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Interface Between Passenger and Freight Operations

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ABSTRACT

The fundamental conflicts between trains with different speed profiles and stopping patterns are outlined. The operation of the Northeast Corridor of the National Rail Passenger Corporation (Amtrak) is presented as an extreme example, with 13 classes of service over the same tracks. Various methods of handling this problem are discussed with specific applications of the concepts cited. Additional track is the first concept reviewed; both addition of lines to existing routes and construction of new separate right-of-way are considered. Examples of the various methods of increasing the permissible speed of passenger trains on the existing infrastructure through the use of pendular suspension and of interactive systems are explored. The changing nature of freight service in North America is examined and the suggestion is made that the scheduling problems to be faced in operating this service will be very similar to the interface between passenger and freight service today. The role of timetable planning and careful scheduling of trains is explored. The relationship between schedules and track configuration, particularly at line stations, is discussed. The nature of the role of the train dispatcher and his capability is explored. The potential role of the modern computer to convert the time spent on clerical tasks to more useful time resolving transportation problems is outlined. The use of computers to handle actual routine decisions is explored. The development of computer simulation techniques from simple train performance calculators to a planning tool capable of handling extremely complex diagrams is discussed. These tools are now being developed to the point of being able to estimate arrival times, conflict points, and other situations on a real-time basis. Alternative courses of action can be tested quickly on the basis of accurate current information. These tools will be available soon and give the dispatchers the ability to handle increasingly complex traffic situations.

Although the title of this paper includes the word "passenger" and the questions and areas of concern are now most pronounced for passenger trains, the fundamental problems discussed are very much applicable to an increasing number of railroads that carry only freight. In fact, one of the most rapidly changing areas, that of computer-aided dispatching (CAD), has been developed and is now in actual use on several railroads in this country that haul freight only.

The sound effects on the radio commercials for the National Rail Passenger Corporation (Amtrak)

Metroliner service succeed in giving the impression of speed. The impression of speed is even more pronounced when the morning New York-Pittsburgh train is receiving passengers at Princeton Junction and the Washington-bound Metroliner roars by at full maximum authorized speed. And this event illustrates the problem of differing speeds dramatically. The solution in this case is the tried and true civil engineering answer--an additional track. This quickly sets the stage for the present discussion.

Some time ago when jackets with patches on the elbows were very much in fashion, I was chided by some as needing the patches as a result of all the work I was doing on schedules. One wag told me that if I didn't have all these different zone trains--just had all the trains make all of the stops--it would make my life simpler. However, if the Metroliner made all the stops of the Trenton local across New Jersey, I suspect that Amtrak's marketing department would fold their tent very quickly. There are many different markets to be served over the same route.

This quickly introduces a second variable, stopping patterns. The nonstop New York-Washington Super Metroliner would be the extreme example in a discussion of the New York-Washington Corridor. The Metroliner Express with only one stop in each state is more common. Let us call the next class of train the "regular" Metroliner with two additional stops (though not necessarily the same stops). All of these can cruise along at a comfortable maximum of 120 mph. Just within this speed classification there are three distinctly different "paths." Each type requires different track occupancy within the same speed range.

To detour a moment, what has just been described is not too different from the operation between Tokyo and Osaka on the Japanese National Railways (JNR) famous bullet trains, which brings up the issue of track productivity. Although the JNR high-speed line is essentially a double-track line, many of the intermediate stations have four tracks in order to allow the superbullets to pass the slower bullets. The civil engineer is ever ready with his solution to the problem.

To return to the Northeast Corridor, consider this list of train types:

1. Metroliner
   a. Nonstop
   b. Express (four intermediate stops)
   c. Regular (six intermediate stops)
2. Standard train
   a. Regular (eight intermediate stops)
   b. Local (many more intermediate stops)
3. Suburban (New Jersey Transit)
   a. Zone express (two intermediate stops in New Jersey)
   b. Local or express (six intermediate stops in New Jersey)
   c. Local (11 intermediate stops in New Jersey)
4. Suburban (Southeastern Pennsylvania Transportation Authority)
   a. Local or express (six intermediate stops in Pennsylvania)
   b. Local (14 intermediate stops in Pennsylvania)
5. Suburban local (stops in Maryland)
6. Freight
   a. Trailer on freight car (TOFC) (Trailvan maximum speed, 60 mph)
   b. Merchandise (preferred maximum speed, 50 mph)
   c. Maximum tonnage (typical speed, 40 mph)
   d. Coal or ore (maximum speed, 30 mph)
   e. Local (serves sidings along route)

And as this outline is developed, it can readily be seen that the parallels in freight service could be detailed into many more types, each with its own path. However, the variety is far greater than this, as any dispatcher will readily attest. The actual track occupancy of a specific freight train is a function of the number and type of cars in the train, weight of the train, characteristics and mechanical condition of the locomotive configuration, track conditions, interference of other trains in the system, and expertise, and, on really difficult portions of railroad, the finesse of the locomotive engineman.

CIVIL ENGINEERING SOLUTION: ADDITIONAL TRACK

The most obvious answer to the problem of different types of traffic can be additional track. Indeed, in Great Britain, the tracks on a four-tracked line are usually labeled Up Fast, Down Fast, Up Slow, and Down Slow. The two center tracks of many four-track routes were maintained to a markedly different standard; the term "high iron" was visually obvious to the casual bystander.

Though seemingly inefficient from the viewpoints of both capital required and repetitive maintenance costs, having separate tracks for each class of service solves a number of problems. The problem of the markedly different curve elevation required for smooth operation of extremely high-speed passenger trains at one end of the spectrum compared with a slow-moving freight train at the other is solved by separating the services. On the new French Railways Tres Grande Vitesse (TGV), grades of 3.5 percent are common. The extremely high-speed TGV trainsets have no problem at all with this, but the dispatcher ordering out a 130-car freight train over that railroad would.

This is probably the point to introduce another issue, namely, maintenance standards. It is difficult to maintain track geometry for the extremely high speeds now common on the JNR bullet train, the French TGV, and the Amtrak Metroliner. However, Amtrak is unique in being required to maintain the track for high speed and at the same time operate heavy freight tonnage over the same track. As more freight traffic is scheduled for higher speed, many more railroads will face this same problem between different classes of freight trains.

Additional track or controlled sidings immediately add another element of cost, that of switches, signals, and controls. The maintenance itself introduces the next problem, that of track out-of-service time for maintenance. Consider a multitrack railroad with different classes of tracks. When the "higher"-speed track is required for engineering work, a whole series of problems follows. The high-speed trains lose time on the slow-speed track as well as requiring decelerating time before the restriction and accelerating time after the restriction. If a heavy tonnage freight train must be slowed or stopped, much time is lost. Service reliability of both classes of service is hurt. And if local or suburban commuter trains are involved and schedule connections are broken, many lives are disrupted.

When the total volume of traffic of all types requires additional trackage, the completely or partially separate line can yield important advantages. For example, the quadrupling of track on the existing route between Paris and Dijon would have been complex and expensive. Not only was the new line less expensive to build but it was only 426 km long as compared with 525 km for the existing line. This is reflected positively in reduced capital expense, reduced maintenance expense, reduced operating expense, and of course improved marketability.

The additional-track solution is under active consideration in the United States. At a recent meeting of parties interested in the continued growth of passenger service across New York State it was revealed that serious consideration is being given to constructing a third track within the existing right-of-way but separate from the two existing tracks in order to allow passenger trains to regularly operate at 110 mph. Several studies are under way for completely new high-speed railroads in various locations in order to attain the higher speeds and greater degree of reliability.

MECHANICAL ENGINEERING SOLUTIONS

Pendular Suspension

Some of the civil engineering problems posed by the operation of widely different types of trains (the extreme example of high-speed passenger service and low-speed heavy freight trains) can be alleviated by new equipment design. The Talgo pendular suspension as developed in the United States some 40 years ago has been tested at 143 mph and operates regularly at 88 mph in Spain and at 100 mph in France.

Lest this be considered an unusual or experimental service, note that the Talgo service has accumulated over 38 million car miles and carried over 471 million passenger miles. In the discussion of reliability, consider that 97 percent of the fleet is available during peak season.

The Talgo trains consist of a series of single-axle cars. One end of each intermediate car is supported on the damped air springs under the top of the car. The springs provide vertical and lateral suspension, and because they are well above the center of gravity of the car, the correct pendular effect is achieved on every curve. The result is a smooth and comfortable ride.

Incidentally, just to make the operation interesting, some of these trains operate between France and Spain. The track gauge in France is 4 ft 8.5 in. but in Spain it is 5 ft 6 in. The trainsets used in this service employ an adjustable-gauge truck, permitting the necessary gauge change to take place with passengers aboard (at a very slow speed).

On the opposite side of the globe, in Japan, a fleet of 277 electric multiple-unit cars equipped with a roller-type natural tilting system has been in regular service since 1973. The car tilts naturally by centrifugal force while running on curved track, cancelling the excessive centrifugal acceleration caused by the shortage of superelevation. These trains of the 381 series are reported to operate at a speed of "standard" plus 15 to 20 km/hr without any feeling of discomfort for the passengers.

Active Tilting System

One factor limiting the maximum speed of a passenger train around curves is the level of comfort of the passengers. Tests conducted in 1983 by British Rail refined the problem even more specifically; the comfort of the standing passengers will be a critical problem. In theory it would appear possible that engineers could design a system that would determine the lateral acceleration as the forward part of the train entered a curve and transmit this information to a mechanism that would tilt the body of the train at just the right degree to cancel out the unpleasant lateral accelerations.

British Rail has gone through the Mark I, Mark II, and Mark III carbody tilting systems and is now developing the Mark IV. The program is an example of the difficulty of converting theory into reality. In the earlier models the sensing accelerometers were mounted locally on each vehicle, and although this should have allowed satisfactory response, it was not actually achieved. Feedback systems, stability margins, desired response time characteristics--all are theoretically possible but the result was delayed tilting on transition curves and a jerky ride. Furthermore, because of the close relationship between tilt performance and lateral ride quality, the total ride quality was poor. Mounting the accelerometers on the preceding vehicle achieved better results.

After many years of trials, British Rail is said to have finally achieved the desired effect, only to have the poor riding quality of the articulated train cause discomfort. It has been reported that British Rail has decided that future high-speed coaches will not be articulated, at least partly because of the poor riding quality of the bogies.

As the development has proceeded, the testing procedure itself has become more sophisticated. A new ride meter (the Jacobmeter) was devised to measure ride quality as perceived by passengers. But there is still far more to the problem because a passenger's comfort is affected by vibration, noise levels, temperature, ventilation, visual environment, expectations of ride quality, and so on.

For example, consider for a moment the visual effects. In order to reduce the effects of claustrophobia, the trend in new equipment is to large windows. However, with tilting equipment, the horizon rises and falls without corresponding cornering sensations. The problem is worse for on-board staff who are standing, and much of their time is spent facing the windows. Motion sickness is a potential problem, as it is also on the Japanese class 381 equipment.

Meanwhile, since 1973, the Swedish State Railways and their vehicle supplier ASEA have jointly carried out their own development project, X-15, concerning the design and testing of a new vehicle concept. This effort appears to be closest to reality and bids have been requested for three prototype cars with an option for 50 production trainsets. The Norwegian State Railways plans to install tilting equipment in one batch of 24 cars to be delivered in February 1986 for trials. Judging by the tediously slow results elsewhere, it would be pleasantly surprising to see actual regular service by this type of equipment before 1990.

In Japan there is a program to develop a system to increase the speed limit on the narrow-gauge lines on curves to a standard plus 25 km/hr. The system uses an air cylinder that increases the tilt beyond that achieved by the roller system of the 381 series cars. The existing wayside devices of the automatic train stop (ATS) system are used as a base for the tilting system. The distance from each curve to the nearest ATS device is known, as is the diameter of the wheels. This information is calculated and stored in the controller. Depending on the direction of the curve, length of the transition curve, length of the curve itself, radius of curvature, and superelevation of the curve, the precise amount and duration of required tilt are calculated and applied to the car body. Tests have indicated that the initial transition at the beginning of the curve and at the end of the curve are important in obtaining an acceptable ride.

RESTRUCTURE OF RAIL FREIGHT MARKET

Although the title of this paper was first set out to be the problems between freight and passenger operations, and it might appear that the topic would

not be of interest to railroads that carry only freight, it is suggested that operators of these lines take careful note. The highest speed at which freight trains operate today is 70 mph. It was not too many years ago that this speed was called "passenger train" speed. A glance at the list at the beginning of this paper indicates five types of freight trains with very different characteristics. In terms of dispatching, the highest-speed piggyback freight trains appear similar to the faster passenger trains. The slower maximum-tonnage trains may well take no more track time than a commuter local making all the stops. The peddler freight "dogs" along from siding to siding and does as much damage to a dispatcher's use of a high-speed freight railroad as it does to the dispatcher in the Amtrak Northeast Corridor.

The historic patterns followed by the railroads are undergoing dramatic changes. Even those railroaders not close to the marketing problems must be aware of thousands (actually hundreds of thousands) of boxcars that stand idle in sidings, yards, branch lines, short lines--seemingly everywhere.

The amount, type, and speed of traffic and the degree of schedule dependability required to retain this traffic are worlds apart from those characteristics just a few years ago. Consider one industry that everyone will agree is a vital component of intercity freight traffic--the automobile. Look at the changes in the components used in construction of each automobile:

	Avg Weight per Automobile (lb)	
Material	1977	1985
Hot-rolled steel	1,419	760
Cold-rolled steel	820	490
Cast iron	620	315
High-strength steel	105	225
Plastics	165	225
Total	3,129	2,015

This type of change in production hits the railroads in at least three ways. First, the reduction of weight of the components reduces ton-miles required. Second, the size and weight of the final product lead to reduced revenue from completed automobiles. Thus, as the components become smaller and lighter, they are more likely to be candidates for movement by truck.

This last point is critical. The railroads will have to meet the speed and dependability of the truck lines in order to retain revenue. As railroads revamp their freight patterns and schedules, the results look much like the passenger train schedules of a few decades ago. There are locations today where relatively new classification yards are operating at only a fraction of their installed capacity and the adjacent TOFC and container-on-flatcar (COFC) terminal is so busy that the capacity of the facility is strained.

If the trends of the Speedlink Service in Great Britain and the restructuring of freight service in West Germany move to the United States, a passenger timetable of a few years ago, complete with cars moving forward on connecting trains within a few minutes of arrival, may be mistaken for the new freight service folder. The problems of "passenger-type" dispatching will be regular occurrences on freight railroads. At the same time the heavy-mineral train and other classes of freight trains will still be plodding along at their traditional speeds. The complexity of scheduling and dispatching will increase accordingly.

OVERTIME AND CAR-HIRE COSTS

The conquest of the problem of efficiently handling trains that traverse widely differing paths creates costs savings for freight railroads that management can really relish. In one of the examples shown in the following, one railroad is realizing savings of two-thirds of a million dollars on just one division with a CAD system. In addition to this reduction in overtime and car-hire costs, it appears that substantial capital costs can be prevented by not building a planned siding. When the capital, maintenance, and direct operating savings from all aspects of this problem on freight railroads are detailed, many people will truly be amazed.

TIMETABLE PLANNING AND TRAIN SCHEDULING

It is a fortunate railroad that faces the problem of increasing throughput. Certainly such problems would indicate no lack of revenue. How this problem is handled will be an important factor in determining how much of this gross revenue is brought down to become net revenue. Both the civil engineer's solution and the mechanical engineer's solutions require substantial additional funds. The role of the planner and scheduler is usually to work within both sets of physical constraints--roadway and rolling stock--and achieve the best possible solution.

Ideal Railroad

It might appear that the ideal railroad would consist of trains all running at the same speed, much like a conveyor belt. This works fine until the first stop is scheduled. As soon as the train decelerates, the problem begins. The traffic signal designer copes with this problem by changing block lengths, increasing the number of blocks, and even increasing the number of signal aspects.

The solution may well be that the ideal railroad line would expand into two tracks as the route approached each station, at a distance to allow safe deceleration without adversely affecting the following train; have separate loading facilities for each track in the station; and then return to one line (in that direction) after a distance sufficient to accelerate to maximum line speed. As mentioned earlier, this is not unlike the plan of the JNR bullet trains. In the suburban service sphere, the Société Nationale des Chemins de Fer Francais (SNCF) achieves amazing throughput on its B line through Paris by just such a scheme.

Real Railroad

These are rare examples, however. Realistically the timetable planner is always trying to increase the number of train movements, handle longer and heavier trains, increase the speeds of all classes of service, and at the same time improve the dependability of the entire matrix.

The marketing manager wants the "name" train handled with priority over everything else. The yardmaster simply wants the tonnage freight to leave the yard as soon as possible and honestly is not concerned whether the dispatcher has any railroad on which to run it. The commuter wants to get home exactly as scheduled, even though the schedule is slow, and before his supper goes up in smoke.

One of the basic problems in scheduling is knowing with a high degree of accuracy exactly how long a given train with a specific locomotive, a specific consist, and a specific crew will require to tra-

verse a given portion of line under given circumstances. Until recently this was all left to the experience of dispatchers and schedule planners. Even the most thorough hand calculations left much to be desired. The problem could be approached by starting with horsepower and tractive effort curves, track charts with grades and curves, the Davis formula, and everything else one could find. A different approach is to review the actual results of day-to-day operation of a given type of train over a sustained period of time and by introducing probability predict a reliable schedule. With these building blocks, the schedule planner balances the needs of all the requests noted earlier.

The use of high-speed computers has brought some degree of sanity to this problem. Computer simulation of all types of trains with many variables can predict train performance with great accuracy. More complex simulations that include the interaction between the trains and signal system, and in turn all other trains in the system, are now the backbone of timetable planning. However, the choice of stopping patterns is still a "given" or "input." Simulation will provide what has been suggested, but there is still a substantial leap from this statement of fact to the choice of which train goes first.

One effective method of increasing throughput is the technique of "fleeting" a series of trains over a portion of line as a group. In cases where densities are really high, some of the running patterns of the fastest trains may have to be relaxed slightly. Immediately the battle is engaged to balance the need to obtain high theoretical speed and also attain a high degree of schedule reliability. It is at this point also that some of the high-speed freight trains (TOFC and COFC) look much like passenger trains on the train graphs of many railroads. The Northeast Corridor with its maximum authorized speed of 120 mph is the obvious exception.

The next development from the fleeting concept is a zonal operating strategy. This method starts with fleeting the trains that are destined for the farthest points first and then scheduling the others by their first station stop, working backwards from the originating location. The technique works best when the headway between the movements is kept to an absolute minimum and time is allowed between the first fleet and the next fleet in order to provide for recovery.

Because one set of schedules determined from one origin is overlaid on the set of schedules from the next major load point, and this process is repeated again and again, the result is complex. Although the initiation of computer simulation of any railroad itself is a complex and demanding task, once it has been developed and used, it enables this sort of scheduling problem to be handled without massive effort.

THE DISPATCHER AND CAD

Clerical Work

It has been stated that the role of an airplane pilot is 99 percent boredom and 1 percent sheer terror. If this is accurate, it is somewhat analogous to the dispatcher on a busy railroad. An unfamiliar observer might come to the conclusion that most of a dispatcher's time is spent simply filling in on-schedule times on large and extremely unwieldy yellow charts. Indeed, in some sense he would be correct because federal law requires that complete records of every train be maintained. This information includes

1. Crew information--names of conductor and engineman, time on and off duty, and amount of rest time between assignments;
2. Locomotive information--specific numbers of locomotives;
3. Train equipment information--the amount of cars (separated between loaded and empty) at the beginning and end of the trip;
4. Details of time of train movement--departure time, intermediate passing times, meeting points and times, final arrival times;
5. Details of train delays; and
6. Record of all unusual occurrences.

A tremendous portion of a dispatcher's time is spent on record keeping and related clerical work. On some railroads it would appear that so much of the decision making is taking place at block towers that the dispatcher is really just following the show and not really controlling it. Some studies indicate that the proportion of the time spent on these clerical-type functions is about 80 percent.

It is in this area that CAD efforts have had their initial impact. There are several different approaches, but once the basic data are entered into the system, the computer does much of the clerical work. This frees the dispatcher for the real problems.

Needed Information

The other part of the picture of a dispatcher's work would be apparent if the observer walked into the dispatcher's office at the more exciting times. At these moments, as instructions are flying back and forth, one wonders how anybody can really remember all of the facts needed to make good decisions. Will a particular train fit in a certain siding? When will a portion of track be released by the engineering department? Exactly where in the interlocking is the troubled train? Which crew will "outlaw" (reach the mandatory maximum hours of time on duty) first?

The second impact of CAD is the ability to bring a great deal of (accurate) information to the dispatcher quickly. There is always a degree of judgement in every situation, but all too often guesses are made based on erroneous information. The facts are caught somewhere between the trains involved and the point of decision, but they are not available in a form that is understandable to the decision maker. The initial impact of the computer is not to replace the dispatcher but to put much more of the information he wants and needs at his fingertips exactly when he needs it. The result is to reduce the size of the leap of judgment. This gives the dispatcher much better odds at making the correct decision.

In some systems the data show up on a visual display unit. The last three arrivals shown on the CRT unit allow the dispatcher both to know the locations of the trains and to have a feel for actual progress. In more advanced systems the train number appears on a central traffic control board. On yet another system, a time-distance graph appears and the trains appear as colored lines showing their progress. In each case, however, the result is to give the dispatcher, or his superiors when the situation requires their involvement, a complete picture of as many of the variables as can be determined.

In the system being developed for the Amtrak Northeast Corridor the complete track diagram from Washington, D.C., to Wilmington, Delaware, will be projected on a large screen spanning the full length of the control center located on the top of the 30th Street Station in Philadelphia. As plans now stand, the actual train numbers will move across the board

continuously, indicating the precise location of each train.

Routine Operations

An honest analysis of a great many things that we do each day will reveal the degree of routine in our society. Most of the dispatcher's decisions are in fact routine procedures. Analysis of the 20 percent of dispatching time left for controlling train operation (after the clerical functions are subtracted) indicates that 85 percent is routine. This degree of routine operation sets the stage for utilization of computers to aid dispatching.

The simplification of train orders by using a blank form on the CRT and then transmitting them electronically cuts through the traditional train order book and all that goes with it. The next step is the automatic clearing of trains from sidings. Clearing signals automatically in front of advancing trains prevents trains from having to reduce speed without real reason. On a high-speed operation like the Northeast Corridor this ability is immediately transformed into highly on-time performance. When heavy freight trains are involved, this ability is seen in reduced fuel consumption and brake wear.

Simulation of Train Performance

The use of the computer to grind through the details of train performance calculation, including the horsepower available, the traction characteristics of the particular locomotives (or multiple-unit cars), the grades and curves of a particular route, the Davis formula, specific local speed limits, and other factors, is known. It is a useful tool in determining new locomotive requirements, economics of line changes, and operating decisions and especially in timetable planning.

The more complex simulation of an entire schedule of trains--each with different operating characteristics and different stopping patterns, including the reaction between trains and the signal system, and in turn the signal system with following and opposing movements on single track and with parallel movements of trains with differing speeds and characteristics in the same direction on multiple track and a series of complex interlockings--has been an essential part of regular timetable planning on the Long Island Rail Road for over a decade.

However, "planning" is a relative term. The computer programs of a decade ago were so laborious that they could only be used for planning of schedule changes targeted for months ahead. In a railroad operating dispatcher's office the term "long-range planning" means tomorrow or perhaps (on the Amtrak Northeast Corridor, for example) even a few hours from now. The planner's computer models were certainly no help to the dispatcher when the "unusual occurrence" portion of his train sheet was overflowing with remarks.

Real-Time Simulation

The modern microcomputer has brought the possibility of rapid and timely simulation of train performance of a number of trains and their effect on other trains in the area into reality. In the simplest systems CAD predicts the estimated time of arrival (ETA) of trains for the dispatcher. If the train is delayed, or if it does not perform as anticipated, the ETA is changed accordingly. Potential conflicts are highlighted in time for corrective action to be taken.

Could the automation of the time-honored "string chart" be far behind? A visit to the Atlanta headquarters of the Norfolk Southern's Alabama and Georgia Divisions will reveal a CRT at the dispatcher's elbow displaying a time-distance graph that shows the actual and projected courses of trains on these divisions. The dispatchers regularly follow the plan developed by computer program that has determined the combination of meets and delays that will result in the lowest-cost operation. However, if the dispatcher wants to investigate an alternative plan, the system can test it quickly. If crews are nearing the 12-hr limit, the dispatcher is alerted. If power is needed for a connection, the CAD system flashes a warning.

The present planning for the Amtrak Northeast Corridor includes train identification, train status, track and track power monitor, and the control and validation of commands to interlockings. The system is designed to be expanded to include traffic management techniques including train graphs, meet-pass planning, conflict prediction, and other features as funds for implementation are made available.

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