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Transportation compatible land uses and bus-stop location

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Abstract

Public transportation works most effectively where high activity levels, unlimited parking, and quality pedestrian and transit access could be found. Such activities or land uses can be considered as public transportation compatible. Effective public transportation system operations depend on the way the community is designed and particularly how its land uses relate to its road network. Relationships connecting the spacing between bus stops and some crucial factors are presented. Curb bus stops are discussed as a common type of bus stop in urban areas. In order to obtain final designs and locations in a given traffic corridor it is necessary to consider a set of issues, such as the available space, the location of the demand points, and the behaviour of drivers and passengers. The decision making process for the selection of a bus stop location could not solely be based in optimisation terms, but criteria of land use compatibility to traffic conditions and public transportation needs should be used.

1 Introduction

Buses are the major means of public transportation in most cities all over the world and, therefore, measures for improving the level of service are always welcome. The definition of a bus stop is quite straightforward in most urban areas. It is usually a single location between, but not close to, junctions, well identified by signs and physical features. A bus stop is basically a bus zone plus the bus stop itself. The bus zone is usually 25 to 50 meters long, the space for the bus to pull in and out to serve the bus stop. The bus stop area needs to be large enough to accommodate the anticipated number of passengers that will board and alight there.

The performance of a bus stop is fully specified if its elements and external conditions are known. Such basic elements and features of a bus stop are: The bus stop area, the berth configuration, the use of berths, entry and exit discipline, bus size and doors configuration, fare collection method, driver's discipline, and the regulation of bus operations.

Traffic adjustment measures could protect bus performance in traffic networks with frequent traffic congestion. However, for high levels of bus flows and high passenger demands, the delay experienced in bus stops is greater than that in interchanges. Bus stop delays are dependent on the point where they are located, the frequency of their appearance on the artery, the passenger demand and other characteristics. It has been suggested (Gibson et al. [2]) to keep the frequency of bus stops under control and to increase their capacity. For such a goal to be achieved, three conditions must simultaneously be fulfilled: the existence of adequate physical space, ease of access for the passengers, and good users' behaviour.

2 Criteria for transportation compatible land uses

Among the benefits of creating public transportation compatible environments to the community, of great importance is increased mobility for many types of trips taken for shopping, jobs, school and recreation. Public transportation compatible land uses have to be defined using a variety of criteria. Few of these criteria have a permanent character, because there always will be variations caused by local conditions or the type of public transportation service available.

Three types of land uses -residential, non-residential, and employment- have the ability to generate transit riders. Ridership on public transportation increases as residential density increases. Low-density residential areas cannot sustain traditional bus services. However, these areas may be served by new public transportation services.

Land uses should have the potential to generate ridership throughout the day and, ideally, during the off-peak periods -midday, evening hours, and weekends. High levels of off-peak ridership can greatly improve public transportation efficiency. Even more than residential densities, public transportation ridership increases as employment density rises. Concentrated employment areas offer the greatest opportunity to generate ridership on public transportation.

Ridership for all types of public transportation increases as the price of parking increases or as the availability of parking decreases. Zoning ordinances can limit the amount and location of parking. For example, regulations can require that parking lots be located at the sides or rear of a building, leaving "front door" access for bus users and pedestrians. Restricting parking requires that adequate alternatives be in place. Before communities consider dramatic changes in parking policy, they must work with transit operators to assure that quality public transportation service is available.

The greatest number of transit riders can be found in the middle of activity centres where land uses are concentrated and parking is expensive and scarce.

Historically, the proximity of activities to a downtown has been substantial. In the future, this factor may not be as important, since so many activities are locating in suburban areas. What is more important is the concentration of activities within activity centres in suburban areas. Generally, the closer a land use is to the middle of an activity centre, the better.

Bus and rail services work better where activities are mixed together and people can walk between activities like offices, restaurants and retail stores or small shops located within residential areas. People can take care of several activities without making multiple auto trips.

Land uses must be located near a bus stop or other public transportation facility or a planned route. A site is not public transportation-compatible if service is not currently provided at, or planned for, that location.

The likelihood of people using public transportation increases if the start point and the end of a trip are close to a bus stop. For example, isolated activities, even high-density activities, do not generate riders if public transportation is difficult to reach. People can be expected to walk no more than 300 m to a bus stop or a park-and-ride parking space (Regional Transit [7]). For rail station access, the walking distance increases slightly, to 400-500 m. Distances are not measured in a straight line, but by the actual walking distance, given circuitous roadways, missing sidewalks, and other obstacles. The distances people will walk are reduced dramatically by steep grades, a lack of weather protection, and a lack of paved, hazard-free surfaces. On the other hand, walking increases as the environment improves.

Bus service can work most effectively where bus facilities, such as bus stops or transfer centres, are designed into buildings, residential developments, roads, and building entrances. People are not motivated to use public transportation services if buildings do not provide convenient, quality access, even if they are located close to a bus route. Building entrances and paved walkways need to lead directly to a bus stop.

3 Criteria for bus stop location

In defining the location of a bus stop several organisations and researchers have posed miscellaneous criteria. These criteria are based either on the type of the road, land uses, and walking distances, or on functional features like the fleet-size and the generalised cost. For instance, it has been assumed that in the process of acceleration and deceleration, a bus spends 20 seconds per stop in urban areas (Pretty and Russell [6]). Taking the cruise speed, the mean acceleration and deceleration rates equal to 50 km/h, 1.0 m/sec^2 and 2.0 m/sec^2 respectively, bus stops should not be closer than 200 m in order for buses to reach cruise speed.

In residential areas, the bus stops should be installed taking into account walking distances. If the mean walking speed is assumed to be 80 m/min and the longest walking distance to a bus stop should not exceed the 5 minutes, then this distance should be less than 400 meters. In general, a range of 200-400 m for bus stop spacing is recommended. A proposed minimum distance between bus stops is 180 or 200 m, while its maximum value ranges between 300 and 400 m (Canadian Urban Transport Association [1]).

From a fleet-size and capacity viewpoint, when the overall cost remains unchanged, the problem for the distances between bus stops again arises, because the time needed for a full cycle on the route is a function of the number of bus stops. That is, $T = t + s\ d$, where T is the cycle time of a vehicle in seconds, t is the mean travel time without stops, in seconds, s is the average number of stops per bus in one cycle, and d is the average duration of each stop, in seconds/stop. Therefore, the fleet-size, N, could be expressed as $N = f\ T/k$ where f corresponds to the passengers' flow from the system (passengers per second) and k is the capacity of the vehicles (passengers per vehicle).

A theoretical model (Lesley [4, 5]) for an urban bus route has been used to determine the distance between bus stops which minimises the passenger generalised cost. Lesley assumed a circular catchment area surrounding each bus stop, where land use is homogenous. According to that model, the optimum bus stop spacing is equal to twice the radius of the catchment area, in meters. This model has the advantage of being independent from various costs and from energy consumption.

4 Major aspects in bus stop location

In order to locate bus stops along transit routes, linear or point aspects could be used. When line options are considered, the characteristics of bus stop locations along bus routes are reflected by three variables, namely bus stop spacing, bus stop market area and transfer points. Because bus stops are commonly served at the sidewalk curbs, they could be characterised as near side, far side or mid-block curb bus stops, using a point and block classification.

Bus service levels along a route could be improved if the bus speed is increased by restricting the number of stops. Obviously, bus stops in a close spaced arrangement provide short walking distances to public transit, but they tend to increase the jerkiness of the ride and bus travel times. Therefore, the overall capacity of the system is reduced. As a sequence, the need for a standard for prescribing the minimum and maximum distances between bus stops emerges. Traffic engineers should seek for maximum safety, comfort speed, and capacity, while at the same time the walking effort required to access a bus stop should be minimised. As a rule of thumb, spacing is one bus stop per city block, if city blocks are longer than 150 m, or one bus stop per alternate city block, where city blocks are less than 150 m in length. However, in practice the spacing varies significantly from city to city and large transit systems in urban areas with high population density, use different criteria for establishing distances between stops.

There is a general agreement among traffic managers and engineers that bus stops should be located at major demand sources such as employment centres, shopping centres, schools, hospitals and densely populated neighbourhoods.

A bus stop market area is considered to be that zone covering the walking distance to the transit stop. This area could range from 50 m to 800 m in central

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business district areas and from 100 m to 1000 m or more in areas with small numbers of occupants. In general, a walking distance of 400 m could be considered as an acceptable standard for all areas.

Theoretically, a bus stop market area is half of the bus stop spacing, provided that bus stops are spaced equal distances apart on a bus route along a straight road. The bus stop market area provides a principle by which the distances between bus stops could be determined. It has been indicated (Wanderlof [8]), the passengers desire to walk no more than 400 m from their origin to the catchment point. In establishing the maximum distance between bus stops in commercial and rural areas, these opinions should be taken into consideration.

A basic assumption in public transit planning is that direct service should be provided by the system and that accommodation of the majority of travel demand through routing of buses between major traffic generators, should be offered in such a manner that transferring will not be necessary. However, a small number of transit patrons will always be required to transfer between routes. The bus stops connecting bus routes are transfer points. Transfer points need to be located in high-density areas.

Bus service can work most effectively where bus facilities, such as bus stops or transfer centres, are designed into buildings, residential developments, roads, and building entrances. Furthermore, in order to assure a safe, convenient and easy transfer, the transfer point or the transfer centre should be located at major street intersections (Institute of Traffic Engineering [3]). At points where two bus lines, proceeding in the same direction, coincide, there should be a common bus stop. Thus, the confusion of two loading points for the same direction of travel will be avoided, or if there is any transferring, the transferee's walking effort will be eliminated.

4.1 Curb bus stops

Bus stops can be located immediately before or immediately after an intersection or they can be located mid-block. Each has its advantages and disadvantages and each has its own bus zone dimension requirements. The local transit operator can help evaluate potential bus stop locations and provide designers with their adopted standards. Bus stops served at sidewalk curbs to be grouped in one of the following categories (figure 1):

- bus stops located at the approach to an intersection, called near side bus stops
- bus stops located at the exit from an intersection, called far side bus stops
- bus stops located in the middle of a city building block, called middle-block bus stops. If a crosswalk is provided in the middle of the block, the bus stop could be installed at the near side or the far side of the crosswalk. Such bus stops are named near sided and far sided midblock bus stop respectively.

In selecting the type of bus stop location, transportation engineers should consider several factors, such as:

- safety considerations for pedestrians and vehicles
- passenger demand, that is, how many people will use the stop

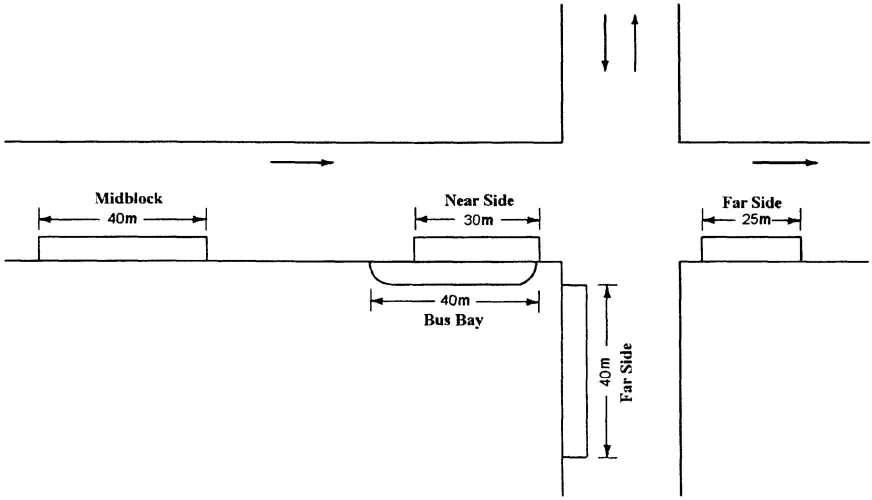

Figure 1 Alternative locations of isolated bus stops

- local regulations
- impacts on private property
- efficiency of operations (what will this stop mean to overall operating speeds and timed transfers)
- sight distances must be such that drivers and passengers have clear views on either side of the stop (generally not less than 100 meters).

To consider the "safety" factor, four different movements could be analysed, i.e. passenger movements, pedestrian movements, vehicular movements and the circulation of non-bus traffic.

Passengers leaving a bus have a tendency to immediately walk across the street through the crosswalk. This practice obviously poses hazards to the passengers, if the bus stands at the near side of the crosswalk. Drivers approaching from the rear cannot see the passenger crossing in front of the bus. On the other hand, when the bus has finished alighting and attempts to leave the stop, crossing passengers constitute an undesired and needless interference. At the far side of the crosswalk such situations are not present.

Transportation engineers should provide visual and physical pathways to streets with transit facilities. Transit centres or bus stops must be integrated with other pedestrian areas. A far side stop has a definite safety advantage, because the stopped bus does not block a pedestrian's view of traffic approaching from behind the bus. Also, the pedestrians do not conflict with the bus as it leaves the stop. Numerous pedestrian accident surveys have shown that 3% or more of such accidents are bus stop related. Conversely, in cities where bus stops were initially installed or relocated to the far side, no accidents related to bus stops are recorded.

The far side stop has definite advantages in providing buses with manoeuvring space. At far side stops more access space is available for the bus to pull out of the through-travel lane into the curb lane. Therefore, the potential of sideswiping parked vehicles is reduced. To prevent the obstruction of the traffic lane by the rear of a stopped bus, the bus should be parked parallel to the curb and as close as possible to it.

At near side stops, drivers may find sight conditions unfavourable, because of the visual obstruction created by the standing bus, which hides signs and signals. Also, near side stops pose hazards to other vehicles when a bus is loading or discharging passengers, because the vehicles following often attempt to bypass the standing bus and, thus interfere with other traffic and the bus as it leaves the stop. This type of bus stops also creates a dangerous condition for drivers making right turns in front of the bus standing at the stop.

Cars may suffer delays because a stopped bus reduces the road capacity for the duration of the stop. Delays would depend on the platooning of other traffic and therefore on the closeness of the stop to signal controlled junctions. In terms of traffic signal delay, a near side stop has a timesaving effect because a portion of the delay is combined with the passenger service operation, but, if there is a high volume of right turning vehicles or a large number of pedestrians crossing the street, then a far side stop may be advisable.

Usually, the bus-driver pulls out of the traffic stream more easily than he re-enters to it. At a far side stop, when the signal light turns red behind the bus, the driver can find a gap to reenter the traffic stream. At a near side stop, as the bus leaves the stop, it always conflicts with vehicles on the travelling route. Bus-vehicle and resulting vehicle-vehicle conflicts cannot be eliminated unless bus-exclusive lanes are provided.

Bus drivers are not the most important factor among those affecting the decision for a bus stop location selection. However, the driver's characteristics and his mood should be taken into account for such a selection. At a near side bus stop, the driver's attention is not diverted by cross traffic or turning vehicles when he pulls into the stop. A driver stopped at a near side stop has a direct view of the three directions where passengers may come from, while he is waiting. A far side stop tends to encourage the driver to maintain greater approaching speed near the intersection, in comparison to a near side stop. The drivers tend to violate the traffic signals more frequently in reaching a far side stop.

5 Land Use Considerations in Bus Stop Location

Publicly provided transportation is a valuable but limited resource. For a community to benefit fully from this scarce public resource, the location, design and patterns of use of its residential, commercial and industrial areas and particularly its streets and public facilities need to support public transportation. The measures of the success of these land use changes will be greater public transportation ridership and increased numbers of people who know they have real alternatives to the single-occupant automobile.

Planning for public transportation does not imply a radical departure from current development practices. The issue is not to change the land uses that make up a community, but rather to influence their mixture and design. Locating apartment houses on major streets with bus routes and installing sidewalks to bus stops are examples of planning for public transportation. A community can influence the public transportation compatibility of a plan by considering public transportation as it addresses each of these development issues:

- pedestrian access
- the amount, cost, and location of parking
- the location of townhouses and apartments
- the location and design of shopping and employment centres
- the location of transit facilities
- the location of community facilities, schools, parks, etc.
- the mix of land uses
- design of residential developments, building complexes and their surroundings
- the design of streets and intersections

In terms of land use, the bus stop should be installed wherever there is a wide sidewalk and where the stop will not block entrances of local business. On the other hand, shopping centres very seldom provide any attractive way for pedestrians to reach the building entrance from a bus stop without a lengthy walk through a parking lot or across landscaping. If there is a broader road pavement on one side at an intersection, it should be used for the bus stop in order to minimise traffic conflicts and enhance land use.

The proximity of a bus stop to passenger origins and destinations could be identified as the first ranked element for proper location, whether the bus stop type is near side, far side, or midblock. For local development and the promotion of public relations, it is desirable to install bus stops at locations where they are compatible with commercial activities and parking needs and where minimal annoyance to adjacent owners would be caused. In congested commercial areas it is favourable to locate bus stops at the major establishments where the greatest amount of pedestrians is generated, so that the pedestrian crosswalk movements can be minimised.

In urbanised areas, the lack of parking space is essentially a serious problem. Parking strategies are influenced significantly by the installation of bus stops along any arterial street. Due to bus manoeuvring characteristics, the length of the bus loading zones at near side and far side stops is much shorter than that at midblock bus stops. Thus, the installation of stops at the intersection can provide better utilisation of the curb to meet parking requirements. When the bus is not standing at the stop, the space could be used for additional intersection capacity. However, the best-designed bus stop is useless if parking regulations are not strictly enforced. Parking prohibitions at near side or far side stops can easily be enforced, because drivers are familiarised to the standard parking regulations. The restrictions are more difficult to be enforced at midblock bus stop loading areas where drivers are used to have some parking privileges.

New bus stops could be located through a procedure having as main steps:

1. measurement and data collection for the location under selection
2. location and design of the bus stop in order for the effects on the variables of

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the study to be optimum
3. identification of problems (delays, safety, diversion of land uses etc.) that could arise from the bus stop location, bus stop design or both
4. provision for standards for the study variables involved with the possible problems in the previous step and,
5. alteration of appropriate variables in order to mitigate the adverse impacts through alternative designs.

6 Evaluation of bus stop location

Each bus stop location should be evaluated separately. However, it is essential to design all bus stops of a transit system in the same way. That is, the mixture of near side and far side stops must be avoided. Table 1 summarises some bus stop location criteria. The symbol (√) is used to show which location choice best covers a certain criterion. As can be seen from this table, far side stops are generally best suited in most cases.

Table 1 Bus stop location evaluation criteria

Criterion	Location Selection			
	Far side	Near Side	Midblock	
			Far Side	Near Side
Passenger movements	√		√	
Pedestrian movements	√		√	
Bus movements at stop	√		√	
Bus turning-movements	√	√	√	√
Traffic movements	√		√	
Conflicts between bus and traffic	√			
Land use	√	√	√	√
Parking needs	√	√		
Commercial activities	√	√	√	√
Bus driver's attitude		√		

The best way to recognise all crucial issues is to ask the transit system users' opinion and preferences using questionnaires.

7 Conclusion

Bus stops are a critical element in any transit system. The bus stop is the first point of contact between the passenger and the bus service. The spacing, location, and design of bus stops significantly influence transit system performance and customer satisfaction. Because of the importance of bus stop location and design, guidelines should be developed for locating and designing bus stops in various operating environments. These guidelines can assist transit agencies, governments, and others (e.g., developers) in locating and designing bus stops that consider bus patrons' convenience, safety, and access to sites, as well as safe and efficient transit operations and traffic flow. Bus stops already installed may have to be moved in order to improve traffic operations or curbside stops should be redesigned to a bus bay design.

The decision making process for the selection of a bus stop location could not solely be based in optimisation terms, due to the nature of alternative solutions, the difficulty in finding an objectively appropriate function and because of the kind of limitations involved in the process.

The relationships presented in this paper, as well as others found in literature, are very useful for the treatment of the bus location issue. However, the distances between bus stops are only the first step towards an optimum design. In order to obtain final designs and locations in a given traffic corridor it is necessary to consider a set of issues, such as the available space, the location of the demand points, and the users' behaviour. In high-speed roads, bus stops should be located close to trip generation points, where a protected crosswalk is available.

Bearing the safety issues in mind, it is strongly recommended that bus stops be located at the far side of the intersection or at the far side of a midblock crosswalk, in order to minimise visual interference.

Quality design of bus stops requires criteria for the location of new stops and implies modifying criteria for existing ones. The categories, which have to be considered during the bus stop location and design process, are bus operations, area type or land use, passenger safety, roadway features, and traffic conditions.

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