

Katz, Donald and Rahman, Md. Mizanur

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**Authors:**

Donald Katz (corresponding author)

*Current Affiliation:* Georgia Institute of Technology

*Other Affiliation to be used:* U.S. Fulbright Student

*Other Affiliation to be used (cont.):* Bangladesh University of Engineering and Technology

1 Ethan Allen Road

Freehold, NJ 07728, USA

Phone: 732-233-5430

donald.katz@gmail.com

Md. Mizanur Rahman

Associate Professor

Bangladesh University of Engineering and Technology

Department of Civil Engineering

Dhaka-1000, Bangladesh

Phone: 880-2-966-5650

Fax: 880-2-861-3026

mizanur@ce.buet.ac.bd

**ABSTRACT**

Overcrowded buses are a common sight in Dhaka, Bangladesh, swerving between rickshaws and auto-rickshaws, blaring their horn, and shouting out the next spot the bus will stop. Two primary bus services operate in the city, ticketed and local, differing in fare collection, stop patterns, and price. They carry the largest share of trips in Dhaka, and both are overcrowded. Understanding the differences between the two, and how crowding affects their curbside operations, could show which is the more effective way of moving passengers. By developing a method to evaluate a system which seems disorderly from the outside, the effects that crowded conditions have on performance were studied. Data was collected over half a year through on-board studies of the dwell time and loads the buses carry. Despite the uncomfortable conditions crowded buses create for passengers, they operate more efficiently for the volumes they carry. Local buses in particular were shown to be more effective in transporting the population. Crowding is a necessary issue that Dhaka must live with, until a relieving mass transit system can be built.

## INTRODUCTION

Any resident in Dhaka, Bangladesh will speak of how overcrowded their city streets have become in recent years. Constant traffic jams are not unexpected, as it is the capital city of the densest country in the world. Unfortunately, Dhaka's struggles will continue because it is growing at the second fastest rate of the twenty most populated metropolises in the world (1). The roads of the city are clogged with vehicles all day long making travel unbearable. All shapes and sizes of vehicles are part of the traffic: hand-pulled carts, pedal rickshaws, auto-rickshaws, tempos, taxis, private cars, and a wide array of buses. Although a circular waterway ferry system is in planning and several rapid transit train plans are being debated within the national government, all current major travel modes must make use of the crowded roadways. The bus system, consisting of mostly private operators, handles the largest share of those using the streets. These buses typically ply overcrowded, but the extent to which they do so differs by the type of bus service.

## BACKGROUND

At first glance it would seem that Dhaka has a good transportation system with plenty of low emission vehicles and a high rate of public transport usage. The problems arise due to a lack of transportation infrastructure in the city and absence of a transit system to handle the volumes that currently exist. Ideally in a city with a well functioning transportation system, about 25% of the land usage should be for road transport. Dhaka, however, sits at around 8% and two-thirds of these are non-engineered surfaces (2). Dhaka could perhaps handle such a lack of road infrastructure if there were other options for travelers, but it lacks a mass transit system as well as an organized bus system, the only city of its size worldwide to be in such a position (2). Dhaka's total number of buses is not enough to comfortably handle the number of passengers that desire to use bus services. Haque and Hossain describe in their report that Colombo, Sri Lanka has 7600 buses for 4.6 million people, while Dhaka is desperately lacking with only 2000 for ten million (3).

Few people living in the dense urban fabric of Dhaka own automobiles. Private automobiles are owned at a rate of only 33 per 1000 persons, lagging behind all other Asian cities (4). Non-motorized transport dominates 80% of movement: over 400,000 rickshaws clog city streets (5) and pedestrians pack the remaining space. Pedestrianism is higher in Dhaka than in any other city of its size, with 60% of residents choosing this mode for convenience or economic reasons. Rickshaws account for 50% of the traffic flow, and are the most popular choice for short distance trips (2). Rickshaws only carry travelers so far, however, and restrictions on where they can travel in the city forces many trips to be done by bus. So despite the large amount of non-motorized transport, buses are still carrying over half of Dhaka's travelers although they only account for 10% of all vehicles (6).

While other Asian megacities have high rail usage as one of their public transit options, Dhaka's rail travelers within the city are a miniscule fraction of the total. Without a rail system to supplement the volume on the roads, travelers going longer distances must board the wide array of privately owned buses that operate on the city streets (4). To meet the fast growth demands the number of buses may have to increase up to seven times larger within fifteen years. In order to meet the demands of travelers and to survive financially, the private bus companies must overcrowd their buses in order to keep operating. As a result, they are not investing in updating or enlarging their fleets (6). These factors have all helped to produce a bus system which is overcrowded and marked by safety, performance, and comfort issues.

### Buses in Dhaka

Dhaka has several types of buses plying the streets. The 2004 Dhaka STP (6) divides buses into several categories: minibuses (41%), microbuses (30%), large buses (13%), auto tempo/laguna maxi (12%), and staff and school buses (4%). Residents of Dhaka understand the bus system as divided mainly into ticket buses (Figure 1), local buses (Figure 2), and tempos.

The first two of these categories were the subject of this study. Ticket buses have set stoppages on their routes, which can be located by the companies' respective ticket counters. Their fares are collected on the curbside from ticket sellers associated with each private company and have a single conductor on board who checks tickets at the doorway. Almost all of the large buses are ticket buses and a significant number of the minibuses operate as ticket buses.

Local buses have stoppages that are unmarked, but they are fairly consistent with where they stop

on their routes, and have on-board fare collection. Local buses can also be boarded and alighted from at any point on the route, at the conductor's discretion. They typically operate with two conductors, one who collect fares and one who stands at the doorway finding potential riders from the side of the road. There are a handful of large buses that operate as local buses, but the vast majority of local buses are minibuses.

There is a noticeable economic gap between the riders of ticket and local buses. Ticket bus fares are always higher than local bus fares, usually by a few Taka. This slightly higher fare pushes away riders who have lower incomes and cannot afford to spend a few extra on a ticket bus. The ticket bus, with its higher fare, is typically quicker and has an interior which is better kept than a local bus, such as less holes in seats. Additional benefits may sometimes include hanging handles to grip for standing passengers to hold (rather than a metal bar suspended from the ceiling), organized waiting lines at stops, and ceiling fans. The socioeconomic response to this is that riders of ticket buses are typically of a higher social class, and even view local buses as beneath them, since riding one carries a slight stigma of poverty.

Bus behavior in Dhaka varies significantly depending on the drivers and conductors operating them. Skipping of stoppages, cutting routes short, and dwelling for very long periods at the curb occur unpredictably, although this is more often observed in local buses. These annoyances to travelers can vary between off-peak and on-peak periods. It is for these reasons that many travelers choose to avoid riding buses (7). Common complaints from bus riders in Dhaka include long waits for buses, unexpected delays while the bus is moving, lack of comfort, and long walks from origins and destinations to the bus stops (8).

### **Overcrowding On Buses**

The buses of Dhaka are bursting at their seams with passengers, with travelers, forced to hang out the door frames in the most extreme conditions, filling all available space in the aisles, as seen in Figure 3. This not only is a comfort issue for many passengers but also affects the safety level at which the buses operate. For many passengers, the link between crowding and safety is strong, with some feeling not only less comfortable but also less safe amongst their co-passengers during crowded conditions (9). In a report about the ergonomics of bus riding, Kogi describes how passengers are able to handle the crowded conditions, but tolerance for such conditions decrease after a certain threshold. As either the number of passengers and the length of time for being crowded independently increase, passengers reach a point where they are perplexingly discomforted (10). In Dhaka this can be a serious issue because traffic jams are prevalent. As the bus sits in traffic, the amount of passengers walking past and boarding the bus increases, while concurrently passengers are enduring long waits under these increasingly crowded conditions.

How the operations of buses change when they are crowded is not a greatly understood topic. Most of the studies focus on the dwell times of the bus, the amount of time it waits at the curb. The lack of research in this area is due to the amount of time needed to gather this type of data, requiring a lot of man-hours at a high cost, only to produce a small sample size. It is generally accepted that the time for alighting is less than that for boarding, but figures on how much this changes per passenger varies significantly between studies (11). As well, it is shown that the time the bus spends at the curb is linearly related between the number of boarders and alighters (12), but how it relates to the bus's current loading is not considered. Many studies have considered the volumes at which buses' travel at and how it relates to capacity, but do not relate them to dwell time (12, 13, 14).

### **METHOD**

In Dhaka's bus system the wide array of bus types, high tolerances for crowded conditions, and reactionary behaviors for operation by the conductors and drivers create an interesting environment to observe the effects of crowding on bus operations. The structure of the study was aimed to target certain variations in bus types and examine the way they performed when overcrowded. Because the goal was to capture what happens at individual stops, as opposed to the route as a whole, it was decided that a variety of buses needed to be captured in the data collection. Of primary importance was the differences in how the two main bus types, ticket and local, operate. A stratified sample of buses was chosen for riding, ensuring that data would be collected about different door numbers and arrangements on both ticket and local buses. Ultimately, 90 ticket bus trips and 45 local bus trips were collected. Ticket buses have a

wider variety of door arrangements and more were collected to not emphasize any certain bus design. Local buses were generally all the same bus design. Additionally, ticket buses have less stops than local buses, so more ticket buses were needed to increase their sample size of stops. Each of the routes were ridden three times in each direction. Routes were chosen from all parts of the city, and when possible, a route which started and ended within city limits. All buses would be ridden only within the city limits. For this study the study riding limits were set at Abdullahpur in the northeast, Jatrabari in the southeast, and Gabtoli in the northwest.

All routes were ridden from origin to destination, or the geographical limits of the study. The researcher sat on the door side of the bus, in order to observe what happens at the curb. A voice recorder was used to count each board and alight, the arrival and departure time of the bus from the stop, and the point at which the bus rejoined the traffic stream. Passengers who boarded and alighted in between stops were noted as early or late in reference to the previous or next stop. The number of people standing before the first row of seats and immediately in front of the middle or back doors was recorded as a measure of a bus's crowding levels. The number of people who remained at the bus stop who could not board and the number of passengers with some part of their body outside the doorframe were also recorded.

The riders' opinions of riding crowded buses was collected over a two hour period at one of the busiest bus stops in the city. The site was selected because the stop's design had ticket bus passengers boarding several bus lengths upstream from the local buses. This made separating the ticket bus and local bus passengers into survey groups very simple. Additionally, upstream of the stop was an intersection controlled by traffic police, and the buses came in bursts, leaving ample time in between for surveying. The survey was three questions long and was conducted through face-to-face interviews. The questions were phrased for "yes" or "no" responses and were tailored to be quickly asked to riders waiting for their bus. The survey was written in English and translated into Bengali before delivered to the subjects.

## RESULTS

Differences between ticket buses and local buses are very clear. Local buses almost always get crowded at some point during the route, much more frequently than the ticket buses. All of the local buses ridden for the study had passengers standing. This differed from ticket buses, of which only 66 of the 90 ridden had riders in the aisles. The larger size of ticket buses means it is more difficult to fill them, but also meant that they can hold immense numbers of passengers when necessary. Five ticket bus routes had over 50 standing passengers at some point during their route.

The difference between the frequency of crowding is due to their passenger collection methods. A local bus will commonly remain at a stop for several minutes until the conductor feels the bus is sufficiently loaded, which typically means every possible space is filled. Some local buses will leave a stop when a second bus of the same route arrives, but schedules are roughly kept so that the first bus will already be sufficiently crowded by the time of the second bus's arrival. Ticket buses, however, typically wait only for the passengers already waiting for the bus at the stop to board before departing, although there are occurrences where the bus will wait at the stop for passengers. The consequences these operational practices have on crowding are that local buses leave almost all their stops with people standing inside, while ticket buses are much more likely to leave with partial loads.

The operational practices are reflected in the total ridership of the routes. Local buses carried on average 174 riders for each run, compared to only 70 riders for ticket buses. One reason for the higher ridership is that potential passengers have higher exposure and access to local buses. Local buses average over seven more stops on their routes than ticket buses, 24 to 17 respectively, providing opportunities for people to get on, and attracting more riders by allowing them closer access, through more departure options, to their destination. The reduced number of stops, and the practice of local buses waiting at stops to increase ridership, meant that ticket buses finished their routes nearly 20 minutes faster than local buses. Local buses though, because of their higher ridership, still transport twice the number of passengers per hour on the road than ticket buses. Local buses transported on average 117 passengers per hour, ticket buses only 59.

Breaking the entire routes down to the stops that make them up, the manner in which a route gets crowded with passengers, and to the degree they get crowded, is realized. Over all the ticket buses, only 28 percent of all visited stops (1549 total) actually had passengers standing after departing, averaging five

standing passengers per stop. Solely examining the 446 ticket bus stops when standing actually occurred though, there was an average of 18 standees. The distribution of the stops at which standing occurred is seen in Figure 4a. Local buses departed crowded at a much higher rate, nearly 60 percent. The local buses had an average of nine standing passengers over 1071 observed local bus stops, with fifteen standees for the 635 stops that had standing. Figure 4b shows the distribution for those stops after which standing occurred. In both parts of Figure 4, each bar has a bin size of five. Local buses are crowded much more often than ticket buses, although ticket buses see higher amounts of people standing due to their typical larger size.

In order to take into account the size of the vehicles, the load factor for the bus after each stop can be calculated. Doing so allows buses with a range of number of seats to be compared. The load factor is the ratio of number of passengers on the bus over the number of seats available. In Figure 5, the ticket and local bus routes' stops' load factor distributions are compared. Local buses see a much greater share of stops that have higher load factors compared to ticket buses. In Table 1, the Level of Service (LOS) levels and the equivalent qualitative description are shown. The dividing line in Figure 5 represents the threshold of passengers having to stand. Although ticket buses had several buses with high numbers of standing passengers, it is seen now that the more significant issue of crowding occurs in local buses, as a much higher percentage of those are traveling at LOS F, when passengers are crushed in the aisles.

The level of crowding throughout the route peaks in the middle for both ticket and local buses. The typical bus route in Dhaka does not start a major transit hub, but instead on a less busy street. Due to a lack of storage facilities, buses must be parked curbside when not in use. Operators thus prefer to locate their route origins just past a busy part of the route, usually one or two stops past. Here they can service buses and allow drivers to break for meals when necessary. In order to see how packed a bus became at different portions of its route, bus routes were split into fifths and the distribution of load factors for stops in each segment of the route are visualized in Figure 6. In both of these cases, the beginning and ending stops near to the origin and destination are less likely to reach a bus's capacity. However there are several instances of ticket buses characteristically getting fully crowded at the beginning of the route and retaining such levels until the final stop when heavy alighting occurs. For local buses, the several runs that were crowded at the beginning and end of their routes typically had delays, and passengers were left queued at stops, filling the bus up early on. For both bus types, it is the middle of the route where the maximum crowding levels are seen.

Typically the standing passengers congregate around the doors of the bus. Although this would seem to indicate that there would be extra delay during the stop, due to passengers needing to push through large groups of people to alight and board, it is not as severe as it could be. Passengers have adapted to the crowds and know to get to the door before the bus reaches the stop. Figure 7 displays that as a result of passenger adaptation, there is very little change in the rate at which passengers board and alight. Variation in the rate when the bus is crowded can many times be contributed to the bus being stuck in a jam of other buses and arguments between passenger and conductor. Ticket buses and local buses which wait to fill up their bus with passengers are those with a load factor below 1.0 and with ten seconds or more per boarding and alighting passenger those. Otherwise, the typical rate for Dhaka buses is between two to six seconds per passenger. What is not happening is any particular trend indicating that a crowded bus has longer dwell times,

The dynamics inside the bus that allow such consistency, even at the most crowded levels, involve a bit of pushing and aggressiveness. Figure 8 shows a bus that has every standing space occupied, although still not at the maximum load, it still forces passengers to have to shove one another to board and alight. Any sitting passenger who stands to go to the door to alight is instantly replaced by an eager standing passenger. Alighting passengers force their way through the crowd and others shift towards the back to allow room at the front. Thus, the majority of the passengers who desire to alight from the bus are already at the door by the time the bus arrives at the stop, which cuts down dwell time. This leads to boarding passengers having space to board on the bus directly by the door, with limited pushing involved, helping to reduce dwell time. The conductor of the bus is many times an integral part of maintaining the best performance, yelling to passengers to move back if their stop is farther along the route.

## Passenger Surveys

248 bus passengers waiting at the Sat Rasta bus stop in Tejgaon were surveyed. Approximately half were local bus riders, the remaining half boarded ticket buses. Nearly 90% of the surveyed passengers were male. The results of the surveys indicate that overall the large majority of passengers say they are frustrated with overcrowding, with a slightly higher number of local bus passengers reporting this statistic. This makes sense, as the local bus passengers are more likely to experience crowded conditions. Despite this frustration, most passengers say they would not avoid a crowded bus. Only a quarter of local bus respondents said they were willing to pay for more space. Appropriately, this number was higher for ticket bus riders, nearly half said they would be willing to pay for more space. Effectively, that is how ticket buses operate now.

## **DISCUSSION AND CONCLUSIONS**

Local buses, by their nature, are prone to be crowded. Conductors and drivers eager for earning more money aim to crowd the bus. The results showed that local buses do take slightly longer to complete their routes because of this curb dwelling, but the number of passengers they transport per hour is twice that of ticket buses. Although ticket buses do provide solace for passengers willing to pay for more comfortable non-crowded conditions, they are not exempt from it, and often become crowded mid-route. Effectively, a local bus is more efficient over its route, and it is safe to say that overcrowding is a necessary issue for Dhaka.

The two service types have to a degree been blended by some companies in operation, but with no particular success. A bus service with off-board ticketing but non-set stoppages is not a practical combination unless a citywide fare card could be instituted and accepted by a large number of operators. Combining on-board fare collection with set stoppages is already how some local buses with strict stopping rules operate. This, however, still results in long dwell times at pick-up locations, and passengers still alight as they please because slow operating speeds do not discourage it.

Prior to the start of data collection, it was hypothesized that crowding on buses would cause delay in dwell times, and this delay would increase in a non-linear fashion. It was reasoned out that each additional passenger on the bus has to push through increasingly more people to get off or on the bus. It was reasonably assumed that each additional passenger would take a bit longer to board the bus than the passenger before. This would result in a non-linear increase in dwell times. The results do not show what was initially hypothesized. It is possible that due to the passengers' adaptation to the crowded conditions, dwell times were inadvertently reduced from what would exist if all riders did not adjust. Before the bus has even reached a stop, most of the passengers who want to alight have already stood up from their seats and are waiting by the door. If the bus is extremely crowded, passengers begin making their path to the door extra early, knowing they have a large number of other passengers to squeeze through. If a bus spends more time at the bus stop it is generally not because the bus was crowded or not.

In Dhaka, crowded buses may in fact be a solution to a much larger problem. Due to the extreme levels of congestion in the streets of the city, buses cannot keep consistent schedules. This means that passengers will prefer to board a crowded bus, even at the risk of their personal safety, rather than wait an unknown length of time for the next bus to start. This was particularly evident when headways between buses of the same company shrunk due to the unpredictability of traffic flows. A crowded bus would arrive at a stop, followed quickly after by a non-crowded bus of the same company. Most boarders fought to squeeze into the few spots on the first bus, rather than take the open spots on the bus which would leave a minute or two later. The operators do not appear to discourage these large loads. Any countermeasures against crowding, such as bypassing stops when crowded, were left mainly to the conductor's discretion. Unless Dhaka's traffic situation improves, there is little to motivate operators to reduce crowding and move to more consistent scheduling and operations because even the passengers are content to handle it.

Overall, although Dhaka's bus riders may not like the crowded conditions, the majority will still use the crowded system and are not willing to pay extra to board vehicles with open seats. For this, the city's planners should be relieved. A reduction in bus overcrowding would mean increasing the number of buses on the road, something that Dhaka cannot afford. An increased number of vehicles on the road would jam up its roads more. Until the traffic situation can be improved through a planned mass transit system, whether it be rail or bus rapid transit, there is no motivation to make efforts to reduce the loads

Dhaka's buses carry. This relieving infrastructure is still a decade or more away, and its current system must find ways to cope.

Dhaka is currently trying out new bus transportation options to help maximize the use of the road. Articulated buses have recently been purchased to be used by private companies, meaning one bus can carry higher loads if current crowding conditions remain the same. Also plans to institute a digitalized ticket system on the busy Uttara to Azimpur route. All existing companies on that route will run under one name and ticket system instead of competing with each other. These new operational implementations in Dhaka should be studied to see their effect on overcrowding situations and dwell times. The various improvements may have some success in reducing delay, but ultimately, crowding of the buses will remain necessary until a mass transit system arrives. Since it was seen that overcrowded buses operate at the curb similarly and often quicker, crowding should not be discouraged.

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**LIST OF TABLES AND FIGURES**

TABLE 1 Passenger Loading Level of Service Thresholds

FIGURE 1 Typical large bus operated as a ticket bus.

FIGURE 2 Typical minibus operated as a local bus.

FIGURE 3 Passengers on an overcrowded ticket bus hang out the door, grasping the doorframe to stay on.

FIGURE 4 Histogram of crowding levels for (a) 446 ticket bus stops (28% of total) and (b) 635 local bus stops (59% of total) that had crowding.

FIGURE 5 Distribution of load factors at stops for ticket and local buses, normalized for the sample size of each. Load factors to the right of the vertical line indicate a bus where some passengers must stand.

FIGURE 6 Distribution of load factors for (a) ticket buses and (b) local buses by the segments of the route, split up into fifths. Load factors are described by LOS level.

FIGURE 7 Distribution of time required per passenger for boarding and alighting to occur, compared to the crowding level of the bus.

FIGURE 8 Passengers on a crowded ticket bus have to force their way through others to get to the door.



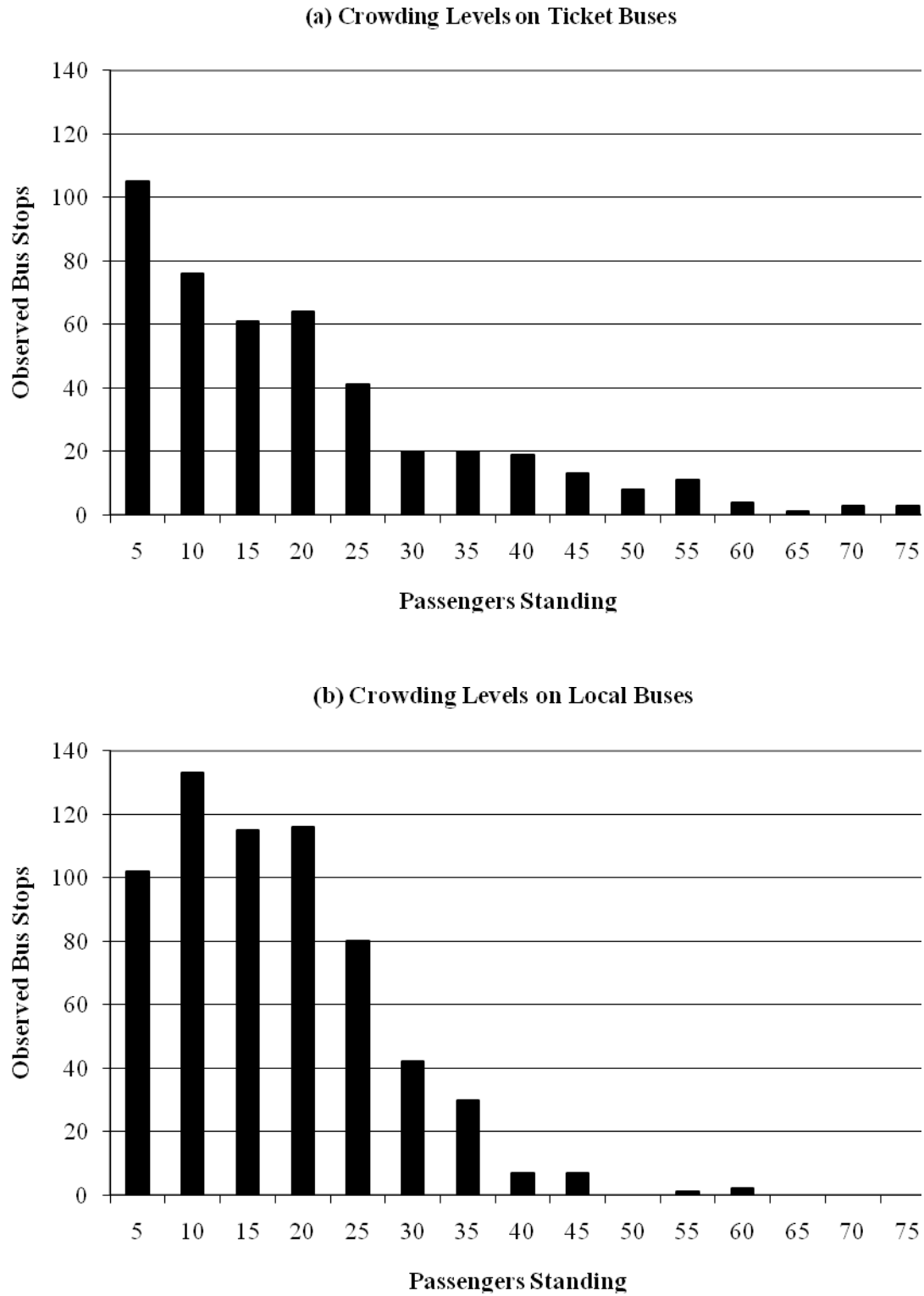
**FIGURE 1** Typical large bus operated as a ticket bus.



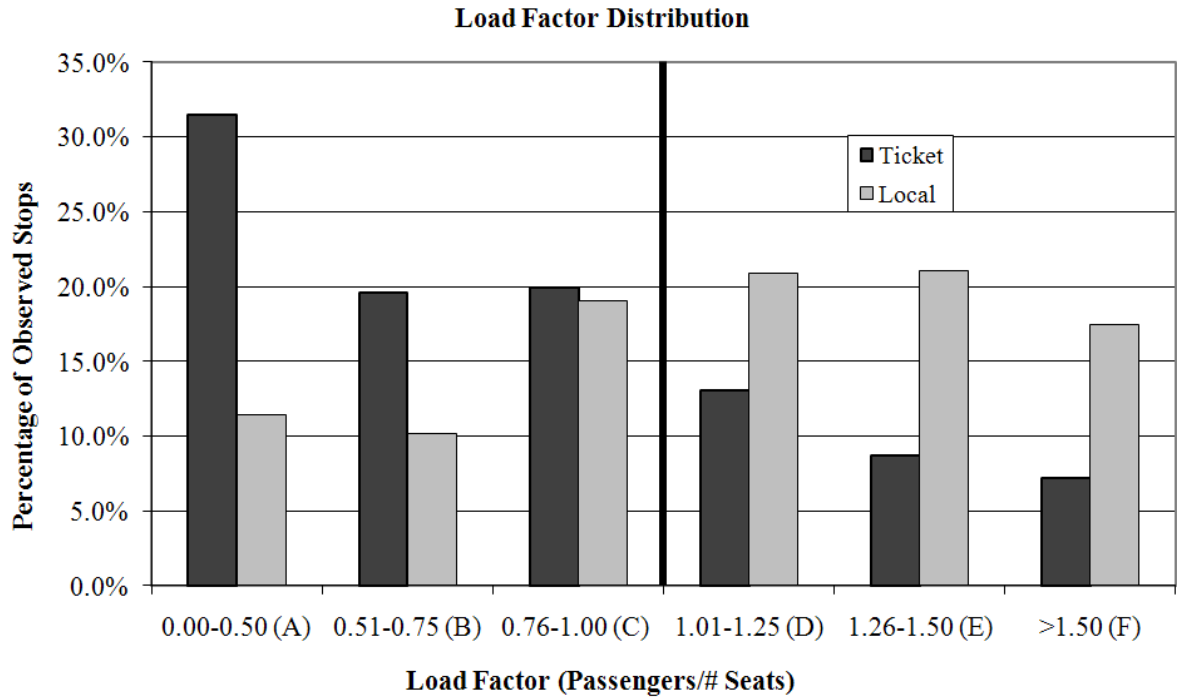
**FIGURE 2** Typical minibus operated as a local bus.



**FIGURE 3** Passengers on an overcrowded ticket bus hang out the door, grasping the doorframe to stay on.



**FIGURE 4** Histogram of crowding levels for (a) 446 ticket bus stops (28% of total) and (b) 635 local bus stops (59% of total) that had crowding.

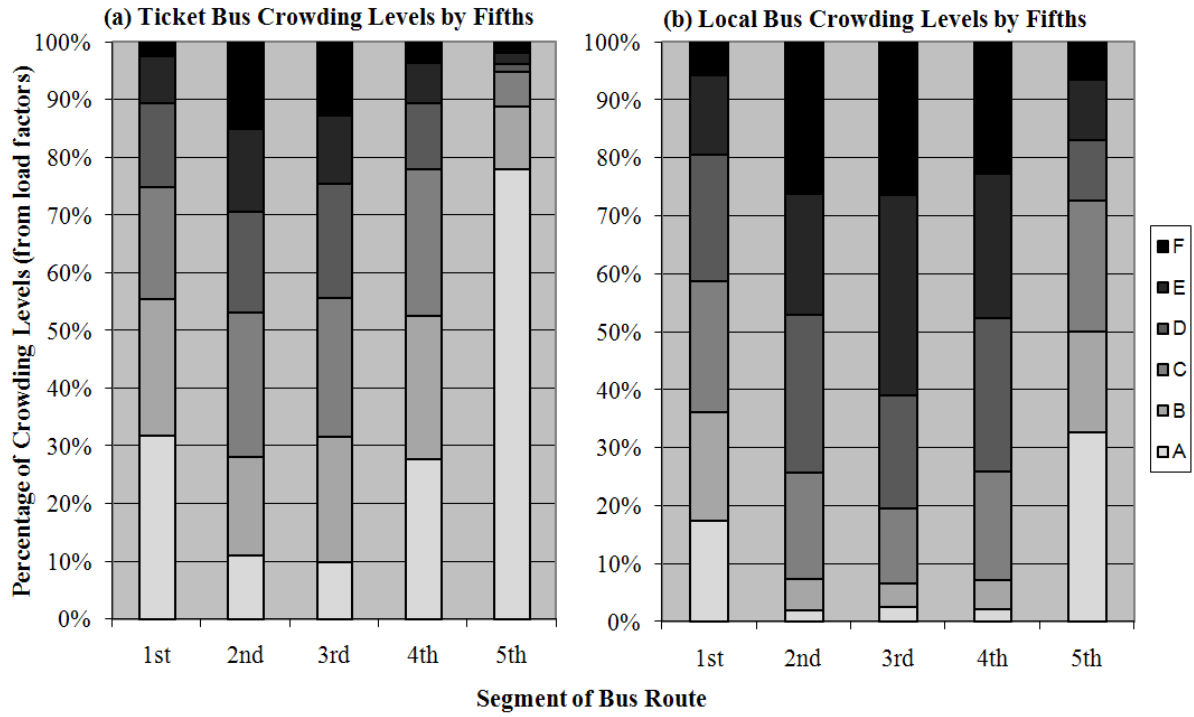


**FIGURE 5** Distribution of load factors at stops for ticket and local buses, normalized for the sample size of each. Load factors to the right of the vertical line indicate a bus where some passengers must stand.

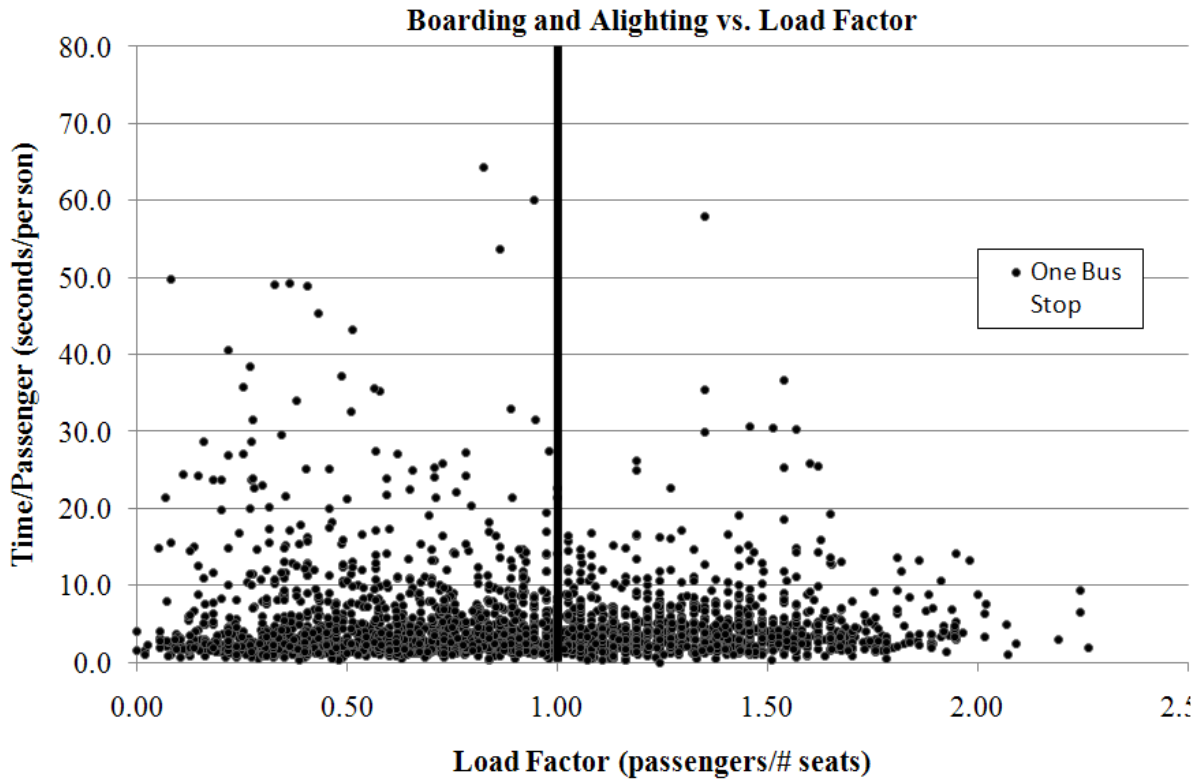
<b>LOS</b>	<b>ft<sup>2</sup>/pass. (m<sup>2</sup>/pass.)</b>	<b>Load Factor</b>	<b>Qualitative Threshold</b>
A	>12.9 (>1.20)	0.00-0.50	No passenger needs to sit next to another
B	8.6-12.9 (0.80-1.20)	0.51-0.75	Passengers can choose where to sit
C	6.5-8.5 (0.60-0.79)	0.76-1.00	All passengers can sit
D	5.4-6.4 (0.50-0.59)	1.01-1.25	Comfortable standee load for design
E	4.3-5.3 (0.40-0.49)	1.26-1.50	Maximum schedule load
F	<4.3 (<0.40)	>1.50	Crush loads

**TABLE 1 Passenger Loading Level of Service Thresholds**

*Note: Adapted from Perk et. al*



**FIGURE 6** Distribution of load factors for (a) ticket buses and (b) local buses by the segments of the route, split up into fifths. Load factors are described by LOS level.



**FIGURE 7** Distribution of time required per passenger for boarding and alighting to occur, compared to the crowding level of the bus.



**FIGURE 8** Passengers on a crowded ticket bus have to force their way through others to get to the door.