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SPEEDING UP COMMUTER RAIL SERVICE: COMPARATIVE ACTUAL PERFORMANCE OF DIFFERENT TRAIN AND STATION PLATFORM DESIGNS

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ABSTRACT

Speeding up commuter rail service can be achieved by various changes in train and/or station design. This paper summarizes the results of an analysis of the effect of car design intended to achieve low station dwell times. These are termed *short dwell time entranceways* (SDEs). This study used actual timetable data from commuter rail systems that had different designs to estimate the timesaving from using SDEs compared to traditional *end vestibule entranceways* (EVEs). This required development of a new procedure to characterize speed (or run time) performance of trains that accounts for differences among run characteristics (e.g., station spacing, speed limits), and this procedure is presented. The validity of the procedure is assessed, and its usefulness as a complement to Train Performance Simulators is discussed. The lines analyzed had speed limits averaging 60 mph (96.6 kph) and average station stop spacings of 1.25 mi (2.01 km) to 5.0 mi (8.04 km). The timesaving resulting from use of SDEs instead of EVEs at low level platforms is slightly more than 5% at the shortest station spacing, about 2% at the longest. Interestingly, these gains approximately equal those from electrification retaining the EVE car design. Thus car design to achieve low dwell time is a very important option. Since EVE car designs are most prevalent on lines with a mixture of high level and low level platforms, the implications for such lines (including ADA accessibility considerations) are discussed.

INTRODUCTION

The purpose of this paper is to present the results of research that had two objectives:

1. To determine the actual speed increase (or decrease in travel time) in commuter rail service that results from providing technologies that reduce dwell time, i.e., car entranceways that, in conjunction with the type of station platforms used, permit rapid boarding and alighting. Actual timesaving was based on timetable data.
2. To present the method developed to measure this gain using timetable data.

We believe that the method is novel, in that no prior work using this approach was found in the literature. Thus this paper will present this method in some detail, and discuss its general usefulness, as a complement to Train Performance Simulators (TPSs), which are the primary alternative means of developing data on train speed performance and run times.

The empirical results on the speed-up of service should be useful to those who are considering various methods for improving the speed of service. By virtue of the systems analyzed, the results include not only the speed-up resulting from reduced dwell time but also permit comparisons with the speed-up resulting from electrification and use of self-powered multiple unit (MU) cars.

We analyzed schedules of selected lines of four major U.S. commuter railroads to determine the increase in average schedule (commercial) speed, or conversely the run timesavings, resulting from major technical design options. These design options are:

(A) The base design: Diesel locomotive propulsion and cars having the traditional *end vestibule entranceway* (EVE). Diesels have relatively poor acceleration performance. Each end vestibule on the cars has only a single lane for passengers. Only one vestibule can be used by passengers in the cab car when it leads the train (in the push mode), and in newer cars no vestibule is provided at the cab end. These, and other features explained in more detail below, lead to comparatively lengthy dwell times.

(B) Retaining diesel propulsion, but replacing end vestibules on the cars with *short dwell time entranceways* (SDEs): These include powered remotely controlled (train-lined) doors designed to minimize dwell time by having a high ratio of available door lanes to seats on each car and ensuring that all doors are opened and closed at all stations. These features (and others discussed later) ensure short dwells.

(C) Replacing the diesel locomotive of alternative A with higher acceleration rate self-propelled electric MU cars while retaining the end vestibule entranceways for both LL and HL platforms.

(D) Further enhancing alternative C by installing SDEs on cars and installing HL platforms for level boarding and alighting at all stations.

The plan of the paper is as follows. First, the method for characterizing speed performance using timetable data is presented. Its validity is discussed, as is its usefulness as a complement to using TPSs to estimate train speed performance. Then, after a complete definition of EVEs and SDEs, the data and results regarding the effect of SDEs are presented. This provides some further tests of the methods used. Finally the conclusions regarding the potential for changes in car design, in particular designs to reduce dwell time, to speed up service are discussed.

UNDERLYING THEORY AND METHOD

The method uses published timetables as the best generally available data on actual speed performance. But at the same time important differences between the systems had to be accounted for in the analysis. The approach was as follows.

Figure 1 illustrates the speed performance of a train, from departure at one station stop to the next. Figure 1(a) shows the speed of the train as a function of time-- acceleration from rest to cruise speed, operation at cruise speed until deceleration begins, deceleration to rest, and finally the dwell time at the second station. This results in a linear relationship between (1) the time from one station stop to the next (i.e., start to start) and (2) the corresponding distance, so long as the train can reach its cruise speed within that distance, as shown in Figure 1(b). The minimum distance required for one acceleration-deceleration cycle between rest (zero speed) and the cruise speed is termed the *critical distance*. Also shown there, is the curved dashed line, which extends the relationship into inter-station stop distances less than the critical distance. (Further details on these charts may be found in any basic book on transportation engineering, e.g., (*1*).)

Such a relationship can be related to timetable data as follows. The time required by a train to operate from start at one station to start at the next can be described by

$$\mathrm{TIME(i) = Y+Z \bullet STADIST(i)} \qquad (1)$$

where:
i = a segment of track defined by two adjacent station stops on the train's run
STADIST(i) = the inter-station distance between the endpoints (stations) of segment i
TIME(i) = time required by train from departure from station at beginning of segment i to departure from the next station
Y, Z = parameters of the equation

Note that this assumes

$$\mathrm{STADIST(i)} \geq \text{critical distance (minimum distance for acceleration and deceleration given the cruise speed)} \qquad (2)$$

The inverse of Z (Z being in units of time per unit distance) is the cruise speed of the train.

The scheduled run of a train consists of a succession of station to station segments i (i = 1, 2,…, N) of length STADIST(i). Given equation 1, these result in an overall time over N segments (from start or departure at the beginning station on segment 1 to start or departure at the end station on segment N) corresponding to a *trip* of distance TRIPDIST as follows:

$$\mathrm{TRIPTIME} \quad \sum_{i=1}^{N} \quad = \quad \mathrm{(Y+Z \bullet STADIST(i))} \quad = \quad \mathrm{Y \bullet N + Z \bullet (TRIPDIST)} \qquad (3)$$

The summation of segment distances equals the entire distance traveled, of course, so we substituted TRIPDIST for this in the equation above. equation (3) can be estimated from timetable data, since each train run has a specified TRIPTIME (the run time), TRIPDIST (the run length) and N (the number of inter-station stop segments).

A more useful but equivalent form results from dividing equation (3) by the number of segments (N), yielding:

$$\mathrm{SEGTIME} = Y + Z \bullet \mathrm{SEGDIST} \tag{4}$$

where
SEGTIME = TRIPTIME/N = average time per (station to station) segment
SEGDIST = TRIPDIST/N = average distance per (station to station) segment

It is evident that equation (4) can be readily related to timetable data. The timetable will yield, for each train run, the average segment time and average segment distance. Thus this equation can be estimated from timetable data yielding the values of Y and Z.

Timetable Data Considerations

In using timetable data, there are details that are important to ensure that the data are consistent with the assumptions underlying the equations. One is that the time should include the dwell times at N stations, by taking the time from departure at the first station to arrival at the last. The trip may correspond to the entire run of the train, or a portion of it.

Another condition is that the cruise speed of trains included in the data must be identical, or essentially so, as assumed in the derivation. Because of speed reductions for curves, junctions, etc., the observed cruise speed is likely to be less than the speed limit.

A third consideration is the assumption that the average dwell time on a run is constant, and identical among the trains in any one regression estimate. This bears consideration. First, it is clear that equation 3 does not assume that all station dwell times in a run are identical. Clearly there are differences in station dwell times on a run. An extensive recent analysis of dwell times is in *Transit Cooperative Research Report 13* (2). The estimating equations there indicate that the expected value of dwell times for both high level and low level platforms systems are primarily a constant to which a relatively small amount is added per passenger. The relationships developed there used data from heavy rail and light rail transit lines only, but these are similar to those at HL and LL platforms on commuter lines, respectively. And the constant time added for surveillance of the insecure EVE (where the entranceway is left open between stations) at LL platforms before departure will reinforce the tendency toward constant dwell time. All this suggests that the assumption here of a constant average dwell time for each type of commuter rail train on its trip consisting of many station stops is probably not unreasonable.

Finally, it is assumed that all the timetables include essentially the same allowance for random factors such as slow orders, variations is crews skill, etc. and that all timetables are equally realistic.

This then provides the basis for the use of timetable data. First, lines and trains were identified which had the desired characteristics. Then the peak period was identified, based on information in the timetable, usually indicating when peak period fares applied. Third, speed limits of lines were examined in order to focus on lines that had identical or nearly identical cruise speeds. This part of the analysis of lines revealed that all possessed quite low speed limits in the vicinity of the central business district station. We explored using data for only outside of those very low speed areas with the alternative of using data for the entire terminal-to-terminal run. The results were superior in quality of fit and in comparability of cruise speed with the low speed sections omitted.

ENTRANCEWAY TYPES

Before describing the data and analysis, the two types of car entranceways (and associated station platform configurations) should be defined more fully.

Traditional End Vestibule Entranceway (EVE)

Each EVE vestibule consists of a stairway for access to low level (LL) platforms (nominally 8in (203.2mm) above the rail (ATR)) from the car floor (usually 4ft 3in (1295.4mm) ATR), a normally manually-operated trap to provide approximately level boarding from high level (HL) platforms (nominally 4 ft (1219.2mm) ATR), and an exterior door above the trap (often remotely-controlled (*train-lined*) so that it can be operated by one crewmember). Each has only a single lane for passengers. Only the single non-cab-end vestibule can be used by passengers in a cab car when it leads the train (in the push mode), and in newer cars there is no cab-end vestibule. Thus at least one car per train has only one entranceway lane. Typically other entranceways are not opened also, especially at LL platforms, because of insufficient crewmembers to operate all the traps (and doors if manual).

Dwell is also increased because of surveillance needed to ensure no passenger is preparing to jump on or off an about-to-depart train, and passengers must remain inside the seating compartment until the train has stopped. Finally, with seats and a narrow aisle being located adjacent to the vestibule, passengers maneuvering at seats can block the aisle and lead to queues that block passengers boarding at the entranceway. All these features lengthen dwell time, at HL and LL platforms.

Short Dwell Time Entranceway (SDE)

SDEs have powered remotely controlled (train-lined) doors on each car (distinct from the cab). Dwell time is reduced by (1) ensuring that all doors are opened and closed at all stations (normally by having all doors remotely-controlled (or *train-lined*) by a single crewmember), (2) minimizing unused open door time (including providing buffer space between the doors and seating area to avoid door blockages), and (3) having a relatively high ratio of door lanes to seats on all cars (including the cab car). Current US designs are for either LL or HL platforms only, though new designs (described later) operate with both types of platforms.

DATA—LINES AND SYSTEMS ANALYZED

The specific lines and trains included in the analysis to incorporate the variations in propulsion, entranceway, and platform design are (using the same designations A-D as previously):

(A) New Jersey Transit (NJT) Bergen County/Main Line, Boonton, and Pascack Valley lines (as served from Hoboken): These lines have LL platforms (with some mini-HL platforms). All trains had diesel push-pull (DPP) propulsion, with single level EVE cars seating about 125, for a maximum seats to entranceway lane ratio of about 125 seats/lane (EVE design).

(B) Northeast Illinois Commuter Railroad (METRA) UP-North and -Northwest and MILW-North lines: All METRA trains included were DPP with gallery cars (with a maximum of 165 seats), all stations have LL platforms, and all cars have remotely-controlled (RC, or *train-lined*, meaning controlled from a single location by one crewmember) 3-lane doors. The feature enables all doors to be opened at every station. Thus the nearly uniform, and maximum, seat to entranceway lane ratio is 55 seats/lane (SDE design).

(C) Southeastern Pennsylvania Transportation Authority (SEPTA) R3-Elwyn and R5-Thorndale lines: Almost all trains were composed of electric multiple unit (self-powered, EMU) cars seating approximately 125, with traditional EVEs, resulting in a maximum seats/lane ratio on every train of about 125 seats/lane (EVE design). Most suburban stations have LL platforms; downtown stations have HL platforms.

(D) Metro-North Commuter Railroad (MNCR) Harlem and New Haven lines: Trains included consisted of EMU cars seating about 120 passengers, all stations have HL platforms, and almost all cars have two RC double doors (at the quarter points), for an essentially uniform and maximum ratio of 30 seats/lane (SDE design).

These four groups of lines enable comparison to ascertain the effect of introducing SDEs while retaining LL platforms in the comparison of design A with B. The effect of introducing SDEs along with replacing a mix of HL and LL platforms with HL platforms results from comparing design C with D.

An important consideration is that all of these trains were able to reach cruise speed in the distance between stations. To check this we compared the average inter-station distance for each run with that critical distance for the type of train used. In all cases the average distance was greater.

Because of low speed restrictions near central business district (CBD) terminals, times are taken to/from the first station outward from the central business district terminal. These are: on METRA, Clybourn and Western Ave.; Arlington, Broad St, Woodridge, Kingsland, or Harmon Cove near Hoboken terminal on NJ Transit, 125th St. on Metro-North, and University City and 30th St. in Philadelphia.

These nine lines have similar speed limits into the suburban area from the station indicated outward. The average speed limit on these lines (taking into account speed restrictions such as for curves) was in the 55 mph (88.6 kph) to 65 mph (85.2 kph) range. The outer endpoints for analysis are determined by either (1) a substantial increase in speed limits beyond that point (which makes comparison impossible due to running speed changes), or (2) use of different train designs (mainly on expresses serving stations beyond that point). This limited NJT data to trains serving NJ only, Metro-North trains to those going no further out than North White Plains or Stamford, and SEPTA R5 trains as far out as Malvern only.

All train trip time data (schedule data) are from public timetables for the summer and early fall of 2001. Distance and speed limit data are from employee timetables and track charts. The trip time data are for peak period trains only, for two reasons. One is that most commuter rail passengers travel during the peak period. The second is that trains are generally full or nearly so during the peak period, and this then would show the effect of essentially full passenger loads on dwell time.

RESULTING TIME-DISTANCE PERFORMANCE RELATIONSHIPS

We developed the trip time relationship of equation 4, estimating the parameters Y and Z. The parameter Y varies between designs, while the parameter Z (inverse of the cruise speed) is the same (by virtue of the choice of lines). Linear regression was used, with indicator variables to identify the different technologies. The resulting equations are:

A. Diesel Push-Pull – EVE Cars – LL Platforms (NJT):

$$\text{SEGTIME} = 1.55 + 1.31 \bullet \text{SEGDIST} \qquad (5a)$$

B. Diesel Push-Pull – SDE Cars – LL Platforms (METRA):

$$\text{SEGTIME} = 1.38 + 1.31 \bullet \text{SEGDIST} \quad (5b)$$

C. Elec. MU - EVE Cars – primarily LL Platforms (SEPTA):

$$\text{SEGTIME} = 1.40 + 1.31 \bullet \text{SEGDIST} \quad (5c)$$

D. Electric MU - SDE Cars –HL Platforms (Metro-North):

$$\text{SEGTIME} = 1.30 + 1.31 \bullet \text{SEGDIST} \quad (5d)$$

where SEGTIME is in min and SEGDIST is in mi.

These all fit the data (for 231 trains) very well. The R-squared value for the overall regression was 98.5% and the standard error was only 0.329. All coefficients—the intercepts, slope, and differences between the technologies were significant at the 95% level of certainty. Figure 2 is typical, showing the closeness of the data to the equation. Data for all designs included average inter-stop distances as short as 1.25 mi (2.01 km) and as long as 4.46 mi (7.18 km). Data for three of the four systems extended to slightly shorter distances, and also to considerably longer distances. The data encompasses the typical station stop spacing range of commuter rail service.

Average or Commercial Speed

These equations enable estimation of times and hence average speeds for any distance (greater than or equal to the critical distance). The relevant equation is:

$$\text{AVSPD} = 60 \bullet \text{SEGDIST/SEGTIME} \quad (6)$$

where AVSPD = average or commercial speed for a run, in mph, and
SEGDIST and SEGTIME are estimated from equation 4, and are in units of mi and min.

Figure 3 presents the four average speed versus average inter-station stop distance curves, one for each technology. The range of speed is quite substantial, from a minimum in the vicinity of 21 to 24 mph (33.81 to 38.64 kph) at short inter-stop distances to over 40 mph (64.4 kph) above a 7 mi (11.27 km) spacing. The cruise speed is 45.8 mph (73.74 kph)—lower than the average speed limit, as it should be given the time lost accelerating and decelerating for speed restrictions and operation below the limit.

Since this method of estimating train performance from timetable data is being proposed, it is appropriate to assess these results. One aspect of this is the fit of actual data to the linear relationship. As already discussed, it was very good for all of the lines studied. (Though not relevant to this study of commuter lines, many other lines were also analyzed, and the fit to the linear relationship was similarly very close.)

Another approach is to compare the results with known relative performance. The results in Figure 3 are consistent with a priori expectations. In particular, design D should be the fastest, and design A the slowest. This is the case. The other two are in between these, again as expected. (More detail on assessments of this type will be given later, after specific numerical running time and speed comparisons are presented.)

The usefulness of this approach viz. a viz. Train Performance Simulators (TPSs), the currently most common approach to estimating train running times, including the effects of changes in equipment, station stops, etc., warrants discussion. This timetable method overcomes the problem often mentioned in connection with TPSs that the effects of dwell time and of factors that increase schedule time from the ideal time (such as slack, actual engineer practice in controlling train speed, and random variations in performance) are difficult to estimate and add to TPS run time results. The differences in magnitudes are not small. For example, in one recent study of alternative commuter train types it was found that TPS results averaged about 17% shorter than the actual times of the trains simulated (3, p. 5). Of course, the timetable method has limitations. For example, the relationship is valid for only the specific train type (e.g. propulsion type, car design) and cruise speed in the data set. The timetable approach provides a means to adjust for dwell times and other factors, and thus it would be a complement to the TPS approach.

Thus, in summary, this approach using timetable data has numerous advantages, is soundly based in theory, and is validated by empirical data.

EFFECT OF SDEs ON TRAIN RUN TIME

The equations developed above yield estimates of the time reductions from using SDEs, one for the case of retaining LL platforms and one for a change from mixed platforms to all HL platforms.

The effect of SDEs with LL platforms, revealed by technologies A and B, clearly yields a rather substantial increase in speed, as shown in the two corresponding curves of Figure 3. At an inter-station stop distance of 1.25 mi (2.01 km) the increase is from 23.5 mph to 24.9 mph (37.8 kph to 40.1 kph). At higher speeds the increase is less, of course. At a 5.00 mi (8.05 km) spacing, the increase is from 37.1 mph to 38.9 mph (59.7 kph to 61.0 kph).

While average speed is of interest, in fact travel time is generally a more meaningful measure. Time is the relevant scarce resource of travelers, and is a direct measure of disutility. (Travel time, not speed, is the independent variable used in travel demand and mode choice models, reinforcing this point. (e.g.,4).)

What do these speed differences mean for travel time? Table 1 show the time required by the diesel technologies (A and B) to cover 20 miles (32.2 km) for inter-station stop distances of 1.25, 2.50, and 5.0 miles (2.01, 4.03, and 8.05 km respectively). These values encompass the range of average inter-station distances of most commuter train runs. Also shown is the percentage of time saved, relative to design A.

The time required to cover the 20 miles is reduced appreciably by SDEs. The differences in dwell time yield the largest percentage run time differences at short station stop distances, so the values for 1.25 miles (2.01 km) will be discussed in detail. (The effect of stop spacing is obvious, but is not the focus here.) Referring to Table 1, design A requires 51.0 min for the 20 mi (32.2 km). In contrast, design B requires 48.1 min, for a time saving of about 2.90 min or 5.4%. The time and time savings are proportional to run length of course, but always differ by 5.4%. These values and those for longer average stop distances are given in the table. Longer inter-stop distances result in smaller percentage time reductions, dropping to 2.1% at a 5.0 mi spacing.

Similar gains result from the comparison of designs C and D, both of which are electric MU cars. However, design D includes HL platforms, which might reduce the dwell time even more. The gains for the same two distances used above are 3.3% and 1.3%. It is important to note that these values are not statistically different from the gains in the diesel case. One factor is the lower base train run time, of course.

These gains result from two important features of car design. These are:

1. a reasonably high ratio of door lanes to seats (in this case about 1 to 55) and
2. a car design enabling all doors to be opened at all stations.

These are features that are available on many car designs, but until recently only found in the U.S. on cars that were designed for one type of platform—HL or LL—not for lines with both. This explains why many orders of new cars for lines with both HL and LL platforms have been for cars that used the traditional end vestibule. Now car designs with entranceways that provide the SDE features at both HL and LL platforms exist (and also meet ADA requirements) (*5*, *6*). Clearly these should be considered on such lines.

Comparison to Electrification

An interesting question is how gains from SDEs compare with the gains from electrification. This is addressed in Table 2, which presents the time required for each design (for the same distance and spacing used above) along with the percentage timesaving from the transition from each technology to a faster one.

At an inter-station stop distance of 1.25 mi (2.01 km), design A requires 51.0 min for the 20 mi (32.2 km). In contrast, the fastest D requires 47.0 min, for a time saving of about 4.0 min or 7.8 %. The time and timesaving are proportional to run length of course, but always differ by 7.8 %.

The other two train and platform combination alternatives (designs B and C) are nearly identical, in between the two extremes. The electric MU with EVEs (design C) cuts the time for 20 mi (32.2 km) by 4.7 %, or 2.8 min., compared to the diesel (design A). Retaining the diesel but using SDEs with all LL platforms (design B) cuts the time almost identically. Thus employing a car entranceway design matched to the base case of LL platforms results in achieving more than half of the speed gains from much larger investments in electrification, self-powered MU cars, and HL platforms, for the situations analyzed here. And if the line is already electrified, then an electric locomotive would probably yield a lower stop-to-stop time than the diesel in our data.

As noted earlier, at longer inter-stop distances, the differences between the required run time for the various designs diminishes. For example, at a 2.5 mil (4.03 km) spacing, the overall time saving of design D compared to design A is 2.0 min, while the saving at a 5.0 mi (8.05 km) spacing is just 1.0 min. Thus the gains from faster designs diminish, in both time saved for the given distance, and in percentages, as one would expect.

These results put the potential for timesaving from car design—specifically the use of SDEs (in conjunction with appropriate platform types, of course) into perspective. For the conditions analyzed, this strategy of speed-up can achieve much of the gain from electrification, at much less cost. However, the higher acceleration rate achieved with electrification combined with the gains in dwell time from SDEs will achieve a much greater speed-up.

Comparison with Prior Related Studies

It is useful to compare the quantitative results of this analysis with the results of other studies. A few reports involving comparisons between the technologies considered here for specific commuter lines have been found.

Particularly relevant is the feasibility study of electrification of the Caltrain line in the San Francisco area. It included estimates of timetable changes from electrification along with increasing the line speed limit to 79 mph (127.2 kph) , from an actual limit of 70 mph (112.7 kph) on most of the line but with one section limited to 45 mph (72.5 kph) . The run timesaving (from electrification and speed limit increase) was estimated using a TPS model and ranged from 7.4% to 8.9% for average station spacings of 1.88 and 4.45 mi, respectively (*7*, pp. 2-15 – 2-18).

These are larger than those estimated in the prior analysis. But this is to be expected, because the diesel is increasingly disadvantaged in acceleration performance relative to electric as speed increases, and the Caltrain speed limit is higher than that on the lines analyzed here. This line uses SDE cars (gallery cars), and it was assumed that this would continue, so no analysis of changes in dwell time was included.

A study of the impacts of speed limit increases provides an approximate adjustment to the previous Caltrain results. This recent study considered the effect of increasing the nominal speed limit on SEPTA's Wayne Junction-Doylestown line from 70 mph with a section at 40 mph to 79 mph. It found that the increase in speed limit reduced the running time of express trains, which had an average inter-stop spacing of 2.43 mi, by 9.6% (8, Appendix, Run 1 vs. Run 17). Recognizing that MU trains accelerate faster than locomotive propelled trains, the distance run at the higher speed limit will be larger for the MU trains and hence the timesaving greater. Interpolating the two Caltrain % time saving values to a 2.43 mi spacing (yielding 7.7%), and subtracting one-half of the MU gain from that 7.7%, yields a time saving estimate of 2.9%. (The calculations are: 7.4((2.43-1.88)/(4.45-1.88))(8.9-7.4)+7.7; 7.7-(9.6/2)=2.9.) This is very close to the 3.1% from the timetable analysis above for the 2.5 mi spacing.

A third study estimated the increase in running time on the Metro-North New Haven line resulting from use of locomotive hauled trains compared to the current electric MUs. "[T]he run time for the HSEL [high speed electric locomotive] was generally...5% longer than that for the existing fleet." (3, p. 6). No analysis of alternative entranceway configurations was included. The increase in time is close to but slightly more than the difference between designs B (diesel locomotive) and D (EMUs) in the analysis above. But again, the difference is at least partly explained by a higher speed limit for much of the line studied--70 mph (112.7 kph)—than the lines analyzed here.

These other study results are consistent with our results. Thus they provide independent support for the methods presented here.

OTHER BENEFITS OF SHORT DWELL TIME ENTRANCEWAYS

It should be noted that there are numerous other benefits of short dwell time entranceways. One is that they reduce the crew duties related to operating the traps and doors of conventional end vestibules. This should enable reduction in crew sizes. A significant reduction in the percentage of commuter rail operating costs associated with train operating crews has been noted on systems with train-lined doors, with either all low level or all high level platforms, compared to systems with mixed platform levels and the labor intensive end vestibule (9). Another is a statistically significant reduction in boarding and alighting injuries (by at least 75%), when train-lined doors which are open only when the train is at the station are used (*10*). This is in contrast to the practice with traditional end vestibule cars, especially at low platforms, of leaving the doors open and the traps up between closely spaced stations. (It should be noted that there exist designs that provide remote control operation at both HL and LL platforms, and these are coming into more widespread use --as described in (6). Also described there are new designs which are intended to meet Americans with Disability Act accessibility requirements at both HL and LL platforms with the same car.) All of these can lead to lower operating costs, which can translate into greater frequency of service. This is in addition to the speed increase, already described. Both service improvements can lead to increases in passenger traffic and revenue.

CONCLUSIONS

The conclusions that follow from this effort fall into two categories. One relates to the use of timetable data to estimate speed performance curves. The second relates to the different technologies and means to achieve speed performance improvements.

Turning to the first, the use of timetable data to estimate speed performance appears to worthwhile, for many reasons. First, it is based on sound theory (well known in the transportation engineering profession), and the relationship between segment time and segment distance fits actual data very closely. Thus it is possible to obtain statistically reliable estimates. Second, it incorporates some factors that are very difficult to include in Train Performance Simulators, specifically actual dwell time, the effect of random variations and slack, and actual locomotive engineer and other behavioral influences. It is not suggested that this is a substitute for TPS calculations, for this method is obviously limited to specific trains that are actually in use. However, it is a useful complement. Indeed, this effort suggests that a fruitful area of research for the future would be to explore whether or not timetable based approach might be combined directly with a TPS approach to overcome the limitations of each.

The second area of conclusions concerns the effect of changes in car design, propulsion options, and station platform type on speed performance. First, analysis confirmed some well-known comparative relationships, and these serve in part as a test of the method.

A substantial reduction in dwell time (and hence run time) can be achieved by use of short dwell time entranceways (SDEs). In the lines analyzed here, the gain as revealed by actual train operation ranged from about 4 to 5% at an average station spacing of 1.25 mi (2.01 km) to about 1 to 2% at a 5.0 mi (8.05 km) spacing. These differences were observed in going from the traditional end vestibule (EV) car, which normally has only one door (with one lane for passengers) open on at least two cars per train, to cars that had a uniform number of door lanes open of three or four. The ratio of seats to door lanes open in these two cases was 125 lanes/seat for the EVs, and from 30 to 55 lanes/seat for the SDEs. While each additional door lane per car decreases dwell time, the reduction appears to be at a decreasing rate.

To put these time savings into perspective, they were compared to those from electrification. In the cases analyzed, slightly more than half of the time reduction (or gain in speed) can be achieved even at short station stop spacings the use of short dwell time entranceways. While the advantage of electrification is likely to be larger in many cases, this suggests that SDEs are an important option that should be considered. This is particularly important for lines with mixed HL and LL platforms, where EV car designs are still being purchased. Designs for entranceways that provide the SDE features at both types of platforms in the same car now exist (and some also meet ADA requirements at both HL and LL platforms), and should be considered.

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LIST OF TABLES AND FIGURES

TABLE 1. Run Time Reductions from using Short Dwell Time Entranceway (SDEs) Cars instead of End Vestibule Entranceway (EVE) Cars on a 20 mi (32.2 Km) Run.

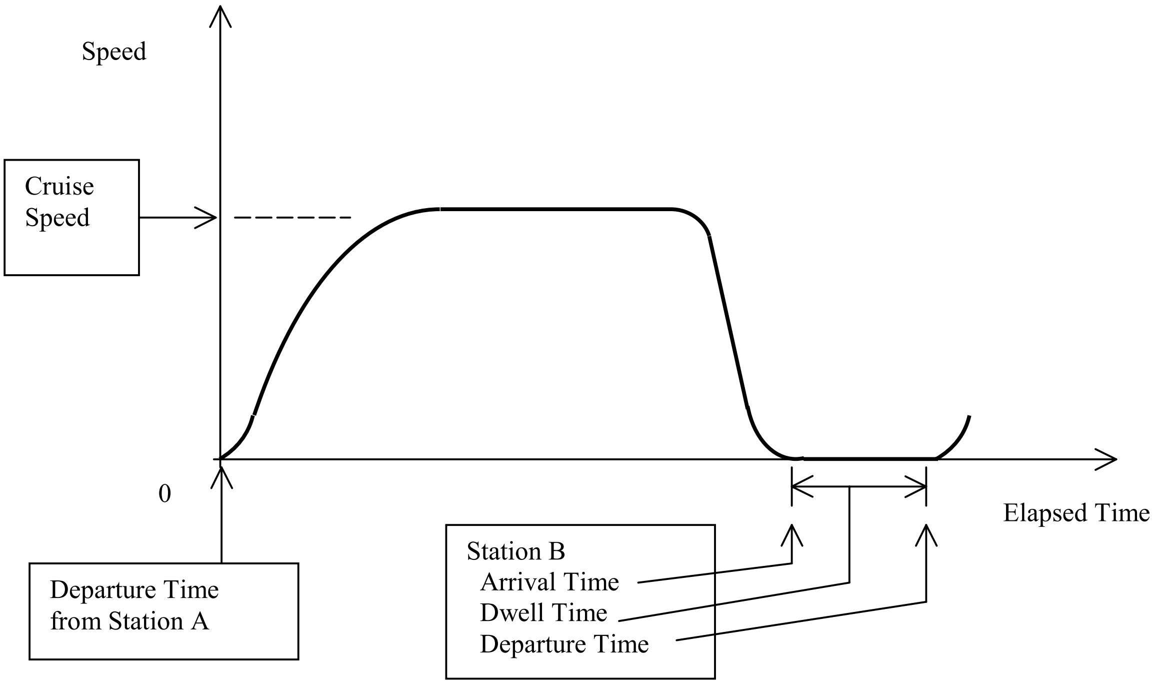
Propulsion Type	Run Time (min) EVE Car Design	SDE Car Design	% Time Saved Using SDE vs. EVE Design
Diesel Push-Pull Trains	(A)	(B)	
Average Inter-station Stop Distance			
1.25 mi (2.01 km)	51.0	48.1	5.4
2.5 mi (4.03 km)	38.6	37.2	3.6
5.0 mi (8.05 km)	32.4	31.7	2.1
Electric MU Trains	(C)	(D)	
Average Inter-station Stop Distance			
1.25 mi (2.01 km)	48.6	47.0	3.3
2.5 mi (4.03 km)	37.4	36.6	2.1
5.0 mi (8.05 km)	31.8	31.4	1.3

Notes on car and platform designs:
(A) Two 1-lane doors per car, but only one door open on leading cab car and often others; LL platforms only.
(B) One 3-lane entranceway per car, all doors open at all stations; LL platforms only.
(C) Two 1-lane doors per car, but only one door open on leading cab car and often others; primarily LL platforms.
(D) Two 2-lane quarter point entraceways per car, all doors open at all stations; HL platforms only.

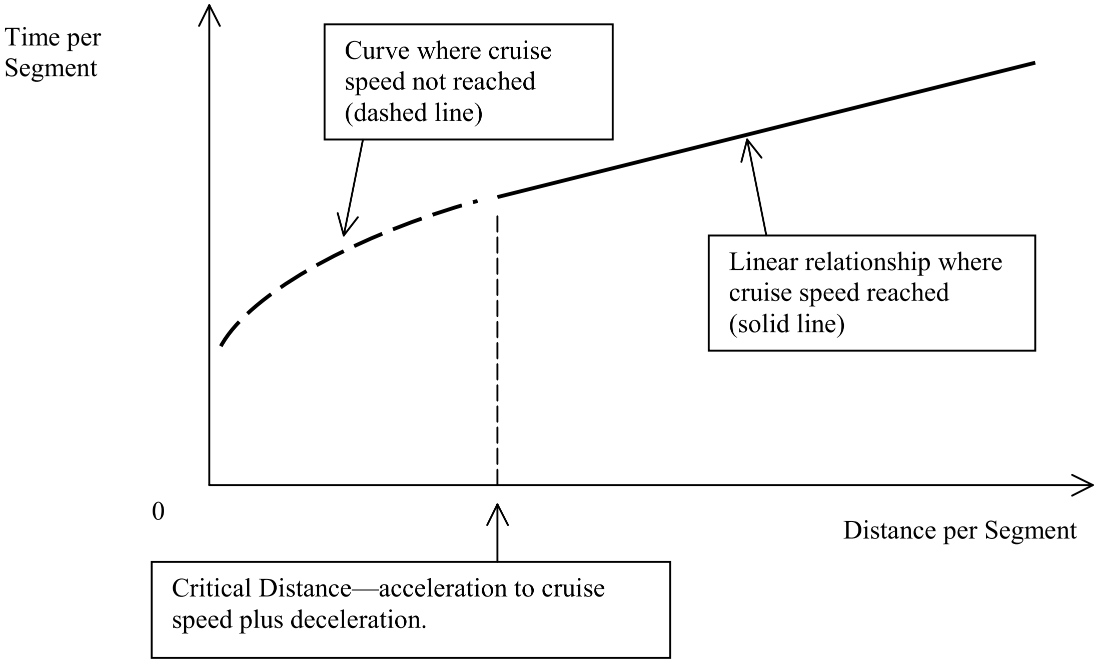
TABLE 2. Time savings from Entranceway and Propulsion Options for 20 Mile (32.2 Km) Run.

	Average Inter-station Stop Distance											
	1.25 mi (2.01 km)				2.5 mi (4.03 km)				5.0 mi (8.05 km)			
	Run Time	% Time Saved With Base			Run Time	% Time Saved With Base			Run Time	% Time Saved With Base		
Train Design and Platform Type	(min)	(A)	(C)	(B)	(min)	(A)	(C)	(B)	(min)	(A)	(C)	(B)
(A) Diesel, EVE Cars, LL platforms	51.0	na	na	na	38.6	na	na	na	32.4	na	na	na
(B) Diesel, SDE Cars, LL platforms only	48.1	5.4	0.8	na	37.2	3.6	0.5	na	31.7	2.1	0.3	na
(C) Electric MU, EVE Cars, primarily LL platforms	48.6	4.7	na	na	37.4	3.1	na	na	31.8	1.8	na	na
(D) Electric MU, SDE Cars, HL platforms only	47.0	7.8	3.3	2.5	36.6	5.2	2.1	1.6	31.4	3.1	1.3	1.0

Note: na indicates not applicable

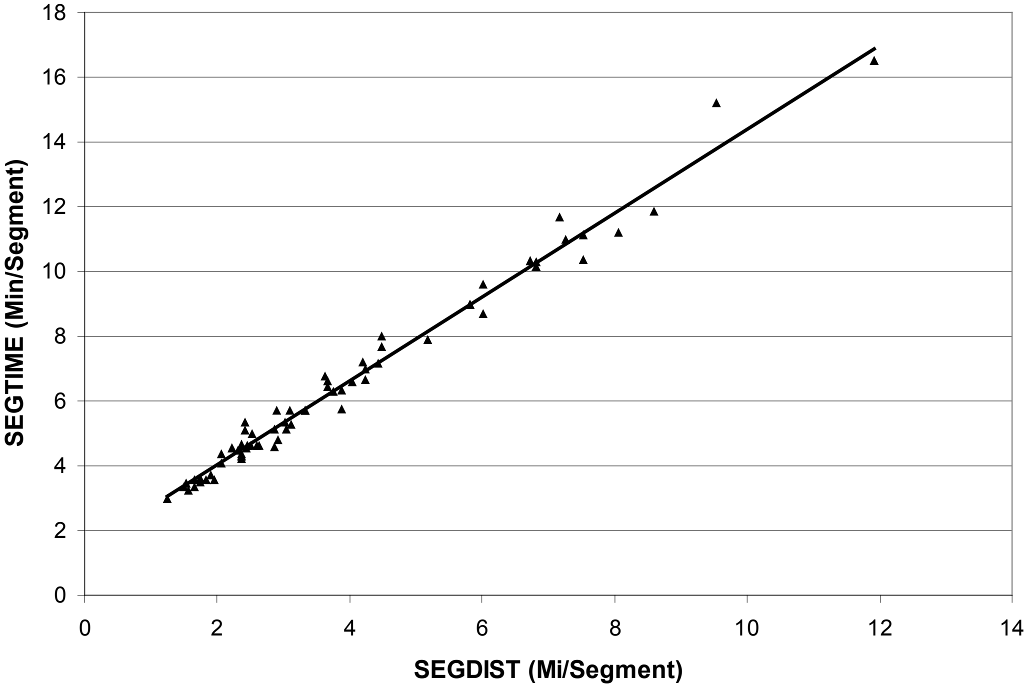


(a) Speed versus time.



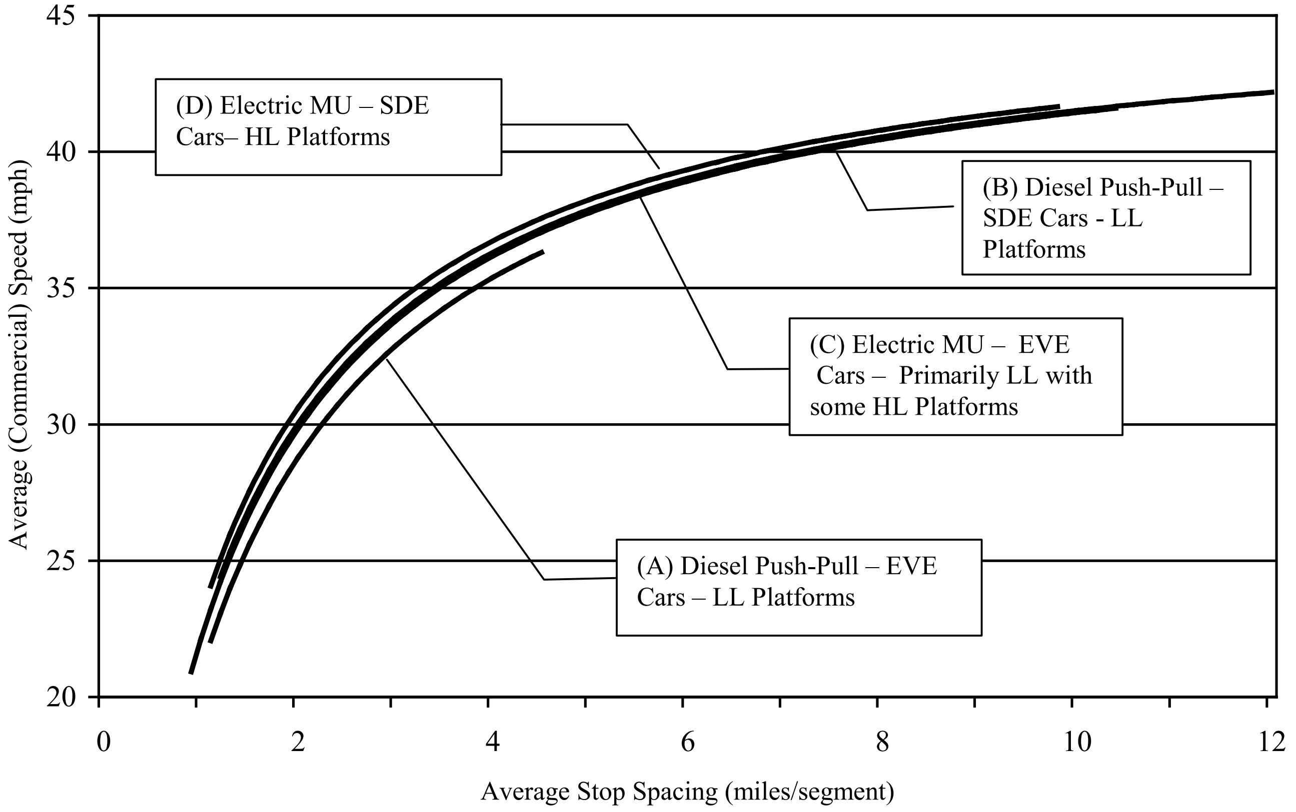
(b) Time versus distance.

FIGURE 1 Speed and running time of a train over one segment--from one station stop to the next (including one station dwell time): (a) Speed versus time and (b) Time versus distance.



Notes: (1) Range plotted is range of actual schedule data.
(2) Segment distance is distance between station stops; SEGTIME and SEGDIST are averages.

FIGURE 2 Example of regression lines and data plot of segment time vs. segment distance for one design: Design (B).



Notes: (1) Range plotted is range of actual schedule data.
(2) Curve (B) is slightly above curve (C).
(3) Approximate minimum ratios of door lanes to seats are: (A) 1:125, (B) 3:165, (C) 1:125, and (D) 4:120.

FIGURE 3. Effect of propulsion, car entranceway, and platform type on speed performance