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NO. 1726

Public and Nonmotorized Transportation in Other Nations; Women's Issues in Transportation

Safety and Human Performance

TRANSPORTATION RESEARCH BOARD

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A PEER-REVIEWED PUBLICATION OF THE TRANSPORTATION RESEARCH BOARD

TRANSPORTATION RESEARCH BOARD — NATIONAL RESEARCH COUNCIL

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Transportation Research Record 1726

Contents

Foreword

The papers contained in this volume were among those presented at the 79th Annual Meeting of the Transportation Research Board in January 2000. Nearly 1,600 papers were submitted by authors; more than 1,000 were presented at the meeting; and approximately 600 were accepted for publication in the 2000 *Transportation Research Record* series. The published papers will also be issued on CD-ROM, which will be available for purchase in late 2000. It should be noted that the preprint CD-ROM distributed at the 2000 meeting contains unedited, draft versions of presented papers, whereas the papers published in the 2000 Records include author revisions made in response to review comments.

Starting with the 1999 volumes, the title of the Record series has included "Journal of the Transportation Research Board" to reflect more accurately the nature of this publication series and the peer-review process conducted in the acceptance of papers for publication. Each paper published in this volume was peer reviewed by the sponsoring committee acknowledged at the end of the text; members of the sponsoring committees for the papers in this volume are identified on page ii. Additional information about the *Transportation Research Record* series and the peer-review process can be found on the inside front cover. The Transportation Research Board appreciates the interest shown by authors in offering their papers and looks forward to future submissions.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TRB	Transportation Research Board

How Chaos Does Not Destroy Ridership

Operations of an Exclusive Busway Carrying More Than 35,000 Passengers per Hour per Direction

Arturo Ardila and Daniel A. Rodríguez

Busways have been reported to carry up to 28,000 passengers per hour per direction (pphpd). However, recent passenger counts indicate that the exclusive busway in Bogotá, Colombia, has a flow of more than 35,000 pphpd. This passenger flow is achieved despite poor operating conditions and a general lack of maintenance without a city busway management and operation authority. Consequently, there is little police control, no systems management, and scarce information for users. These conditions should affect passenger flow negatively, but the Bogotá busway carries more passengers than all busways for which data are available. The analysis suggests that the Bogotá busway is able to move high passenger flows due to three concurrent and interactive sets of factors. First, the high competition among bus operators provides drivers with an incentive to operate more efficiently. Second, the design provides two lanes, allowing for vehicle overtake, as well as stations that enable six or more buses simultaneously to pick up and discharge passengers. Third, the buses move in platoons along the busway. Each platoon consists of 12 to 16 buses with average 96-s headways. Furthermore, time-distance diagrams indicate that the platoons are not stable, because vehicles keep changing from one platoon to another. The analysis underscores the importance for transit planners of trade-offs among passenger flows, level of service, and optimal system operation.

Busways have been reported to carry up to 28,000 passengers per hour per direction (pphpd) (*1*). However, recent passenger counts indicate that the Troncal exclusive busway in Bogotá, Colombia, has a flow of more than 35,000 pphpd, reaching up to 42,000 pphpd according to some sources (*2*). Some features of the Troncal are similar to those of other busways that move high volumes of passengers: two lanes in each direction for the exclusive use of buses, clearly designated bus stops or stations, and a large fleet of high-capacity buses. Other mainly operational features of the Troncal Busway, however, are radically different from most high-yield busways. Examples are the almost full deregulation that translates into high competition among operators; the lack of a city authority to manage and operate the Troncal; the limited police control and enforcement of regulations; and the lack of adequate timing of the traffic lights at the many intersections along the busway.

Although the similarities with other busways might explain the high passenger flow in the Troncal, the differences imply that the Troncal operates in a chaotic manner that should reduce flow. This paper seeks to answer the question of why this busway, despite operating in a chaotic way, is able to carry more passengers than most, if not all, the busways in the world.

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TRONCAL BUSWAY CHARACTERISTICS

The Troncal Busway is located in a large and dense city, Bogotá. This city has a population of approximately 6.5 million people, distributed in approximately 35 000 ha (86,420 acres). The density, therefore, is on the average of 186 people/ha (47,542 people/mi^2). The Troncal is the main public transportation corridor in the city, which moves primarily by public transit. Approximately 75 percent of the motorized trips in Bogotá are made by this mode, and the remaining 25 percent by private car (*3*). The central business district (CBD) of Bogotá concentrates approximately 700,000 jobs and spreads over 1 000 ha (2,469 acres) (*4*). The Troncal Busway starts in the north end of the CBD and runs south for 16 km (10 mi) across the entire CBD, and it ends 4 km after the south border of the CBD. Consequently, the Troncal enjoys the advantage of serving the most important origin and destination in a city that is very apt for mass transit due to its high density.

The Troncal is a busway as defined by Cornell and Cracknell [quoted in Smith and Hensher (*1*)], because it includes devices that physically separate buses from the general traffic lanes. The segregation of the bus lanes is achieved by the use of a small physical barrier attached to the pavement that impedes cars from entering the bus lanes but that allows buses to exit the busway either for routine matters or for emergencies. The Troncal has a total of eight lanes, two for the busway and two for general traffic in each direction. Buses run in the inner four lanes, and stations are located between the busway lanes and the general traffic lanes. The Troncal is not fully segregated because intersections are at grade, approximately every 300 or 400 m. There are traffic lights at all intersections to regulate crossings, and left-hand turns are prohibited in all but a pair of intersections, where buses are given the exclusive right to turn.

The Troncal Busway also has bus stops or stations, where vehicles stop to collect and drop off passengers. Stations are located every 500 m (1,640 ft), are 100 m long (305 ft), and are divided into four sections (*5*). Passengers can access the station at each end and, in some cases, in the middle of the station. Each station has pedestrian barriers that channel passenger flows toward pedestrian crossings (*5*). Each station consists of a platform 0.30 m (1 ft) high with a small shelter for passengers. This height is presumed to help passengers board the buses, which have a door at a higher level.

A wide variety of buses uses the busway. All of them, however, are considered high capacity by local standards, with a capacity of 80 to 120 passengers. Older buses look like U.S. school buses with modifications such as handles for standees. Although newer buses have a more modern-looking design, they remain in essence similar to the U.S. school bus. All the buses are mounted over a truck chassis, and consequently the doors are at a high level. Passengers enter through the front door and pay the driver, who is in charge of simultaneously collecting fares, providing change, and operating the vehicle. Passengers exit through the rear door. Doors are narrow, only 0.70 m (2.3 ft) in the best case, but this feature as well as the rest of the design of the bus complies with the Colombian norms for public transport buses (*6*).

PLANNING AND THEORETICAL OPERATION OF THE TRONCAL BUSWAY

The Interinstitutional Transport Group of Bogotá (GIT), a group that assembled the best planners and engineers from the many city offices that deal with transportation policy and planning, planned the Troncal Busway. The group also received help from Brazilian experts, who had experience with this type of transportation facility (*5*). The corridor chosen to build the busway was the main public transportation corridor in the city.

Planners faced several constraints. First, bus routes in Bogotá are very lengthy, cover most of the city, and enter and exit the existing road corridor at several points. Second, Bogotá's citizens are not accustomed to making bus transfers, because less than 15 percent of the trips by bus imply a transfer (*3*). Third, existing demand was very high at 27,000 pphpd, but existing bus speeds were very low.

The main consequence of these constraints was that it was impossible to assemble convoys of buses that would run together for the entire length of the busway. It also meant that the design had to provide for several entry and exit points. In turn, this translated into two key operational features of the Troncal Busway. First, there would be two lanes in each direction so that buses could overtake other vehicles if necessary. Given that there would be no convoys, it was considered useless to force a bus to wait in line for a bus ahead to start moving. By allowing overtake, the operations of buses could be expedited. This would also allow a better handling of the several exit and entry points (*5*). Second, each bus stop or station was divided into four sections, identified by a letter. Each section grouped routes with a similar destination. In theory, passengers would learn which segment of the station to stand in, and bus drivers would only stop in that segment of the station. These modifications would enable the high volume of passengers to be handled in a faster and more orderly manner (*5*).

Given that the operation of a busway is complex due to the high number of passengers and buses, planners proposed the creation of an office for the exclusive handling of operation and maintenance of the Troncal, within the city Department of Transportation. The main functions of this office were to monitor, detect, and solve problems regarding bus and general traffic patterns, pedestrian and passenger movement, and stations and pavement maintenance. Additionally, this office would have enforcement capabilities through direct authority over 60 to 80 traffic police officers, and a staff of 50 people.

With everything in place, the theoretical capacity of the Troncal was 380 buses per hour per direction (phpd), which would be able to move 28,000 pphpd (*5*). This figure is not significantly above the 27,000 pphpd that moved in the corridor before the busway was built. However, before it was built, buses and general traffic shared, or rather competed for, the same road space. As a result, the speed during the morning peak was only 12 km/h (7.5 mph) northbound and 10 km/h (6.25 mph) southbound. Therefore, the main objective of building an exclusive busway was not to significantly increase passenger flow but to increase speed. This was immediately achieved after opening the busway because speed increased by almost 70 percent in both directions (*5*).

CURRENT OPERATION OF THE TRONCAL BUSWAY

The proposed office to oversee operation and maintenance was never created by the city. The Troncal, consequently, functions without this important office. Moreover, the traffic police were only present for a couple of months, while users adjusted to the changes implied by the new facility (*5*). Since then, police are only occasionally present, mainly when there is an accident; however, it can take several hours for police to arrive to clear the accident. Police may also show up when traffic lights stop working due to a power failure.

This situation, however dramatic, is not specific to the Troncal Busway. Rather, it is a reflection of the general situation in Bogotá. The city Department of Transportation altogether has a very limited capacity to plan and manage a transportation system for a city the size of Bogotá, largely due to insufficiently trained personnel and budget. Traffic police are scarce throughout the city and are mainly devoted to taking care of accidents and managing traffic at bottlenecks. They are less involved in enforcing traffic regulation (*7*). As a result, pedestrians and motorists frequently disobey traffic laws.

These transportation problems spill over into the Troncal Busway and are often exacerbated because the special office to operate the Troncal was never created. Therefore, the actual operation of the Troncal Busway is very different from the planned or theoretical model. First, buses stop several times at one station for passenger pickup or drop-off (however, buses rarely stop outside the stations). At the same time, passengers do not know in which section of the station they must stand because there are limited traveler information aids (*5*). This causes additional delays and excessive maneuvering by drivers to avoid stop-and-go traffic in the stations.

Second, lack of enforcement allows buses to occasionally use the general traffic lanes and the general traffic to use the busway. This tends, on average, to reduce the capacity of the busway, due to the interference of different types of vehicles and the competition for scarce space. Lack of enforcement also allows low-capacity buses to circulate in the busway, which also reduces the capacity.

Third, maintenance is scarce. For example, pavement can have potholes, pedestrian barriers can be damaged, and stations might have no lights. This interferes with passenger and vehicle flows and contributes to making the operation of the Troncal unsafe.

Fourth, the timing of the traffic light system is very poor. Large bus queues at some intersections cause several blocks of gridlock. Other research indicates that delays caused by poor traffic-light timing were almost nine times more likely to cause delays than passenger boardings and alightings (*8*).

Last but not least, the overall operation of the busway is unsafe. Accidents occur because of careless driving and because passengers do not always use the designated entrances to the stations, but try to jump the barriers and access the station at any point. Accidents also occur because buses pick up and drop off passengers not only in the lane adjacent to the station but also in the outermost lane (*9*). Interestingly, however, accident rates in the Troncal are lower in absolute terms than for other mass transportation corridors in Bogotá (*3*), and even lower if normalized for by numbers of passengers carried (*10, 11*).

ANALYSIS OF PASSENGER THROUGHPUT

During four continuous academic semesters, civil engineering students in the transportation engineering course at the University of Los Andes in Bogotá collected ridership information on the Troncal

Busway. In the last semester, students also collected information regarding vehicle speeds, boardings, and alightings. Passenger counts were conducted using manual point checks, in which students categorized every bus based on the number of passengers. Once a bus was assigned to a category, one of four students was asked to board the vehicle and count the real number of passengers. This was done to calibrate each category with an average number of passengers. This process was followed every semester. A high degree of consistency was found between the calibration for the categories from one semester to another.

Results of the passenger counts are shown in Table 1. The volume of passengers is consistently higher during the morning peak compared with the evening peak. The highest volume measured was 35,564 pphpd, in August 1998. This measurement was taken at an intersection in the middle of downtown, in an area that concentrates a large amount of employment. Several other measurements northbound are above 33,000 pphpd. The results also show that in the morning the main direction of travel is northward toward the CBD and along it. Flows in the opposite direction tend to be significantly lower. In the afternoon the pattern is reversed.

Several other transport studies in the city of Bogotá confirm these results. A recent transport study for the first three subway lines for Bogotá conducted point checks to determine passenger volumes at the busway (*2*). The counts reached 42,000 pphpd in the south-north direction at the busway intersection with 11th Street; however, little detail regarding the methodology for carrying out the count is provided.

In 1999 a demand modeling exercise for the first metro line was conducted, and passenger flows were measured in several corridors of the city. The results are shown in Table 2. Although the counts were done on different intersections than the ones shown in Table 1, the figures are similar, thus reinforcing the validity of the results. In this case, the maximum volume was 36,596 pphpd, slightly above the maximum figure shown in Table 1.

It is also important to show the evolution of ridership on the Troncal Busway over time (Table 3). Immediately following the opening of the first stage of the busway project in 1990, the southern end, ridership actually decreased slightly. This probably can be attributed to the change in bus routes that the opening of the busway implied, because small-capacity buses were moved out to other corridors, and to the fact that the project was not complete. Indeed, when the Troncal was completed in 1992, ridership increased to 32,500 pphpd. From then on, the flow continued to increase, except for 1999, when the Colombian economy was experiencing a deep recession.

The number of buses follows a pattern similar to that of passengers (Table 3) and increases with time, well above the 380 buses phpd considered to be the busway's design capacity. The average number of passengers per bus initially increased, but then as the number of buses grew faster than the number of passengers it started to decrease. Apparently, right after opening, the Troncal Busway became very profitable for bus owners due to the increased ridership. Because of deregulation and the lack of a government office to operate the Troncal, other owners sent their buses to use the busway, thus increasing competition.

Finally, it is important to point out that, thanks to the busway, speeds have increased substantially, as noted above. Specifically, before the busway was opened, average speed was around 12 km/h (7.5 mph). Immediately after opening, speed increased to 20 km/h (12.5 mph), then decreased slightly to 18 km/h (11.25 mph) (*5*). By 1999, however, measurements made by students of the University of Los Andes showed average speeds close to 24 km/h (15 mph). Considering that the average trip in Bogotá is only 9 km (5.6 mi), these improvements in speed translate into savings of 22.5 min per trip on the busway.

PASSENGER FLOW: A COMPARISON

Busways have been reported to move up to 28,000 passengers phpd (*1*). The Troncal Busway moves a volume significantly above this figure and compares very well with the figures for metros (Figure 1). The Troncal passenger flow, consequently, contributes evidence to the argument that busways are a reasonable substitute for rail transit, given that they can move high volumes of passengers per hour, and thus serve the peak period even in very dense cities, such as Bogotá. However, the argument may differ if service supply figures rather than only service consumption figures are also taken into account.

Although the Troncal moves a high volume of passengers, most transportation corridors in Bogotá also move high flows, even if buses have to move in mixed traffic (Table 4). The Troncal is currently the only busway in the city, and there are no metro lines. Even if some of the flows are close to those of the Troncal—and superior to most busways in other cities in the world—the speeds in these corridors are lower (*5, 9*).

WHY IS THE TRONCAL BUSWAY ABLE TO MOVE SO MANY PASSENGERS?

As discussed above, many of the operational features of the Troncal Busway are radically different from what the designers planned. Gardner (*12*) found that for a busway to achieve high performance and

TABLE 1 Passenger Flows at the Troncal Busway at Various Intersections (pphpd)

Date	Morning Peak			Evening Peak		
	13th St.	19th St.	45th St.	13th St.	19th St.	45th St.
August '97						
South-North		34,296	33,645		8,056	29,692
North-South		4,595	15,640		21,343	21,177
February '98						
South-North		34,001	33,987		13,663	16,011
North-South		9,399	15,844		19,163	26,215
August '98						
South-North	32,555	35,564		6,682	10,159	
North-South	7,272	8,160		15,852	18,332	
February '99						
South-North	30,759			7,226		
North-South	5,370			13,925		

TABLE 2 Passenger Volumes on the Troncal Busway at Various Intersections According to Cal y Mayor and Associates (1999)

	44th South St.	Communes Ave.	26th St.	32nd St.	63rd St.
	Morning Peak				
South-North	34,209	36,596	34,779	34,524	26,247
North-South	9,925	8,528	12,870	9,276	26,671
	Evening Peak				
South-North			9,276	10,569	12,592
North-South			22,495	22,496	26,278

TABLE 3 Evolution of Maximum Flow over Time in the Troncal Busway

Year	Passengers per hour per direction	Buses per hour per direction	Average number of passengers per bus
1986 (prior to opening busway)	27,000	715	38
1990 (South part of busway opens)	25,000	377	66
1992 (North part of busway opens)	32,500	450	72
1993		604	
1997	34,296		
1998	35,564	627	57
1999	30,759	562	55

Source: Acevedo (*5*) and authors' counts.

realize its full potential, a good design has to be complemented by operational and management measures. These latter factors, as seen, are absent in the Troncal Busway (*12*). A casual observer could think that the chaotic way in which the Troncal Busway is operating should imply lower flows than those found in busways elsewhere with higher operating standards. Despite this, the busway is able to move more passengers than all busways for which information was available.

Moreover, Gardner found that "with very heavy flows, however, buses can arrive at a rate of one every 15 s, producing a constant 'call' which renders simple vehicle actuation inoperative" (*12*, p. 186). In the Troncal Busway, the average headway by vehicle during the morning peak is only 6 s. Buses, however, achieve speeds substantially above those reported by Gardner, and move many more riders than expected.

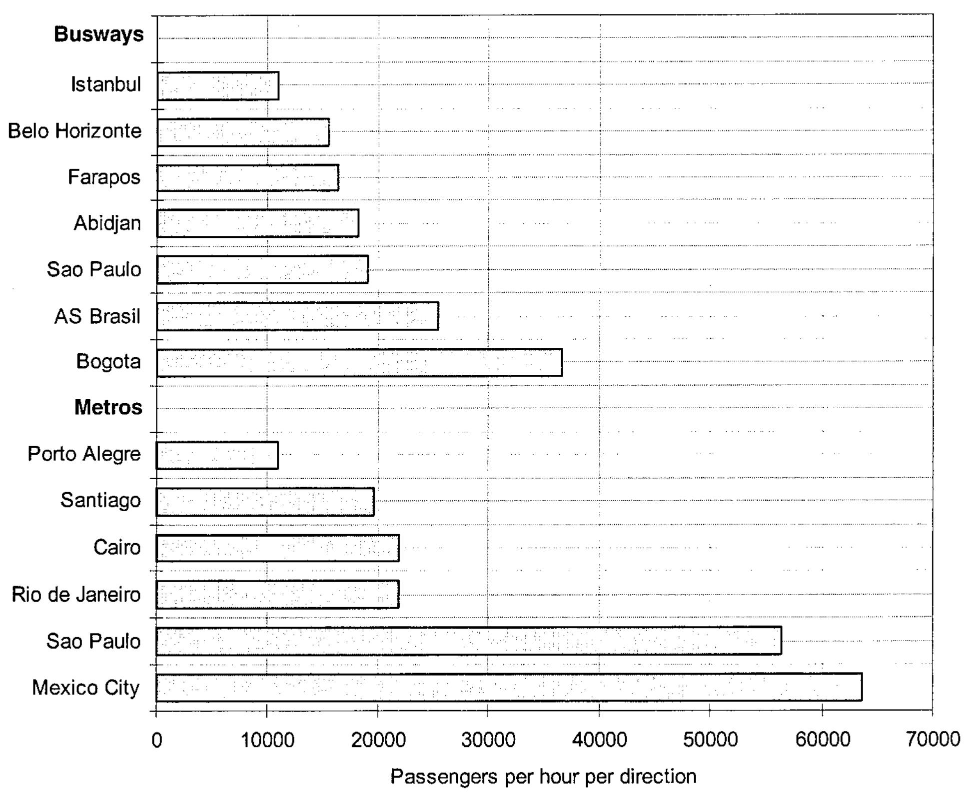

FIGURE 1 Maximum passenger flows for selected metros and busways [source, Gardner (*12*) and authors' data].

TABLE 4 Passenger Volumes at Various City Corridors

Corridor	Volumes (pphpd)
Troncal Busway	36,596
7th Avenue	10,657
80th Street	30,405
68th Street	18,757
Avenida de las Américas	32,647
10th Avenue	29,066

Source: Cal y Mayor and Associates, unpublished data, and authors' data.

Why, then, is the Troncal Busway able to move such high passenger flows? According to this research, it is the combination of three sets of factors: first, the high competition among bus operators; second, the design of the busway; and finally, the large platoons in which the buses move through the busway.

High Competition Among Bus Operators

Bus service in Bogotá is almost completely deregulated for all practical purposes. Although the government establishes the routes and frequencies, as well as the fare, there is a high level of competition among bus operators. Each route is in itself a small monopoly assigned to a bus company, that in turn affiliates individual bus owners who run their buses on the route (*9*). However, because routes are on average 25 km long, they end up being identical in almost 90 percent of the course (*3, 6*). Consequently, many buses from different routes compete through most of the trajectory (*6*). This is particularly true in the main transportation corridors, such as the Troncal Busway.

Competition is strengthened by the local structure for the provision of transportation services. Buses are typically owned by one or more people (*6*), and the profitability of each bus is directly proportional to the number of passengers carried per day. Buses are affiliated with bus companies that receive a monopoly on routes through the city from the government. Companies have an incentive to affiliate as many buses as possible, because their income is derived from fees and not from passengers. In the late 1980s and early 1990s,companies lobbied effectively for the introduction of more buses to the city streets. The number of passengers, however, did not increase accordingly (*6*), and as a result competition among bus operators became even stronger.

In the Troncal Busway, this high competition translates into drivers motivated to lose as little time as possible and to operate the buses as quickly as possible. Fieldwork in the busway shows that drivers will try to overtake stopped buses, and as soon as they collect or drop off their passengers they start to advance again in the search for more passengers, either in the same station or in another. Elsewhere, we showed that low dwell times have been attributed to the highly competitive environment of the busway (*9*). This clearly expedites the movement of buses in the busway and contributes to the high passenger flow observed.

Competition also has an important implication in terms of safety. Driving can be careless, bus maintenance can be poor, and some maneuvers can endanger the safety of other buses or pedestrians. Careless driving is reinforced by the absence of police and of the planned office for operating and managing the Bogotá busway. Although accidents occur, as shown above, accident rates in the Troncal Busway are lower than those found in other corridors of the city, where competition among bus operators takes place in mixed traffic conditions. Hence, although the negative consequences of high competition are not condoned, the results suggest that busway technology can contribute to lower accident rates in the absence of other measures such as driver education and police enforcement.

Busway Design

Because busways separate buses from the rest of the traffic, they tend to increase the volume of passengers moved and the speed of the buses (*1, 12*). In essence, buses that tend to stop and start frequently are assigned a special segment of the road for their exclusive use. In the Bogotá busway, this explains in part the high flows of passengers observed. However, two other characteristics of the design are also crucial in this regard: the existence of two lanes per direction, which allows overtake, and the long stations that order boardings and alightings and that allow six or more buses to pick up and discharge passengers simultaneously.

First, the busway has two lanes in each direction not only at the stations but also along its alignment. This allows overtake at any moment. Buses, therefore, have to stop or travel at the speed of the slowest moving buses for shorter amounts of time, thus reducing delay times. Furthermore, the two lanes allow de facto express and limited stops services. Field observations suggest that if only a few passengers are in the station, and if no one on board requests a stop, drivers tend to express their bus and stop only if necessary, many times one or two stations ahead. This behavior is further fueled by competition, because at times it is more profitable to overtake several buses, using the additional lane, and collect more passengers ahead.

Second, stations have ordered, in general terms, passenger boarding and drop-off, because with a few exceptions passengers and buses use them. Before the busway was built, buses could pick up and drop off passengers on any point along the corridor. With the stations, passengers are grouped and buses have to stop every 500 m. Stations, moreover, are divided into four segments so as to group passengers with a common destination. This feature, however, does not work adequately because of lack of information for passengers and bus drivers, insufficient enforcement, and the high competition. This implies that buses might have to stop several times per station, thus reducing the gains from having a station.

Stations are also 100 m long and allow six or more buses to pick up and discharge passengers simultaneously. Once a bus finishes, it can use the second lane to leave the station and continue its route. Another bus, moving relatively slowly in this lane, can use the space left by the first bus to collect passengers who are flagging it. Thus many buses per minute can use the station.

In the stations, however, the second lane can have a negative effect as well. Occasionally buses cannot approach the lane closest to the station to pick up or drop off passengers. This is mainly because of the high number of buses using the busway—a number well above its design capacity—occasionally congesting the stations. Causing passengers to cross one of the lanes of the busway is clearly dangerous.

Bus Platooning

The existence of two lanes per direction and the large stations does not fully explain why the Bogotá busway moves so many buses and passengers. An explanation of how the buses actually flow through the busway remains. Given that on the average 600 buses phpd use the corridor, or one bus every 6 s, an initial hypothesis could be that the busway is completely filled with buses flowing at low speeds, analogous to a bus-originated conveyor belt.

This, however, is not the case, as the variation in the vehicle flow for counts made every 2 min shows (Figure 2). The variations are very large, ranging from 6 to 26 buses every 2 min. Even for continuous periods, the variations are large. This discards the conveyor belt hypothesis; otherwise, variations should not be as extreme. Uniform flow of buses is also difficult to achieve due to the high need to coordinate buses, traffic lights, and boardings and deboardings. Indeed, dwell time will be a critical variable, and coordination of all buses in the corridor according to the longest dwell time will be needed.

It is believed that, rather than a continuous flow of buses, the Troncal Busway operates in platoons. Due to its design, the busway allows the movement of a large number of buses in a very short period of time. Fieldwork done as part of this research suggests that the average size of the platoon is in the range of 12 to 16 buses. This implies a maximum capacity of 1,100 to 1,500 passengers per platoon and an average throughput of 800 to 1,050 passengers. It is estimated that a platoon passes on average every 96 s. This would imply a maximum capacity for the busway of 56,000 pphpd. However, this figure is not reached currently because buses are not used at their maximum capacity. Moreover, it is probably impossible to achieve due to crowding of the stations and high vehicle acceleration and deceleration times.

The platoons, however, are not stable; that is, they do not consist of the same buses all throughout the busway. Rather, buses change from one platoon to another. This pattern is suggested by the high variations in the number of buses every 2 min (Figure 2), which indicate that the platoon size changes constantly. Buses indeed change from one platoon to the other, but they do not do it instantaneously; rather, they do it over several 2-min periods.

Sometimes buses lag behind their original platoon. It is possible that being at the end of the platoon implies picking up fewer passengers, and this creates an incentive for lagging behind. By doing so, these buses become the front buses in the next platoon and thus can compensate their income. After a while, other buses will be in front of these, thus starting the cycle again. Platoon stability is also affected by changes in the demand profile over time and by the traffic signals, which affect running time.

The time-distance diagram for 11 buses shown in Figure 3 further corroborates this behavior. Civil engineering students at University of Los Andes did the fieldwork in February 1999. Every student boarded a vehicle with a difference of approximately 2 min between one another. On entering the vehicle, students had to record the type of bus and number of onboard passengers. Thereafter, each student recorded alightings, boardings, dwell time, and lane on which the bus dropped off or picked up passengers. The time-distance diagram in Figure 3 shows that the trajectory for each bus crosses several times the trajectory of other buses. Thus, buses overtake one another several times during the length of the journey from south to north, thereby indicating that buses change platoons in a pattern similar to the cycle described above. It is interesting to note that between each bus shown there are 10 to 20 buses that were not recorded. This is due to the 2 min between the successive boardings by students and the prevailing low headways.

CONCLUSIONS

The Troncal Busway is able to move extremely high levels of passengers and buses due to three factors:

- High competition among operators, which induces them to lose as little time as possible and complete operations rapidly;
- A two-lane design that allows buses to overtake one another, and stations that allow many buses to stop at the same time, improving efficiency; and
- Buses flowing in large convoys or platoons, with a total capacity similar to a metro and with a rate of frequency similar to metro rail lines.

The Troncal Busway shows that even in a city with low institutional capacity in the transport sector (7), busway technology can work adequately. In Bogotá, the lack of institutional capacity is the main cause of planning and transportation problems that affect the entire city, including the Troncal Busway. Driving is careless because there is little enforcement and education. Traffic lights are not timed adequately because the city does not have enough engineers. Streets are poorly maintained. Pollution is high due to problems carrying out annual motor vehicle inspection (7). Finally, many public facilities are not aesthetically pleasing due to poor design or lack of funds. Accord-

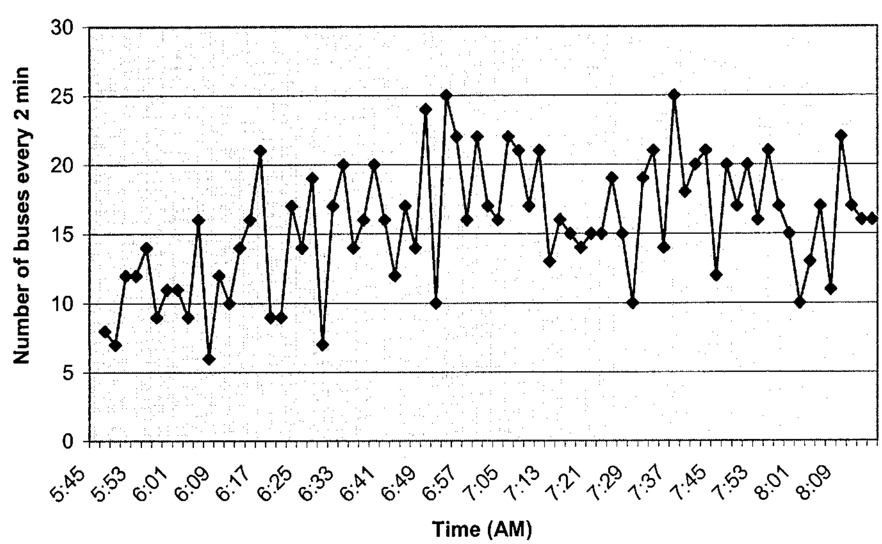

FIGURE 2 Number of buses every 2 min, south-north direction, morning peak.

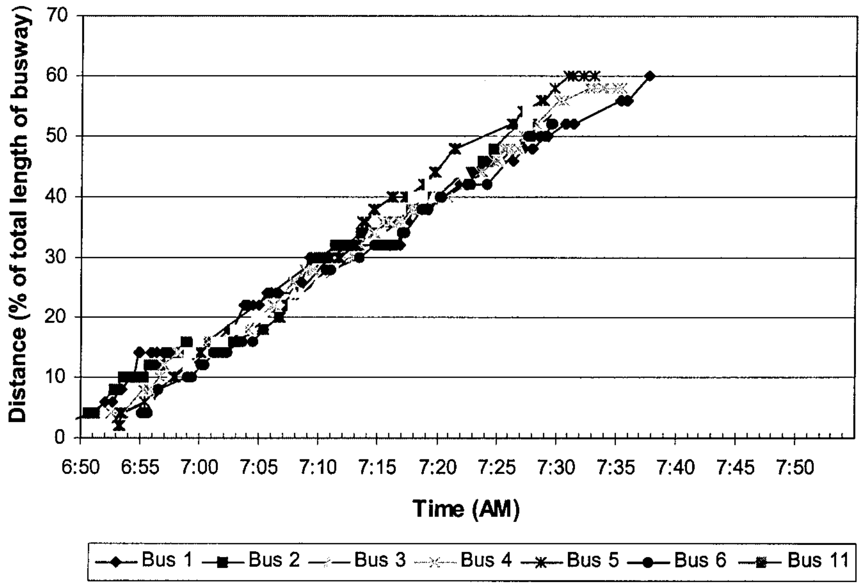

FIGURE 3 Time-distance diagram, south-north direction, morning peak.

ingly, in the busway driving is also careless, traffic lights are not timed, maintenance of the facility is poor, the pollution level is high, and the aesthetics of most transport facilities are not good.

Despite this chaos and the lack of an office in charge of operations and maintenance, the Troncal Busway moves more passengers than all busways for which data were available. This shows that the busway technology is robust and can be used in other cities that lack administrative capacity in the transport sector. Clearly, however, the negatives of the current busway need to be addressed and solved. Specifically, a minimum level of law enforcement and of operations and maintenance is needed to improve passenger and pedestrian safety.

Currently the city is undertaking a new project, Transmilenio, which may change many of the negative aspects of the busway shown here. A new fleet of large-capacity buses, with cleaner technology, will be used; the stations will require that riders pay fees on entering the station; and service will be planned and managed by a city company. Moreover, the project implies not only upgrading the current busway, but also building 100 km of new busways. Although these are certainly important improvements, the new scheme will imply abolishing competition and reducing the size of the fleet and consequently the frequency of service. Under these circumstances, the question that remains to be answered is whether the capacity of the new busway will be sufficient to move as many passengers as the current busway. Preliminary designs indicate it is possible, but only the actual operation of the system will prove or disprove these assertions.

In sum, the research presented here underscores a larger point: transit planners face multiple trade-offs when designing a system. Solutions need to be tailored to local operating conditions and priorities.

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Promoting More Efficient Use of Urban Areas in Developing Countries

An Alternative

Renato da Silva Lima, Antônio Nélson Rodrigues da Silva, Cintia Yumiko Egami, and Luiz Francisco Zerbini

Planners can apply a relatively simple and user-friendly tool to control the expansion of urban areas in developing countries. This tool, presented here, is based on a traditional accessibility index, which may be taken as a measure of urban development. The entire process of construction and analysis of the networks based on the accessibility index was carried out using a geographic information system for transportation (GIS-T). The tool has been tested in São Carlos, a medium-sized Brazilian city, in which the effects of some proposed real estate developments on the accessibility patterns have been studied. The results of this application show that the tool is suitable for selecting the best site for a new development among many alternatives, promoting more efficient use of the urban area.

Urban sprawl is a serious problem faced by cities worldwide and is a frequent topic of research in developed countries. The costs of urban sprawl and the search of methods and techniques to control it are some of the issues in which several authors have worked on the last 30 years, as mentioned by Souza and Silva (*1*). A study that illustrates well the concerns of urban policy makers in the 1970s is *The Costs of Sprawl* (*2*), one of the most significant studies of alternative urban development patterns. According to Silva et al. (*3*), in the late 1980s and in the 1990s, some authors reviewed the literature and presented different conclusions about optimal urban forms. Newman and Kenworthy (*4, 5*), for instance, presented three strategies that can save energy through the improved use of urban land—densification, centralization, and traffic restraint policies that include improvement of public transport.

In general, the studies of urban sprawl were developed in the industrialized countries looking for tools to control and to reduce the sprawl itself and some of its undesirable effects. Its reduction could decrease urban transportation needs (favoring in many cases nonmotorized modes) and fuel emissions, as well as the total length of several infrastructure networks. In Brazil, urban sprawl is a reality in several different cities, including the medium-sized ones, in which the lack of consistent planning exacerbates its consequences.

The fact that the developing countries have not, in general, paid much attention to the problems of urban sprawl because of different pressures arising from social and economic problems was a stimulus for this study. The objective is to present a relatively simple and user-friendly tool that planners can use to control the expansion of urban areas in developing countries. The analyses, performed in a geographic information system (GIS) environment, were based on a traditional accessibility measure, which is the mean separation between all intersections in the entire network of streets, and may be taken as a measure of urban development.

The main advantage of this tool is to allow for previous analyses of the possible effects of new real estate developments, in terms of changes in the global accessibility level. This characteristic of the tool makes it possible to identify, among many alternatives of new developments, the one that will produce the smallest impact in the global accessibility level of the studied city. The application of this tool is expected to be useful for city growth control, considering that developments that are not desirable for the city as a whole can be detected before they are implemented. In this way, it is possible to analyze the effects that any change introduced in the urban area would produce on its overall accessibility, having as a target the increase (or the smallest reduction) in the accessibility level.

The tool has been tested in São Carlos, a medium-sized Brazilian city, in which the effects of some proposed real estate developments on the accessibility patterns have been studied. The results are presented here, including a brief description of the approach used for the analysis of new developments; a description and the results of the evaluations of the best place for new real developments in São Carlos; review and discussion of the results of the applications; and conclusions.

A PROCEDURE FOR THE ANALYSIS OF URBAN NETWORKS

The first issue in this study was to build or to identify some sort of analytical tool for evaluating the urban networks. It had to be simple, because of the poor data usually available in most cities of developing countries, and flexible enough to allow comparisons among different situations. Some transportation accessibility measures fit perfectly into this definition, particularly those that deal only with the graphic elements of the networks.

The transportation accessibility concept has many distinct definitions, based on different theories formulated during more than 100 years of research on the topic. Some of these definitions can be found in well-known articles, such as those written by Ingram (*6*) and Morris et al. (*7*), and also in books, as in Bruton (*8*). In general, accessibility could be taken as a measure of the effort needed to overcome the spatial separation between the opportunities available to a person or group of persons to perform their regular activities of work, leisure, and so on The access of individuals to places of work, study, leisure, and public services also has been studied by the few researchers who work on the subject in Brazil [such as Sanches (*9*), Raia and Silva (*10*), Lima (*11*), and Silva et al. (*3*)].

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Sanches (*9*), for instance, suggested that the accessibility measurement may reveal the difficulty level experienced by the population of a certain area in reaching the job opportunities and social services of the studied city. Raia and Silva (*10*) stressed that accessibility depends not only on the land uses throughout the urban area but also on the characteristics of its entire transportation system. In fact, accessibility analysis should take into account several factors, such as time of day, trip purpose, and others. Depending on the way the accessibility indicators will be used, their complexity may vary considerably, ranging from simple, straight distance measures between trip origins and destinations to complicated, combined indexes.

Accessibility also plays an important role in land values. Considering that a location with high accessibility levels is usually more attractive than one with low accessibility levels, the former tends to have higher market values than the latter. Hence, any change in the accessibility levels of a region will certainly influence the land values in the area. Moreover, an increase in the accessibility levels of an area is generally a sure way—although not the only way—to stimulate the area's development at both urban and regional levels. On the other hand, Lima (*11*) observed while working with the issue in a developing country that any action that reduces, in relative or absolute terms, the accessibility of an area may have social implications, especially if there already are other drawbacks in the region.

Returning to the international scenario, more recent works on the subject have been written by Allen et al. (*12*), Tagore and Sikdar (*13*), Davidson (*14*), Helling (*15*), Silva et al. (*16*), Sathisan and Srinivasan (*17*), and Schoon et al. (*18*). The work of Allen et al. (*12*), however, has to be emphasized here because it is the essence of the analytical tool now proposed for the evaluation of urban networks. Likewise, the work of Allen et al. (*12*) was developed after Ingram (*6*) and his concepts of relative and integral accessibility. Although the first accessibility concept was defined as the level of connectivity between two points, the second one was explained as the level of integration of each point to all other points of a network, as shown in Equation 1.

$$A_i = \sum_{j=1}^{n} a_{ij} \qquad (1)$$

where a_{ij} is the relative accessibility between Points i and j, and A_i is the integral accessibility of each Point i.

In the same way that Ingram (*6*) found the integral accessibility by the integration of the relative accessibility of all other points of the network, Allen et al. (*12*) developed a new index for the entire network, based on the integration of all integral accessibility values found for each point in the studied area. The new index, called global accessibility (E) is a natural extension of the original work of Ingram (*6*), and it is able to quantify the accessibility level of an entire region, allowing for comparisons of regions and not only of points within a region. Equation 2 shows Allen's index, whereas Equation 3 defines the global accessibility.

$$A_i = \frac{1}{N-1} \sum_j C_{ij} \qquad (2)$$

$$E = \frac{1}{N} \sum_j A_i \qquad (3)$$

where

A_i = accessibility of Zone i,
N = number of zones used in the calculation,
C_{ij} = cost perceived by the traveler between Zones i and j, and
E = global accessibility of N zones.

A common characteristic of the two measures is that in both cases the authors defined accessibility only as a measure of the effort to overcome the spatial separation between points within an area. They did not take into account demand-supply conditions or user behavior components in their models. This made the models very simple measures because only one type of information (either travel distances or travel times) is needed for calculation. In addition, even though the costs considered in the original studies were travel time or distance, other elements may be added as components of the cost.

The work of Allen et al. (*12*), however, has been severely criticized by Pooler (*19*), who stated that the index is nothing more than the average travel time, which definitely is not new in the transportation planning literature. The arguments of the analyst may be right, but they do not seem strong enough to destroy the utility of the accessibility measure when no data other than the average travel time or distance are available, as is often the case in cities in developing countries. Moreover, when comparing the use of two accessibility measures with different complexity levels in medium-sized Brazilian cities, Raia and Silva (*10*) found similar results in terms of zone ranking. One of the measures considered in that study was Allen's index, whereas the more complex measure was a gravity-type model proposed by Davidson (*14*). Raia and Silva (*10*) concluded that, despite its simplicity, the accessibility index based on the mean spatial separation is good enough to represent the accessibility levels of the medium-sized Brazilian cities.

It was assumed therefore that the accessibility measure proposed by Allen et al. (*12*) is suitable for the purpose of this study, based also on the following points: (*a*) the objective of this work is to present a technique or analytical tool that may help to use the urban areas of developing countries in a more efficient way; and (*b*) a way to reach the stated objective is through an increase in the intraurban accessibility levels. Because the use of Allen's global accessibility index in the way suggested here makes it possible to foresee the impact produced by any new real estate development before its actual implementation, it is possible to compare different alternatives of design and location for the development.

Once the accessibility index that could be the basic element for the proposed analysis had been defined, the next step was to develop the entire concept, what has been done through an application in a real city. The next section describes the methodology used for the accessibility calculation and compares the effects of new real estate developments proposed for the city of São Carlos in Brãzil.

CALCULATION OF THE ACCESSIBILITY INDEX

São Carlos, the case studied here, is a medium-sized city with approximately 180,000 inhabitants located in the central area of the Brazilian state of São Paulo. The impacts of the expansion of the urban network are analyzed for several scenarios, based on the accessibility values obtained with the index proposed by Allen et al. (*12*), which measures the mean spatial separation of zones or points. In the present case, the values are estimated from every node to all other nodes of the urban network of streets. For the purpose of this work, a node is the initial and final point of any link belonging to the network, and it may be at an intersection or at the extremity of a link without any other connections at the end.

The actual travel distance through the network was assumed as the cost perceived by the traveler, although Allen et al. (*12*) have worked with travel time in their original work. There is no reason to believe that this assumption is not valid, considering that we are dealing with a medium-sized city in which the congestion levels are not crucial. In this case, travel times and distances may be seen as equivalent for the estimation of accessibility values.

Accessibility Index in São Carlos

The calculation of the accessibility values in the city of São Carlos required a file containing the network of streets, which has been obtained with a GIS for transportation (GIS-T) software by the representation of the centerlines of streets and avenues (Figure 1). A GIS-T is able to interpret these lines and the associated nodes as an actual network, in which shortest-paths calculations can be performed. This characteristic is extremely useful for the accessibility evaluations that were conducted here.

Using the shortest-path routine available in the GIS software, the distances from every node to every other node of the network have been calculated. The results, stored in a matrix file, have been used in the estimation of the accessibility values, after the computation of the column sum values and their division by $N - 1$ [more details can be found in Raia and Silva (*20*)]. The results indicate the mean distance (in kilometers) from any node to any other node of the network.

Nodes with low values of accessibility have a high accessibility level (the average distance from that node to any other node is low, which means that on average the node is not far from all other nodes). The average of all accessibility values found for the nodes gives the global accessibility value for the city, named E by Allen et al. (*12*). The values of E are clearly dependent on the accessibility values found for the nodes.

New Developments

After some adjustments of the network file and the estimation of the global accessibility index for the city of São Carlos in its present network configuration, the analysis of the impacts that new developments could produce on the index (and, as a consequence, on the city) was begun. Six new developments were individually introduced in the network, each containing 280 additional nodes. The proposed changes, shown in Figures 2 through 7, belong to two distinct categories. Scenarios 1, 2, and 3 are built filling in the empty spaces of the existing network, whereas in scenarios 4, 5, and 6 the new developments are only joined to the present network. In the second case, there are no empty areas between the old and the new developments, following what is done in practice. The global accessibility index was then calculated for the six scenarios.

The global accessibility index was also estimated for circular cities with the same number of intersections as the existing city and its variations (the six alternative scenarios). These are assumed to be ideal network configurations, because the links are evenly distributed (following the 100-m pattern usually found in Brazilian cities) and there are no large empty spaces within the network. These are conditions that reduce the average distance calculated in Allen's accessibility

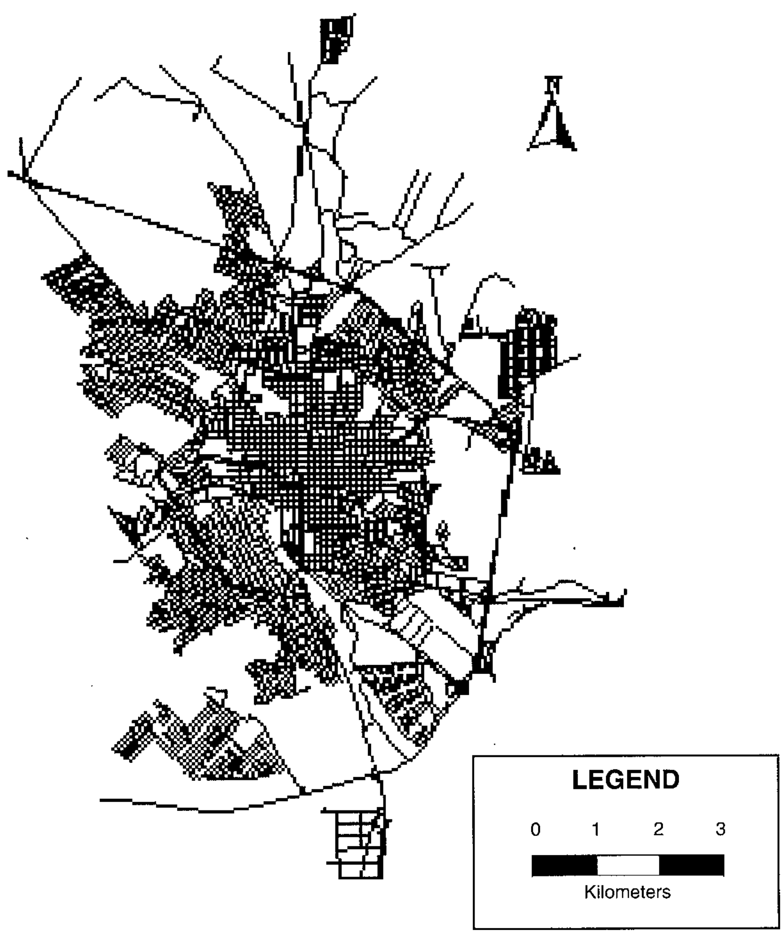

FIGURE 1 São Carlos, actual urban network system.

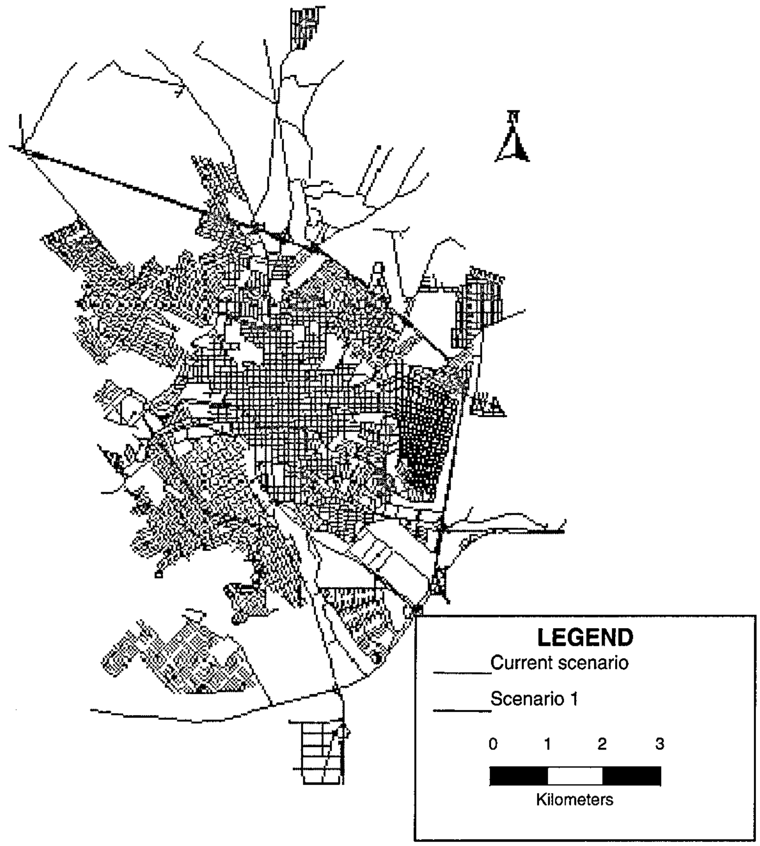

FIGURE 2 Modified Network 1.

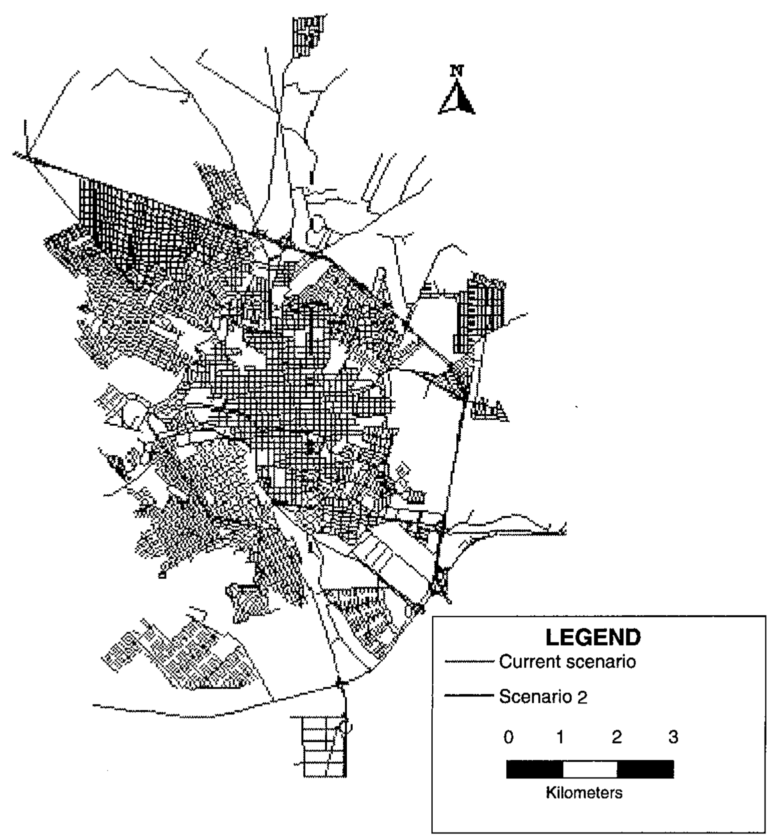

FIGURE 3 Modified Network 2.

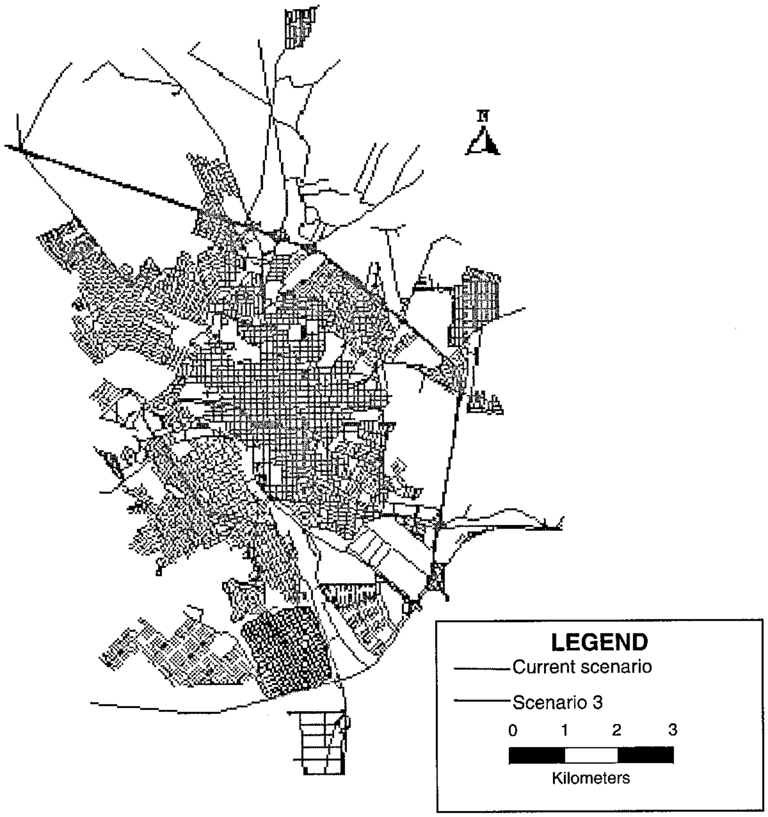

FIGURE 4 Modified Network 3.

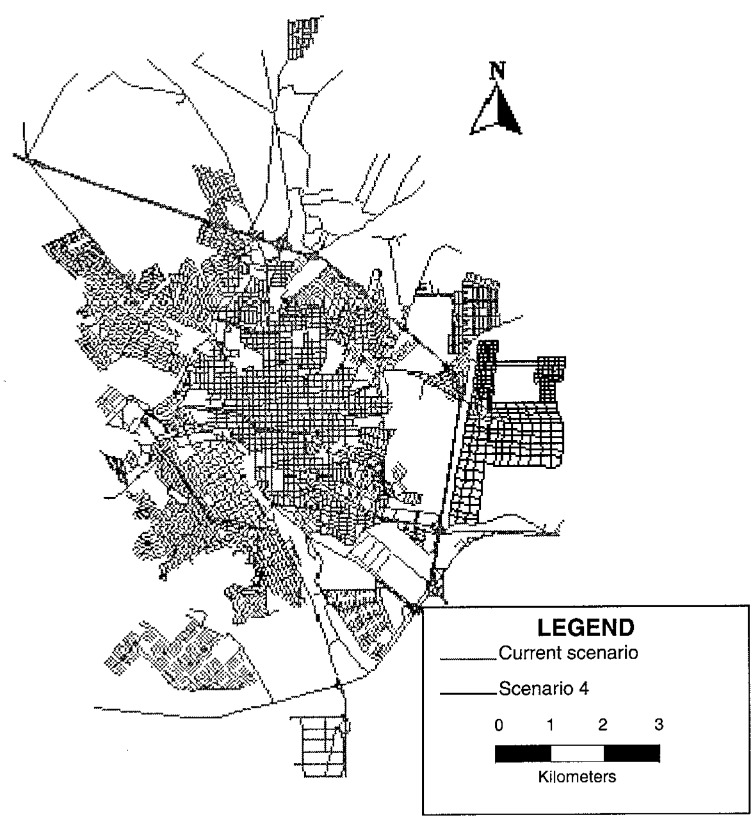

FIGURE 5 Modified Network 4.

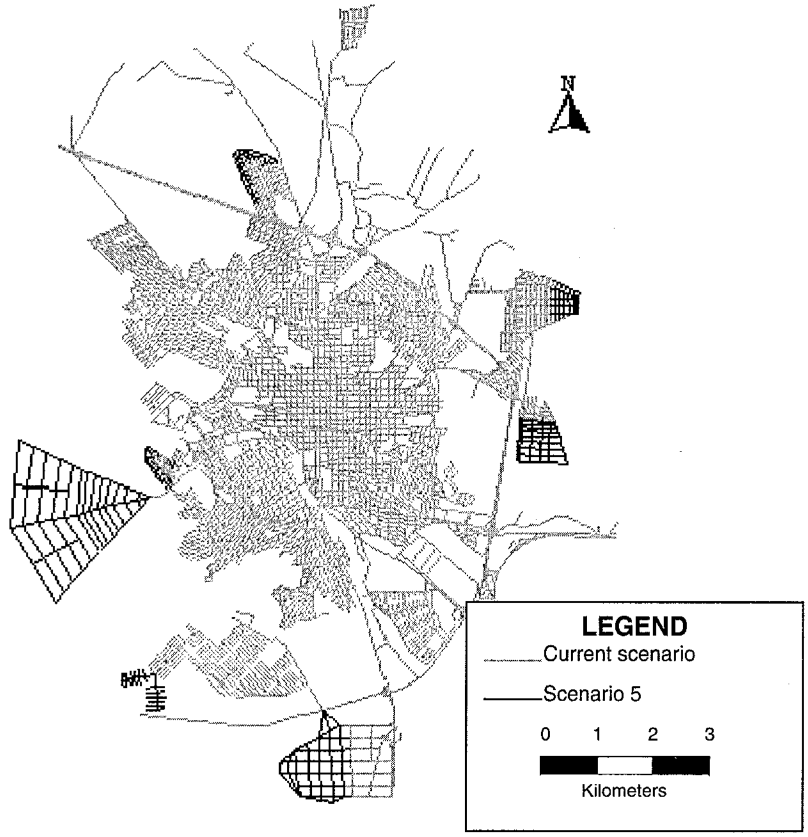

FIGURE 6 Modified Network 5.

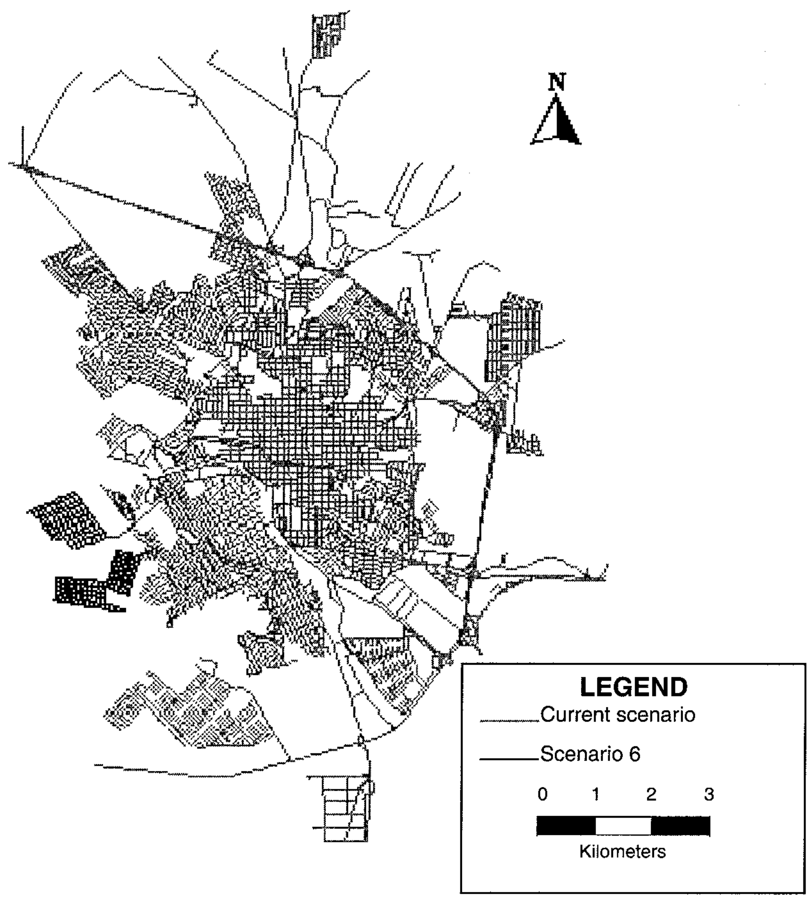

FIGURE 7 Modified Network 6.

index for each node and, as a consequence, the global accessibility index for the entire city.

The global accessibility index for circular cities is taken here as a reference value for ideal network conditions. It can be estimated by Equation 4, obtained by Lima (11):

$$E = 0.0727 \cdot I^{0.4994} \quad (4)$$

where E is the reference index and I is the number of intersections in the circular city.

ANALYSES OF THE RESULTS

The global accessibility values described in the previous section are shown in Table 1 for all cases considered. In this table, the number of nodes in each scenario are also shown, along with comparisons of the real and reference conditions, which are presented as percentages in the last two columns of the table. The values in the Variation 1 column are obtained by the division of the global accessibility index of each scenario by the same index for the current network configuration. The values in the Variation 2 column are obtained by the division of the global accessibility index of each scenario by the same index found for the circular cities (reference index).

The analysis of Table 1 shows a small variation in the values of Variation 1 for scenarios 1, 2, and 3, in which the new developments have been built in the empty areas of the current network. The change is so expressive that the values are negative in cases 1 and 3 (−1.22 percent and −1.12 percent, respectively). This decrease in the global accessibility index means an increase in the accessibility levels of the city, showing that it is possible to improve the global accessibility of the city even considering the growth of the network resulting from the addition of a new development.

The importance of the location of new developments is also made clear by the analysis of the values of Variation 1 found for scenarios 4, 5, and 6. In those cases, the index increases significantly (2.73 percent, 4.84 percent, and 2.45 percent, respectively), showing a reduction in the accessibility level of the entire city for those scenarios.

The determination of the best sites for new developments is made possible by the analysis of the Variation 2 column, in which real accessibility values are compared with the reference values found for circular cities. The variation found for cases 1, 2, and 3 is around 7 percent, which is smaller than the 12 percent found for the three other scenarios. It is important to stress that scenarios 4, 5, and 6 are those in which the new developments are simply joined to the existing network. The current configuration of the network also has a high value for Variation 2 (11.19 percent). This may suggest that new developments built in the empty areas inside the existing network can improve the global accessibility level of the city, as already shown by cases 1, 2, and 3. In these scenarios, the actual accessibility index approaches the reference index.

It is important to mention that the new developments have the same value for the reference index (5.04 km) because they all have the same number of nodes in the network.

CONCLUSIONS

The authors' objective was to present a relatively simple and user-friendly tool that planners can use to control the expansion of urban areas in developing countries. This tool, which is based on a traditional accessibility index, was tested in a medium-sized Brazilian city (São Carlos) by analyzing the impacts produced by six new developments.

The accessibility index used here, which is basically an average travel distance, seems to work well for the kind of analysis proposed in this study. Although it is a quite simple formulation, it may be used to compare the accessibility levels of different situations in the same city, as was done here. The use of direct variables (travel time or distance) makes it quite easy to understand. Considering the difficulties of data collection and management and the fact that these data usually are not available in medium-sized Brazilian cities, the use of simple procedures for urban and transportation planning is not only accepted but also advised.

The results show that the global accessibility index E can be applied as a supplementary tool to choose the best location for new real estate developments. In the case studied here, the scenarios in which the new developments were located in the empty spots in the interior of the existing network led to a smaller increase in the global accessibility index values of the city than scenarios located outside the network. In two cases, the results of the inclusion of new developments pointed to reductions in the value of E, which means an improvement in the whole accessibility level of the city. This is a consequence of the location of the development, which may reduce the mean travel distances, favoring, in this case, nonmotorized transportation modes.

The results also suggest that the use of the procedure presented here for the selection of the best location for new developments can help the city to approach the reference values encountered for circular cities. In the case studied, the location of the new development could be responsible for a decrease from the current value of 12 percent of variation to only 7 percent.

The main conclusion of this work is that an accessibility measure can be used as an urban planning tool, through the analysis of the

TABLE 1 Comparative Values of Accessibility Index

Scenario	Number of Nodes	Index E (actual) (km)	Index E (reference) (km)	Variation 1 (%)	Variation 2 (%)
Current	4,576	5441	4893	0.00	11.19
1	4,856	5374	5040	-1.22	6.63
2	4,856	5487	5040	0.85	8.86
3	4,856	5380	5040	-1.12	6.74
4	4,856	5590	5040	2.73	10.89
5	4,856	5704	5040	4.84	13.17
6	4,856	5574	5040	2.45	10.59

$$\text{Variation 1} = \frac{\text{Actual Index (new scenarios)}}{\text{Actual Index (current scenario)}} - 1$$

$$\text{Variation 2} = \frac{\text{Actual Index (all scenarios)}}{\text{Reference Index (all scenarios)}} - 1$$

impacts produced by new developments on the global accessibility levels of the city. The comparison of the E values obtained in the actual city with those of a hypothetical reference city makes it possible to estimate the influence of the new development on the accessibility value of the entire city. In this way, the city administration can measure the effects of alternative locations for new developments, looking for those options that improve the global accessibility level of the city. This is a simple way to benefit the whole community without stopping the natural development of the city.

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Bus Accidents in India, Nepal, Tanzania, and Zimbabwe

T. Pearce, D. A. C. Maunder, T. C. Mbara, D. M. Babu, and T. Rwebangira

Countries of the developing world are characterized by rapid urbanization, high growth rates of traffic and congestion, and decreasing regulation of public transport. Because the majority of the developing world's inhabitants depend on public transport services for their mobility needs, safe, effective, and efficient public transport is essential to ensure adequate and affordable accessibility and the sustainable development of livelihoods in the rural and urban sectors. The operational environment of the public transport sector in Nepal, India, Tanzania, and Zimbabwe is examined, as well as the extent of accidents involving public transport vehicles and the likely causes. Finally, recommendations are made to reduce both the severity and the number of public transport accidents.

Worldwide, there are estimated to be approximately 1 million road accident fatalities and 10 million people injured annually, with many of the injuries leading to long-term disabilities (*1*, Tables 2 and 4). Almost 70 percent of these accidents occur in the developing or emerging world. Although the number of fatalities in industrialized countries is generally declining, the opposite is true elsewhere. If account is taken of levels of motorization by expressing accident statistics as rate per registered vehicle, then less developed countries (LDCs) have rates at least 10 to 20 times higher than the industrialized countries with the lowest accident rates. The worst countries in these terms have fatality rates 100 times higher (*2*), as shown in Figure 1.

Considerably higher proportions of persons who are (reported as) injured in road accidents consequently die from their injuries in the developing world compared with industrialized countries. Thus, not only is the proportion of people injured per vehicle very high, but also the death rate is higher in developing countries.

Fouracre and Jacobs (*3*) calculated that, for any country, the cost of road accidents was equivalent to approximately 1 percent of its gross national product, although currently it is thought to be between 1 and 3 percent. However, using the 1 percent figure gives an estimated annual global cost of road accidents on the order of U.S. $230 billion, with the cost to LDCs being around U.S. $36 billion, a sum that they can ill afford.

Countries throughout the developing world are characterized by rapid urbanization, high growth rates in traffic, and consequently, congestion and decreasing regulation of public transport. Because the majority of the developing world's inhabitants depend on public transport services, safe, efficient, and effective public transport services are essential to ensure adequate and affordable accessibility for sustaining livelihoods and rural and urban development.

The Transport Research Laboratory (TRL), funded by the British Government's Department for International Development Knowledge and Research Programme, is currently evaluating the safety and roadworthiness of public transport vehicles. The work assesses the scale of the problem and the effect of varying maintenance practices on bus fleets' roadworthiness. The effects of accidents on passenger comfort and safety are also being investigated and recommendations developed for safer public transport services. The 3-year study, which commenced in July 1997, is being undertaken in a number of countries that are assumed to be representative of the developing and emerging nations. Studies have already been undertaken in Nepal, Zimbabwe, and Tanzania, and in the Indian state of Maharashtra. Thailand will be the last country to be studied.

This paper aims to establish the current operational environment of the public transport sector in each of the countries, and the extent and likely causes of bus accidents. Accident data have been collected from official sources in the countries and interviews undertaken of police, bus owners, operators, drivers, conductors, passengers, and associations to obtain opinions as to the causes of bus accidents. In addition, vehicle condition and driver behavior were monitored by teams from universities. Conclusions and recommendations are discussed to reduce both the severity and number of public transport accidents in the future.

NEPAL

Background

The first bus services in Nepal commenced in 1957 and since then the fleet has grown substantially, especially since 1992. By 1996, a total of 7,800 conventional buses and 2,752 minibuses were operating public transport services throughout the country (*4*).

About 95 percent of buses are owned and operated by the private sector; the remaining 5 percent are owned by the public or semipublic sector. Although vehicles are operated mainly on an individual basis, the "dial system" predominates as associations or syndicates manage routes on behalf of owners. The dial system ensures equal operational trip making for each operator in the association/syndicate, as vehicles have to wait in a queue before departure. It does, however, constrain the number of trips made by each bus. Thus, although the supply of permits is liberalized, the actual provision of services is constrained by what amounts to a cartel in districts throughout most of the country. In addition, owners who do not belong to an association or syndicate frequently encounter operational difficulties at bus parks.

Vehicles of 6 years or less are operated on long-distance night services whereas vehicles more than 6 years old tend to be operated as local buses. The local buses tend to be used within and around urban

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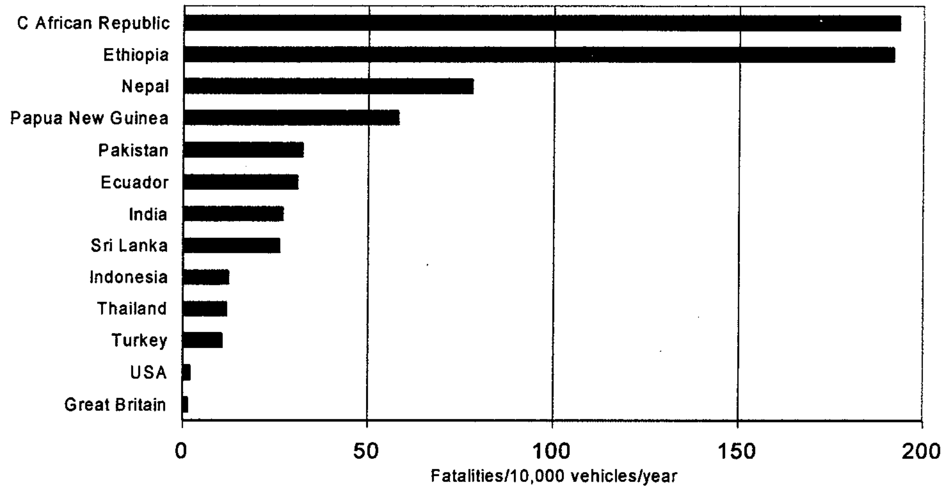

FIGURE 1 Fatality rates for selected countries.

areas but can include routes over some of the worst-maintained roads in the country.

Accident Rates

During the period July 1995–June 1996, a total of 3,379 accidents were reported to the police nationwide (urban and long distance), with bus accidents representing 14 percent of the total. However, the 479 serious bus accidents resulted in 365 fatalities and 1,751 injured persons. Those totals represent 39 percent of all road fatalities during the 12-month period and 60 percent of all road casualties. (Figures for the 18-month period of November 1996 to April 1998 are similar in terms of the percentage of bus accidents and fatalities.) Bus accidents therefore represent a significant proportion of all road accidents and injuries in Nepal.

Figure 2 illustrates the predominance of injuries and accidents caused by bus-only accidents in Nepal for 1995–96. Bus-only accidents are defined as those in which the driver loses control and the bus either leaves the road or overturns. These are the most frequently occurring bus accidents, resulting in 71 percent of total injuries and 63 percent of fatalities. Of the remaining bus accidents, bus-vehicle collisions resulted in 21 percent of injuries and 14 percent of fatalities and bus-pedestrian 8 percent and 24 percent respectively. Unsurprisingly, pedestrians are very much at risk and are more likely to die than to be injured if hit by a bus.

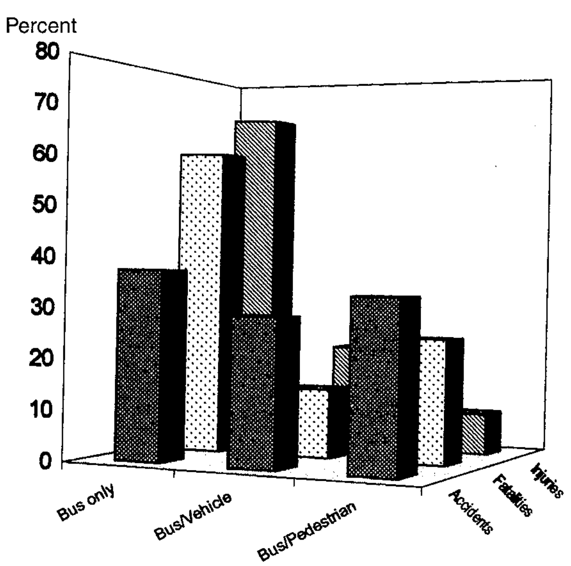

FIGURE 2 Bus accidents in Nepal, 1995–1996.

Probable Causes of Accidents

From comments made by the diverse groups interviewed, the likely causes of bus accidents can be categorized as follows:

- Drivers and driving habits,
- Vehicle condition,
- Road condition, and
- Other factors.

Data for the 18-month period (November 1996–April 1998) recently analyzed suggest that driver error was the major factor in 74 percent of bus accidents, external factors in 18 percent, and vehicle condition in 8 percent.

Everyone agreed that one single factor was unlikely to cause an accident and that a combination of causes was the likely explanation. The factors raised with respect to drivers and their driving habits were

- Ease of obtaining a heavy vehicle license,
- Lack of knowledge of the highway code and the road,
- Driver fatigue due to long working hours,
- Overloading of vehicles to maximize revenue,
- Night drivers consuming alcohol or drugs, and
- Speeding at night or for the road condition.

Because of the dial system, most buses are said to be overloaded at certain times on the route as drivers/operators attempt to maximize fare revenue. The queuing makes drivers wait around for hours in the bus park, and consequently they are tired before driving as they do not sleep but sit around chatting in groups. Interviewees suggested that drivers worked excessive hours in order to make additional trips and obtain extra allowances. Drivers also mentioned the use of drugs and alcohol as ways to keep awake.

In terms of vehicle condition, factors included

- Lack of maintenance due to cost,
- Worn tires and duplicate parts used to minimize costs, and
- Irrelevance of the vehicle fitness test.

Surveys of vehicle condition noted that 65 percent of buses had one or more faults in terms of tires, wheel fixings, and front or rear lights. Yet all had passed a vehicle fitness test and were legally fit to operate. The condition of the vehicles gives cause for concern, and the fact that all had fitness test certificates illustrates the irrelevance of the scheme and the ease of obtaining a certificate, whatever the vehicle condition.

The poor condition of roads resulting from deficiencies in maintenance, alignment, traffic signs, and safety features were all identified as possible accident causes. Weak enforcement of traffic regulations and a lack of road sense by pedestrians in rural areas, especially when herding animals on the road or generally crossing the road, were also mentioned as contributory factors.

INDIA

Background

Public transport in India is characterized by a wide range of vehicle type, from nonmotorized modes such as cycle rickshaws to surface rail and metro. Both public ownership and private ownership exist. The scale is immense, with 64 public-sector road transport undertakings operating a fleet in excess of 110,000 representing only 30 percent of the national bus fleet.

Because of the size of India (250,000 reported accidents leading to 60,000 fatalities and more than 250,000 casualties in 1995), it was decided that the study should be restricted to the state of Maharashtra, in the west of India. Maharashtra, one of the most prosperous states, has a mix of manufacturing industry, agriculture, and the bustling financial center of Mumbai.

Accident Rates

During the period 1961–1996, the registered motor fleet grew by more than 40 times while the road network increased by 3.5 times; thus the growth in vehicles far outpaced the quantum of road network and other infrastructure. As a consequence, during the two decades 1975–1995 the number of road accident fatalities increased by 282 percent and injuries by 220 percent. An average of 200 accidents were reported daily, leading to 23 fatalities and 134 injured persons.

During 1991, 23 percent of accidents occurred on the state highways that led to 38 percent of fatalities; state roads accounted for 14 percent of accidents and 27 percent of fatalities; and other roads 63 percent of accidents and 35 percent of fatalities. The police attributed 66 percent of accidents and 80 percent of fatalities to poor driver behavior. During the same year, the registered bus fleet in the state accounted for 1 percent of the total motor fleet, yet buses (including those from other states) were involved in 14 percent of reported accidents and 12 percent of fatalities.

Data for 1995 show that buses and heavy goods vehicles (HGVs) were involved in 35 percent of accidents; taxis cars, and jeeps in 32 percent; two-wheelers in 22 percent; and other vehicles in 11 percent. Of these accidents, the motorized vehicle driver was at fault in 51 percent of accidents, nonmotorized drivers in 37 percent, and other causes the remaining 12 percent.

Data were obtained from the state-owned Maharashtra State Road Transport Corporation (MSRTC), which operates bus services throughout the state in competition with privately owned and municipal operated bus companies. MSRTC is the second largest operator in India, with a fleet of 17,073 buses, employing 110,073 staff. It carries 7.5 million passengers a day. Figure 3 illustrates the survey responses of the bus management identifying primary causes of accidents involving its own buses, which during the operational year 1996–97 were involved in 4,149 accidents and 688 fatalities.

MSRTC bus driver was at fault for almost 50 percent of accidents, with stated causes including "inaccurate judgment, speeding, following too closely, reckless overtaking, and reversing." Fifty-seven percent of all accidents happened on a straight road, and in 70 percent of cases the road surface was described as "good." Sixty-nine percent of accidents occurred in daylight and 78 percent in fine weather. Driver inexperience appeared to be a probable cause, as 37 percent between 24 and 32 years old, and 46 percent had been driving for less than 4 years.

Probable Causes of Accidents

The opinions of the various drivers, conductors, traffic police, and passengers interviewed throughout the state suggested that the same probable causes relate to the Indian situation as they do in Nepal and for the same reasons. For instance, the transport sector is looked on as an "employment generator," and the result is that generally raw and untrained persons often having little or no formal education are employed as drivers. Frequently, the minimum regulations for obtaining licenses are not strictly implemented, with touts operating outside the offices of regional transport officers offering license renewal services. Many driving schools in the state offer training and the (guaranteed) granting of licenses to learner drivers.

Most private-sector buses are repaired and maintained in roadside workshops lacking adequate infrastructure and using duplicate parts to minimize costs. Public-sector undertakings enjoy vehicle repair workshops, but often these are not well equipped or maintained. Surveys of bus condition produced the results illustrated in Figure 4.

The high percentage of vehicles without one or both windshield wipers is alarming, especially in view of India's monsoon weather conditions. Equally alarming is the near 50 percent of vehicles without brake lights, a fifth with at least one front light missing, and

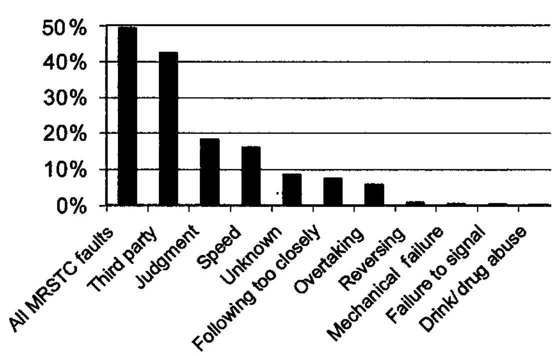

FIGURE 3 Primary causes of MSRTC bus accidents in Maharashtra, 1996–1997.

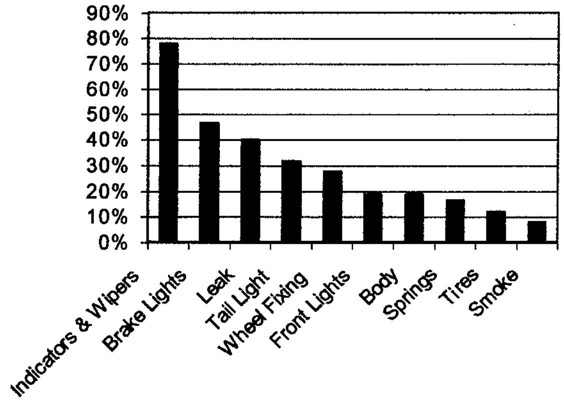

FIGURE 4 Faults identified during bus surveys in India, 1997.

approximately one-third of vehicles surveyed with one rear light missing. Driving a bus on narrow, badly maintained, and unlit roads during the night, monsoon, or thick smog without a comprehensive lighting system at both the front and rear of the vehicle is clearly dangerous. The other area of concern is that more than a quarter of buses had one or more wheel nuts missing.

Other related issues include road users generally being unaware of traffic rules and regulations or ignoring them when negotiating the road network. Pedestrians frequently take potentially suicidal actions, causing drivers to take evasive action and lose control of their vehicle.

ZIMBABWE

Background

Urban public transport services are provided by the Zimbabwe United Passenger Company (ZUPCO), now wholly owned by the government, which operates both conventional buses and minibuses (*5*). There are also privately operated commuter omnibuses consisting of various vehicle types and capacity (*5–7*). Introduced in 1993, they have been allowed to proliferate with few controls. Long-distance bus services (intercity and rural) are provided by ZUPCO and the private sector.

Accident Rates

The police collect accident data in Zimbabwe, and the Zimbabwe Traffic Safety Board analyzes the data and organizes safety education and training programs on behalf of the government. In 1992 there were 27,150 reported accidents leading to 1,066 fatalities and 13,458 injured persons. By 1996 the totals had increased to 38,777, 1,205, and 18,070 respectively. Table 1 illustrates that, although most bus accidents (and consequently injuries) take place in urban areas, most fatalities result from long-distance bus accidents.

Probable Causes of Accidents

Police statistics for bus accidents in 1996 showed that 58 percent of the accidents were classified as blameworthy (i.e., human error) and led to 76 percent of bus fatalities and 75 percent of injuries.

Clearly, driver misjudgment—including factors such as excessive and reckless speeding, following too closely, overtaking and reversing errors, failure to give way, and others—is the key element (82 percent) of blameworthy accidents as apportioned by the police in Zimbabwe, with vehicle condition being responsible for 7 percent of accidents.

As in Nepal, many individuals and organizations involved in operating, regulating, or using public transport services were interviewed as to their opinions of the causes of bus accidents. The same three broad categories evolved from the discussions:

- Driver behavior,
- External factors, and
- Vehicle condition.

The most frequently quoted factors involving driver behavior included reckless driving, inattention and lack of judgment, speeding, driver fatigue, and the use of unqualified and inexperienced drivers. One long-distance operator suggested that "speed is used as a marketing tool" whereas in urban areas "speed is used to maximize earnings." In addition, liberalization has led to unrestricted numbers of commuter omnibuses in urban areas. To maximize their profitability, consideration for other road users is sacrificed for speed, and so driver behavior remains poor.

External factors include road conditions, stray animals, weak enforcement of regulations, and adverse weather such as during the rainy season. Observations of vehicles showed that vehicle condition is generally satisfactory and that genuine spare parts are used.

TANZANIA

Background

The organizational structure of the bus industry in Tanzania can broadly be categorized into urban operations and long-distance, including rural services.

Urban Buses

Urban operations presently comprise conventional buses and minibuses (Daladalas). The fleet of the state-run bus company, Usafiri Dar es Salaam (UDA), has dwindled and now comprises few conventional buses and minibuses.

Daladalas operate in almost all municipalities throughout the country. The fleet is diverse in both type and capacity, but most have a passenger capacity of between 16 and 36. On most routes the Toyota Hiace with a capacity of 16 passengers dominates. The routes operated range from less than 3 km to long routes of approximately 30 km,

TABLE 1 Bus Accidents in Zimbabwe, 1996

	Bus accidents		Fatalities		Injuries	
Long Distance/Rural	1583	28%	69	74%	467	22%
Urban	4166	72%	24	26%	1607	78%
Total	5749	100%	93	100%	2074	100%

the latter being periurban routes. Services are not scheduled, and vehicles leave a rank only when they are full. Daladala drivers usually start work at approximately 4:30–5:00 a.m. and finish at 11:00 p.m.–midnight.

Most drivers employed in the Daladala business are young, and staff turnover is very high. Driver remuneration is generally not fixed but is commission based. Some operators stipulate revenue targets to be achieved by their drivers. Both methods of remunerating the Daladala drivers encourage speeding, overtaking, poor parking, and frequent vehicle stops to pick up or drop off passengers on the way to anticipated destinations.

Most Daladala operators have an operating fleet of fewer than 15 vehicles and lack proper maintenance facilities or programs. Vehicle maintenance for minor repairs is carried out at backyard workshops. Major repairs are undertaken at external workshops, the majority of which belong to friends. The operators alleged that they do not undertake vehicle services regularly due to the high costs of servicing and spare parts. During the study it was found that UDA undertake routine maintenance regularly, while major repairs or vehicle services are undertaken quarterly. The difference between the Daladala operators and UDA is stark.

Long-Distance Buses

The Tanzania trunk road network has 3306 km of paved roads and 6290 km of unpaved roads. The routes operated on trunk roads are long (the longest within the country is Dar es Salaam to Bukoba, approximately 1425 km). Most routes have their origin or destinations in a city/ town. The services operated are

- Interregional, which are services between cities and towns within the country on paved and gravel roads;
- Urban-rural, including a high proportion of services on gravel roads; and
- Cross-border services.

The most common buses have a capacity of 45 to 65 seats. The majority of successful long-distance operators have a proper maintenance program and an average fleet size of less than 10. Minor repairs are undertaken daily or after long-distance buses reach their destinations. Major repairs and services are undertaken weekly for some companies or after 25 000 km for other companies.

The operational environment for long-distance services changed recently. Quantity and fare controls on routes have been liberalized, and entry into the industry is now very much dependent on the roadworthiness of the vehicle.

Driver turnover is very high. Some long-distance drivers now prefer to drive Daladalas in urban centers because they realize that income opportunities are better despite the lack of job security. Due to the increased number of passenger fleet over the last 2 years, buses compete for passengers by employing touts who often force passengers to board buses not of their choice. It is also alleged that buses race against each other to pick up intermediate passengers along the route. On the other hand, the competition for passengers has resulted in some operators introducing semi-luxury and luxury coaches on selected routes to attract more passengers.

Accident Rates

The number of reported accidents increased from12,595 in 1993 to 14,335 in 1997 (i.e., by 14 percent). The number of fatalities increased each year from 1993 to 1996, but declined by approximately 10 percent to 1,625 in 1997. Measurable injuries have remained at a fairly constant level compared with reported accidents. It should be noted that national figures for 1998 have shown a decline, likely due in part to the effects of the global recession as well as increased safety awareness and enforcement.

Despite difficulties in collecting data during this study, it proved possible to obtain accident fatalities and casualties by vehicle type from traffic police records for two complete years—1997 and 1998—by manually collating and analyzing the data. Table 2 summarizes the accident data by vehicle type for 1997 and 1998.

In total, conventional buses and Daladalas accounted for 24 percent of vehicles involved in accidents during 1997–98 but generated 39 percent of fatalities and injuries (see Figure 5). It can be calculated that on average each long-distance bus involved in a road accident resulted in 5 fatalities and 39 injuries whereas the approximate unit fatalities and injuries for other vehicle classes are insignificant. Within the public transport sector, long-distance buses represented 1.3 percent of vehicles involved in accidents and accounted for 41 percent of fatalities and 45 percent of injuries whereas Daladalas represented nearly 98.7 percent of vehicles involved in accidents and accounted for 59 percent and 55 percent respectively. This indicates the lower severity of urban road accidents.

Probable Causes of Accidents

Findings from Police Records

The police are not informed of all accidents involving personal injury, especially when minor injuries are involved, so only fatal acci-

TABLE 2 Road Accident Statistics in Tanzania, 1997–1998

Vehicle Type	1997			1998			Average distribution (%) 1997–1998		
	Vehicles involved	Fatalities	Injuries	Vehicles involved	Fatalities	Injuries	Vehicles involved	Fatalities	Injuries
Private Cars	8903	425	3452	8485	361	3251	50.7	24.5	28.0
Pickups	2814	325	2610	2682	312	1668	16.0	19.8	17.9
PSV Buses	54	242	1974	52	274	2197	0.3	16.1	17.5
PSV Daladala	4140	364	2615	3946	380	2395	23.6	23.2	21.0
Private Hire	27	5	115	26	4	192	0.2	0.3	1.3
HGVs	731	75	575	696	68	516	4.2	4.5	4.6
Motorcycles	433	122	689	413	97	594	2.4	6.8	5.4
Pedal Cyclists	460	67	460	438	87	568	2.6	4.8	4.3
TOTAL	**17562**	**1625**	**12490**	**16738**	**1583**	**11381**	**100%**	**100%**	**100%**

PSV = public service vehicle; HGV = heavy goods vehicle

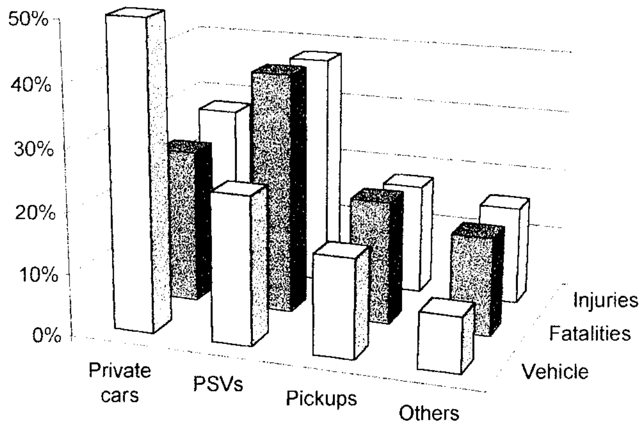

FIGURE 5 Casualties by vehicle class in Tanzania, 1997–1998.

dent reporting is complete. Figure 6 presents information obtained from the traffic police records as to the causes of road accidents in Tanzania from 1993 to 1997. The causes of all road accidents (bus accidents reflect the same trends) can be divided into three main categories:

- Human factors—76 percent,
- Vehicle condition—17 percent, and
- External factors—7 percent.

Public Perception of Bus Accidents

A questionnaire survey of 200 randomly selected passengers and drivers of Daladala and long-distance buses and interviews of 20 major organizations involved in the public transport industry were carried out in order to ascertain public opinions and perceptions.

It is clear, from both passengers and drivers, that long-distance buses are erroneously perceived to have more accidents than Daladalas. Some passengers and drivers also indicated that urban bus accidents are not as serious (i.e., do not result in high rates of casualties and fatalities) as long-distance bus accidents due to lower speeds. One explanation for why the majority of passengers and drivers think that long-distance buses have more accidents than other modes of transport may be the fatality rate and the wide reporting of such accidents in newspapers and television. On the other hand, professionals and operators interviewed were correctly of the opinion that urban buses have a higher accident rate. This accident rate (up to 20 times more likely to be involved in an accident than long-distance buses), however, results in a lower casualty rate of 0.1 fatalities and 0.6 injuries per accident compared with an average of 5 fatalities and 39 injuries per long-distance bus accident.

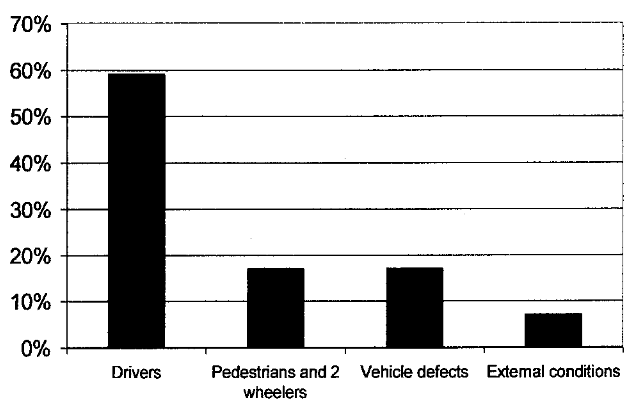

FIGURE 6 Causes of road accidents in Tanzania, 1993–1997.

The perceptions of all interviewees were that human errors are the principal contributory cause of accidents. The causes of bus accidents as revealed by both sets of respondents can therefore be divided into four main categories:

- Human factors,
- Vehicle condition,
- External factors, and
- Lack of enforcement.

Human Factors

The human factor is perceived to be the principal cause of most bus accidents. A number of subfactors within the human factor, however, were mentioned by both sets of respondents:

- Misjudgment,
- Alcohol and drugs,
- Reckless driving,
- Overloading,
- Parking errors,
- Driver fatigue, and
- Careless pedestrians, passengers, cyclists, and cart pushers.

The traveling public blames deregulation of the public transport system for the increased number of accidents occurring on both urban and long-distance services. Inevitably this has led to an increase in the number of buses servicing the network, although demand has not similarly increased.

Reckless driving, speeding, and driving errors were cited as the most common causes of bus accidents with respect to long-distance and urban buses. For instance, a fatal long-distance bus accident in Moshi that killed 19 passengers and injured 13 others in 1996 was attributed to reckless driving when the 65-seat bus collided head-on with another bus.

Some respondents revealed, ironically, that some passengers encourage drivers to speed without considering the increase in accident risk. However, other drivers use speed as a marketing tool to encourage passengers to travel in their buses. Consequently, buses compete for passengers by speeding.

Other factors contributing to accidents include poor parking and stopping of Daladalas, little respect for other drivers shown by Daladala drivers, and the use of drugs and alcohol to combat tiredness.

The contribution of human error in causing accidents is not confined only to drivers. Passengers and pedestrians also contribute to accidents. It is common for passengers to try to disembark from a bus while it is in motion or to distract the attention of the driver. Pedestrians, especially in the rural areas, are also not very conversant with traffic regulations.

Some fatal bus accidents may occur when drivers make irrational decisions—often encouraged by passengers—and attempt to cross flooded rivers. For instance, the road accident said to be the worst in recent history occurred in 1998 and claimed the lives of about 70 passengers. More than 25 others were injured when the bus they were traveling in was swept away by floods overflowing a bridge on the Segera-Tanga road. The bus was supposed to carry 65 passengers but was considerably overloaded (95+).

In brief, most respondents perceived human error to be the main cause of bus accidents in Tanzania. The survey findings are therefore consistent with police records on bus accident causes.

Vehicle Condition

In 1995, according to statistics from police records, approximately 20 percent of bus accidents were caused by bus defects. This figure was significantly reduced to approximately 17 percent in 1997 due, in part, to ongoing economic reforms that have led to a growth in vehicle sales and hence a younger bus fleet. To ascertain vehicle condition, surveys were undertaken of a number of buses, both urban and long distance, in Dar es Salaam, Tanga, and Morogoro regions. Table 3 illustrates the results from the surveys and highlights the generally good condition of long-distance buses compared with Daladalas.

External Factors

The external factors mentioned by both sets of respondents include

- Poor road condition,
- Poor road engineering and alignment,
- Lack of road signs and markings, and
- Intermittently operating traffic signals.

There are signs that the existing infrastructure is being overloaded as the number of vehicles increases. Many roads outside urban areas are in a very poor state of repair. Even those in the urban areas are frequently narrow and ill maintained and lack adequate bus stands. A number of bridges on roads outside urban areas are also very narrow and can accommodate only one vehicle at a time. Potholes and sandy soils on roads were also mentioned as contributing factors. Both individuals and organizations appeared to agree that there is a lack of adequate provision of road signs through the network. In urban areas, power outages are common and so traffic signals may fail, resulting in accidents at high-volume intersections.

DISCUSSION OF FINDINGS

In all four countries where TRL has undertaken studies, road accidents are increasing over time. Public transport vehicles appear to be involved in a higher proportion of accidents than their numbers warrant. However, this is principally because buses cover a high annual mileage through their duty cycles. Considering the number of passengers transported, a safety culture should be active and evident, but that does not appear to be the case. A summary of the results obtained so far is given in Figure 7.

TABLE 3 Faults Identified in Tanzania, 1998

Component	Long-distance buses	Daladalas
Number of vehicles	30	50
Good bodywork	<5%	10%
Mirrors	<5%	30%
Windscreen wipers	<5%	10%
Tires	5%	15%
Wheel nuts	5%	12%
Front lights	0%	15%
Rear lights	0%	14%
Brake lights	0%	30%

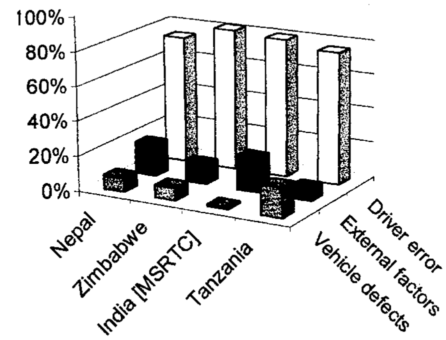

FIGURE 7 Comparison of bus accident causes by country, 1996–1998.

Public transport in Nepal has not undergone the same stresses of privatization as elsewhere in the world, but the existing situation does indicate some of its consequences. In India, Zimbabwe, and Tanzania, public transport services are owned and operated increasingly by the private sector as liberalization is encouraged. This has inevitably led to a philosophy, by the private sector, of profit maximization by minimizing costs rather than increasing efficiency. Driver behavior also appears to suffer under the auspices of liberalization and low enforcement.

Figure 8 compares fatality and injury rates across the four countries. The need for high standards of driver behavior and vehicles in Nepal, where nearly all the public transport sector is privatized, is emphasized by the significantly higher severity of accidents. The fatality rate is twice as high and the injury rate more than three times as high as in Tanzania. Some of this difference may be due to the difficult terrain over which buses are operated.

Subjectively there does appear to be a link between the degree of privatization and the amount of regulation or enforcement that is present. Figure 9 attempts to illustrate this by plotting estimates of priva-

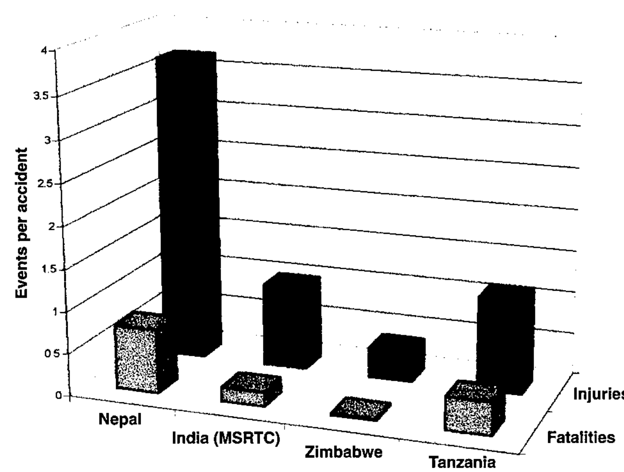

FIGURE 8 Comparison of fatality and injury rates.

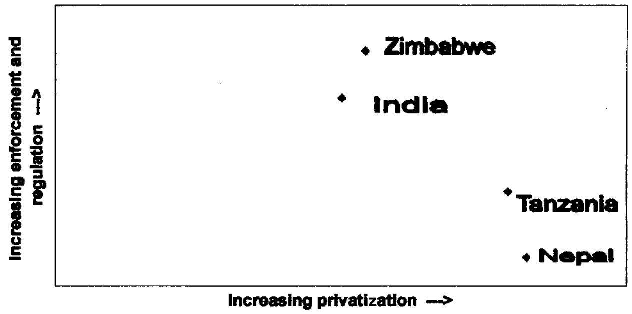

FIGURE 9 Comparison of privatization status and enforcement level.

tization and enforcement for the four countries. It is recognized that these estimates are not quantifiable, but they do provoke thought.

CONCLUSIONS

The overriding factor to be addressed is how to improve bus driver behavior. Suggestions are listed below. It is clear, however, that drivers need to be better educated and better trained when initially learning to drive. In particular,

- They should be taught not just the technical skills to pass the driving test but also the social and psychological skills required to be a safe and responsible professional driver.
- Bus drivers, like all HGV drivers, should participate in refresher driver training courses so that the inevitable bad habits acquired can be eliminated at a relatively early stage.
- Owners should be encouraged to provide financial incentives for drivers who have been "accident free" during the previous 12-month period.
- Medical and health checks need to be provided regularly for drivers, especially aging drivers.
- Owners and drivers should be encouraged to work within existing legal maximum hours.

These steps may increase costs but are likely to be less expensive in the longer term than the cost of human tragedy, vehicle replacement, and other third-party costs.

In addition to improving the behavior of the bus driver, road safety campaigns need to be funded and encouraged so that all road users are better educated as to how to behave when crossing and using the road and when herding animals on the rural road network.

Many owners and operators need to be encouraged to maintain their vehicles to a much higher standard than at present. Preventative maintenance can improve performance and productivity and extend the operational life of the vehicle. A safe, smart vehicle is more likely to attract passengers than an unsafe and poorly maintained vehicle, and passengers also might be encouraged to afford a slightly higher fare for such a vehicle/service. Owners and operators also need to understand that regular vehicle maintenance is a sound, effective business practice that can minimize vehicle downtime and costly, time-consuming breakdowns while in service.

Improvements in bus safety cannot be achieved by one individual or discipline. They are a collective responsibility, and a collective spirit is required of all those involved, including

- Bus owners, drivers, conductors, and mechanics;
- Operator associations and unions;
- Police and government departments;
- Road safety associations;
- Driver training schools;
- Manufacturers and repairers of vehicles, spare parts, and tires; and
- All road users.

Hence, whenever liberalization is being considered for provision of public transport services, existing (and new) legislation regarding vehicle condition, numbers allowed to operate, etc., needs to be strictly enforced. Operational regulations and procedures also must be implemented rigorously to ensure that safe and effective service prevails for passengers.

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Effect of Residential Location and Access to Transportation on Employment Opportunities

Piyushimita Thakuriah and Paul Metaxatos

Women who have been on public assistance need to obtain and maintain steady employment because they stand to lose their public benefits and also because it is the only way out of poverty. Although the sociodemographic and general economic influences on job retention have been examined in the literature, the effects of transportation and of place of residence in a metropolitan area vis-à-vis entry-level job locations have not been studied systematically. Four sets of factors—transportation, location, sociodemographic, and family effects—are examined for their effect on job retention. In particular, it was found that employment security for female welfare clients or former clients does not come from job retention (i.e., tenure with the same employer) but from "employment retention" (i.e., jobs with different employers, possibly with a trend toward upward mobility). The effects of transportation and location on job and employment retention are complex. Although access to a vehicle is important for increasing employment retention, even more important is the number of job opportunities accessible by private vehicle or public transit within a tolerable travel time. Female welfare clients who retain a job longer and hold more jobs within a 2-year period are more likely to live in subareas of the metropolitan area with greater access to jobs within reasonable travel times; the competition for those jobs from other low-income individuals is low. Furthermore, female welfare clients with a high school diploma, when given the appropriate accessibility and location opportunities, enjoy increased job retention.

Cost-effective access to economic opportunities is vitally important for low-income women's participation in the labor force. Since the passage of the welfare reform law of 1996, this issue has received substantial attention from academics and the public sector. A number of efforts are under way to link welfare clients to jobs by reliable and affordable private and public transportation initiatives.

In 1997, approximately 85 percent of the adult Temporary Assistance for Needy Families (TANF) clients in the greater Chicago area (a six-county area in northeastern Illinois comprising Cook, DuPage, Kendall, Lake, McHenry, and Will counties) were women (*1*). About 32 percent of these women did not have previous work experience, and about 15 percent had a child less than 1 year of age at home. With little exception, these women have been expected to find and maintain employment after specified time limits.

Various factors have been cited in the literature as affecting the ability of female welfare clients to obtain and maintain employment. Attributes of female clients that have been detrimental to their employability are low educational level, little or no previous work experience, presence of young children at home, lack of affordable day care, and absence of reliable transportation services. Entry-level jobs that are appropriate for these women are scarce, and when they are available in the same metropolitan area, they tend to be separated from residential locations by large distances. Often, there is inadequate labor market information and limited information on travel options.

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This study assesses the importance of transportation and the residential location of welfare clients (in terms of the accessibility vis-à-vis entry-level job locations) in their ability to obtain employment and maintain steady participation in the labor force. It analyzes which factors increase job tenure, meaning the length of time a female client was employed in the same job over a period of 2 years. Job tenure could be zero, meaning that the client had no job during the last 2 years. Four types of factors or effects were considered: location, transportation, family, and sociodemographic.

To capture the effect of the residential location of the client on job tenure, a "location index" was created. This index is the output of a spatial interaction model (*2–4*). The location index combines travel times from residential origins of welfare clients to job destinations, with estimated competition for entry-level jobs by welfare clients. The index thus reflects impediments imposed by travel factors as well as economic opportunities for each welfare client residential origin. For transportation-related factors, the impacts of access to private vehicles and dependence on public transportation on length of job retention were examined. The "location" and "transportation" effects are examined along with other often-mentioned variables affecting employability, including the availability of affordable child-care and the presence of young children in the household (called the "family" effects). In addition, the effects of educational level and whether the client is currently undergoing education are examined (these are termed the "sociodemographic" effects). Interactions among these factors are also examined, in terms of their impact on job tenure.

The following information is presented: an examination of the importance of using employment tenure as a surrogate for improved quality of life and the need to examine the effects of transportation and residential location characteristics on increased tenure; the study approach and data used; findings; a summary; and conclusions.

JOB RETENTION, TRANSPORTATION, AND RESIDENTIAL LOCATION

The objective is to assess which factors contribute to job retention. The length of tenure with the same employer was used as the measure of job retention. The median number of years that wage and salary workers had been with their current employer was 3.6 years in February 1998 (Labor Force Statistics from the Current Population Survey, 1998), with the median tenure for women being 3.4 years. Workers in the service occupations, where large numbers of welfare clients have historically found employment, have the lowest median tenure (of 2.4 years) among the major occupational groups. Among clients who leave welfare for work, substantial numbers lose their jobs and do so quickly. Studies show that between 25 and 40 percent of clients who leave welfare for work return to welfare within 1 year and as many as two-thirds return by the end of 5 years (*5, 6*).

Although increased tenure with the same employer is usually viewed positively from the perspective of employment security (this would be a desirable attribute for low-income women), it may be a constraint on upward mobility if the chances for promotion within the same employer are limited. Hence, in order to separate reduced tenure due to upward or lateral mobility from reduced tenure due to job loss, one should concurrently look at the total number of jobs held by the person within the same window. Looking at job tenure over a period of time and the total number of jobs held during that same time would give a better sense of the client's "total employment" situation.

Although newly employed welfare clients and their employers share an interest in job retention and value transitional supports, their needs and perspectives may be different. Employers are interested in keeping the individual in the company, often at the same job, to realize a return on their hiring and training investment. For welfare clients and former clients, however, the issue is not so much "job" retention but "employment" retention, which includes finding reemployment quickly if they lose their job or taking advantage of new and better employment opportunities, either with their current employer or another employer. "Reemployment agility" of this nature prepares the welfare client to be in an employed status for a longer period of time and perhaps provides a means of upward mobility.

Numerous factors determine the labor market experiences of female welfare clients. Pavetti (*7*), in a study of the work experiences of women during early adulthood, found that transitions from joblessness to a good job or from a bad job to a good job were significantly more likely for women with higher levels of education, women who resided in urban areas or labor markets with low unemployment rates, and women with a previous employment history. They were significantly less likely for women with children under the age of 1 and women with low basic skills. It is possible that work experiences of clients also vary by their spatial location within a metropolitan area and with access to reliable transportation.

It is also important to note that in a good economy, the transition from joblessness to a job may be a quick and relatively easy one. However, barriers such as unavailability of reliable transportation and adequate child care may make continued tenure on the job difficult. The effect of transportation and locational accessibility on job retention of welfare clients has not been systematically examined, to the best of the knowledge of the authors. Job retention strategies are usually examined in the context of family, sociodemographic, or other personal factors, or in terms of general economic factors such as number of jobs and growth rates (*7*). Further, the impact of where the client lives vis-à-vis jobs and her access to transportation is also important in understanding "reemployment agility" as a contributing factor to employment retention.

RESEARCH APPROACH

The objective is to estimate the effect of locational, transportation, family, and sociodemographic factors on job tenure of female welfare clients. The statistical model used, variables examined, and data sources are presented in this section. In order to examine the relationship of the four sets of factors to job tenure, an integrated database of the sociodemographic, transportation, and other variables was created for a sample of female welfare clients in the northeastern Illinois region.

Model

A model was developed to estimate the relationship of the transportation, location, sociodemographic, and family effects to the job tenure of female welfare clients. The response variable (length of time employed in the same job during the last 2 years) is ordinal and defined to have the following values for the k categories:

- $y_i = 3$ if the ith individual held the same job between 1 and 2 years,
- $y_i = 2$ if the ith individual held the same job between 6 months and 1 year,
- $y_i = 1$ if the ith individual held the same job between 1 and 6 months, and
- $y_i = 0$ if the ith individual held no job in the 2-year period.

A logit model was used to estimate the cumulative probabilities of length of job retention, with separate intercepts for each category but the same slope parameters (a parallel lines or proportional odds model). That is,

$$\log[\theta_k/(1 - \theta_k)] = \alpha_k + \beta_k x$$

where

θ_k = the cumulative probability up to and including Category k,
α_k = the intercept for Category k,
β = the vector consisting of parameters common to all categories, and
x = the vector of the explanatory variables used.

The theory behind the proportional odds model can be found in any introductory econometrics textbook. It suffices to say here that this model was chosen compared with, say, a standard multinomial logit model because it is easier to interpret when the response variable is ordered and the hypothesis tests are more powerful. Indeed, as discussed later, the proportional odds assumption was found to be adequate when tested with appropriate goodness-of-fit measures.

Variables Examined

Table 1 gives the distribution of welfare clients in the four job categories. About 40 percent of the clients were employed for some period during the 2-year observation period. The explanatory vari-

TABLE 1 Distribution of Clients Among Categories

Category	Time at job (months)	Frequency	Percent
0	0	24,724	60.4
1	< 6	3,919	9.6
2	6-12	3,257	7.9
3	12-24	9,069	22.1
Total		40,969	100.0

ables used are sociodemographic and family effects, transportation effects, and location effects.

Sociodemographic and Family Effects

These effects were represented by dummy variables indicating whether the respondent (*a*) lives in a household in which the age of the youngest child is 5 years or less, (*b*) does not have adequate child care, (*c*) possesses a high school diploma, (*d*) is in a violent relationship, and (*e*) is in school. In addition, continuous variables were examined, such as (*a*) age, (*b*) number of children below the age of 13 years, and (*c*) number of different jobs held by respondent in the last 2 years.

The sociodemographic and family variables were obtained from two data sets that were merged to establish a combined data set on about 40,000 female TANF clients in the six-county northeastern Illinois area. The two data sets are

- Client Data Base (CDB), which was obtained from the Bureau of Planning, Illinois Department of Human Services (IDHS). The data set consists of individual-level data on addresses, sociodemographic, and public assistance categories of all individuals on public assistance in the Chicago area. Address information was geocoded to the quartersection level [0.5 mi by 0.5 mi (0.8 by 0.8 km) planning zones].
- Employability Review (ER), also provided by IDHS, which contains individual-level data from detailed, face-to-face interviews with selected TANF clients with the intention of developing employability profiles of clients and determining barriers to employment.

The combined data set also provided data on the response variable.

Transportation Effects

The transportation effects were represented by dummy variables for (*a*) access to a vehicle, (*b*) possession of a driver's license, and (*c*) reliance on public transportation. The combined data set provided the data for these variables. The access-to-a-vehicle variable was used to assign values of the location index variable, described next.

Location Effects

The location effects were captured by means of an index that is similar in spirit to other accessibility indices in the regional science and urban economics literature. The question was asked, Which residential locations (quartersections) offer welfare clients a comparative advantage in terms of access to economic opportunities? Two factors are important in answering this question:

- How many entry-level jobs are within a "catchment area" of a travel time that is cost-effective for a client at the wage rate that he or she will receive, and
- How many other clients are competing for those jobs in a client's catchment area.

For the first factor, a rule-of-thumb benchmark number of a one-way, home-to-work trip time of 90 min was used. The Chicago Area Transportation Study Task Force on Welfare Reform used that number as a standard for trips to entry-level job destinations. In other words, the number of entry-level jobs that can be reached within 90 min of travel by private automobile and by the fastest mode of transit was estimated. As an aside, the fastest transit mode referred to in this study is an artificial mode comprising the travel times of regular and express bus, subway, commuter rail, and walking, weighted properly (*2*).

This estimate of the number of entry-level jobs within a catchment area of 90 min by the two modes (automobile and transit) was obtained for each quartersection where welfare clients reside. It is possible that travel times lower than the cutoff of 90 min are more reasonable—for example, it has been held that a job for welfare clients must be accessible with no more than a 1-hour, one-way commute from home to work (*8*).

The analysis showed that whereas 100 percent of all entry-level jobs in the Chicago metropolitan area are accessible within 90 min from many origin zones by private automobile, the case is not the same for riders of public transportation. In fact, the maximum number of jobs that can be accessed from any quartersection within 90 min by public transportation is only 60 percent.

The second factor—the number of clients competing for jobs within a catchment area—connotes that physical proximity to a job does not necessarily imply that a client's employment potential increases. If there are numerous other low-income individuals also in close proximity or conveniently linked by transportation access routes, then physical proximity may give the client little locational advantage because the same entry-level job would have a large number of competitors. Essentially, even if an individual client is located close to a job, the probability of that one individual obtaining the job may be very small due to the strong competition for it.

The previous two factors were operationalized by a spatial interaction model, the objective of which was to estimate the expected flows of welfare clients and entry-level job destinations (*2–4*). The output of this model was two accessibility indices for each quartersection j in which a client resides:

- $I_{j,a}$ based on automobile travel time along the shortest path to each job destination quartersection, and
- $I_{j,t}$ based on the fastest mode of transit between the origin quartersection and job destination.

The accessibility index may be thought of as a weighted combination of travel times to jobs and competition for jobs faced by clients residing in j. [See Metaxatos et al. (*2*), Sen et al. (*3*), and Thakuriah et al. (*4*) for technical details.]

Figures 1 and 2 show the spatial distribution of the accessibility index for the automobile and the fastest transit modes. The straight lines in the map demarcate the six counties. Although the City of Chicago central business district (CBD) is estimated to have 13 percent of all annual entry-level job openings in the six-county area, Figure 1 shows that the accessibility index for origins around the CBD is lower than expected. This is due to a large concentration of TANF clients around the CBD area and, hence, strong competition for jobs in the CBD area. Figure 2 shows that welfare clients in the area south of the CBD are worse off using transit than automobile. In contrast, Figure 1 shows that the highest index values are found in the north and northwest parts of the region, especially in McHenry County. This is due to the lower concentration of TANF clients in this direction (lower competition) and also relatively higher estimated job openings (compared to many other subareas in the six counties). The lowest values of the accessibility index are located in the southern part of the area where travel times are high and TANF concentration is large, and

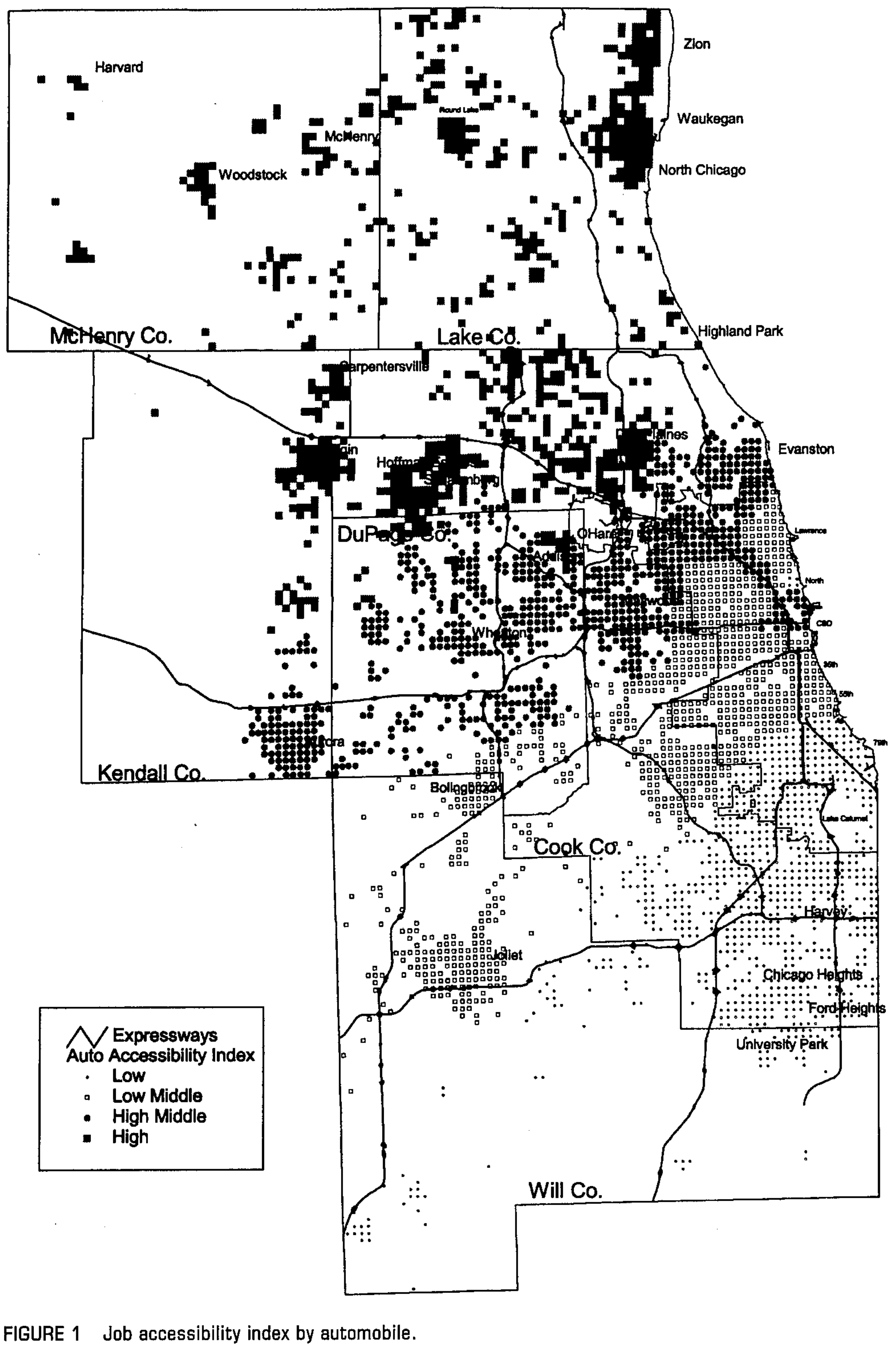

FIGURE 1 Job accessibility index by automobile.

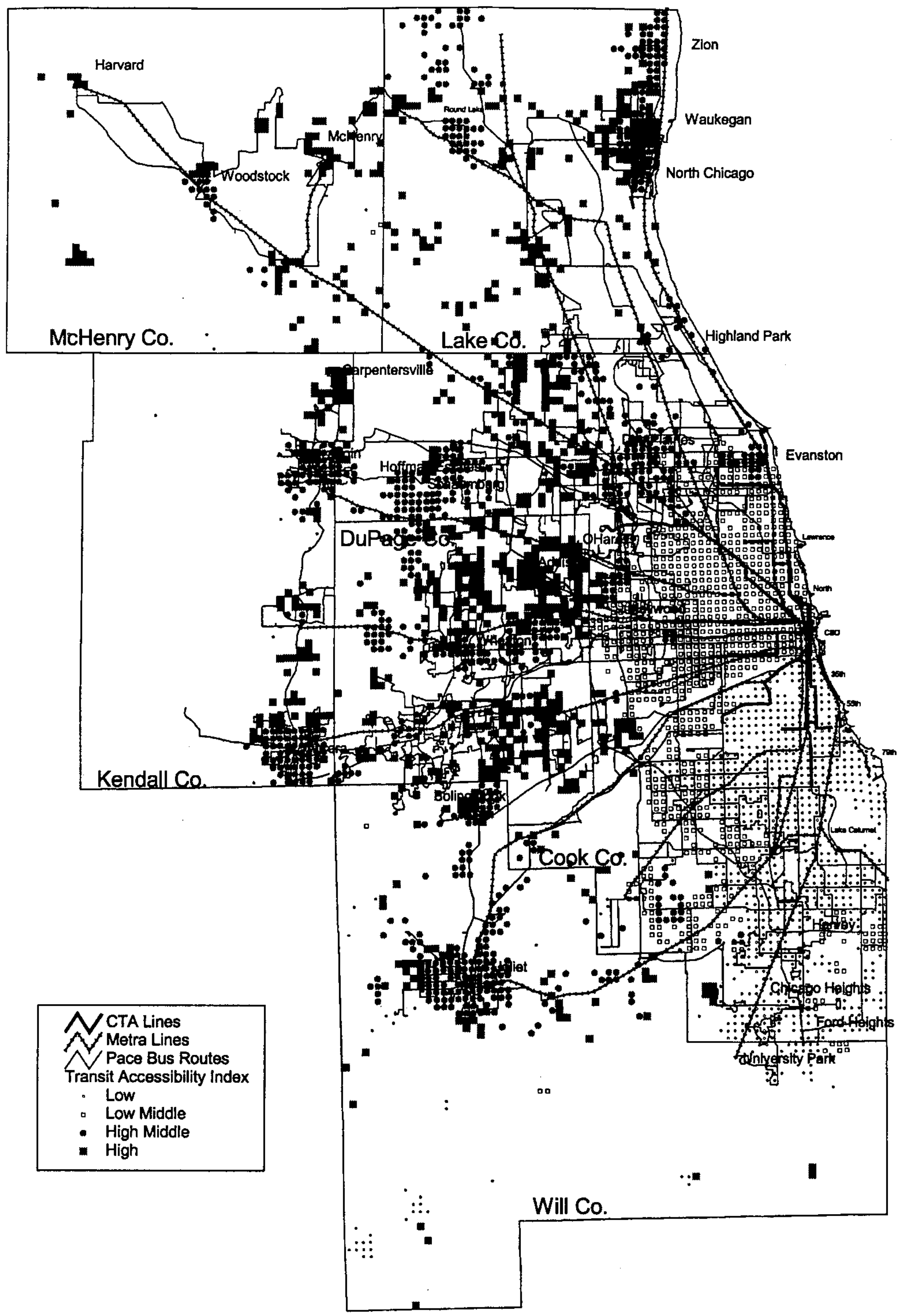

FIGURE 2 Job accessibility index by public transit.

TABLE 2 Location Index by Length of Employment in the Same Job

Quartile	% in category 0	% in category 1	% in category 2	% in category 3
High	19.19	25.27	26.79	34.76
High-Medium	29.81	29.91	27.31	25.58
Low-Medium	31.20	27.96	27.21	23.00
Low	19.80	16.86	18.69	16.66
Total	100.00	100.00	100.00	100.00

hence competition for jobs are high and the number of job openings are low. Job accessibility by automobile, however, appears to be rather homogeneous for large areas within the six counties. In contrast, job accessibility by transit, as shown in Figure 2, appears to be much more fragmented and concentrated around areas served by transit.

To create the accessibility index, the CDB was used to identify residential locations of all TANF clients. The location of projected entry-level job openings (by quartersection in the Chicago area) was estimated by a detailed process (*2–4*) using data from the Illinois Department of Employment Security, Northeastern Illinois Planning Commission, and Public Use Microdata Sample of the Bureau of the Census. Automobile travel times between origin-destination pairs were based on a standard traffic assignment of all vehicles in the network, so these times reflect congestion patterns in the six-county Chicago area. Transit (using all fixed-route modes of transit including rapid transit, fixed-route bus, and commuter rail) travel times include access and egress times and wait time penalties. [See Metaxatos et al. (*2*), Sen et al. (*3*), and Thakuriah et al. (*4*) for more details.]

For the purposes of estimating the model presented above, a location index for each respondent i is defined as follows: $l_i = I_{j,a}$ if the ith individual living in quartersection j has access to a vehicle, and $l_i = I_{j,t}$ if the ith individual living in quartersection j does not have access to a vehicle, with $I_{j,a}$ and $I_{j,t}$ as defined previously.

Results from the combined data set indicate that female welfare clients who held the same job during the 2-year period tended to reside in areas with higher scores on the location index compared with women who had no employment during that period or women who were employed for shorter periods of time. Table 2 shows the distribution of the location index for quartersections in which the sample of women in the data set resided. In this table, Low indicates respondents who live in quartersections in the lowest quartile of the distribution of the location index, Low-Medium the second lowest, High-Medium the second highest, and High includes respondents who live in quartersections in the highest quartile of the distribution of the location index.

About 35 percent of the women who had job tenure between 1 year and 2 years during the 2-year period lived in quartersections in the highest quarter of the location index compared with about 19 percent of women who worked for 0 months during that period, 25 percent of women who worked for the same employer for less than 6 months, and about 27 percent who worked between 6 months and 1 year. The differences are not very striking in the middle two quarters. However, about 20 percent of women who did not work at all during the 24 months lived in the lowest quarter of the distribution of the location index, compared with about 17 percent of women with the longest job retention

DISCUSSION OF RESULTS

The results of the model described in the previous section are given in Table 3. Job tenure was estimated using three combinations of variables, leading to Model I, Model II, and Model III. The χ^2/df ratios are in the range of 2.5 to 1.6.

Job Tenure Versus Employment Retention

The response variable considered is job retention, which was defined as the number of months that a client worked at the same job. Job tenure may be contrasted with employment retention, which refers to the total length of time that a client spends in employment during the observation period. The number of jobs held during the observation period and the length of time spent at one job together provide a comprehensive picture of employment retention. If, within a 2-year period, the client has spent a relatively long time at one job and also has held a number of other jobs, there is reason to believe that the client remained employed for a large part of the 2-year period and therefore had high employment retention. Direct measurements of employment retention were not available for the study.

The models estimated lend support to the conjecture raised earlier that employment security for female welfare clients or former clients comes not necessarily from job retention (that is, tenure with the same

TABLE 3 Estimates of Factors Explaining Length of Job Retention

Parameter	Model I	Model II	Model III
A. α_1	-3.85*	-3.82*	-3.70*
	(0.08)	(0.08)	(0.08)
B. α_2	-3.22*	-3.18*	-3.06*
	(0.08)	(0.08)	(0.08)
C. α_3	-2.47*	-2.43*	-2.32*
	(0.08)	(0.08)	(0.07)
Sociodemographic Effects			
D. Number of jobs in last 2 years #	1.68*	1.68*	1.69*
	(0.02)	(0.02)	(0.02)
E. Age #	-0.02*	-0.02*	-0.02*
	(0.002)	(0.001)	(0.002)
F. High school [Education] ##	0.03*	0.03*	N/A
	(0.03)	(0.03)	-
G. Currently in school ##	0.14*	0.12*	0.11*
	(0.04)	(0.04)	(0.04)
Family Effects			
H. Adequate childcare unavailable ##	-0.03*	-0.04*	-0.03*
	(0.03)	(0.03)	(0.03)
I. Number of young children #	-0.10*	-0.10*	-0.11*
	(0.01)	(0.01)	(0.01)
Transportation/Location Effects			
J. Possess driver's license ##	0.36*	0.44*	0.49*
	(0.03)	(0.03)	(0.03)
K. l #	N/A	0.004	N/A
	-	(0.003)	-
L. l x Education	N/A	N/A	0.011*
	-	-	(0.005)
M. Access to vehicle ##	0.26*	N/A	N/A
	(0.03)	-	-
χ^2/df	2.5	1.95	1.59

* significant at the 0.05 level. Quantity given in parenthesis is the standard error. #: continuous variable - ##: dummy variable

employer) but from employment retention (jobs with different employers in rapid succession). The mean number of jobs held in the 2-year period is 1.56. The estimates in Table 3 indicate that increasing job tenure is significantly related to an increasing number of jobs held in the last 2 years. This indicates that subgroups of female clients who enjoy longer job security with the same employer are also likely to find reemployment quickly if they lose their job or if they see a better opportunity.

Transportation and Location Effects

Model I shows that access to a vehicle, which indicates the availability/unavailability of a vehicle to a client, has a significant relationship to job retention. Because the number of jobs held in the 2-year period increases with an increase in job retention, vehicle availability also contributes to reemployment agility and greater employment retention. For example, Table 4 shows that the percent of clients with access to a vehicle increases as the number of jobs held increases.

It is important to point out that the ER survey (described in the previous section) that provided the data on access to vehicles did not ask respondents about vehicle ownership, but rather about vehicle availability to a client. An analysis of the Nationwide Personal Transportation Study showed that persons in low-income households are much less likely to have a vehicle (*9*). But in spite of lower vehicle ownership, people in low-income households still make most of their trips in private vehicles, which are likely to be owned by a friend or relative. This indicates that private automobile travel for low-income individuals involves trip chains and access to several destinations to drop off and pick up passengers. The implication is that access to vehicles may not provide the same type of mobility as ownership of a vehicle that the individual can use at his or her discretion.

Models II and III, which included the location index *l*, had better overall fit (in terms of the chi-square ratio) than Model I. The primary difference between Model I and the other two models was that in Model I, the dummy variable Access to Vehicle was regressed directly against the response. This may be contrasted with Models II and III in which the effect of vehicle availability/unavailability and consequent access to economic opportunities was introduced by using the location index *l*.

Using *l* rather than vehicle availability/unavailability alone is a better approach because it is not enough simply to have access to a vehicle or, for that matter, even to own a vehicle, for which data are not available. If the individual lives in a remote area far away from job openings, or if she has a large number of competitors for the jobs within the travel time that she is willing or able to tolerate, given her wage rate, then access to a vehicle may not be a solution to her employment problems. Relocation of that household to an area with better economic opportunities (in terms of travel time to jobs and the number of jobs relative to the number of welfare clients or other low-income individuals) or creation of more entry-level jobs within the travel-time catchment area of the client by means of economic development incentive programs would probably be better solutions than better transportation.

Along the same lines, the value of using distance to a transit station as a surrogate for level of accessibility to jobs can be questioned. If the transit line does not go to potential job destinations and clients need to make a number of difficult connections before job-rich areas can be accessed, then living close to a transit station does not offer much of an advantage for employment opportunities. In addition, the same arguments made in the previous paragraph regarding tolerable travel times and competition for jobs apply to public transportation systems.

From Model II in Table 3, it can be seen that the residential location of a client within a metropolitan area relative to job locations and the travel times to these jobs (the location index *l*) is by itself not significantly related to job tenure. However, when the effect of a multiplicative variable (with education level) is examined (in Model III), the relationship is found to be significant. This result implies that female clients who are high school graduates, when given the appropriate accessibility and location opportunities, enjoy increased job retention.

Table 4 shows that the mean value of the location index *l* is greater for female clients who had a greater number of jobs during the 2-year period than for those who changed jobs less frequently. As discussed earlier, the percent of clients with access to a vehicle increases as the number of jobs held increases (about 34 percent of clients who had four jobs or more had access to a vehicle compared with only about 17 percent of clients who had no job and about 27 percent who held only one job). Further, a greater percentage of women who held more jobs had valid drivers' licenses compared with women who had fewer jobs (the percent of women who had a valid driver's license among the no-job group is about 28 percent compared with about 46 percent for the group that held four or more jobs during the 2-year period). Access to employment opportunities (as indicated by higher location index averages), access to vehicles, and valid drivers' licenses have contributed to the reemployment agility of these women. They enjoyed greater periods of fuller-term employment retention during the 2-year period than clients who did not have such location and transportation benefits.

Clearly, the causes of greater employment retention cannot be separated here from its effects. Better residential location, greater access to vehicles, and greater share of driver's license possession may all be outcomes of increased employment retention. Improved employment stability may have contributed to relocation to better residential locations vis-à-vis jobs, greater access to vehicles, and maybe even vehicle ownership and acquisition of other material possessions

TABLE 4 Transportation and Location Factors by Number of Jobs Held During a 2-Year Period

Number of Jobs	Location Index Mean	Location Index Standard Deviation	Percent with Access to Vehicle	Percent with Driver's License
0	0.60	3.36	17.39	27.60
1	0.88	4.02	27.76	41.04
2	1.11	4.52	32.02	46.06
3	1.05	4.51	32.10	44.87
4	1.17	4.65	34.39	45.50

or skills that, in turn, further improve employment retention. Vehicle ownership makes an interesting example. Recent evidence shows that poor households expend dollars into vehicle ownership at high rates (*10*). This is perhaps indicative of the fact that, once low-income families achieve stable employment of some sort, a first priority is to purchase a car. This, in turn, allows easy access to greater economic opportunities.

Family and Social Effects

The results presented for the models in Table 3 indicate that job retention decreases with age and increases with education qualifications of high school and above. The effect of education on improving an individual's group membership (from a lower tenure group to a higher tenure group) is greater than the effect of reducing an individual's group membership due to increasing age. Younger women and more educated women tend to show more fuller-term employment (exhibit greater reemployment agility) compared with older women and less educated women (Table 5). The mean age of women who had four jobs or more was 26.74 years, whereas the mean age of women who held one job was 29.03 years. Also, the number of women with four jobs or more who had at least a high school diploma was about 56 percent whereas for those with one job it was about 54 percent. Of the no-job groups, about 46 percent had a high school diploma compared with 56 percent of women who held four or more jobs.

Table 5 shows that job retention decreases with lack of adequate child-care availability. Job retention also decreases with an increase in the number of young children in the household. These are two of the constraints faced by women vying for job retention. Frequently, no option is left for these women but to leave their jobs and seek employment with other employers. However, Table 5 shows that the percentage of women who had no child care does not vary a great deal with the number of jobs held in the 2-year period. The mean number of children in the household also does not vary very much with the number of jobs held in the 2-year period. However, the number of women with inadequate child care is about 30 percent for all groups, which is relatively high. Lack of adequate child care and presence of young children in the household appear to be chronic impediments to the employment status of female welfare clients. It appears that other factors, such as the location and transportation effects and education and age, are probably more important in differentiating which clients will seek and obtain reemployment when their tenure with a particular employer is over. Similarly, although Table 5 shows that being in school increases job retention with the same employer, there is little variability in the percentage of women who are in school across groups that differ on the basis of number of jobs held during the 2-year period.

SUMMARY OF FINDINGS

The following findings emerged from the study.

- Welfare clients who enjoy better job retention (longer employment in the same job) also enjoy more employment retention (longer periods of employment, but not necessarily at the same job).
- Individuals who enjoy increased job retention and employment retention are younger and more educated compared with those who do not enjoy such employment security. Job retention and employment retention also decrease with lack of affordable child care and with an increase in the number of young children in the household.
- The relationship of transportation and location effects to job and employment retention is complex.
  - Female welfare clients with the longest job retention tend to reside in areas where a large number of appropriate job openings are easily accessible within reasonable travel times and also where the competition from other clients for those jobs is lower.
  - Access to vehicles, while an important predictor of job retention, is not as useful as a variable that combines the competition for jobs and the number of jobs that can be accessed by a vehicle within "tolerable" travel-time limits.
  - Client residential location vis-à-vis job locations is, by itself, not significantly related to increased job retention. Female clients who have the necessary educational background, when given the appropriate job accessibility and locational advantages, enjoy increased job retention.
  - Clients who have access to a vehicle and a valid driver's license have greater job retention and employment retention rates.

CONCLUSIONS

The objective of this paper was to find out which factors affect job retention of female welfare clients. It was found, in particular, that employment security for female welfare clients or former clients comes not necessarily from "job" retention (that is, tenure with the same employer) but from "employment" retention (jobs with different employers, possibly with a trend toward upward mobility). The effects of transportation and location factors on job and employment retention are complex. Although access to a vehicle is important in increasing employment retention, of greater importance is how many job opportunities the client can access by a private vehicle or public transit systems within tolerable limits of travel time. Female welfare clients who retain a job longer and hold more jobs within a 2-year period are more likely to live in subareas of the metropolitan area where there is greater access to the number of jobs within reasonable travel times and where the competition for those jobs (from other low-

TABLE 5 Family and Sociodemographic Factors by Number of Jobs Held During a 2-Year Period

Number of Jobs	Percent with HS Diploma	Percent with no Child Care	Percent in School	Age Mean	Age St. Dev.	Children Mean	Children St. Dev.
0	45.94	33.70	9.14	31.69	8.19	2.01	1.30
1	54.01	34.07	11.82	29.03	7.22	1.85	1.15
2	59.58	30.08	11.60	27.38	6.45	1.82	1.13
3	56.65	29.88	12.01	26.79	6.18	1.80	1.08
4	56.09	30.86	10.42	26.74	5.99	1.80	1.12

income individuals) is low. Further, female clients with a high school diploma, when given the appropriate accessibility and location opportunities, enjoy increased job tenure. Access to employment opportunities, access to vehicles, and possession of valid drivers' licenses have contributed both to increased job retention and to the "reemployment agility" of female clients compared with clients who did not have such location and transportation benefits.

The implications of this study for the development of flexible transportation services to provide job accessibility to female welfare clients are profound. The provision of such services is a necessary prerequisite for successful job retention and economic independence.

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Women's Travel Patterns and the Environment

An Agenda for Research

Laurie Schintler, Amanda Root, and Kenneth Button

Demographic change, new family structures, and concerns about personal safety are contributing to a growing use of motorized transportation by women. The increasing importance of women as travelers has implications for the ways in which transportation policy must be reviewed in an era when sustainable development has become a key issue. An appreciation of the particular nature of women's travel behavior, and their designed behavior, could facilitate an easier path to sustainability. The travel patterns, needs, and psychology of women are examined, as well as the influence of these patterns and behavior on efforts to promote sustainable development. Women's travel patterns differ in important ways from those of men. In particular, gender differences arise in (*a*) the distance traveled, (*b*) the mode of travel, and (*c*) the complexity and purpose of trip making. The particular psychology of women contributes to these patterns. In comparison with men, women tend to be prone to ambivalent feelings, but their analysis of these feelings can prompt leaps in thought and creative solutions to problems. In addition, women are more risk averse than men. Risk aversion may affect women's travel decisions—for example, when security is a concern. Changes in the economy also are placing new demands and constraints on women, their lives, and their travel patterns. Future research on women and transportation should focus on the psychological aspects of women's travel, the special travel needs and circumstances of women, and the influence of changing economic conditions on women's travel patterns and the environment.

Concerns about the environmental implications of transport and about managing the expanding demands for its use are central issues in transportation planning and policy making today. This trend is largely universal and not a feature of only one particular country (*1*). Transport forecasts indicate that personal travel and freight transport will continue to grow for the foreseeable future, ensuring that the environmental damage will increase unless travel patterns change dramatically. Linked to this is the appreciation that society is willing to commit only a limited amount of resources to transport infrastructure. In practice much of this growth appears likely to take place in countries of the Third World and in the former communists states of Europe (*2*). In the United States, overall levels of transport are currently low, and the amount of mechanized transport used by women is less than in the industrialized countries forming the basis for this discussions.

An important element in the increased amount of travel being experienced is the enhanced mobility of women. The distances traveled by women have over the past 50 years tended, on a per capita basis, to be less than that of men. In the last 20 years, though, women's overall mobility patterns have begun to look increasingly like men's. Aggregate patterns, however, can be deceptive. In the United States, there has been an increase in the number of women on the road, largely due to the changing role of women in society; more women are entering the workforce. Since 1969, the number of women in the U.S. workforce has increased by 122 percent. This is in sharp contrast to men, whose numbers in the workforce have increased by only 47 percent (*3*). At the same time, women continue to be the primary caretakers of household and family obligations. Demographic change, new family structures, and concerns about personal safety are also contributing to a growing motorization of women. As a result, at the micro level, the travel needs and patterns of women have tended to differ significantly from those of men.

The increasing importance of women as travelers has implications for the ways in which transport policy must be reviewed in an era when sustainability has become a key issue. At one level is the issue of gender equity in terms of the ways in which transport strategies are devised. But in addition, appreciation of the particular nature of women's travel behavior, and their designed behavior, could facilitate an easier path to sustainability. This paper examines the travel patterns, needs, and psychology of women, and the influence of these patterns and behavior on efforts to promote sustainable development.

The paper contains six sections. The first section reviews the concept of sustainable development. The second section identifies differences between men's and women's travel patterns and needs, while the third section attempts to understand these differences from a psychological perspective. The fourth section examines some safety concerns of women as they relate specifically to transportation. The fifth section discusses how changing economic conditions at the macro level are affecting the travel patterns of women but also are offering more opportunities for female participation in the transportation planning process. Lastly, the paper concludes with an agenda for future research.

TRANSPORT AND SUSTAINABILITY

Sustainability is a global concept. It is for this reason that notions of "sustainable transport" or "sustainable mobility" really have limited meaning other than as guideposts. The question of developing a transport strategy that fits within this global framework involves deciding which social and environmental objectives are to be promoted (*4*). This task was most famously undertaken in the Brundtland Commission's definition of sustainability as "ensuring that the needs of the present are met without compromising the ability of future generations to meet their needs" (*5*). Although succinct and memorable, it

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should be noted that there this definition does little to actually clarify how the needs of the present generation are to be balanced with those of future generations. There is also an ongoing debate about the extent to which sustainability in transport should involve (*a*) conserving social "goods" (e.g., communities or "social capital" such as trust) (*6*) or (*b*) giving priority to protecting or upgrading the physical world (improving air quality, reducing noise, or preserving tranquil landscapes, for example). In itself, the definition also says nothing about sustainability in transport or any other sector. Indeed, it takes little imagination to develop quite plausible scenarios in which the expansion of transport may be the preferred option from the perspective of sustainable development. Much depends on the way resources are used outside of transport and the links between transport and other activities (*7*).

Although the process of climate change is complex and the full effects cannot be predicted, there is broad international agreement that anthropogenic change is taking place. Transport is responsible for some 23 percent of carbon dioxide, the main "greenhouse gas" emissions, in Organization for Economic Cooperation and Development countries, up from 19 percent in 1970 (*8*). In 1995 transport was responsible for about two-thirds of forest-damaging nitrogen oxides in the United Kingdom. At the local level, transport damages urban environments and rural landscapes—through ozone smogs and physical destruction of landscapes for road building, for example (*9*). Many transport emissions are recognized as toxic and potentially damaging to health (*10*). The importance of these meso- and local levels of environmental intrusion, besides their immediate impact, is their effect on sustainability of sociopolitical systems. Sustainable development, although couched largely in environmental terms, also implies a sustainable social and political infrastructure if it is to be durable (*11*). Environmental spillover can, for example, lead to international and interregional tension. A degraded local or urban environment poses social problems and is a severe handicap for economic development. Thinking of sustainability simply in global warming terms is, therefore, inadequate. It is in this broader sense that, for example, the European Union (EU) has attempted to develop its integrated transport and environmental policy (*12*).

WOMEN AND MOBILITY

The mobility patterns and travel needs of women have several implications for sustainable development. These patterns differ in a number of important ways from those of men. In particular, gender differences arise in (*a*) the distance traveled, (*b*) the mode of travel, and (*c*) the complexity and purpose of trip making. While there has been some convergence between genders on the first two differences, the last difference does not show signs of convergence. Future demographic changes, and in particular those that relate to aging of the population, are likely to further these trends, but also create new patterns based on the travel needs and desires of elderly women.

Distance Traveled

In western society, women traditionally have been less mobile than men, although this situation is changing. In the United Kingdom, for example, women in all age groups are increasing the distances that they travel by mechanized transport and especially as car or van drivers (Table 1). During the last several decades, the mobility of women from all age groups in the United States has also improved. Between 1969 and 1995, the average annual person-trips taken by women increased by 11 percent (*3*). This rate of increase was less for men, despite the fact that the population growth rates of men and women were both about 40 percent over the same time period.

Improvements in mobility can be attributed largely to more women becoming licensed drivers. Since 1969, the number of licensed female drivers in the United States has increased by 95 percent, whereas for men it has increased by only 53 percent (*3*). Furthermore, in the 1980s and 1990s the increase in women drivers exceeded that of new men drivers. This situation is not unique to the United States. In the United Kingdom, there was a 90 percent increase in the proportion of women with driving licenses between the mid-1970s and mid-1990s, but only a 17 percent increase in the proportion of license-holding men. In 1975–76 women drove 17 percent of the miles driven by men, but by 1994–96 this proportion had increased to 37 percent. Further, in 1975–76, almost twice as many men could drive as women, but by 1993–95 the difference had lessened to 81 percent men being able to drive and 55 percent of women (Tables 2 and 3). The situation is similar in Germany, where women aged 25 to 34 years have the highest levels of vehicle ownership (Figure 1). In addition, the 18-to-40 age group is catching up with men's levels of driving-license holding: 80 percent of women and 90 percent of men having a full driving license for ages 18 to 40 compared with respective figures of 82 percent and 52 percent for all ages (*13*).

These trends could reflect the declining quality and availability of public transport in some countries or more general trends of greater population dispersion as incomes rise, higher labor force participation rates, and changes in family structure. A more geographically dispersed population, for instance, requires more complex travel patterns to meet traditional household care-taking and family obligations, let alone labor force participation.

Mode of Transportation

Despite their increase in automobile use and enhanced mobility, women still travel shorter distances than men, and when they do travel, they travel on what are generally considered less prestigious modes of transport. In the United States, women drive only 60 percent to 70 percent as many miles as men (*3*), and on average they travel 27.8 person-miles a day, which is slightly less than the 35.2 person-miles a day that men travel. In 1994–96, women traveled less far than men in the United Kingdom by all modes apart from buses, walking, and as passengers in private cars. Statistics on aircraft, ship, and channel tunnel journeys according to gender are not available for the United Kingdom, but they probably would tell the same story. In addition, women are passengers for about half the travel they do, while men are passengers for only one-fourth of the time (*3*). In 1975–76, women drove about a fifth of the miles driven by men, but by 1994–96 the gap had closed somewhat, and women drove about two-fifths of the miles that men drove (*14*).

In Germany, many adult women have less car availability than men and are therefore more likely to be captive transit riders. Fewer women, both unemployed and employed, have a car available. The biggest differences, however, are between men and women who have a car available to them in the household but do not have a driving license (*13*).

Complexity and Purpose of Trip Making

Overall, women seem to have somewhat different reasons for traveling than men (*14*). Women's entry into the workplace has created a new set of trips, referred to here as "knock-on" trips, or trips gen-

TABLE 1 Distances Traveled per Person per Year in the United Kingdom by Main Mode, Age, and Gender

	17-20 Years		21-25 Years		26-39 Years	
	Male	Female	Male	Female	Male	Female
Walk						
1975/76	496	514	383	456	308	415
1985/86	536	546	449	464	336	399
1994/96	444	452	357	401	287	335
Bicycle						
1975/76	156	40	153	58	111	45
1985/86	214	74	121	50	114	32
1994/96	180	50	145	21	118	35
Car/van driver						
1975/76	3,358	858	8,042	1,726	9,755	1,686
1985/86	3,243	1,814	8,361	2,710	10,876	2,982
1994/96	4,382	2,447	9,984	4,498	13,766	5,049
Car/van passenger						
1975/76	3,140	3,230	1,913	3,850	1,188	3,243
1985/86	2,874	3,689	2,281	3,885	1,356	3,550
1994/96	3,595	4,163	2,869	3,737	1,739	4,049
Motorcycle						
1975/76	942	64	425	106	122	16
1985/86	507	92	427	71	175	31
1994/96	87	43	116	35	148	16
Local bus						
1975/76	1,315	2,033	824	1,026	465	750
1985/86	1,014	1,228	557	800	293	456
1994/96	913	1,198	449	620	224	401
Rail						
1975/76	1,245	1,377	774	768	1,045	351
1985/86	707	800	1,003	1,148	992	526
1994/96	728	1,024	974	1,198	998	657
Total distance travelled						
1975/76	11,228	8,594	13,096	8,280	13,424	6,775
1985/86	9,787	8,939	13,717	9,731	14,709	8,451
1994/96	11,140	10,172	15,450	11,111	17,831	10,966

NOTE: Distances are given in kilometers. Total distance travelled includes other modes not listed in the table.
SOURCE: U.K. Department of Environment, Transport, and the Regions. National Travel Survey 1994–96. HMSO, London, U.K., 1997.

erated by the substitution of home production for market production. Statistics show that women are more prone than men to make these types of trips. Approximately 50 percent of all person-trips made by women in the United States are for family and personal business, and two-thirds of the trips women make are to take someone else someplace (*14*). In 1994–96, women in the United Kingdom made 28 percent fewer commuter journeys and 68 percent fewer trips during their work than men. Evidence in the United States shows that women take a greater share of household responsibilities, and, linked to this, they are making 65 percent more "escort education" journeys (taking children to school) and approximately 30 percent more shopping trips. The same pattern appears across the previous

TABLE 2 Full Car Driving License Holders in the United Kingdom by Age, Gender, and Year (*14*)

	Male			Female			All adults		
Age	1975/76	1985/86	1993/5	1975/76	1985/86	1993/5	1975/76	1985/86	1993/5
17-20	35	37	50	20	29	42	28	33	46
21-29	77	73	82	43	54	68	60	63	74
30-39	85	86	90	49	62	74	67	74	81
40-49	83	87	89	37	56	72	60	71	80
50-59	75	81	88	25	41	59	50	60	73
60-69	59	72	82	15	24	39	36	47	60
70 or over	33	51	61	4	11	19	15	27	35
All adults	69	74	81	29	41	55	48	57	67

Source: UK Department of Environment, Transport and the Regions (1997b).

TABLE 3 Number of Full Car Driving License Holders in the United Kingdom by Gender and Year (*14*)

	1975–76	1985–86	1993–95
Male	13.3	15.1	17.4
Female	6	9.1	12.7
All adults	19.3	24.3	30.1

NOTE: Values given are in millions of persons.

10 years. Category changes make longer comparisons impossible for the United Kingdom.

In the United Kingdom, there also appears to be a correlation between the distance traveled by women and the need to tend to child care, caring for the elderly, and domestic responsibilities. In this sense, the pattern has changed little in recent years. In 1994–96, until the age of 20, women in the United Kingdom were typically traveling distances almost identical to men. In 1995–96, travel for women between the ages of 26 and 59—the prime years of domestic caring responsibilities—dropped to just over half that of men, a pattern that was broadly the same as 20 years earlier. The pattern is not unique to the United Kingdom or the United States. Hanson and Hanson's work (*15, 16*), for example, offers insights into the importance of married women's employment for travel patterns in Sweden, and Dyck (*17, 18*) covers similar issues in Canada.

Complex travel behavior such as trip chaining is also more common for women than men (*19*). This is certainly the case in the United States, even when both males and females are in employment (Table 4). Women make more stops to run household errands than do men, on both inward and outward commutes, irrespective of the number of persons in a household or its structure. On average, two in three American women make stops on their way home, and 25 percent make more than one stop. The places visited differ, with women tending more often to visit schools, day-care centers, and shops. Men are twice as likely to go to a restaurant or bar. The trend for these more-complex commuting patterns is upward. In the United States, the number of intermediate stops on the way to work has grown by about 50 percent since 1980 and the number on the way home by about 20 percent (*3*).

Future Trends

Demographic trends indicate further improvements in mobility for women and continued growth in the number of women drivers on the road. Many of these drivers are likely to fall in the older age cohorts (e.g., 65 years of age). In the United States, between 1969 and 1995, the highest rates of growth in population were in these cohorts. In 1995, almost 65 percent of the 75-year-old-and-over population was female (*3*). Currently, elderly women are predominantly not driving-license holders (*13*) and consequently have only limited use of cars as passengers. This picture will change dramatically when the current cohorts of younger and middle-aged women begin to enter the older age categories. A far higher proportion of these women, at one-third from German evidence (Figure 1), will have been car owners for the majority of their lives and will expect to use cars for their mobility in their old age.

As these trends continue, the share of elderly women on the road is likely to increase dramatically. Many of these women will be highly educated, wealthy, licensed to drive, and as a result extremely mobile (*19*). Furthermore, life expectancy figures suggest that because, women are outliving men, they will wish to be mobile for longer. Life expectancy is greater for women than for men in both North America and the EU. Additionally, if, as demographers suggest, the whole population ages, the proportion of very elderly women who still have mobility requirements will increase further. These points suggest that as the female population ages, gender differences may be reduced or even disappear. At the same time, they might suggest an increase in leisure-related travel on the part of women.

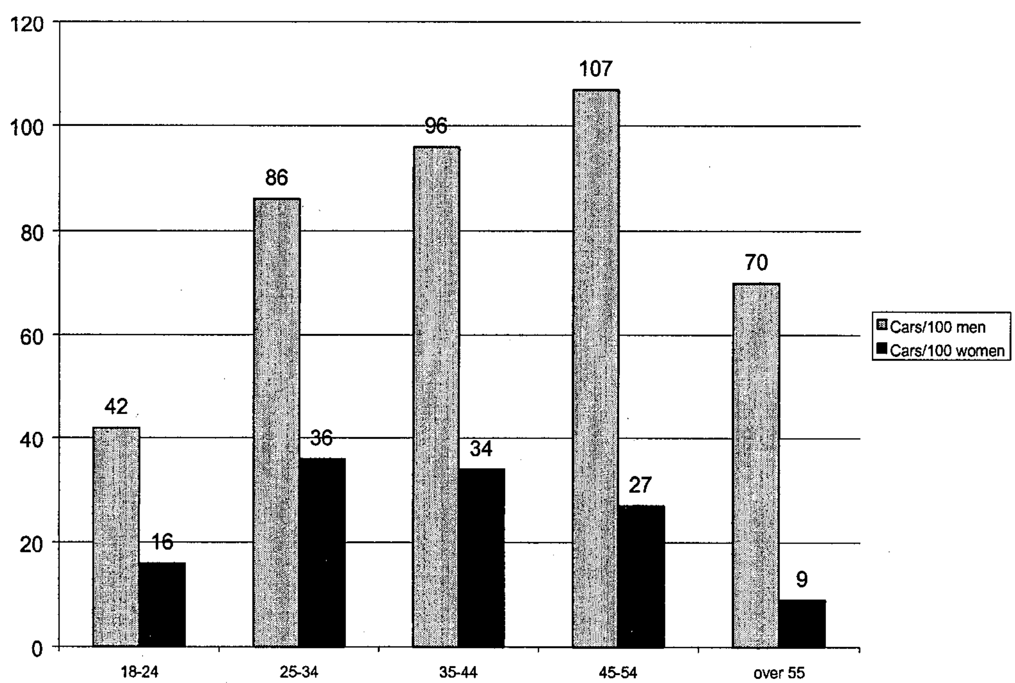

FIGURE 1 Passenger car ownership in Germany by age group, 1986.

TABLE 4 Commuters Stopping for Errands in the United States During the Morning and Evening Commute, 1995

	One Stop		Two or More Stops	
	Men	Women	Men	Women
Between home and work				
1 adult, no child	11	15	5	5
2 adults, no children	13	14	6	8
1 adult, child (age 0–5[a])	32	41	1	23
2 adults,child (age 0–5[a])	15	38	6	15
1 adult, child (age 6–15[a])	14	32	16	14
2 adults,child (age 6–15[a])	17	25	5	12
Between work and home				
1 adult, no child	32	29	20	31
2 adults, no children	29	30	17	25
1 adult, child (age 0–5[a])	15	31	32	49
2 adults,child (age 0–5[a])	28	42	19	29
1 adult, child (age 6–15[a])	29	38	34	32
2 adults,child (age 6–15[a])	29	33	16	29

[a] Age of youngest child.
Source: US. Nationwide Personal Transportation Survey, 1995.

These trends and patterns in women's use of transportation have implications for sustainability, or our ability to move closer to sustainable development. From an environmental perspective, multiple stops could have adverse implications for atmospheric pollution because of the larger amount of "cold running" entailed. At the same, short trips, if linked together as in a trip chain, may be beneficial to air quality. Trip chaining helps reduce emissions by eliminating the cold start and reducing vehicle miles traveled (U.S. Department of Transportation/Environmental Protection Agency, 1999). The types of diversions undertaken by women also suggest that a larger amount of time is spent in noise-sensitive areas and areas susceptible to the adverse effects of exhaust gas emissions. From a transport policy perspective, there is also the problem that the diversity of variations in trip patterns is larger for females. The multiple purpose of trips also means that many forms of fixed-track transport are not well suited to women's travel needs. As a consequence, women are increasingly relying on the automobile as a primary mode of transportation. Some would argue, however, that complex travel behavior such as trip chaining is the product of creative problem solving on the part of women. This argument, which relates to the psychology of women, is discussed next.

PSYCHOLOGY AND WOMEN

Psychology contributes to many transport choices and problems. Research has shown that men and women differ in terms of their psychological attributes. For example, compared with men, women tend to be more ambivalent. Feelings are never simple, nor unequivocal in their linkage to behavior, but it is appropriate to discuss ambivalence in the context of transport choice. Women are, in general, considered more exposed to ambivalent feelings than men in their role as parents. Parker (*20*) claims that "we can speak of the creative outcome of manageable [maternal] ambivalence."

Similar arguments have been taken by the sociologist Giddens (*21*), who argues for greater recognition to be given to complex emotions such as ambivalence which are inscribed in "private" and well as "public" life. In another instance, Samuels (*22*) argues for the importance of recognizing ambivalence as an important area of interconnectedness, tension, and interplay between the psychological and the sociopolitical worlds. He also suggests the need for engagement with the forces that push simple, nonpluralistic answers in the real, political world as in the mind. Parker goes further with her theory that maternal ambivalence allows some women to make qualitative leaps forward in their thinking. The experience of ambivalence can be an intellectual catalyst, not necessarily a confused or negative process.

It would appear that many social groups, but particularly some groups of women, are especially prone to ambivalent feelings but that their analysis of these can prompt leaps in thought and creative solutions to problems. This brief overview suggests that gaining a better understanding of the ways in which women use ambivalence might contribute to further insights into why women are currently choosing to travel more ecologically than men.

Women also tend to be more risk averse than men (*23*). Although this issue was not studied conclusively, some evidence suggests that women are more risk averse than men when it comes to making travel-related decisions. In studies of traveler information services, women are often less prone to switch routes after receiving travel information on alternative routes (*24*). In a stated preference survey of Los Angeles, California, travelers, women tended to be more conservative in their selection of travel alternatives. When given the hypothetical choice between two routes—for example, one that is relatively long but predictable in terms of travel time and another that is less predictable but potentially shorter in terms of travel time—women tended to select the former and men the latter (*24*). In addition, risk aversion may affect women's travel decisions when security and safety are a concern.

SECURITY AND WOMEN

Women are generally physically smaller than men and more often travel with vulnerable children. This both poses real fears of attack and affects perceptions of the safety of travel. In the United Kingdom, "stranger danger" fears appear to be reemerging, compared with the middle years of this century. In the late 1980s, it was found that between 50 percent and 70 percent of women were frightened of going out after dark in cities (*25*). In the mid-1990s, one in eight women surveyed said that she felt so unsafe on public transport that she avoided using it (*26*). Eleven percent of women interviewed never ventured out after dark. Nevertheless, despite the difficulties of travel, it appears that women were, in general, less confined to their homes at the end of the century than earlier in the century. This was largely because of car ownership (*27, 28*). There is irony in the fact that fewer men worry about attack, but they are more likely to suffer from it. According to the *British Crime Survey* (*26*), 9 out of 10 attacks by male strangers are carried out against men.

Women's experience of traveling at night often makes them feel unsafe when compared with traveling in the day. For example, 10 percent of women in the United Kingdom felt "Unsafe" or "Very Unsafe" waiting on a railway platform in the day, but this figure rose to 53 percent at night (*29*). Similarly, women experienced heightened fears in relation to waiting for underground trains or walking to a car in open or multistoried car parks. More attacks happen during the day, but, due to fewer numbers traveling at night, the probability of attack at night is higher. Thus the common perception of the danger of traveling after dark is grounded in actuality.

However, women are more often attacked by people they know, and in the home, than by strangers outside (*30*). Yet the fear of public spaces and stranger danger in them dominates the lives of particular groups of women, especially middle class and younger women, "whose fears reflect the geographies of risk less accurately" (*31*). Thus, as Pain notes, ideologies of public and private space distort perceptions of safety.

Despite these concerns, more women now travel at hours later in the evening. Currently, about half of all "moonlighters" in the United States, for example, are women (*19*). Furthermore, for many women who work during the day, trips for household and domestic duties must be completed in the evening hours. These trends raise security issues for women, particularly for those who choose to travel by public transit. Security will increasingly be a concern as more women demand transportation. This increase in demand has been and will continue to be precipitated by the new, "post-Fordist" economy. This topic and its relationship to sustainability are discussed next.

POST-FORDISM AND WOMEN

The term "post-Fordism" is controversial. It represents a set of changes that have happened in the post-World War II period in both the United States and Europe. Post-Fordist change has been described as,

> A shift to the new "information technologies"; more flexible, decentralized forms of labor process and work organization; decline of the old manufacturing base and the growth of the "sunrise," computer-based industries; the hiving off or contracting out of functions and services; a greater emphasis on choice and product differentiation, on marketing; packaging and design; on the "targeting" of consumers by lifestyle, taste, and culture rather than by categories of social class; a decline in the proportion of skilled manual working class, the rise of the service and white collar classes and the "feminization" of the work force; an economy dominated by multinationals, with their new international division of labor and their greater autonomy from nation state control; and the "globalization" of the new financial markets, linked by the communications revolution. (*32*)

Typically, in labor market terms, post-Fordism involves a financial system that is increasingly volatile and unsteady, with economic cycles being rapidly transmitted through the system, undermining the basis for stable development. In employment terms, this can mean (with national and regional variations) the rise of temporary jobs, the polarization of highly skilled and deskilled workers, and the local state being less well able to meet social welfare objectives. Post-Fordism does not, however, only involve transformations in employment. It also affects consumption, creating a "maximization of individual choices through personal consumption" (*32*) and rendering leisure journeys even more important as forms of consumption.

Post-Fordism is imposing new demands and constraints on women, their lives, and their travel patterns. These constraints, however, cannot operate without resistance. They also position women, with a large degree of congruence, in the role of those categorized above as likely to value accessibility more than mobility. Traditionally, however, men have done transportation planning and engineering. To a large extent, this is still true today. In 1995, less than 10 percent of all civil and architectural engineers were women (*33*). Although the number of women in the field of planning is increasing, they represent only 40 percent of the field. Specific numbers for transportation planning are not readily available (personal communication, R. Mattox, director, Women's Division, American Planning Association, 1999). It might be argued that women, who are increasingly users of transport, are likely to understand the values of traffic management and restraint better than those, such as engineers, whose professional and personal lifestyles are geared toward mobility. In other words, post-Fordist changes in the economy and cultural sphere have led, and are leading, to qualitatively new situations in which women are likely to be most appropriately positioned to develop new cultural patterns and to participate critically in constructing what Castells (*34*) calls the "space of flows."

AGENDA FOR FUTURE RESEARCH

Better understanding the travel characteristics and trends of women can ease the path to sustainability. More research in this area is needed, specifically research that addresses the psychological aspects of women's travel, the special travel needs and circumstances of women, and the influence of post-Fordism and other economic conditions on women's travel patterns. Advancements in modeling, theory, and empirical knowledge are all encouraged.

Psychological Aspects of Women's Travel

It would be useful to examine how women's ambivalence is transferred to decision making about cars, mobility, and accessibility, and whether this leads to more creative and ecological travel decisions. This research might provide some insight on the complex ways in which many women want the benefits of cars and an automobile lifestyle and at the same time want a cleaner, safer, quieter, less carbon dioxide–filled world, with more pedestrian-friendly streets and public space. A recent survey in the Washington, D.C., metropolitan area found that women were more likely than men to adopt strategies for air quality improvement, even if those strategies required behavioral changes in travel. In addition, women were more willing to accept personal accountability for air quality, in contrast to men, who thought it was the government's responsibility (*35*). An understanding of this psychology could facilitate the path to sustainability.

Understanding how risk influences women's travel decisions is also important. The effectiveness of traveler information services in reducing congestion, improving air quality, and promoting sustainable transportation, for example, depends largely on the reactions of travelers to information provided through these services. Traveler information services are increasingly seen as a tool for travel demand management. Current modeling efforts are focusing on developing methods for simulating the effects of traffic information on an individual's choices of departure time, route, mode of transport, and destination. Gender differences should be reflected in these models. It would also be useful to explore the decision-making process of women—for example, in terms of the way choice sets are formulated and how alternatives are selected. This information could be incorporated into newly emerging modeling frameworks that assume travelers are boundedly rational, or that they select the best alternatives according to some perception of desirability and set of feasibility constraints. Nonlinear utility functions should be explored that reflect women's attitudes toward risk.

Special Travel Needs of Women

Traditional travel demand theories and models assume that each traveler's primary concern is to minimize travel time or cost regardless of gender. One possibility highlighted in this paper is that other factors such as safety, comfort, and accessibility to opportunities may be more important than travel time to many women. It would be useful to explore this empirically. Travel demand models should be revised to reflect any gender differences.

There is also further work to be done to make modeling combine female as well as male values and priorities. For instance, because many of women's journeys are likely to combine work and nonwork functions (such as shopping on the way to work), time valuations need to be adjusted to reflect this. Similarly, valuations of waiting times for trains are assigned by the socioeconomic class of passengers or by the mode of transport by which they arrived at the station (a proxy for class). Given the complexities of claims on women's time, many of which cannot be "read" via socioeconomic class distinctions, it would be useful to include weights that reflect women's needs.

One rapidly developing area of research is activity-based travel demand and modeling. To complement these efforts, additional research should be conducted to explore differences between men and women in terms of desired activities and the travel patterns that result from carrying out these activities. One area of focus might be leisure travel, for example.

Women and Transportation in a Post-Fordist Economy

Several ways in which the post-Fordist economy is influencing the transportation needs and patterns of women have been discussed. Understanding how economic circumstances such as those present in the new economy influence the travel characteristics of women is important. One interesting question, for example, is whether or not there is a correlation between regions with more advanced economies and changes in transportation usage by gender.

CONCLUSIONS

Due to the progression to the post-Fordist era, there have been dramatic cultural, social, and economic changes for both genders, but particularly women. They are frequently positioned in gender-specific ways in the labor market and in the domestic sphere. These factors contribute to a juggling of home with paid work responsibilities, creating gender-specific travel patterns and needs, and creating a situation in which women are more likely to be tied to particular localities. This localization of complex journeys and lifestyles could mean that women continue to make more short trips than men and that they value safe local streets, relatively clean air, and low levels of traffic noise more than men do. They also are more likely to be able to relate traffic levels to damage to social relations and community networks. As a consequence, women are less likely to adopt the dominant attitude of valuing mobility above accessibility. These qualities mean that some groups of women could respond more positively to the challenges of environmentalism in transport.

Arguments have been developed that suggest a need to ensure that women's different experiences of mobility and accessibility are recognized in transport modeling and policy development. It is not clear, for example, how the conventional models of travel demand, with their focus on travel time and monetary costs, truly reflect all the attributes that potential women travelers consider. The example was given of how fears about safety limit the freedom of the majority of women in some cities to go out alone after dark.

But the argument also has been made that there are some causes for hope that women will be able to lead moves toward more sustainable transport. Some of the reasons for making this argument are summarized under the label "post-Fordism." It is argued that women's experience as marginalized workers who combine home and work responsibilities can make them both more able to change transport habits and also more aware of the values that accompany the notion of sustainable development. Also outlined have been some reasons that women are more prone to ambivalence and the ways in which these complexities could be leading women to question the current orthodoxy of car-dependent mobility. Finally, recognizing the ambivalence of women toward cars—appreciating cars' utility and simultaneously knowing the environmental and social harm they cause—is perhaps the biggest methodological challenge facing those concerned with making transport more sustainable.

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