CAN TRANSPORT POLICY DECISIONS CHANGE URBAN STRUCTURE?

by

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Paper presented at the Transportation Research Board Annual Meeting
Washington, D.C., January 1978
The paper suggests that policy decisions on travel and urban structure tend to be based in part on established beliefs which, upon close inspection, do not appear to be substantiated by the available observations. Two examples are cited.

The first is the belief that people in compact cities need less motorized travel than in dispersed cities because more destinations are within walking distance. To test this assumption, a comparison of travel characteristics in a wide range of cities in both developing countries and the US was conducted. The trip rate per capita was found to be unsatisfactory as a common denominator since household size in the former cities is about double that in the latter cities. Hence, the rest of the comparisons are based on the travel per car. The results show that the daily travel distance per car is remarkably similar in all cities, whether small or large, compact or dispersed. Based upon this and additional observations, it is suggested that car drivers, on average, tend to travel a certain minimum distance per day, for which they are willing to expend relatively stable maximum amounts of time and money under "equilibrium conditions", namely when the daily travel can be satisfied within the lower constraint of travel distance and the upper constraints of both time and money. The paper also discusses cases of "disequilibrium conditions" and their possible effects on urban structure.

The second example refers to the belief that, by increasing the cost of travel, in money and/or time terms, dispersed cities may be encouraged to coalesce back into compact ones. However, all available observations suggest that instead of residences gravitating back towards the jobs at the city center, the opposite process occurs under increased travel costs, namely that jobs disperse outwards, towards the residences.

Although the comparisons are based on scanty data, they appear to be disturbing enough to suggest that more attention be given to inter-city comparisons, on an international basis. It is suggested that international organizations, such as the World Bank, could greatly assist in furthering the understanding of the interactions between urban travel and land use, and that such an understanding would lead to better policy decisions on urban development.
INTRODUCTION

Decisions about the future of cities depend on the interpretation and understanding of the phenomena and trends observed in them. However, practically all of the theories of and techniques for the analyses of urban structures and travel have been developed upon the experience gained in developed countries and, hence, tend to reflect a limited range of conditions, which are not necessarily universal, neither between cities nor when applied to one city over time.

This paper presents examples of several cases where the interpretation of observed phenomena could lead to erroneous policy decisions if not free of past beliefs. For instance, it is generally believed that compact cities, such as typically found in developing countries, require comparatively little motorized travel since more opportunities in them are within walking distance than in dispersed, low-density cities. This belief can easily lead to the conclusion that changing dispersed cities into compact ones would result in less motorized travel. But, is it true that people in compact cities travel by motorized modes less than in dispersed cities? And if travel in dispersed cities is made to be more difficult/expensive by policy decisions, will such cities contract to a more compact structure? Such questions are of extreme importance especially now, when the predicted energy shortage and the ever-increasing prices of gasoline, make travel a prime target for conservation measures.

1. THE NEED FOR MOBILITY

1.1 The first example deals with the observed trip rates in a selection of cities in developing countries versus a selection of cities in the US, as detailed in Table 1 (1). All the following data were derived from the original published reports on the comprehensive transportation studies carried out in each city, as follows: Trips are the linked-trips;

(*) This paper incorporates material collected and prepared by the author when working as a consultant to the Urban Projects Department of the World Bank. The Bank does not necessarily endorse the findings and opinions presented in this paper.
the car trip time is either the reported time or derived from the trip frequency distribution; the car trip distance is either the reported distance or derived from the (inter-zonal) assignment; the estimated speed is the quotient of trip distance over trip time; and the observed speed is either the reported daily average speed or derived from the assignments (some unexplained small differences between the two speeds are evident). Furthermore, no data on walking trips were available in these cities.

It is also to be noted that the population densities in Table 1 are not fully representative of base year conditions since the metropolitan study areas usually include undeveloped spaces that are expected to be urbanized in the future. One of the principal criteria for the selection of cities was the availability of the travel components that appear in Table 1.

| Table 1: City and Motorized Travel Characteristics in Selected Cities in the US and Developing Countries |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| **City**        | **Monroe**      | **Orlando**     | **Cincinnati**  | **Twin Cities**| **B.C.**        | **Philadelphia**| **DEVELOPING COUNTRIES** | **Tel Aviv** | **Kuala Lumpur** | **Singapore** | **Darmaas** | **Bogota** | **Bangkok** |
| **Population**  | 96,530          | 355,620         | 1,391,970       | 1,874,380       | 2,558,100       | 3,012,460       | 2,124,370       | 912,490         | 1,536,000        | 1,729,000        | 2,339,600       | 4,067,000       | 1,972           |
| **Area, sq. km.** | 200             | 1,400           | 3,495           | 7,680           | 3,060           | 3,040           | 3,495           | 3,060           | 3,060           | 3,060           | 3,060           | 3,060           | 3,060           |
| **Population**  | 480             | 250             | 400             | 240             | 750             | 1,250           | 1,250           | 1,250           | 1,250           | 1,250           | 1,250           | 1,250           | 1,250           |
| **Gams**        | 31,650          | 137,260         | 484,770         | 717,000         | 1,018,900       | 1,087,900       | 1,087,900       | 1,087,900       | 1,087,900       | 1,087,900       | 1,087,900       | 1,087,900       | 1,087,900       |
| **Motorization**| 32.8            | 36.6            | 34.8            | 38.3            | 39.8            | 28.5            | 39.8            | 41.2            | 3.28            | 3.96            | 3.96            | 3.96            | 3.96            |
| **Car Trips**   | 183,356         | 594,820         | 1,759,080       | 2,953,670       | 3,342,000       | 4,303,750       | 4,303,750       | 4,303,750       | 4,303,750       | 4,303,750       | 4,303,750       | 4,303,750       | 4,303,750       |
| **Car Trip Rate** | 5.79            | 4.33            | 3.63            | 4.12            | 3.28            | 3.96            | 3.96            | 3.96            | 3.96            | 3.96            | 3.96            | 3.96            | 3.96            |
| **Person Trips** | 287,630         | 915,990         | 3,067,690       | 4,976,730       | 5,288,780       | 8,045,490       | 8,045,490       | 8,045,490       | 8,045,490       | 8,045,490       | 8,045,490       | 8,045,490       | 8,045,490       |
| **Person Trip Rate** | 2.98            | 2.58            | 2.20            | 2.66            | 2.07            | 2.11            | 2.11            | 2.11            | 2.11            | 2.11            | 2.11            | 2.11            | 2.11            |
| **Trip Distance, km.** | 4.51            | 6.92            | 8.85            | 8.19            | 10.59           | 7.88            | 7.88            | 7.88            | 7.88            | 7.88            | 7.88            | 7.88            | 7.88            |
| **Trip Time, min.** | 7.3             | 9.7             | 13.7            | 12.5            | 15.6            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            |
| **Car Daily Distance, km.** | 86.1            | 30.0            | 30.1            | 35.7            | 34.7            | 31.2            | 31.2            | 31.2            | 31.2            | 31.2            | 31.2            | 31.2            | 31.2            |
| **Car Daily Time, h.m.** | 0.71            | 0.70            | 0.63            | 0.66            | 0.85            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            |
| **Speed, Estimated, kph.** | 37.1            | 42.8            | 38.6            | 39.3            | 40.7            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            |
| **Speed, Observed , kph.** | 35.1            | 48.6            | n.a.            | 37.9            | 40.9            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            | n.a.            |
Figure 1 shows the total daily trip rate per capita by motorized modes (private + public modes) in the selected cities. As expected, motorized trip rates in the US cities are indeed significantly higher than in developing countries, presumably because more destinations in compact cities are within walking distance than in the dispersed cities of the US.

![Graph showing person trip rate vs. city size](image)

**Figure 1: Person Trip Rate by Motorized Modes vs. City Size**

However, there are other possible explanations for the lower trip rates in the developing countries' such as: (i) lower income and motorization levels, which tend to reduce mobility; (ii) higher congestion levels, which reduce mobility by increasing the costs of travel, in both time and money terms; and (iii) larger household size, about double that in the US, with many young children, which reduces the trip rate per capita.

1.2 In order to resolve the above difficulties and base the inter-city comparisons on a common denominator, all the rest of the relationships are for car travel only, where the car is the basic unit for comparison.

Figure 2 presents the relationship between the car daily trip rate versus city size.
Figure 2: Car Trip Rate vs. City Size

A surprising result is that although cities in developing countries are more compact than in the US, and hence are expected to generate fewer motorized trips per average car, the actual car trip rates are significantly higher in the former cities than in the US. For instance, the car trip rate in a 1-million city in developing countries is found to be about 6.5 versus only 4 in a comparable city in the US, namely higher by about 60 percent.

1.3 One possible explanation for the above result is that trip distances are expected to be shorter in compact cities than in dispersed cities. Indeed, this expectation is borne out in Figure 3, where the car trip distances in cities of developing countries are observed to be significantly shorter than in cities of the US.

Figure 3: Car Trip Distance vs. City Size
Put in another way, it would be reasonable to expect trade-offs between trip rates and trip distances within the total travel distance that can be generated within the constraints on travel, such as the travel money and time constraints. Hence, the attention will be shifted now to the car total daily travel distance.

1.4 The product of the daily trip rate and the daily average trip distance results in the total daily travel distance. Such total daily distances per average car are shown versus population size in Figure 4, versus speed in Figure 5, and versus the physical size of the study area in Figure 6.

![Car Daily Travel Distance vs. City Size](image1)

**Figure 4: Car Daily Travel Distance vs. City Size**

![Car Daily Travel Distance vs. Speed](image2)

**Figure 5: Car Daily Travel Distance vs. Speed**
Figure 6: Car Daily Travel Distance vs. Study Area

It becomes evident from these three figures that, remarkably enough, no clear relationship between the car daily travel distance and the characteristics of the urban area can be defined. Namely, the values are relatively stable, within a range of 25 to 35 kilometers per average car per day, clustering around the 31 kms. level. (In small cities, such as Monroe, the daily travel distance within the study area is somewhat lower than the average, probably because a substantial part of the car travel is external, to destinations beyond the small study area). Of special interest is that cities of both groups intermingle in Figures 4 and 6, with no clear distinction between them.

1.5 It may tentatively be inferred at this stage (based on only few examples) that cars tend to be used in order to travel a certain distance per day, regardless of city size or of speed. (Put in another way, the spatial cognition of car drivers appears to be relatively stable in all cities).

The same results are also found in Europe. Table 2 presents an example from England for the relatively small city of Kingston-upon-Hull and the large metropolitan area of London. Indeed, although the size of the study area of Kingston-upon-Hull is only 4.4 percent that of London, the daily travel distance per average car is practically the same in both cities. Furthermore, the trip rates and the trip distances are inversely related within the total travel distance.
Table 2: Urban and Travel Characteristics of Kingstone-upon-Hull and London

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Kingston-upon-Hull</th>
<th>London</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>1967</td>
<td>1962</td>
</tr>
<tr>
<td>Population</td>
<td>344,890</td>
<td>8,857,000</td>
</tr>
<tr>
<td>Area, Sq.Km.</td>
<td>107</td>
<td>2,450</td>
</tr>
<tr>
<td>Population Density</td>
<td>3,220</td>
<td>3,620</td>
</tr>
<tr>
<td>Cars</td>
<td>43,185</td>
<td>1,249,450</td>
</tr>
<tr>
<td>Cars/100 Persons</td>
<td>12.5</td>
<td>14.1</td>
</tr>
<tr>
<td>Car Trips</td>
<td>238,000</td>
<td>4,119,000</td>
</tr>
<tr>
<td>Car Trip Rate</td>
<td>6.25</td>
<td>3.27</td>
</tr>
<tr>
<td>Trip Distance, km.</td>
<td>4.15</td>
<td>7.18</td>
</tr>
<tr>
<td>Trip Time, Min.</td>
<td>6.9</td>
<td>13.7</td>
</tr>
<tr>
<td>Car Daily Distance, km.</td>
<td>25.9</td>
<td>23.5</td>
</tr>
<tr>
<td>Car Daily Time, hrs.</td>
<td>0.72</td>
<td>0.75</td>
</tr>
</tbody>
</table>

This result also suggests that travel demand models, which are generally based on trip rates only, should consider both the trip rates and the trip distances, as well as the trade-offs between them, as affected by city size. The travel demand models could then begin to be transferable between cities.

1.6 Figure 7 shows the relationship between the observed car daily travel time (as the product of trip rate and trip time) versus the daily average speed in the same selected cities as in the previous figures. The diagram also includes the lines of 20-30-40 kilometers that can be traveled during given daily travel times and speeds.

Figure 7: Car Daily Traveltime vs. Speed
It becomes evident that since the daily travel distance is relatively stable in all cases, around the 31 kms. line, the total daily travel times are inversely related to the speeds. Hence, the car daily travel times are significantly higher in cities of developing countries than in cities in the US when related to the available speeds. In other words, car drivers (and their passengers) in the former cities have to pay more in both time and money for the same amount of travel-distance than in the US.

1.7 There are also strong indications to suggest that travelers are willing to allocate for travel a daily "travel time budget", which was found to be relatively stable both between cities and over time in US cities. This door-to-door average daily travel time budget (including access time), derived from the trip times as reported by respondents in the conventional home-interview surveys, was found to be about 1.1 hours, as shown in Table 3 (*)(2).

Table 3: Daily Door-to-Door Traveltime per Average Traveler

<table>
<thead>
<tr>
<th>City</th>
<th>Year</th>
<th>CAR (2) TT,hr.</th>
<th>CAR (2) Speed, kph.</th>
<th>TRANSIT TT,hr.</th>
<th>TRANSIT Speed, kph.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washington, D.C.</td>
<td>1955</td>
<td>1.09</td>
<td>18.8</td>
<td>1.27</td>
<td>10.7</td>
</tr>
<tr>
<td>&quot;</td>
<td>1968</td>
<td>1.11</td>
<td>23.3</td>
<td>1.42</td>
<td>10.0</td>
</tr>
<tr>
<td>Twin Cities &quot;</td>
<td>1958</td>
<td>1.14</td>
<td>21.5</td>
<td>1.05</td>
<td>12.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>1970</td>
<td>1.13</td>
<td>28.5</td>
<td>1.15</td>
<td>12.1</td>
</tr>
<tr>
<td>St. Louis</td>
<td>1976</td>
<td>1.04</td>
<td>n.a.</td>
<td>1.12</td>
<td>n.a.</td>
</tr>
<tr>
<td>All US (1)</td>
<td>1970</td>
<td>1.06</td>
<td>47.4</td>
<td>0.99</td>
<td>23.6</td>
</tr>
</tbody>
</table>

(1) Including Inter-urban travel;  
(2) Car Driver + Car Passenger.

Namely, when the door-to-door speeds are above a minimum threshold (about 11-12 kph. in the above cases), allowing travelers to satisfy their minimum daily travel distance, they are willing to allocate for travel about 1.1 hours per day. Thus, even though speeds increased over time in Washington, D.C. and Twin Cities (Minneapolis - St. Paul) by 24 and 33 percent respectively, no travel times were saved, as such, (*It is to be noted that the car daily travel times in the previous tables and figures refer to network-times, as derived from a calibrated model, while the daily travel times in Table 3 are the door-to-door travel times as perceived and reported by the travelers themselves.
but were traded off for more travel distance. The same seems to apply to the network time of car travel, which appears to remain stable at a minimum level of about 0.8 hours (in cities above a certain size). For example, in the Los Angeles region in 1960, with over 7.5 million people residing in a large area of 23,300 sq.km., the average car still traveled 0.8 hours per day, at a relatively high network speed of 52.8 kph., thus traveling a daily distance of 42 kilometers.

If, however, speeds are low, travelers have to pay in as much time as it takes to travel their minimum daily travel distance, as was the case for transit travelers in Washington in 1955 and 1968.

It is to be noted at this stage that while variations in the travel components within each city are wide, depending on socio-economic and other characteristics of households, the total average traveltime budget and travel distance, as controlling totals, appear to suggest an underlying stable behavioral trend, at least for car travelers, under favorable travel conditions.

1.8 An additional result is that the trip rate and trip time are inversely related within the total daily travel time, as can be seen in Figure 8. (The curves represent an average daily travel time of 0.79 hrs. in the US and 1.25 hrs. in developing countries). The same relationship is also evident in Table 2 for the cities of Kingston-upon-Hull and London.

![Figure 8: Car Trip Rate vs. Trip Time](image-url)
1.9 In conclusion, the common belief that the population in a compact city require less motorized mobility (defined as the total travel distance per traveler per day) than in a dispersed city is not supported by the above comparisons.

All in all, it is suggested that car drivers, and probably all other travelers as well, seem to have a preferred minimum daily travel distance which, despite differences associated with individual characteristics within each urban area, appears to be stable for urban areas as a whole. Furthermore, if the rapid increase in motorization levels in cities of developing countries is regarded as a process by which travelers can satisfy their need for a minimum daily travel distance, it may then be concluded that the remarkable similarity of this minimum distance in all the above cities is not incidental, but expresses an intrinsic behavioral characteristic.

Hence, it appears that the logical assumption that close spatial opportunities, within walking distance, reduce the amount of motorized travel, is not substantiated by the available data. Thus, any policy decision based on such an assumption could lead to unforeseen, and probably undesirable, results. For instance, a policy of reducing car speeds (either by regulatory measures or by inhibiting road system improvements), with the belief that it would reduce the amount of car travel, or save gasoline, could lead to opposite results: the cars could travel for longer periods at lower speeds, thus resulting in a loss of time to travelers and higher consumption of gasoline, at higher costs.

Nonetheless, one important difference between compact and dispersed cities should be emphasized at this stage: the speeds of travel in compact cities tend to be lower, thus making car usage more costly. Hence, the income threshold for owning a car becomes higher, resulting in an inhibiting effect on the level of motorization. Namely, decreasing speeds will price away an increasing number of travelers from car travel. Coupled with a more efficient public transport system in compact cities, the net result is an overall lower motorization level in compact cities than in dispersed cities. In this sense, an efficient rapid transit system may serve as a partial substitute for cars.
Nonetheless, those who are able to own cars under such conditions still travel the same daily travel distance as in dispersed cities.

Moreover, those cars that do remain on the road system in compact cities travel their 31 kms. at a lower speed, thus remaining a longer time on the road system, which then counterbalances part of the reduction in the number of cars. For example, it can be seen from Figure 7 that the travel of, say, 100 cars at a speed of 25 kph. results in 31/25x100 = 124 vehicle-hours on the road network. This would be equivalent to about 160 cars traveling at 40 kph., namely 31/40x160 = 124 vehicle-hours.

Furthermore, the costs per kilometer at speeds of 25 and 40 kph. are in the proportion of over 1.4. Hence, although the reduction of speeds from 40 to 25 kph. may reduce the number of cars, say from 160 to 100, the expected savings in the total vehicle-hours of cars and the total cost of car travel (and savings in gasoline) are only marginal, if at all. Indeed, while motorization levels in compact cities in developing countries may be only 1/10 the levels in dispersed cities in the US, traffic congestion, air pollution and noise levels are much higher in the former cities than in the latter cities of comparable size.

Even so, the rapid increase in motorization levels in cities of developing countries suggests that the need for a higher mobility (as expressed by the daily travel distance per traveler) is still far from being satisfied even in these compact cities.

Let it now be assumed that in spite of the above indications, the policy maker still wishes to change a dispersed city into a compact one. The question, then, is whether a dispersed city can be encouraged and prodded to become more compact by policy measures aimed at discouraging car travel? This question, however, touches upon urban structure, which is an entirely different subject, as discussed in the next section.
2. CITY STRUCTURE

2.1 The spatial distributions of population and jobs are treated separately in most analyses of urban structure. Thus, the urban models developed for prediction purposes are based on two separate distributions. For instance, the future job distribution is usually assumed first, while the population distribution is then allocated to it by iterative steps under certain constraints, such as travel, until a postulated equilibrium condition is approached. Even a simultaneous allocation of population and jobs is still based on an assumed equilibrium condition between the two distributions (2;4;5).

Two major questions arise: (i) should one distribution be assumed first while the other is made to depend on it, or should the two be distributed simultaneously?; and (ii) should an equilibrium condition be assumed a-priori?. Before answering these questions, let an additional problem be raised; most urban/economic models suggest that an increase in income allows more money to be allocated to travel and thus encourages dispersion. Namely, the availability of more money for travel (and housing) will allow people to travel at higher speeds and thus allow them to cover longer distances within their time and money constraints. Hence, their spatial opportunities will increase, including the distance between their residence and job locations, resulting in the dispersion of residences outwards from jobs.

Up to this stage the models tend to describe, and even explain, the observed trends. However, when using the same models backwards, they suggest that increasing the cost of travel will result in people gravitating back towards the center, thus gradually changing the dispersed city back into a compact one. The question, however, is whether the soundness of a model remains intact when applied backwards?. It is suggested here that it is not, and that increasing the cost of travel in a dispersed city may result in the further dispersion of jobs towards the residences, as discussed below.
2.2 The issue of separate versus simultaneous allocation of population and job spatial distributions was already treated by the Differential Accumulation (D/A) process (6). This process considers the simultaneous interaction between the two distributions and expresses the accumulated differences between them from the city center.

In more precise terms, the D/A process assumes, as a starting point, that workers try to minimize the travel distance between their residence and job locations under certain constraints and, hence, the difference between the numbers of workers and jobs is accumulated by distance, starting from the urban fringe towards the city center. Namely, it is assumed that workers prefer to find a job near their home, and if there are more workers than jobs in a certain area, the rest of the workers will have to travel further in the search of a job. As a result of this assumption, no travel to work is required when the two spatial distributions are completely equal, while maximum travel, both in amount and distance, is generated when all jobs are concentrated in the center while all workers reside at the fringe of the city. Furthermore, it is also clear that whatever the actual spatial distributions are, the D/A process would then reflect the minimum possible amount of travel to work.

In spite of these simplifying assumptions, it was found that the weighted average distance of the D/A curve to the city center approximates with remarkable regularity the observed average trip distance in the city, as derived from a comprehensive transportation study.

Figure 9 presents examples of the D/A curves in Bangkok and Washington, D.C., where the spatial distributions of population (representing workers) and jobs were normalized in percent and, hence, the D/A curves express the differential accumulation of the percent-difference between the two distributions. The summarized data are detailed in Table 4.
Table 4: The D/A Process in Bangkok and Washington, D.C.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>BANGKOK</th>
<th>WASHINGTON, D.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>1972</td>
<td>1955</td>
</tr>
<tr>
<td>Population</td>
<td>3,567,700 (1)</td>
<td>1,425,320</td>
</tr>
<tr>
<td>Jobs</td>
<td>762,500</td>
<td>736,000</td>
</tr>
<tr>
<td>Trip Distance by D/A, km.</td>
<td>7.30</td>
<td>6.64</td>
</tr>
<tr>
<td>Trip Distance Observed, km.</td>
<td>7.40</td>
<td>6.68</td>
</tr>
</tbody>
</table>

(1) Within the urbanized area

![Graph showing Differential Accumulation of Population vs. Jobs by Distance from the City Center, Bangkok and Washington, D.C.]

Figure 9: Differential Accumulation of Population vs. Jobs by Distance from the City Center, Bangkok and Washington, D.C.

It becomes evident from Figure 9 that the spatial distribution of population and jobs in Bangkok are more evenly distributed than in Washington, D.C., thus requiring less travel to work, the reasons being low speeds and low motorization levels.

In Washington, D.C., on the other hand, the strong differentiation between the two distributions generates about three times more travel to work. Furthermore, the differentiation between the two distributions even increased substantially during 1955-1968, signifying a strong dispersion force.
The point to note at this stage is that cities where speeds are low tend to be compact, and the population and job distributions evenly dispersed. However, if speeds increase and land use is uncontrolled, the city will start to expand from within, since travelers will then have better spatial opportunities, including their residence-job locations, within their travel constraints such as the travel-time budget.

Cities in developing countries, on the other hand, mostly expand from the outside by poor new-comers who settle at the fringe of the urban area, while travel speeds continuously decrease under ever-increasing traffic congestion.

2.3 The D/A process also enables us to forecast possible changes in the urban structure under various exogenous policy decisions. For instance, and as already mentioned in Section 2.1, most of the current models of urban structure suggest that substantial increases in the cost of travel will result in people gravitating back towards the city center, in order to shorten trip distances. As a result, the city is expected to become more compact, requiring less travel.

In contrast to this scenario, the new findings suggest that, first, the amount of travel distance generated per car is practically the same in cities of different sizes and shapes, whether compact or dispersed, and second, that instead of people gravitating back towards the city center, the jobs will disperse towards the population. (Some households will move back towards the city center, but in total, jobs will disperse outside).

The above scenario can already be seen in all large cities, including those in developed countries: when traffic congestion in and around the city center puts a too heavy burden on travelers, in both time and money terms, the end result is that, generally speaking, residences do not gravitate towards the center -- it is the center which disperses towards the residences.

There are several reasons for this trend; first, in order to move back towards the city center, households will have to sell their houses
in the suburbs. Hence, not only will it become impossible to do so if all households wish to move, but a new household will move into each house sold; second, the households moving back into the center will have to compete price-wise for the limited supply of space, thus negating part or all of the possible savings in travel costs. Therefore, the solution involving minimum effort is likely to result in the outward movement of jobs rather than the inward movement of residences.

2.4 The data available at this stage suggest the following interactions between travel demand, system supply and urban structure:

(1) Travelers are willing to expend stable (maximum) proportions of time and money in order to travel a certain (minimum) distance per day. The daily door-to-door travel time per traveler within an urban area in the US is observed to be stable at about 1.1 hours under favorable travel conditions, as detailed in Table 3, while the money outlay is about 12 percent of income for car owning households. (It should be mentioned again that though the variations of travel behavior within each city on a daily basis far outweighs the variations between cities, the mean values are remarkably stable);

(2) An equilibrium condition between travel demand, system supply and urban structure can be defined as the case where travelers are able to travel their desired daily distance within the allocated time and money budgets. A disequilibrium condition is the case where one or more of the factors is not satisfied;

(3) If travel speeds change, as a result of changes in the number of vehicles, system supply, travel costs, or city size, a disequilibrium condition may arise, which would generate certain force vectors.

It is possible to distinguish between two kinds of disequilibrium: Stabilizing or de-stabilizing. The forces set up under a stabilizing disequilibrium will tend to produce a new equilibrium after a certain "relaxation time" of the system (equivalent to "negative feedback" leading to damped oscillations). For example, the car daily door-to-door speeds in Washington, D.C. and Twin Cities
increased during 1955-1968 and 1958-1970 by 24 and 33 percent respectively. All the travel time thus "saved" was traded-off for more travel, within a stable travel-time budget of 1.1 hours, thus allowing travelers to reside further from their job places. As a result, the urban area expanded by residence dispersion, and a new equilibrium condition was reached or, at least, approached. Another example of such a case is when travel conditions in and around a city center deteriorate to such an extent that either travelers have to expend more time and money than allowed for by their customary travel budgets - which they are reluctant to do - or the city center starts to disperse towards the residences in order to shorten trip distances between jobs and residences.

It is to be noted that even if the process can, or may, reach a new equilibrium condition, the population will be under various degrees of disequilibrium during the relaxation time of the urban system.

The forces set up under destabilizing disequilibrium will tend to move the system away from equilibrium (corresponding to "positive feedback", resulting in increased oscillations). For example, buses in mixed traffic seem to lose out to cars at an increasing rate since their decrease in speed, due to traffic congestion, induces more bus travelers to switch to cars, which further decrease bus speeds. Indeed, bus travelers in Washington, D.C. in 1955 had to expend 1.27 hours in order to travel 2.3 trips per day. In 1968, after 13 years, door-to-door speeds of bus trips declined further, while the city expanded, thus forcing bus travelers to expend 1.42 hours of daily travel time in order to be able to make only 2.1 trips per day;

(4) Cities in developed countries usually change at moderate rates and hence their populations can adjust their urban structure to changing conditions within reasonably short times. Some cities in developing countries, on the other hand, double their population every decade, the changes in their size and structure being largely due to migration from outside. Furthermore, the new-comers are mostly poor; their trip distances increase; and travel speeds decrease.
As a result, the destabilizing disequilibrium in such cases can become dangerously acute since the travelers are forced to expend ever-increasing amounts of time and money on travel, much above those found in stable cities, with no equilibrium in sight. For example, it is reported that workers who travel from the Northern suburbs of Rio de Janeiro spend four hours for traveling to and from work, and expend 25 percent of their income on public transport fares (7). The same trends are also found in other fast-growing cities.

The main conclusion from the above indications is that special care should be exercised in policy decisions not only in developing countries but also in cities of developed countries. More specifically, no major policy decision with respect to travel or city structure should be taken before we have a better understanding, in quantified terms, of the close interactions between travel demand, system supply and urban structure, and their relaxation time. Indeed, one of the recommendations of the Committee on Equilibrium Modeling, at the Third International Conference on Behavioral Travel Modeling was that "The dominant issue is the need to model a process that is generally in disequilibrium, but with interdependencies" (8).

2.5 In conclusion, the two questions asked in Section 2.1 can be answered now: the two spatial spatial distributions of population and jobs should preferably be allocated simultaneously (by such methods as the D/A process); and insted of assuming that all alternative policies must always result in equilibrium conditions, it would be preferable to seek the amount of possible disequilibrium that each alternative could produce, with special attention focused on the population segments affected most.

Much research has been done lately on the question of how to reduce the amount of travel in US cities. For example, one study tested alternative urban structures in order to identify the structure that results in the minimum total travel time to work within an urban area, with the result that long-term shifts of population and jobs may
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2.5 In conclusion, the two questions asked in Section 2.1 can be answered now: the two spatial spatial distributions of population and jobs should preferably be allocated simultaneously (by such methods as the D/A process); and instead of assuming that all alternative policies must always result in equilibrium conditions, it would be preferable to seek the amount of possible disequilibrium that each alternative could produce, with special attention focused on the population segments affected most.

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paper, based on scanty data, are not enough to prove that the established beliefs are wrong. But they appear to be disturbing enough to suggest that there may be other interpretations than the conventional ones to explain the observed facts.

3.2 In order to study the relevant relationships between travel and urban structure, it is necessary to observe a wide range of variables. Therefore, it seems that we should first observe in more depth the travel behavior of people in cities, large and small, of different structures, compact and dispersed, poor and rich, before reaching final decisions about the future of our cities.

International organizations, such as the World Bank, could greatly assist the study of urban development by encouraging the collection of key data in a form that would enable inter-city comparisons to be made readily. This paper has suggested that the results of such comparisons could be of great value to planners and policy makers in developed and developing countries alike.

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ACKNOWLEDGEMENTS

I am grateful to Mr. E.V.K. Jaycox, Director, Urban Projects Department, the World Bank, for the permission to refer in this paper to results from studies conducted for the Department, and to Mr. G.J. Roth for his comments and suggestions. However, the views expressed in this paper are those of the author and not necessarily those of the World Bank.
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