GOODS TRANSPORTATION BY THE FRENCH NATIONAL RAILWAY (SNCF): THE MEASUREMENT AND MARKETING OF RELIABILITY

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Abstract—Rail transportation that is timely and dependable can compete with the trucking mode for Just-In-Time (JIT) deliveries. SNCF, the French National Railway, has a number of such offerings that emphasize reliability of freight shipments. We describe several of these SNCF products. They have in common the nature of regularly-scheduled service: planned connections to specific trains at classification yards. We discuss ways that SNCF can measure reliability, monitor it, and market it. Third-party logistics services of the SNCF are summarized, as is marketing research by SNCF to update their product line in goods transportation. We conclude with possibilities for future research.

1. INTRODUCTION

La Société nationale des chemins de fer (SNCF) is the French National Railway. Although its revenues are approximately evenly divided between passenger and goods movements, the present paper will concentrate exclusively on freight. In particular, we will discuss a number of SNCF services that emphasize reliability of goods transport.

Everyone is aware that in the past few years, business organizations have cut back on inventories of all kinds. Manufacturing firms have opted for smaller, more frequent deliveries of components and raw materials. With relatively little stock to buffer against late arrival of inputs to the production process, such inbound deliveries must be highly dependable.

In Canada, the knee-jerk response to the increased precision necessary for Just-in-Time (JIT) replenishments has been an almost exclusive market share for trucking. The same is essentially true in the United States. Although one or two American railroads (e.g. Burlington Northern, Santa Fe) have successfully operated JIT-rail services (Higgins and Bockbinder, 1990), motor freight is highly dominant.

That does not seem to be the case in France. In what follows, we will describe several premium services offered by SNCF which feature dependability and timeliness, hence are ideally suited to compete in the JIT market.

Section 2 is devoted to the two-phase programme, RO and RA (Régime ordinaire and Régime accéléré). RO is regular service, "ordinary" in the European context but still quite good by North American standards. RA is a premium service, for which particular train connections are guaranteed, hence a definite lead time is promised for shipments. In Section 3, possible definitions of a reliability index for these two regimes will be proposed and compared. Section 4 summarizes, in a nonmathematical way, various analyses of the performance of the RO, RA service.

The SNCF has recently decided that a single new regime (ETNA, loosely translated as technological evolution for dispatching) should replace RO, RA. Qualitative arguments in favour of this change, as well as a summary of extensive market research upon which the new product was based, are presented in Section 5. We also outline the service elements that comprise ETNA.

Three other time-sensitive SNCF offerings are noted and discussed in Section 6. Garantie cargo promises very specific lead times between particular rail yards in France and designated others in the Netherlands. Nord Méditerranée guarantees speedy and reliable lead times from cities in southern France (e.g. Marseilles and Lyon) to German locations such as Hamburg or Bremen. This service, too, is guaranteed in either direction (i.e. from a German origin to a French destination). Distri+, the final offering discussed, is limited to France itself. However, this service is wider-ranging than the other two because it includes various third-party logistics activities. Among these are break-bulk, warehousing, and local deliveries associated with replenishments. Distri+ is carried out in conjunction with SERNAM, the trucking affiliate of SNCF.

The paper concludes with a research agenda in railroad reliability and JIT services by rail in post-1992 Europe.

2. THE REGIMES RO AND RA

In this section, we describe in more detail the two systems (RO, RA) of forwarding or dispatching rail cars (Bulot, 1984). Each of these SNCF regimes is
based on the usual movements through classification yards. RO and RA have their individual "dispatch plans" (intended connections to specifically scheduled trains), and interestingly, sometimes their own line-haul movements and particular classification yards.

A word is in order regarding differences between SNCF policy and the practice in North America. In France, a freight train will leave as scheduled, even if there are only a few cars. In the United States or Canada, it is less common that there be a schedule of goods movements, and in any case, the train would not depart until the arrival of more cars headed in the same direction.

The system RO was originally designed for goods that are heavy and durable (e.g., raw materials, semi-finished products). RA was intended for perishable merchandise, such as live animals or fresh fruits and vegetables. The two regimes would have to be more broadly defined today. RA should be characterized as a priority service appropriate to higher value-added industrial products or to "courier-type" parcels. In light of the importance of Just-in-Time production, RA could also be appropriate for industrial products of average added value, which are on an important inbound chain of physical supply.

The urgency associated with the name RA is reflected in a lower planned waiting time in classification yards, and in trains whose average speed is 25% greater than that of RO. One reason RA has lower waiting time than RO, is the considerable traffic in the 45 to 50 yards handling RO service. The busiest of these were classifying upwards of 2000 cars per day.

Although certain prototypical goods were envisioned for RA, nothing prevents a shipper of "ordinary" merchandise from opting for the premium service and paying that price. It should also be noted that RA is not the highest priority overall, but rather the highest available for groups of one or several cars. (Unit trains have a higher priority still, since they bypass classification yards, but for that very reason are excluded from the present paper).

Examination of the distribution of lead times between origin and destination revealed a mean advantage for RA of about one-and-a-half days over RO, when averaged over the entire network. This refers to speed, however. While that may have been the initial distinction between RO and RA, it is clear that today, for a given average speed, reliability is more important. This is the subject of the next section.

3. DEFINITION OF RELIABILITY INDEX

Several railroads have utilized measures of the quality of their products. As one example, British Rail employs a "Q-statistic" (Trotter, 1987) for the degree of sureness in its timetable. This statistic is adjusted to take into account differences between peak and off-peak periods.

We now propose a "reliability index" to quantify and predict the timeliness and dependability of SNCF service. This should be defined in terms of probabilities, rather than as an absolute figure, as can be seen by considering a given rail car. In a particular plan of the railway for dispatch and routing involving transfer at intermediate yards, this car will either arrive as promised or it will not. Such a 0–1 performance measure is common in the real "track-level" environment of a railroad, in which there is no middle ground; something either works or it does not. However, this would not be a helpful definition. One seeks a reliability index for use as a tool in planning and marketing.

It is better to imagine a probability \( \rho \) that the car arrive as promised. Suppose \( \rho_1 \) and \( \rho_2 \) are the probabilities of successful dispatch and receipt between, respectively, yards \( Y_1 \) and \( Y_2 \), and yards \( Y_3 \) and \( Y_4 \). (These probabilities would be estimated by observing the results of two large samples of dispatches, one from \( Y_1 \) to \( Y_2 \) and another from \( Y_3 \) to \( Y_4 \).) If \( \rho_1 > \rho_2 \), it may be meaningful to say as part of a marketing plan that the first dispatch is "more reliable," and to possibly charge a premium price for cars routed between yards \( Y_1 \) and \( Y_2 \) (i.e. between cities 1 and 2).

The notion of successful dispatch and receipt conveys the idea of "according to plan." As is often the case for a stochastic model, however, there are a number of random factors which can lead to a favourable (successful) outcome or to an unfavourable one. For example, a car could be on time at the end, having made up for time lost at an earlier stage of the journey. Or, the dispatch and early transfers could be good, but our particular car got left behind at an intermediate yard due to an excess in weight or in the number of cars in the train being put together.

This delay at a particular stage can possibly be made up, if many trains in the desired direction are put together there (i.e. if the schedule is favourable at that transfer station). Alternatively, it may be impossible to make up this particular delay. That car is then doomed to be late. We will see later that this corresponds to an absorbing state in our Markov-chain model.

One is thus led to the following definition: "For a given dispatch, an index of reliability equal to \( \rho \) indicates that, with probability \( \rho \), the particular rail car will arrive at the destination in conformity with the original dispatch plan."

Several comments are in order. First, note that the car in question need not be followed in detail at each transfer yard. (As opposed to a micro definition (Turnquist and Daskin, 1982) given by queuing models of delay in a classification yard, our definition has more a "macro" character.) The key yard is thus the next-to-last, although the dispatch process there can be related to those at yards earlier in the sequence by various conditional probabilities.
In addition, by "conformity with the dispatch plan," one indicates an arrival as part of the "right train" as opposed to a later train. This right train may be on time (hopefully) or it may be a bit late, by say \( \Delta \). Since the intermediate classification yards often have only a single daily-scheduled train, \( \Delta \) will normally be much less than the interval before the scheduled arrival of the next train. Conformity with the dispatch plan may thus suffice for goods in a JIT chain of physical supply (Bookbinder and Dilis, 1989), if a manufacturing firm were willing to carry more than "zero inventories." In any case, conformity with the dispatch plan does not \textit{per se} indicate "on time."

Finally, we mention that in order to estimate a reliability index in which we can be confident, a good deal of data may be required. It may thus be possible, for example, to stratify departure data by day-of-the-week and hence construct reliability indices for each week-day. Rather, one has in mind a \textit{mean} index that pertains for at least a given season of the year.

4. ANALYSIS OF RELIABILITY OF THE RA SERVICE

This section is devoted to a nonmathematical summary of the way in which reliability of the RA regime may be calculated. Our objective is to make more precise the notion of reliability index, and thus to point out how one might estimate the dependency of any new service that may be designed and offered.

In a Master's thesis (Bullot, 1984) supervised by one of us (P.D.), a three-state Markov chain is suggested to study the attainment of promised lead times in the RA regime (see also Bullot, 1985). The state space consists of \( R \) ("right" train), \( F \) (the train directly following \( R \)), and \( I \) (irrevocably late). State \( R \) at time \( i \) would indicate that our particular rail car is part of that specific train indicated in the dispatch plan.

Let us denote by \( P_R(t) \) the probability that at time \( t \), the system (the given rail car) is in state \( \{ R, F, I \} \). The desired reliability index is thus \( P_R(t) \), where \( t \) is the time promised to the consignee or shipper, at which that car is to be received in the local classification yard.

At first glance, it might appear straightforward to express \( P_R(t) \) as the product of marginal probabilities \( q_1, q_2, \ldots, q_n \), that transfers number 1, 2, \ldots, \( n \), required between trains as part of the dispatch plan, be successfully carried out. However, such a product would underestimate \( P_R(t) \). The reason is \textit{rattrapage}, the possibility of making up for a correspondence missed earlier by gaining back some time lost. Thus, not all transfers need to be made exactly as specified. To make up such lost time, it would be necessary to have a favourable schedule (a large layover specified in the dispatch plan), or an extra train (unscheduled), or both.

\textbf{Defining the states}

The state \( F \) is thus understood to include a possible extra (nonscheduled) train, one between that desired in the dispatch plan and the next regularly scheduled departure. For example, an additional train may result when an overflow of traffic at an intermediate classification yard did not permit all the cars there to be carried on a train being made up. Alternatively, if excess freight were received under the \textit{Régime accéléré}, SNCF would mandate an additional train to avoid late arrival of those cars carrying priority goods.

Our three-state Markov chain therefore has a transition matrix

\[
M = \begin{bmatrix}
R & F & I \\
1-a-b & a & b \\
c & d & 1-c-d \\
0 & 0 & 1 \\
\end{bmatrix}
\]

\( a \) is the probability of a one-step transition from \( R \) to \( F \). Such a state transition means the dispatch plan had been on target (\( R \)), but a connection was now missed, resulting in the particular rail car being part of the very next train (\( F \)). This need not be serious. There is a probability \( d(\ F \rightarrow R \) that, between two successive planned transfers at classification yards, the car continues to be only one train behind. With probability \( c(\ F \rightarrow I \), the dispatches get back on track through \textit{rattrapage}.

Note that the very name \textit{(irrevocably late)}, as well as of course the third row of \( M \), indicate that \( I \) is an absorbing state (Ross, 1989). The rate \( b \) denotes the probability that a car will make a direct transition from state \( R \) to state \( I \). The case of such a one-step transition (rather than in two stages, \( R \rightarrow F \rightarrow I \)) is bound to be technical breakdown of a train. Such a failure could almost never be repaired in time to catch up, hence a direct transition to the absorbing state \( I \).

We remark that the parameters \( a, b, c, \) and \( d \) are of interest during the passage of a train through a rail yard when cars are moved around, classified, and inspected. It is at these times that a transition (other than \( R \rightarrow I \)) can occur. There is no point in attempting to estimate these parameters in between such periods, when one can only follow the given car by referring to the train of which it is part.

It is important to recognize that the process is memoryless. Clearly for a long string of transitions between times \( t_0, t_1, t_2, \ldots, t_{n-1}, t_n \), what is important at time \( t_n \) is the state in state \( R \) or \( F \). At earlier times \( t_0, t_1, \ldots, t_{n-2} \) several transitions may have been made between \( R \) and \( F \) and back again, but the state at time \( t_n \) should depend only on whether the state at \( t_{n-1} \) is \( R \) or \( F \). Naturally, we had already taken for granted this memoryless property, in presuming to describe the transition by the matrix \( M \) for a Markov chain.
Numerical examples

As a first illustration of the preceding concepts, consider the transition matrix

\[
\begin{pmatrix}
R & F & I \\
R & 0.9 & 0.085 & 0.015 \\
M = F & 0.2 & 0.7 & 0.1 \\
I & 0 & 0 & 1 \\
\end{pmatrix}
\]

The parameters \(a, b, c, \) and \(d\) are thus 0.085, 0.015, 0.2, and 0.7, respectively.

Let us obtain the reliability index for the case of three transfers between yards, assuming that at time \(t_0\), the given rail car is a part of the right train: \(P_R(t_0) = 1, P_F(t_0) = P_I(t_0) = 0\). Transfers are anticipated to take place at times \(t_1, t_2, t_3\), while between those times, the rail car remains in a given one of the states.

A well-known result in the theory of Markov chains is that \(M^3\) will be the transition matrix whose elements represent probabilities of state changes between the same and three periods later (Ross, 1989). Taking the cube of the matrix \(M\), we obtain the reliability index \(\rho = P_R(t_3) = 0.772\). This is not high enough to meet customers' expectations.

Suppose that the one-step probability of the transition \(R \rightarrow R\) could be increased to 0.95, that of \(F \rightarrow R\) increased to \(c = 0.3\), and that of \(R \rightarrow F\) improved \((decreased)\) to \(a = 0.045\), corresponding to a new matrix

\[
\begin{pmatrix}
R & F & I \\
R & 0.95 & 0.045 & 0.005 \\
M' = F & 0.3 & 0.65 & 0.05 \\
I & 0 & 0 & 1 \\
\end{pmatrix}
\]

for this Markov chain. Now taking the cube of \(M'\) yields the new reliability index \(\rho' = P_R(t_3) = A\), where \(A = 0.892\).

For \(\rho'\), we still assumed \((as for \rho)\) that at time \(t_0\), the initial state is \(R\) with probability 1. Suppose, however, there were a distribution of initial conditions: with probabilities \(\alpha\) and \((1 - \alpha)\), the car begins on the right train or the following one. This corresponds to a prior probability \((1 - \alpha)\) that the given car is "left over" at the initial yard. It is easy to obtain \(\rho^* = \alpha A + (1 - \alpha)B\), where \(B = 0.587\) is the probability of a transition from \(F\) to \(R\) in three steps. If, at the initial yard, the given car were equally likely \((\alpha = 1/2)\) to be on the right train or the following one, three transitions later, the probability is approximately \(\rho^* = 3/4\) that this car arrive at the final yard on the right train.

5. ETNA: TECHNOLOGICAL EVOLUTION FOR DISPATCHING

In the previous sections, we discussed ways to measure or forecast the performance of the RO, RA service. Section 3 employed a reliability index, while Section 4 was based on a Markov-chain approach to estimate this index. In fact, however, strong arguments suggested that the RO, RA regimes be critically reviewed.

This two-tiered service requires a certain balance between the demand for each component. With satisfactory total traffic (excluding all unit-train movements), a ratio of 4 to 1 between RO tonnage and that of RA led to a smooth operation. Total traffic will of course decrease during an economic slowdown, but if this same ratio is maintained, the two-tier regime is still viable. However, from 1975 to 1985, the RA tonnage was constant or grew slightly, while RO traffic dropped by 50%. With now only a 2 to 1 ratio in tonnage carried, the two tiers became unprofitable.

It was not so much a question of revenues. Rather, loss of the RO shipments carried with it loss of operating flexibility. RO traffic enables the composition of reasonable-sized trains while respecting the time constraints promised for RA. A smaller percentage of RO traffic requires the makeup of trains with fewer cars, and although revenues could be partially compensated by a change in price, modified operating procedures would be needed. A larger proportion of train connections would become critical as RO shipments decreased.

In any event, that loss of traffic convinced SNCF management of the need for marketing research on a large scale. Speed of shipment was clearly not the only relevant parameter. By better understanding the various market segments, the railway could benefit from this diversity, rather than simply be captive to it. We will first describe the market survey, and then the new service (ETNA) it suggested (Charpentier, 1986).

The market research

The SNCF Department of Marketing decided to study extensively the needs of both current and potential clients. The main focus would be the planning and dispatching of shipments by the railway, with the effects of pricing as a secondary issue. Instead of having a geographically diverse sample whose interpretation might be difficult, the survey was limited to shippers in the region of Nancy. (The detailed structure of traffic originating in Nancy turns out to be quite similar to that of SNCF as a whole.)

Considerable thought went into the several criteria necessary for the extensive polling of clients. The final result was 1,200 telephone interviews with 200 companies, concerning the flows of more than 300 commodity groups. Each of the firms surveyed completed five questionnaires. One of these discussed both shipments and receipts, stratified by selected goods movements.

The overall goal of the survey was to understand the importance to the shipper of parameters such as reliability, speed, frequency of service, and price. The shippers' reactions would also be measured regarding several price/quality scenarios. These would
pertain to possible product offerings in a new scheme of freight dispatching. Shippers were thus asked to comment on potential services which would all be highly reliable but differ by their speed and price.

For example, there were four scenarios on long-distance movements. Denoting consecutive calendar days as A, B, . . . , F, G, Scenarios 1 through 3 corresponded to pickup on day A and delivery on day B, C, or D, respectively. Pickup also occurred on day A for Scenario 4, but delivery would be on day E, F, or G, according to the wishes of the client. It should be noted that, for the scenario whose lead time is the same as that currently in effect, a very high reliability was promised but with no change in price. Other scenarios then considered price changes in the range of ± 30%.

The sample
Almost 80% of the shipments surveyed pertained to movements by motor freight. To put it optimistically, more potential clients than SNCF clients were sampled.

One interesting aspect of the survey concerned the production/distribution cycle. Manufacture-to-order represented 7% of the trucking volumes but essentially 0% for rail customers. Safe-from-stock was a bit higher for rail than for motor freight (34% vs. 42%). Other cycles were defined according to the stage at which the carrier was notified of the impending shipment.

Results
There was greater price elasticity, in each direction, than one might have imagined. Shippers were willing to accept a higher price for a better quality of service, or would be happy with a less-rapid service at a price more competitive than the present one. Responses from trucking clients indicated that they believed their current transportation solutions were a bit costly; these shippers by motor freight appeared ready to respond to lower-level scenarios.

For SNCF, a product around the middle of the scale (fairly slow but very reliable) thus seemed a way to attack the competition. This service should be daily, and extremely economical. The end result was the decision to launch the ETNA project. This would be constructed around three levels, for greater flexibility and operating economy than the previous two levels (RO, RA).

Discussion
To understand the move toward a “lower-level” product, let us recall a major difference between rail services in North America and in France. We noted in Section 2 that SNCF adheres to a regular schedule for freight trains. The key is thus the daily nature of the new offering. Even in the U.S. or Canada, surveys consistently indicate that variability of rail lead times, rather than mean speed, is responsible for less use of rail to supply a manufacturing system. By setting and maintaining a consistent daily schedule, SNCF can still obtain a reasonable share of the market for JIT deliveries.

A related distinction from North America is that in France, apparently, a measured quantity of inventory is not automatically viewed as “waste.” A good return can in fact be demonstrated on this investment (that of extra stocks), whose cash inflow is the decrease in tariff from a premium trucking service to the new SNCF “product around the middle of the scale.” French manufacturers, because they are less swayed than their North American counterparts by the Japanese argument that “inventories are the root of all evil,” have left open the door for SNCF to perform well and to participate in JIT shipments.

6. EXAMPLES OF TIME-SENSITIVE SERVICE

Let us consider several SNCF offerings from among the many available. The particular examples illustrate how a modern railway, indeed any service operation, must develop new products targeted to the needs of clients in key markets.

Garantie cargo
This service assures a lead time for shipments between principal French rail yards and key yards in Holland. It is thus offered jointly by SNCF and NS (Nederlandse Spoorwegen), the Dutch national railway. Transport is carried out at high speed, but no premium is charged for the guaranteed lead time. (That, of course, is an admission of just how much competition there is in freight transportation.)

For the moment, Europe is not yet a homogeneous market. Garantie cargo could therefore not exist if there were slowdowns at the border due to customs clearance. Border delays are avoided by going through customs just before departure and on arrival. (This is similar to the preclearing of American customs at Canadian airports by passengers enroute to the U.S.)

One of the selling points of Garantie cargo and its reliability is that, by knowing in advance when the goods will arrive, smoother inventory management will be possible for the consignee. Knowledge of the transportation leadtime will also permit him or her to better plan shipments and deliveries.

Paris, LeHavre, Lyon, and Marseilles are among several dozen Garantie cargo origins or destinations comprising the entire length of France. Destinations or origins in the Netherlands are fewer in number. This is due partly to the size of that country, but also to the overwhelming influence of the Europort at Rotterdam and the seven or eight other rail sites in the greater Rotterdam area.

The guaranteed lead times basically correspond to overnight service in either direction. Goods must be deposited by 5 p.m. for delivery at 9 a.m. the next morning. Naturally, weekends and holidays are excepted.

It is important to note that SNCF and NS have put their money where their mouths are. For any
lead time that is more than an hour too long, a client can get a 10% rebate off the price. No shipper or consignee really wants to benefit from this, since the "penalty cost" (in the inventory sense) of a late delivery will surely be more than the rebate. However, by offering it, the railways will be giving up most of their profit margin on a late shipment. It is thus unlikely that a lead time be missed under the Garantie cargo regime.

Nord Méditerranée

This service is available five days a week between points in Southern France (Marseille, Avignon, etc.) and major German centres (e.g. Hanover and Hamburg). SNCF and the German railroad Die Bahn guarantee accelerated lead times for imports and exports of goods of virtually all types. The railways' agents describe this service as "borderless," and help achieve that promise by assisting in customs clearance at origin and destination (similar to Garantie cargo). SNCF also assures that each rail car can be followed and traced as reliably on this service as for shipments within France itself.

In general, for Nord Méditerranée as a whole, lead times are quoted in terms of upper bounds: pickup of a rail car need be no earlier than 5 p.m., for arrival at destination no later than 9 a.m. on the morning after the following day. For example, a pickup in Lyon on a Monday at 9 p.m. is promised to arrive in Hanover on Wednesday morning at 4 a.m. The highway distance is 550 to 600 miles. This lead time is therefore competitive with that of a motor carrier, which must (until 1992) stop at the border.

The weekends obviously cause lead times to be modified, but no more than necessary: a pickup at 8 p.m. on a Friday evening in Hamburg is guaranteed to arrive in Marseilles at 4 a.m. on Monday.

The price is negotiable, hence can include whatever reasonable auxiliary services are felt to be desirable.

Distri +

As important as is transportation to and from other countries, intra-France traffic is still very large. Few clients have identical needs, however, and so Distri + was conceived as a set of personalized services. A customer can choose among various modules, mixing and matching to individual requirements.

Distri + is offered by SNCF in conjunction with its trucking affiliate SERNAM (Service national des messageries). Despite its name, SERNAM is not limited to courier shipments of parcels, but is rather employed for goods pickup and delivery.

Among the Distri + modules are a number of third-party services. On behalf of its client, SNCF can manage an inventory intermediate between shipper (manufacturer) and consignee. Hardware and software permit these stocks to be controlled essentially in real time. About a dozen distribution centres (DCs) throughout France are dedicated to Distri +. Each DC has around 75,000 square feet divided into areas for cross docking, rack storage, order makeup, and receipt of shipments.

In more detail, the three possible phases of Distri + correspond to replenishment, operation of a DC, and delivery. "Replenishments" are dispatched from factory to distribution centre, either directly or through a consolidation point, but ultimately involving full truckload, carload, or container shipments. The DC can then perform a break-bulk function. Local delivery by truck may follow immediately, or be preceded by a warehousing of the goods. Even the delivery can be "tailored to measure." Variations include direct shipment to a single consignee at a time, or to several. Truck routes in the latter case can be calculated as particular needs develop; the client may specify minimum weights and/or maximum holding times before a load is dispatched.

Summary

The three services discussed in this section were chosen from among a large group of targeted products that are, or were recently offered by SNCF. The greater the competition in the marketplace, the more it is necessary that a railway fine-tune its portfolio of services to the needs of shippers and consignees. SNCF, as well as such North American railroads as CSX and Burlington Northern, appear to have made good strides in this direction.

7. FUTURE RESEARCH CHALLENGES

It seems appropriate to conclude this paper by discussing the outlook for SNCF and other European railways. Virtually all of these roads have thought long and hard on the post-1992 era. Services similar to Garantie cargo and Nord Méditerranée will become more prevalent as the E.E.C. drops the last vestige of borders between countries. Strategic alliances between railways and trucking companies (headquartered in whatever country) may become commonplace in European inter-modal transport.

As opposed to firms in other industries, railways can only compete with each other in regions where each has the track to operate. This generally means the U.S. and Canada, rather than Europe. Railroads of the E.E.C. countries have thus frequently exchanged information and learned from each other's operations. Indeed, Thuong (1982) has suggested some lessons that American railroads, too, could learn from their counterparts in France and England.

Time-sensitive services, whether in France or in other countries, typically exclude weekends from committed lead times. This is with good reason. However, beyond the offer of transport, weekends confuse the analysis of lead times promised and achieved. Data available from a carrier will typically come into a weekday dispatches with those crossing a weekend or holiday. An interesting study would involve the segregation of weekday and end-of-week
statistics. How do the distributions of lead times compare by the day-of-week the shipment is tendered to the carrier? To counter the effect of weekends, would a price discount be appropriate, and if so, of what size? We remark that these questions are equally important for motor freight as for rail.

Sensitivity issues could be the focus of research on measurement of the reliability index, using the Markov-chain approach of Section 4. Powers $M^n$ of the one-step transition matrix $M$ permit an analytic expression for the reliability index $\rho$ in terms of parameters $a$, $b$, etc. for single-step transitions (Bullot, 1984, 1985; Ross, 1989). Careful use of that analytical formula could answer some general sensitivity questions. For example, what improvement or degradation can be expected if an extra train is scheduled or a present one eliminated? What is the impact if additional time in a rail yard were allowed for a transfer? If less time were allowed?

Besides being able to calculate $\rho$, one can also obtain approximately the probability that the given rail car arrives in the train following the right train. This estimate would not be exact because, in taking state $I$ as an absorbing state, there can be no return to state $F$ even for the case of many transfers. However, the resulting approximation should not be too bad. $P_F(t_j)$ may shed additional light, beyond that furnished by the reliability index, on the quality of the dispatch plan.

One result of the survey (Section 5) leading to the ETNA project was that trucking clients believed their current transportation solutions were a bit pricey. Although French shippers by motor freight appeared ready to respond to lower-level services, this is not in line with current opinion in North America. Has any manufacturer, however, truly costed the effects of small (LTL) inbound JIT deliveries? Perhaps analysis is lacking because a major auto-maker, say, has the financial power to dictate to a supplier the frequency and size of JIT deliveries, and expect that supplier to swallow the extra cost. If a third party were to estimate this price more carefully, additional opportunities may be uncovered for JIT services by rail (Higginson and Bookbinder, 1990).

We also remark that to compete with truck in the JIT market, a railroad may need to adopt a more rigid schedule for dispatching cars to major customers. This might be done if the railway's plans for car management, including any repositioning of empties (Dejax and Crainic, 1987), could be based on direct knowledge of the cars required for shipments by those customers (Bookbinder and Sereda, 1987).

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