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Abridgment

Modeling Transit Service Areas

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Transit access is defined as a measure of the ability or propensity of a population to use transit. Transit access modes are usually defined as walking, park-and-ride, kiss-and-ride, paratransit feeder, transit-feeder, taxi, or bicycle. This research is directed toward the development of tools for planning access to transit systems that address the impact of access characteristics on ridership and aid in the normative definition of the area served by transit. A methodology to evaluate and plan for access is developed. Nonlinear models based on empirical data are developed to estimate cumulative distributions for (a) walk to local bus, (b) walk to suburban bus, (c) walk to express bus, (d) park-and-ride to express commuter rail, and (e) park-and-ride to express bus. Equations are presented that can be used to determine ridership percentages that originate within user-specified times or distances around a transit stop, and the access distances or time within which normatively specified ridership percentages originate.

The means of getting to and from transit systems and the ease or difficulty with which that portion of the journey is made can affect the traveler's decision to use transit as much as can conditions and service on the system itself (1). That portion of a journey that is spent on the transit vehicle or waiting at stops is known as the line-haul portion of the trip. Those portions of the journey spent in getting to the transit system from the trip origin and to the destination from the transit system are know as the access-egress portions of the trip, or simply the access portion. Thus, accessibility to transit, or transit access, deals with characteristics of the trip portions not on the transit system.

Planning for transit access is becoming more of a concern for transit planners. Given the impact of access characteristics on ridership and the need for a normative definition of the service area accessed by transit, the development of a methodology to evaluate and plan for access is being undertaken. This research is directed toward the establishment of empirical tools for planning access to transit systems.

DEFINITION OF TRANSIT SERVICE AREAS

That portion of the urban area from which a transit line derives its patronage is known as its service area. No universal quantitative definition of transit service area can be given because its limits are not fixed, except by the habits (actual or expected) of the transit patrons. A service area centered on a transit stop, or transit line, varies in radius according to the characteristics of the line-haul mode, mode of access, and socioeconomic characteristics of the population to be served. In practice, service area boundaries can be described as follows:

1. Empirically--as the inclusive boundary for the xth percentile of origins and destinations observed for patrons that use a stop, or
2. Normatively--as the arc of maximum distance for convenient or desirable travel to the transit stop.

The terms tributary area or commuter shed have also been used to describe service area. Two of the most-important questions that face transit planners are, How far from the transit line does one draw the boundary of the service area? and, What is the relationship between this distance and some standard of desirable transit accessibility?

DEVELOPMENT OF MODELS OF TRANSIT SERVICE AREAS

The objective of this research is to develop a concept that could be used by planners to determine a set of service area standards (2). These standards could be applied to existing and proposed transit systems to determine the proportion of the urban area served by a transit system. It is known that many factors, such as destinations served, transit travel time, frequency of service, hours of service, fare, security, reliability, accommodations for handicapped, and comfort, must be considered in judging whether transit service is available to an individual. However, access distances and service areas should be included among system evaluation criteria and, indeed, are among the most basic indicators of transit availability.

Development of useful standards for service areas requires the answering of a fundamental question, How close to a transit stop or station should a given location be in order for one to consider that location well-served by transit? One must also define the appropriate unit for measuring closeness. It is not within the scope of this report to unequivocally state specific standards. Rather, we will examine data obtained from a variety of sources and present models that show the cumulative percentile of transit riders included within a given distance or travel-time interval from a transit stop, as derived from observed behavior. These models can then be used in two ways. First, such a model could be used to determine, for a given location at a distnce from a transit line, the percentile access distance score for that location. Second, given a desired percentile score to be used as a normative access standard, the model can be used to find the radius that can be used to determine the normative service area boundary for that transit line.

In order to ensure that accurate and useful models would be developed, it was decided to stratify models by three modes of access: (a) pedestrian, (b) park-and-ride, and (c) kiss-and-ride. Within these three classes, models were further stratified by line-haul mode. For pedestrian access, models were estimated for local bus service in urban and suburban contexts and for express bus. For automobile-access modes, models were estimated for commuter rail and express bus; express bus models were estimated for service from both remote and peripheral parking lots. All pedestrian and commuter rail models were estimated on the basis of distance only; distance was expressed in feet for the former and miles for the latter. All express bus with automobile-access models were estimated for both distance in miles and time in minutes. The aforementioned stratifications were limited by the availability of data. Consequently, no urban rail transit models could be calibrated due to the lack of suitable data.

Empirical Data and Modeling Process

The models presented are developed from access travel distance data (access model was walk) for bus routes in Vancouver, British Columbia; Washington, D.C.; and St. Louis, Missouri, and from access travel distance or access travel time data (access mode was automobile) for commuter rail and express bus service in northeastern New Jersey. Models for seven combinations of access and transit modes are offered:

1. Walk to urban bus,
2. Walk to suburban bus,
3. Walk to express bus,
4. Park-and-ride to commuter rail
5. Park-and-ride to express bus,
6. Kiss-and-ride to commuter rail, and
7. Kiss-and-ride to express bus.

Data for items 1-3 were derived from Peterson (Washington, D.C.) (3), the Bi-State Development Agency of the Missouri-Illinois Metropolitan District (St. Louis) (4), and Piper (Vancouver) (5). The data used to model items 4 and 5 were derived from access distributions around six representative commuter rail stations and four representative express bus stops in northeastern New Jersey. The access distributions were computed from the data collected in surveys conducted at rail stations and express bus park-and-ride lots by the Port Authority of New York and New Jersey between 1974 and 1976.

The curves presented represent access distributions around transit stops in terms of a cumulative percentile distribution or less than ogive. For a given access mode, a cumulative percentile distribution is constructed by summing the percentages of transit riders whose access trips originated within each distance or time interval. The cumulative percentile distribution is not a means of determining access modal split; rather, it shows what percentage of transit patrons who use access mode (y) made access trips of less than access distance (f) or access time (t).

After inspecting the data, we determined that nonlinear models would provide more explanation of the variance than would linear models. However, there were no compelling theoretical reasons to favor one particular nonlinear model over another. Thus, a family of eight alternative model specifications was proposed. An interactive curve-fitting program was written that permitted one to select a data subset and pick one of the model specifications. The program transformed the models into linear form and solved for the parameters by using a least-mean-squares regression technique. R^2 and standard error of estimate (SEE) statistics were computed for fitted models in the nonlinear form by using untransformed variables. The interactive curve-fitting program produced scatter plots of the data with the fitted model curve superimposed, as shown in Figures 1-14. Models were chosen through an iterative process by testing alternative forms and selecting the equation that produced the highest R^2 and lowest SEE. Note, however, that the use of least-squares regression for fitting models that have been linearized by taking logarithms may not produce the best estimates of model parameters. A generalized maximum likelihood approach is recommended (6). Also note that those models, such as the quadratic form, that do not have an asymptote at 100 percent are valid only for data in the appropriate ranges.

Application of the Models

For a given access mode and an access distance, the planner can use the calibrated models to estimate the percentage of transit patrons who originate within the given access distance by using the particular access mode. The models in Equations 1-14 are reformulated with cumulative ridership percentile (y, as a percent rather than a decimal) as the independent varible. These expressions enable the planner to estimate the access distance or time, from which comes a given percentage of transit patrons who use a given mode. For example, the median access distance or time to a transit stop for a given access mode is easily estimated. Also, the planner could determine the radius of the service area (f, d, or t) that corresponds to a particular market penetration for ridership. These calculations would help transit planners to determine the level of service that a transit system or line provides to the community.

Pedestrian Access

Distance to local urban bus stops outside the central business district (CBD):

$$f = 2095.3 - 21\,515\sqrt{0.009\,17 - 0.000\,092\,96\,Y_{pu}} \qquad 0 \leqslant Y_{pu} \leqslant 98.6 \qquad (1)$$

Distance to local suburban bus stops:

$$f = [-488/(\ln Y_{ps} - 4.771)] \qquad 0 < Y_{ps} \leqslant 100 \qquad (2)$$

Distance to express bus stops:

$$f = \exp\,[(Y_{pe} + 127.4)/28.6] \qquad 0 \leqslant Y_{pe} \leqslant 100 \qquad (3)$$

Park-and-Ride Access

Distance to commuter rail stations:

$$d = -2.073/(\ln Y_{ar} - 4.723) \qquad 0 \leqslant Y_{ar} \leqslant 100 \qquad (4)$$

Time to commuter rail stations:

$$t = 13.98 + 4.737\,\ln[Y_{cr}/(100 - Y_{cr})] \qquad 0 < Y_{cr} < 100 \qquad (5)$$

Distance to remote express bus stops:

$$d = -1.751/(\ln Y_{ae}' - 4.664) \qquad 0 < Y_{ae}' \leqslant 100 \qquad (6)$$

Time to remote express bus stops:

$$t = 36.57 - 5.696\sqrt{39.63 - 0.3511\,Y_{ae'}} \quad 0 \leqslant Y_{ae'} \leqslant 100 \tag{7}$$

Distance to peripheral bus stops:

$$d = -12.47/(\ln Y_{ae''} - 4.881) \quad 0 < Y_{ae'} \leqslant 100 \tag{8}$$

Time to peripheral bus stops:

$$t = 64.42 - 16.90\sqrt{12.097 - 0.1183\,Y_{ae''}} \quad 0 \leqslant Y_{ae''} \leqslant 100 \tag{9}$$

Kiss-and-Ride Access

Distance to commuter rail stations:

$$d = -1.438/(\ln Y_{kr} - 4.788) \quad 0 \leqslant Y_{kr} \leqslant 100 \tag{10}$$

Distance to remote express bus stops:

$$d = -0.9301/(\ln Y_{ke'} - 4.635) \quad 0 \leqslant Y_{ke'} \leqslant 100 \tag{11}$$

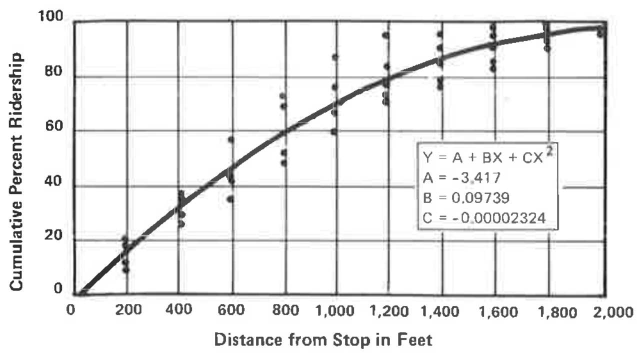
Time to remote express bus stops:

$$t = -6.522/(\ln Y_{ke'} - 4.818) \quad 0 < Y_{ke'} \leqslant 100 \tag{12}$$

Distance to peripheral express bus stops:

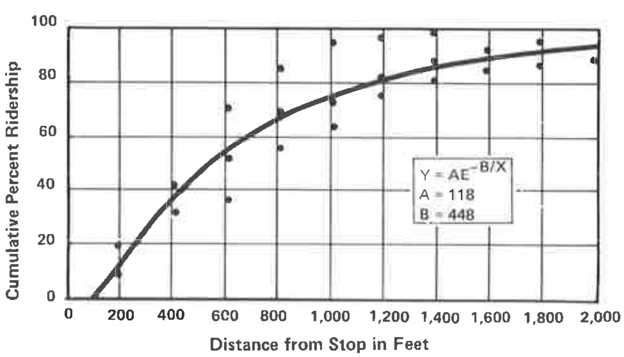
$$d = -9.711/(\ln Y_{ke''} - 4.796) \quad 0 < Y_{ke''} \leqslant 100 \tag{13}$$

Figure 1. Cumulative ridership percentiles: pedestrian access distribution for local urban bus stops.



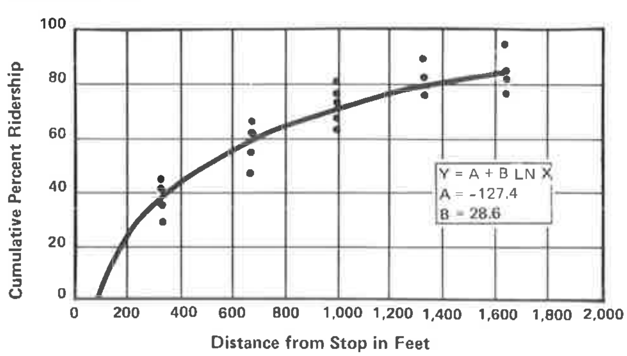
Rsquare = 0.9462 Standard Error of Estimate = 6.542

Figure 2. Cumulative ridership percentiles: pedestrian access distribution for local suburban bus stops.



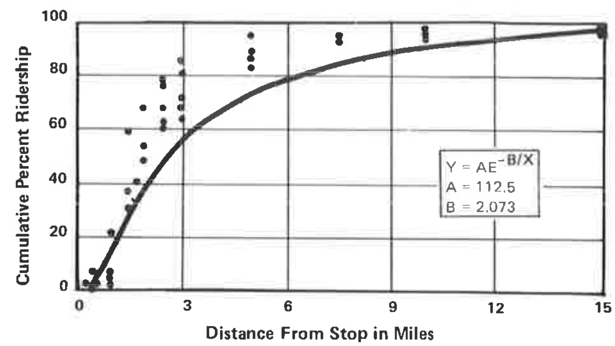
Rsquare = 0.8613 Standard Error of Estimate = 9.765

Figure 3. Cumulative ridership percentiles: pedestrian access distribution for express bus stops.



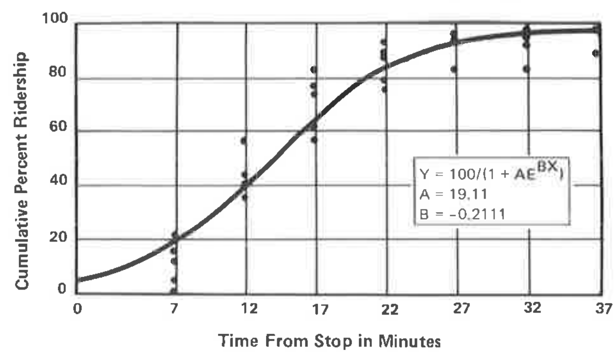
Rsquare = 0.8779 Standard Error of Estimate = 5.849

Figure 4. Cumulative ridership percentiles: park-and-ride automobile drive access distribution for commuter rail stations (excluding Jersey Avenue).



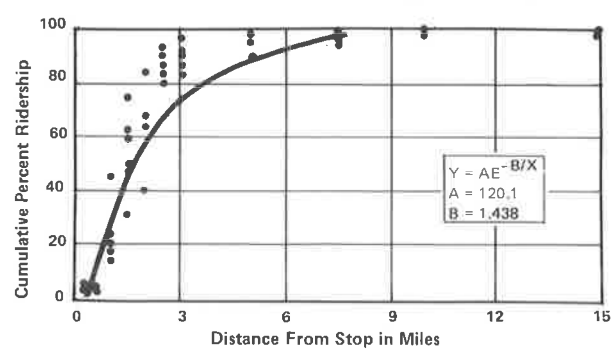
Rsquare = 0.8843 Standard Error of Estimate = 12.4

Figure 5. Cumulative ridership percentiles: park-and-ride carpool passenger access distribution for commuter rail stations (excluding Jersey Avenue).



Rsquare = 0.9351 Standard Error of Estimate = 7.665

Figure 6. Cumulative ridership percentiles: kiss-and-ride automobile distribution for commuter rail stations (excluding Jersey Avenue).



Rsquare = 0.9076 Standard Error of Estimate = 11.55

Time to peripheral express bus stops:

$$t = 57.59 - 15.34\sqrt{12.70 - 0.1304\,Y_{ke''}} \qquad 0 \leqslant Y_{ke''} \leqslant 97.4 \qquad (14)$$

where

- Y_c = cumulative ridership percentile for mode by access mode combination c,
- f = walking distance in feet between origin by destination and bus stop at y,
- d = driving distance in miles between origin and transit stop at y, and
- t = driving distance in minutes between origin and transit stop at y.

CONCLUSIONS

The accuracy and applicability of these models are restricted by the limitations on the data from which these models were constructed. The data, and thus the models, do not make explicit impacts of station or stop competition, street patterns around the stop, ridership habits of the stop's patrons, socio-economic status of the stop's patrons, downtown parking rates, or highway congestion. The only independent variables used in the models presented are transit access trip distance and transit access trip time.

Figure 7. Cumulative ridership percentiles: park-and-ride automobile drive access time distribution for remote express bus stops.

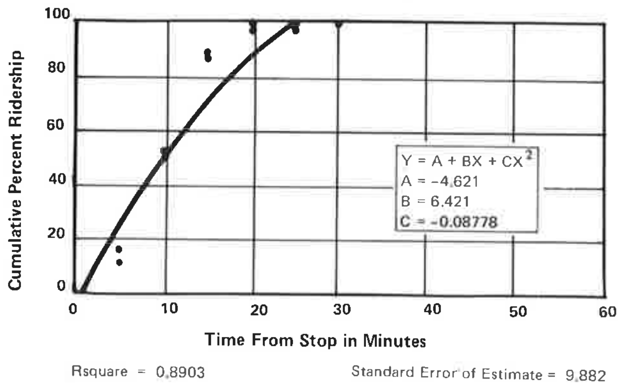


Figure 8. Cumulative ridership percentiles: park-and-ride automobile driver access time distribution for peripheral express bus stops.

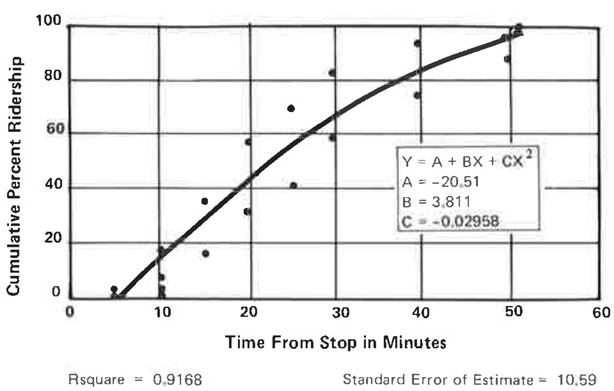


Figure 9. Cumulative ridership percentiles: park-and-ride automobile driver access distance distribution for remote express bus stops.

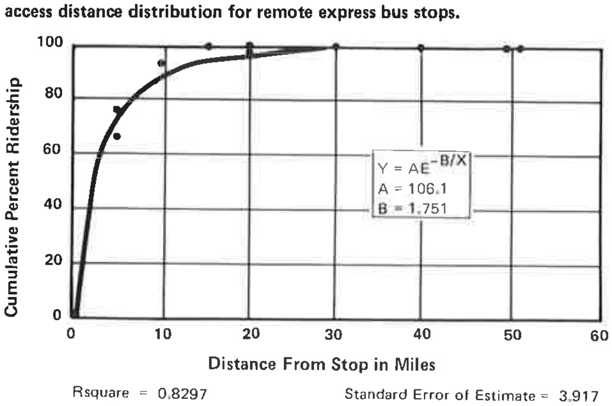


Figure 10. Cumulative ridership percentiles: park-and-ride automobile driver access distance distribution for peripheral express bus stops.

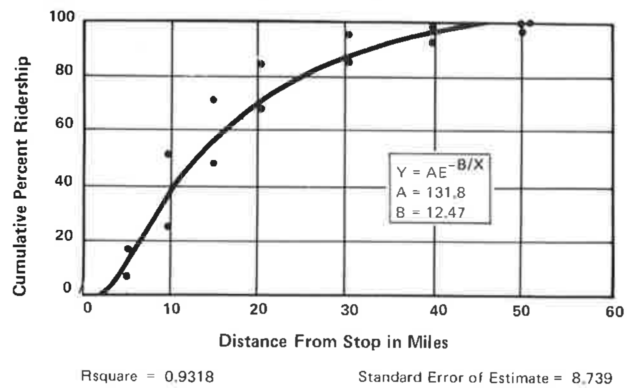


Figure 11. Cumulative ridership percentiles: kiss-and-ride access time distribution for remote express bus stops.

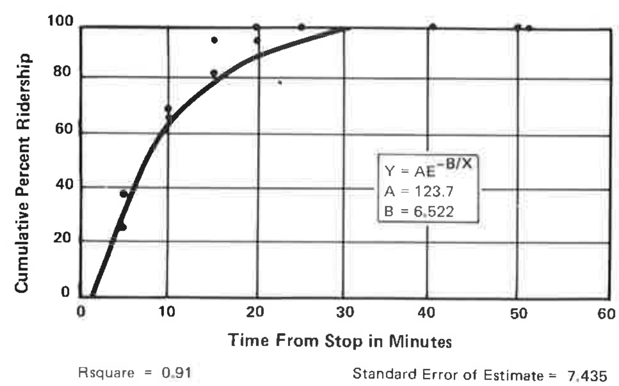


Figure 12. Cumulative ridership percentiles: kiss-and-ride access time distribution for peripheral express bus stops.

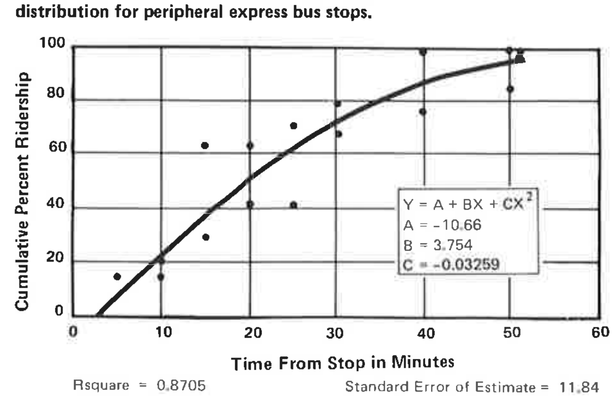


Figure 13. Cumulative ridership percentiles: kiss-and-ride access distance distribution for remote express bus stops.

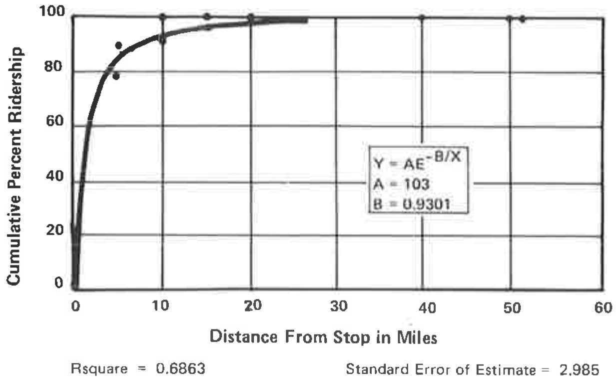
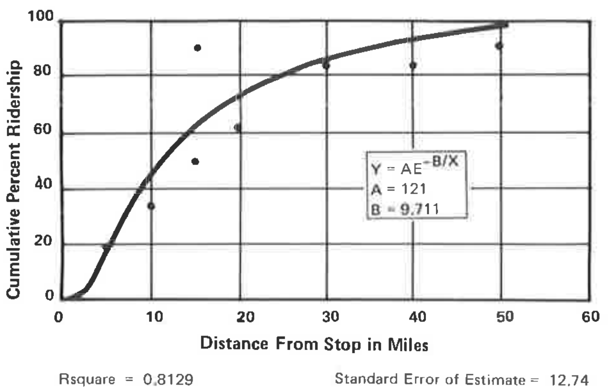


Figure 14. Cumulative ridership percentiles: kiss-and-ride automobile drops access distance distribution for peripheral express bus stops.



These models describe access distributions around an average stop for a given combination of access mode, transit mode, and urban location. They are therefore applicable on a systemwide or areawide basis. As such, these models will be useful in estimating the overall penetration of a transit service market. These models will not aid in making specific decisions about route location or in estimating specific trade-offs between shorter line-haul times and shorter access times.

Models were constructed for all combinations of transit mode and access mode on which data were obtained. These were as follows:

1. Walk to local bus service in an urban location,
2. Walk to local bus service in a suburban location,
3. Walk to express bus service,
4. Park-and-ride to commuter rail service,
5. Park-and-ride to express bus service,
6. Kiss-and-ride to commuter rail service, and
7. Kiss-and-ride to express bus service.

Data were not obtained on subway service or feeder bus service.

Of the combinations examined, some produced better-fitting models than did others. All of the models that describe automobile access distributions for express bus stations were hampered by a lack of data, once the data were divided into remote lot data and peripheral lot data. Thus, although curves were derived that fit the data well, the automobile access distributions for express bus service models are suspect. Perhaps the best models were those that describe walking distance to local bus service in urban locations, walking distance to express bus service, and automobile rider driving times to commuter rail service. Each of these models exhibited a high R^2 and a standard error under 8 percent, which means that each describes the data well and has good predictive capabilities. It is expected that future research and data collection could yield even better estimates. In the use of these models, the individual planner must make the crucial decisions about the appropriate standards to use.

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