GOALS FOR BUS TRANSIT SCHEDULING

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abstract

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Like other transit agencies, SCRTD schedules buses using a peak point constraint on crowding. As a way of clarifying implicit scheduling goals of maximizing seat utilization while minimizing crowding, two indicators were studied; average load factor and average standee ratio.

Riding checks carried out on many lines over an extended period allowed computation of 24-hour averages of these indicators for three types of lines; urban local, suburban local and express. Weighted linear regressions produced a relation between standee ratio and load factor for each service type. Elasticities were estimated to give predictions of increases in crowding due to ridership growth.

A scattergram of standee ratio vs. load factor can be used as a diagnostic tool for scheduling management, to indicate which lines should be given attention, and to indicate improvement or deterioration following schedule revisions.

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When the voters of Los Angeles County provided local tax support for transit, a lower fare was mandated for a three year period. Funds were to be used for making up lost fare revenue and to maintain pre-existing loading standards. Service could not be increased generally, because the fare subsidy was to be removed at the end of the three years and a disruptive cutback in service was to be avoided. This situation provided a powerful incentive to re-think the goals of the scheduling function.

Normally schedules are built with a constraint on crowding. There is no corresponding constraint on underloads, so overall load factors (passenger miles divided by seat miles) are often undesirably low and widely variable between lines.

What seemed to be needed was a way of expressing the goals of scheduling very simply, with indicators which would tell how well a bus line is scheduled overall. This paper describes an investigation of a pair of variables, "load factor" and "standee ratio."

CURRENT PRACTICE

SCRTD has no explicit objective function for scheduling, but like other transit agencies, uses a load standard or crowding constraint. The official statement of loading standards is:

> In order to provide an accessible and dependable transit system, ... All parts of the transit system should ... have adequate capacity for safety and to attract and keep riders.
>
> (1) Loading ratios for individual lines should not exceed 140% measured for the peak 20 minutes at the maximum

the instantaneous functional relation between SR and LF, for a single bus. There are no standees until all seats become full, at which point LF = 1.0 and SR = 0. Then the standee ratio rises asymptotically toward 1.0 according to

$$SR = \frac{LF - 1.0}{LF}$$

until it reaches the physical limit of crowding. For a 40 foot bus with 43 seats the limit is around LF = 2.5.

For scheduling, we are interested in a bus trip, or a stream of buses, or a bus line. For a typical bus trip, the range of possible values of SR and LF is much smaller than the range of instantaneous values. The load factor will normally be much less than 1.0 because it is an average of a load that varies as the bus travels along the route. Since all standee miles are accounted for, the standee ratio will be greater than zero as long as there is standing anywhere along the route.

Accordingly, the range of (LF,SR) combinations for one hour of line operation would be smaller, and the range for 24 hours of operation would be smaller still. The expected ranges would be somewhat as indicated in Figure 1. With each successive level of aggregation, the range diminishes.

EXPLORATION OF THE INDICATORS

The intent of this study was to quantify relationships between the two indicators LF and SR. Is there a clear functional relationship? How would the relationships vary with service type? How does growth of ridership affect crowding?

The software developed at SCRTD moves stop by stop through the record for each trip, accumulating vehicle miles, passenger miles, and the excess of passengers over seats. These numbers are aggregated by line and by direction, but segregated for each hour of the day. The indicators LF and SR are then tabulated for each hour and for the full service day.

It should be noted that data obtained from riding checks tends to understate SR's, since service is known to operate more regularly when being monitored. This is likely to cause a moderate but consistent bias.

Analysis

Analyses were based on data aggregated to the line level. Since management overview is the primary concern here, 24 hour aggregates of LF and SR are used, with each direction of the line treated as a separate case. In other words, each case or data point consists of a 24 hour average load factor and a 24 hour average standee ratio, representing a single line, in one direction, on a weekday.

Differences Between Service Types. There are three basic types of service at SCRTD; urban local, suburban local and express. Regressions were carried out separately for each type, with the cases weighted by size of line, expressed in seat miles, to get a truer reflection of the system as a whole. The results are given in Table 1. The coefficients of determination, r^2, are not very high, yet scatterplots don't seem to indicate a nonlinear relationship between LF and SR.

The regression lines are plotted in Figure 2. Also shown are rectangles representing the ranges of the variables for each line type, as well as the mean load factor values.

Urban local and express are scheduled for the demand, so the load factors are higher than for suburban local. Because express usually has a flatter load profile, it can be scheduled closer to a full seated load over more of its length. this allows a higher LF relative to SR. On the other hand, the policy is not to have standees on express services, ostensibly because of safety considerations in freeway operations. As will be seen, scheduling for a load factor anywhere near 1.0 will result in standees, unless patrons are prohibited from boarding when there are no seats available.

It might be of interest to note that hourly averages of LF can be as high as 90% for urban local, and 110% for express. Hourly highs of SR are 20% for urban local and 18% for express.

Predicting Growth in Crowding. At the system level, we wondered how much crowding (i.e. standing) would increase as ridership rose due to a fare decrease. This can be answered in terms of elasticities of crowding with respect to ridership levels, calculated for the system average, or for the averages of the component service types:

$$\text{elasticity} = e = \frac{\Delta SR/SR}{\Delta LF/LF} = [\text{slope of the regression line}] \times \frac{\overline{LF}}{\overline{SR}}$$

Calculated values are given in Table 2.

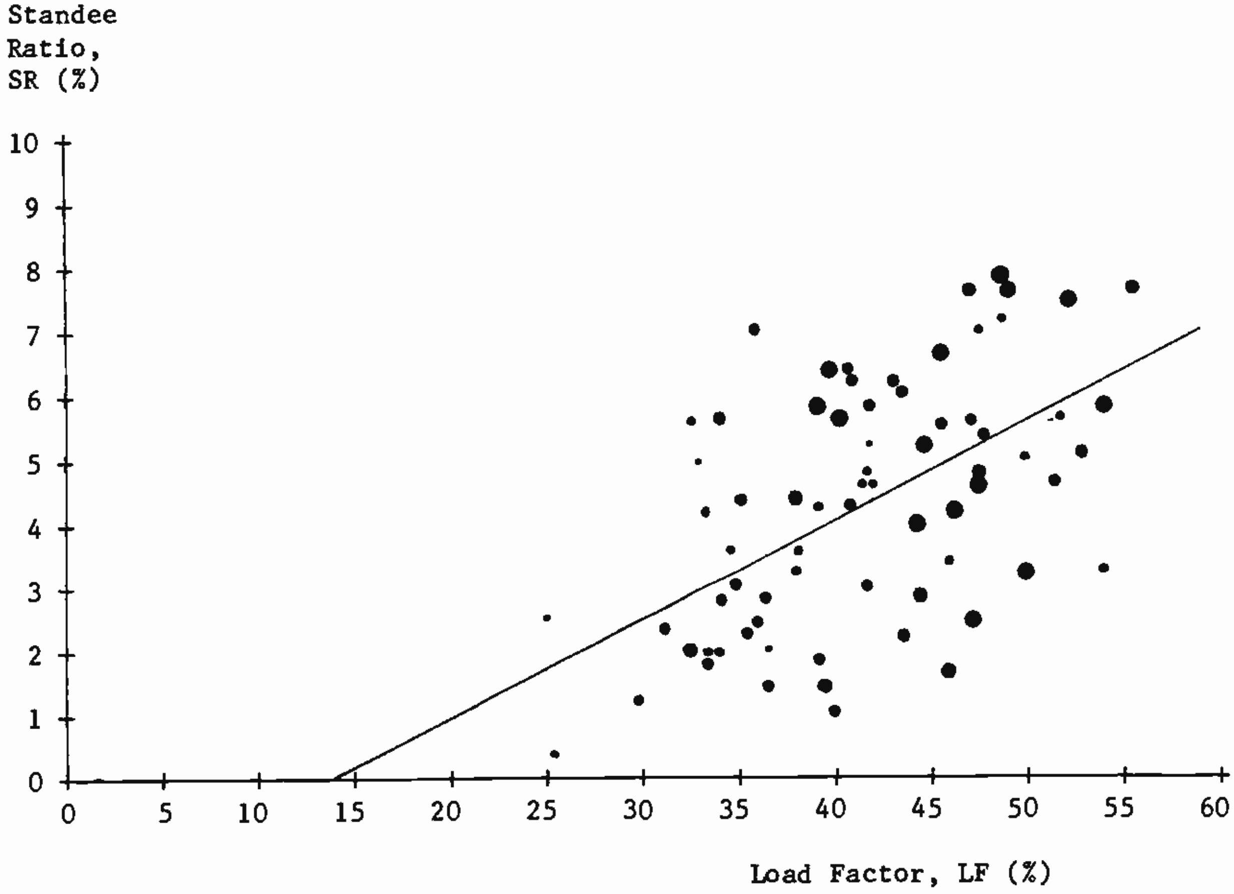
Table 2. Elasticities of crowding with respect to ridership.

Service	Number of Cases*	Mean Load Factor LF (%)	Mean Standee Ratio SR (%)	Slope of Regression Line	e
Urban Local	74	43.2	4.55	.153	1.46
Suburban Local	124	25.1	1.41	.133	2.37
Express	60	37.9	2.44	.152	2.36
Overall	258	36.4	3.06	.151	1.80

as it could be. A corollary is that the poor performance lines might be rescheduled to more nearly match the high performance lines.

Consider the scattergram of SR vs. LF, with the regression line displayed, as in Figure 3. If average bus lines are on the regression line, poorer-than-average lines are above it. In other words, their SR's are too high for their LF's. If such a service is rescheduled, the next check should show a migration toward or even across the regression line.

Figure 3. Scattergram of urban local lines.



imposed for reference. The locus indicates that the schedule is reasonable, in the sense that the highest standee ratios are in the peaks, and the most crowded peak is in the morning. However, the location of the 24 hour average point indicates that some improvement in the schedule is possible, either by bringing down the standee ratio or by increasing the load factor.

The scheduler might choose to look for the reasons for such a high standee ratio in the morning peak. For that she would make the traditional analyses of point check data at peak points and turnback locations, or look at specific trips in the line profile data.

CONCLUSION

The intent of this study was to gain a better understanding of two indicators of scheduling performance, prior to setting quantitative goals. Something has been learned about the current system. Considering the common perception that the system is overcrowded, the 24 hour averages of both load factor and standee ratio are surprisingly low.

Rather than set numerical goals, we plan to monitor the results of schedule changes to assure that load factors generally increase without parallel increases in the standee ratios. Each time a ride check is taken subsequent to a schedule revision, the (LF,SR) point will be plotted, to ascertain that the schedule is actually being improved.

More needs to be done before goals can be set in an informed manner. The transit industry knows relatively little about how well it could do. Quantifying how well it is doing now is just a first step toward determining what is possible. What is needed next is a concerted attempt to push the state-of-the-art of service design and operation. This could give a better indication of just how high the load factors could be, in combination with low standee ratios.