satellites with breakbulks. Senior management, operations planning, or managers in the field may initiate projects. Using SYSNET, operations planning now completes over 200 projects per year, mostly on an informal, exploratory basis. Often groups of people work with SYSNET in the tactical planning room, testing ideas and generating new ones. SYSNET's speed in evaluating different ideas is critical to this process.

Of these projects, about 75 eventually become formal recommendations. Each of these requires a series of signatures before final field implementation. Examples of such projects follow:

—SYSNET was used to evaluate moving a breakbulk to a new location. Operations planning tested various satellite configurations and the ability of the new break to load directs to the rest of the system. With SYSNET they could evaluate different configurations quickly and accurately. The total savings from moving the breakbulk were \$800,000 per year.

—A manager in the field suggested aligning a large end-of-line with more than one breakbulk. Using SYSNET, planners tested simultaneous alignments with three different breakbulks. Under each scenario, they evaluated the impact on directs loaded out

of each of these breakbulks and the impact of changes in flows throughout the system. Total savings were \$720,000 per year.

—After expanding a breakbulk, Yellow used SYSNET to analyze the impact of all operations into and out of the new facility, to optimize the loading of directs, and to determine the impact of the change on other breakbulks within the system. The total savings were \$825,000 per year.

Some projects are based on suggestions from the field. In the past, Yellow often implemented such projects believing that field personnel had a better understanding of actual activities. With SYSNET, it can quickly and accurately evaluate these suggestions. In some cases, suggestions from the field were shown to produce substantial cost increases as a result of network effects.

In 1990, Yellow used SYSNET to identify over \$10 million in annual savings from projects such as these. SYSNET improved the speed with which such analyses could be completed and expanded the scope of each project, allowing Yellow to study system impacts with far greater precision than before. While it is difficult to estimate how much of these savings could have been realized without the system, SYSNET has played a central role in the identification, design and evaluation of these projects.

Improved Service

The savings resulting from SYSNET are substantial compared to its development and implementation cost, producing a pay-back period that can be measured in weeks. At the same time, trucking is an industry dominated by such basic costs as fuel and driver wages, and productivity

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improvements are measured in small fractions of a percent. Such savings can easily be lost on the way to the bottom line if fuel costs change or the economy shifts. It is perhaps not surprising then that following the implementation of SYSNET, management tended to focus on a single statistic that could be traced to the project. In LTL trucking, service is measured by the percent of shipments that are not delivered within a specified number of days, referred to as the service standard. From 1988 to 1990, the number of shipments delivered over standard fell by 27 percent, reducing by over 400,000 shipments the number of late deliveries.

The value of improved service is difficult to quantify for a motor carrier. Over time, better service will translate to higher market share and higher revenues. However, such changes occur gradually and are difficult to attribute to any single activity. At the same time, during the '80s, service and quality proved to be the most important dimension of any business. Many companies have adopted just-in-time concepts as part of broad quality-control programs for reducing inventories and eliminating hidden problems in quality control. Yellow contributes to these programs by providing its customers with timely, reliable service that reduces their need for safety stocks.

Yellow Freight plays an important role in manufacturing, supplying parts and materials for assembly processes and delivering finished goods to market. It is a partner in the extensive quality-control programs introduced by many manufacturers. This involvement has been recognized by several major manufacturers: in 1990, 3M Corporation presented Yellow with their

Quality Achievement Award; Yellow was the only long-haul carrier to receive the Ford Excellence Award; and Motorola, a winner of the prestigious Malcolm Baldrige National Quality Award, gave Yellow its highest service rating.

Closure

Continuing development of SYSNET helps it to meet Yellow's changing needs. Following the initial implementation of SYSNET at Yellow in 1988, a software consulting firm, Princeton Transportation Consulting Group, Inc., was founded to take over development of SYSNET and to support other applications of optimization technologies for the trucking industry. PTCG has enhanced the original system and supported Yellow's transition to a work-station environment.

Internally, Yellow continues to use SYSNET for a variety of planning projects and to continuously monitor and improve the load plan. SYSNET is now used directly within the linehaul operations group responsible for the day-to-day management of flows through the system. In addition, Yellow is using SYSNET as a foundation to expand the use of optimization methods for other aspects of its operation.

SYSNET is now widely accepted and respected within the company for its ability to carry out accurate, comprehensive network planning projects. In fact, often the first question posed regarding a new idea is, "Has it been run through SYSNET?" A final testament to the importance of SYSNET is contained in the following passage quoted from Yellow's 1990 Annual Report:

. . . Other operations advances came from our progress with SYSNET. This computer model of our entire company structure allows us to ob-

tain information about the best load patterns, capacity planning, and most cost-effective line-haul routes system-wide. Some five years in development . . . SYSNET incorporates continuous programming capabilities to keep precise pace with requested information and reports.

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Notes

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