SIMULATION SCENARIOS FOR DEVELOPMENT PLANNING IN L.D.C. REGIONS

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Introduction

Long run comprehensive metropolitan planning is rarely practiced. Planning staffs typically devote little time to analyzing long run growth patterns in a systematic manner and few metropolitan regions have simulation models capable of convincing policy analysis. Perhaps as significant, the range of specialized topic areas in planning education has broadened substantially in the past 10-15 years so little agreement exists as to what the components of a long term urban development plan should be. Conversely, theoretical progress has been made on land use-transportation models and the latter appear to provide a good framework for structuring the components of a strategic long run development plan.

In this paper we suggest a general structure of a development plan based on empirically implementable land use-transportation models. Though pre-revolution Tehran is the empirical focus, the structural components can be readily generalized to other urban-regions in less developed countries. These components include (1) a consideration of the impacts of national and regional policies on the development scenarios, (2) goals formulation and measurement, (3) the specification of base case and alternative development scenarios and (4) the design of feasible policies and their testing on each of the scenarios. The latter are based on three characteristics: alternative rates of aggregate employment/population growth, various sectoral emphasis (government, services, manufacturing and agricultural employment) and the spatial pattern of growth (centralized or de-centralized).

National policies are the context within which regional simulations must be conducted. Though Tehran's population growth rate declined in the early 1970s, food and transit subsidies continued to encourage rural outmigration to the cities. Rent control was also in effect contributing to long residential tenures and erratic journey-to-work patterns. Another important policy was the substantial control government exerted over land use. In Tehran the fear of suburban sprawl had confined development, contributing to rising land values and increased congestion in the regional core. Together, the food-transit subsidies and land use restrictions had made Tehran a city with relatively low labor costs and high rents encouraging firms with labor intensive production techniques to locate there. As with present day Cairo and Istanbul, pre-revolution Tehran was a primate city with high residential densities and a substantial problem of traffic congestion.

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The paper is organized as follows. Section two analyzes the regional policies pertinent to Tehran, their expected impact on model results and their incorporation into the model; a description of the land use transportation model is also provided. Section three describes the specification of development objectives, their measurement, the general principles underlying scenario design and the policies to be tested on each scenario. The results of base case runs are discussed in section four with the distribution of benefits for alternative policies in achieving regional objectives. A final section includes some concluding remarks.

**Land Use Transportation Model**

As noted above, the land restriction is the principal policy to be incorporated in the land-use model; Figure 1 shows the 12 inner model zones, metro lines and restricted growth area between the so-called 5 and 25-year boundaries. The restriction is spatially selective as it applies to areas where rents would normally be lower than in central zones. Excluded firms will tend to have land intensive production characteristics with little ability to substitute capital or labor for land and hence compete for central city sites. Increasing employment densities in the central city increases the destination efficiency of rapid mass transit, but also concentrates air pollutants and increases traffic congestion downtown.

The proposed metro lines are designed to divert auto traffic from central employment zones. As shown in Figure 1, some lines extend into the 5 to 25 year zone so land release in restricted zones would probably increase long distance ridership but also reduce employment densities in the regional core. Erratic trips due to rent control and the non-localized primary and secondary school system are not easy to accommodate by fixed route transit; the doubling of journey-to-work trips by many businessmen during summer hours also spreads out the distribution of trips during mid-day. Optimal metro phasing should give priority to rapidly developing zones and some problems could be encountered with the northward-moving commercial centroid. The limited 4-line, 62 kilometer system may be unable by itself to arrest this movement if metro ridership is low.

A very large commercial-governmental center had been planned in zone 3 and would accelerate the centroid movement to the north. The private component would be complementary with services provided to Tehran’s manufac-

**FOOTNOTES**

1The policy recommendations reflect the official position of the Tehran Development Council Secretariat (T.D.C.S.) with analytical support from Applied Research of Cambridge (A.R.C.) and Harvard University; see reference [1]. The observations in this paper are attributable solely to the author.

2Families frequently transport children across the city at the morning and afternoon peaks. Also, the long commuting patterns evidenced from the household survey conducted by the T.D.C.S. suggest the effects of ten years of rent control and low value of time placed on travel by many low-income households.

3The commercial centroid is probably within a range of six city blocks centered on the zone 1 and 2 boundary midway between their east-west boundaries. As seen in Figure 1, the municipal (5 year) boundary extends well up into zone 10. In 1945, the northern-most east-west arterial was slightly above the zone 1 and 2 boundary.
Figure 1. Tehran map for inner 12 zones
(source: adapted from ref. [1], p. 117)
turing sector but competitive with services growth in the C.B.D. The land area is extensive providing a buffer against rapidly rising land values in central zones, but rapid urban growth elsewhere has eroded its significance in this role. Land release in the 5-25 year zone would be competitive with the development of this center though locational leverage can be exerted over the governmental component and the very specialized commercially-related services planned there.

A major new airport was under construction to the southwest of the city (zone 6) which would substantially influence transit patterns and lead to the development of business-related services nearby. Safer air traffic control and reduced pollution are benefits attained at the expense of user accessibility; the disbenefits may increase with northern growth of Tehran. The long distance may render helicopter service economical and some diversion of auto traffic may be possible. Bus service downtown is needed though C.B.D. hotels may suffer if new commercial facilities are established near the airport. As with the government-center alternative employment and residential populations can be placed in these model zones to estimate the impact on Tehran’s growth.

The impact of dispersed new towns depends on their spatial isolation, the rapidity of Tehran’s growth and the commercial-industrial base these communities are able to attract; the principal new settlements were in zones 10 and 12.4 Closely contiguous towns attract deliveries of residences and goods; probably minor amounts of industrial inputs; town residents will shop at dispersed centers on the urban fringe if their own facilities are limited. Higher order goods and services can only be purchased closer to the regional center so irregular trips will be made for these items. Close-in new town locations may be competitive with central city development and residential growth may be hindered by land release in contiguous zones, pollution abatement in the regional core and the absence of dispersed employment growth. The new towns are designed to encourage a “T” pattern of development east and west of the city.

New freeways and secondary roads will influence travel patterns, metro ridership and the level of land rents near these arterials. Increased accessibility to decentralized locations increases their demand, but the land restriction may confine the benefits of road investments to reduced travel times for through-traffic in peripheral locations. At the five-year boundary land rents fall off sharply so allowed activities may be overly land-intensive and normal free market guidelines are not available to signal the most efficient land uses near these arterials. The construction of new roads will exacerbate materials and labor shortages and network design must be co-ordinated with the metro system. Hub routes should provide access to major metro stations and radial road development will compete with metro if placed close to major lines.

Various traffic control policies should also be tested on the land-use model. Fare changes will influence bus ridership and model tests compare graduated (per kilometer) charges with flat fares. C.B.D. parking charges or restrictions

*These two new towns (named Lavizan and Kan) are primarily residential suburbs with limited commercial development. (Kan in zone 12 provides residential housing for workers employed in the Karaj industrial corridor extending west of Tehran.) Other “growth pole” settlements have been proposed in very dispersed zones, but as noted below model runs suggest that their development be deferred.
will divert traffic to metro, collective taxi or public bus and improve the efficiency with which downtown streets are utilized; lane reservation for bus, one-way streets and intersection flyovers have similar objectives. Traffic policies may also differentially affect inter-zonal accessibility whether concerted or somewhat meager efforts are undertaken. High parking charges, zero metro investment and restricted routing of buses to downtown zones reduce commercial activity and rents in central locations; decentralized growth patterns are encouraged. Alternatively, high parking charges plus a substantial investment in centralized metro is more likely to affect the mix of modal trips rather than the level of C.B.D. activity.

Environmental and urban services problems include air pollution, water and sewer construction. Air pollution in central zones reduces land rents and encourages decentralization of commercial and residential activity. Damages accrue to both structures and humans discouraging unenclosed economic and recreational activities. Water has been viewed as a major constraint on growth but new reservoirs north of Tehran should provide sufficient supplies for the next decade. Sewerage systems are costly to construct and it seems likely that only interim measures, particularly in south Tehran, are likely to be undertaken over the planning period.

Most of these policies are adapted within the land-use transportation model depicted in Figure 2; several characteristics should be noted. 1) The model is a strategic aid to policy formulation and incapable of testing spatially specific changes. Increased parking charges in the C.B.D. can be incorporated, but changing a secondary road to one-way traffic will not yield trustworthy results. The zones in Figure 1 are quite large and all transit linkages are centroid to centroid. (2) National policies (briefly summarized in the first section) cannot be directly tested for their impacts on other regions as the spatial base is confined to Tehran. The assumed effects of national policies on exogenously-determined rates of employment growth in Tehran can be simulated, but secondary impacts outside the region are not estimable.

The regional growth model (see Figure 2) calculates employment and household control totals for allocation by zone in subsequent models. Exogenous investment growth rates are translated into employment growth via regression equations estimated by sector; the government and casual sector rates are determined from household surveys in 1972 and 1976. A probability matrix converts employment by sector to four occupational categories; the latter are the basis for estimating average income, its distribution and income growth rates. Income distributions by occupational group are fitted in the calibration year and average income growth rates are calculated for the period 1972-76. The distributional characteristics of incomes are assumed constant over the planning period with average income incremented separately for each group. Employment by income group is then estimated and converted to household numbers by employee/household ratios. Average family size by income class is used to estimate population and car-ownership is determined by car owner per capita rates estimated by income class.

The land use model’s primary role is to determine the spatial distribution of

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*The following sketch of the Tehran model is discussed in detail in [1]. The model was specified and calibrated in Cambridge, England by A.R.C. personnel with data assistance from planners at the T.D.C.S. Parameter adjustments and the temporal treatment of land use changes were modifications introduced when the model was operational in Tehran.*
Figure 2. Structure of Land-use Transportation Model
(Source: adaptation of Figure 2.1.3, ref. 1, p. 10)
12 employment and residential activities among the 24 zones. The 12 activities have land demand equations specified as functions of rent per unit land and income (in the case of residential activities). Locational cost, by activity, is the sum of land (rent per unit land times the amount demanded), building rent and transportation costs. The allocation of the activity to a particular zone depends on the land area in the zone, locational cost and an attraction index which measures the importance of physical zonal attributes to the particular activity. At each iteration of the model, the land available to the activity (or all activities if land is not zoned) is checked against land demanded at current rents; rents are allowed to rise if current demand is in excess of available land and a portion of the activity is allocated to excess-supply zones. With zoning a unique land rent surface, declining from central to non-central zones, is estimated along with the amount of land used and the zonal distribution of the activity; this is done for each employment and residential activity.

The transport model begins with the estimation of the origin and destination trips for each zone, knowing the zonal employment and residential characteristics estimated in the land use model; separate estimates are made by car ownership status and time of day (peak, non-peak). The modal split sub-model estimates the probability of a person making a trip between pairs of zones by car, taxi, walking and other public transit modes. These probabilities are directly proportional to the out-of-pocket and time cost of travel by a particular mode. The trips are then assigned to specific routes by a sub-model which considers the initial distribution of trips, time plus out-of-pocket costs and the capacity of existing transit links among zones. Finally, the trip time and out-of-pocket costs are calculated for all inter-zonal transit loadings and are used in the next iteration of the model. For car-owners petrol consumption is a function of distance and speed while 1977 fare levels are used for taxi and other public transit modes. Waiting times for public modes depend on link capacities, scheduling frequencies, per vehicle capacities and the number of public vehicles; walking to the car and parking times are estimated for auto-owners. Inter-zonal accessibility indices are also calculated by mode so that the effects of policies on travel volumes can be assessed.

An evaluation model (excluded in Figure 2) then estimates the benefits and costs of policy changes introduced in the model. A consumer's surplus calculation is made of the change in cost (out-of-pocket plus time) attributable to a particular policy and profit changes on all modes. Land users benefit from rental reductions and owners disbenefit by declines in gross rental revenues. A separate calculation is then made of the benefits from rental declines to employers in the four major employment categories. Note that rates of return calculated in this model include the general equilibrium effects of all policies on all regional residents in addition to the direct benefits accruing to users. The capital and operating costs of all major regional policies must, therefore, be estimated before assessing the incremental impact of a specific policy change. This is an improvement over partial evaluative procedures but is difficult to implement in a region where the combined capital accounts of the national and municipal governments have not been estimated.

Several additional features of this model should be noted. (1) Recursively structured, this model emphasizes the impacts of policies in an environment of total change rather than the incremental effect of a single policy change with other activities held constant. This is well suited to rapidly growing regions but substantially increases the possible assumptions regarding the future spatial
and temporal distribution of activities. (2) As a non-maximizing model few clues are available to indicate which policies contribute most to the social net benefits in a single computer run. Shadow prices are not calculated so many runs are necessary to investigate the net benefit surface of policies conducted at alternative levels.

Scenario Design

Goal formulations and their adaptation to the model are important steps in evaluating alternative scenarios in urbanized regions. In the absence of a formal regional commission on development objectives, professional planning staff opinions regarding desirable objectives were solicited in a formalized questionnaire. Indicators for each objective were used to rank the degree of goal-attainment for each policy and were supplements to the formal benefit-cost estimates in presenting policy trade-offs to regional resident decision-makers. The following goals were distinguished:

(1) **Economic development and income distribution.** Moderate growth rates in employment were favored due to factor input scarcities caused by high employment growth rates during the 1950-70 period. Respondents specified no preferences for sectoral emphasis so the mix of activity is not weighted in the various scenarios. Spatially decentralized patterns of growth were preferred due to high C.B.D. land values caused by the land restriction. Indicators included employer, residential, land owners and travelers net benefits and the distribution of net benefits by income class; redistributive policies were preferred due to the impact of inflation on the incomes of poorer households.

(2) **Population growth and decentralization.** Consistent with (1) above, moderate population growth rates within the range of 2.8 to 4.5% were preferred along with residential decentralization outside the 5-year boundary. Retarded rates of net in-migration were favored due to the large proportion of very low-income families, overcrowding in the lower income neighborhoods in south Tehran and suspected declines in the real incomes of poorer households. Indicators are population and employment growth rates by zone and major ring-region (defined below); job ratios (employees per resident) by zone and ring-region measure the balanced nature of spatial growth.

(3) **Environmental quality.** Substantial improvements in environmental quality were favored with equal preference given to reduced levels of traffic congestion, air pollution and energy consumption. Accessibility indices by zone for motor vehicle, taxi and public transport trips were indicators for traffic congestion. Residential densities by zone and ring-region measure crowding and probably deterioration in social infrastructure. Gross emissions of carbon monoxide, unburnt hydrocarbons and nitrogen oxides measure changes in air pollution and energy consumption indicators are petrol (auto and taxi), diesel (bus) and kilowatt hours (metro).

(4) **Urban management.** Government efficiency and decentralization in the provision of city services are important regional objectives, in part seeking more citizen participation in political processes. These objectives are less readily measured by the outputs traditionally produced by land-use transportation models, but the current account net profits earned by public transit modes and revenue or cost changes for parking charges, auto-owner license fees, petrol excises and road maintenance are used as admittedly partial indicators. Job ratios by zone and deviations of zonal income distributions from
regional averages (social mix indicator) measure spatial economic independence and social heterogeneity, but have a tenuous relevance to problems of administrative decentralization.⁶

These objectives suggest the dimensions on which the development plan for Tehran might be based; aggregate growth, employment sector specialization and spatial incidence are implied in the discussion above. (1) High, moderate and low growth rates for the major employment sectors are defined to bracket high and low expected regional population projections for 1991. The moderate growth scenario is consistent with recent experience and second priority is accorded to high growth to protect against a recurrence of historical experience in the 1960s. (2) Sectoral specialization is attained by running a single (or several) sectors at high growth with other sectoral growth rates maintained at moderate levels. High priorities are assigned to services specialization, a manufacturing-services complex and the governmental sector whose employment growth reached 13% per annum in 1972-76. (3) Spatial patterns of growth are influenced primarily by varying rates of land release in the C.B.D. (zones 1, 2), 25 year boundary (zones 3-5, 7-12), inner ring and outer ring. (Figure 1 shows the central 12 zones only; the outer rings are geographically large with low density agricultural populations and ring the central 12 zones in a uniformly circular manner.)⁷ The spatial tests define high rates of land release in a given zone with moderate rates in the remaining three zones; four tests, therefore, define the spatial effects simulated on the model. Due to differences in zonal sizes and development densities varying amounts of land are released in the four maximum tests; our experiments do not test the sensitivity of net benefits to a fixed amount of land released in each zonal simulation.

The proposed development plan is defined by six growth scenarios specifying alternative rates of aggregate or sectoral employment change each with different patterns of spatial decentralization. Policy tests are varied if it is expected that alternative rates of employment growth will affect desired levels at which specific policies should be run. Within each scenario, a base run is defined incorporating these changes and probable (or logical) deviations in policies are tested for their impacts on regional net benefits and the supplementary indicators above. Only single alternatives are discussed in the empirical sector below, though combinations of competitive or complementary policies could be tested. Also base runs were designed as a fixed set of policy levels and not sequentially introduced or cumulated by their probability of being undertaken or, once undertaken, continued. The alternatives are tested against the most probable development future, termed the base case.

**Base case (moderate aggregate growth, decentralized).** Base case parameters result in population growth of about 3.5% per annum, a balanced employment mix and decentralized land release. Expected investment increases in manufacturing and services imply sector employment growth rates of 4.3 and

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⁶The indicators are ranked in a consistent format required of all staff-members writing evaluations from computer output. For the base case (described below) these are comparisons of policy changes to the basic assumptions of the scenario so the ranked indicators are differences between two runs.

⁷Zone 6 is an exception since the 25 year boundary roughly parallels the border of zone 5 and 6. Note that the municipal and 25-year boundaries are rather poor approximations to the zones. The latter were chosen to be consistent with previous work on transportation due to severe data limitations in the region.
2.2% respectively; the small agricultural sector is increased at slightly under 1% per annum. Land release is slightly higher than population growth due to expected low density development outside of central zones.

Capital intensive projects are assumed to be fixed commitments over the 10-year development horizon with moderate investment levels. Two metro lines are constructed simultaneously in the base case with the second two lines added in the second five-year period as a "large-metro" alternative; sequencing tests for all four lines were also conducted. Moderate investment levels are assumed for the governmental center, airport and new towns with land reserved in the appropriate zones. Public housing is constructed at a rate of 1,000 units per year in zones 5, 7 and 8 with an additional 1,000 units added in zones 9 and 12 as a base case alternative; the latter tests the decentralizing capabilities of residential construction coupled with employment increases outside of the C.B.D. zones. Road link capacities are adjusted to reflect current investments planned in expanding freeways. These include the addition of "ringing roads" outside of C.B.D. zones, a major expressway to towns southwest of Tehran and an emphasis on east-west capacity improvements in major arterials within the city.

Initial tests contrast base case levels with "reversible" policies over the 10 year development horizon. High parking charges in zones 1, 2 and 4 are contrasted with 1977 levels; these could also be adjusted in accordance with profitability targets for metro and bus. A per kilometer bus fare is contrasted to existing levels to test increased ridership on non-auto modes. The exempt taxis are primary beneficiaries due to strained bus capacities and the absence of rapid transit.

Alternatives to concentric land release were also considered for the base case. Accelerated land release in zones 9 and 12 (with constraints elsewhere) would promote so-called "T-development"; some planners have advocated this pattern to counteract the northern centroid movement. Selected zoning for services or manufacturing in specific zones was also considered at moderate levels consistent with base case growth rates. (Time constraints precluded governmental advance purchase of land for expansion or resale; there had been some consideration of decentralizing ministerial offices outside of central Tehran.) A problem with spatial tests is the absence of an optimal density algorithm incorporating profit maximizing considerations or explicitly considered legally-imposed density constraints. Some uncertainties are created without such an algorithm, so numerous alternative spatial tests were not conducted. The alternative scenario designs included the following considerations.

1) **High aggregate growth, decentralized.** Under high rates of employment growth in all sectors, spatial decentralization seems inevitable with capacity utilization in major public investments reached earlier in the development plan period. Construction bottlenecks may occur so planners may face hard choices in phasing public works; the optimal mix and rates of retarded development is of interest here. This scenario allows for more inter-zonal spatial specialization in economic activity with higher rates of land release in decentralized zones compared to the base case.

Base run alterations include simultaneous construction of all four metro lines, more liberal zoning for the airport supporting services and the government complex, public housing construction of 5,000 per annum in decen-
tralized zones, higher parking charges and increased petrol taxes. (The increased taxes encourage spatial decentralization and auto diversion to the larger metro.) Experiments include a residential-intensive new towns strategy by changing zoned land for services and industry to residential in anticipation of high population growth rates and spatial decentralization. The road network is redesigned with increased investments in ring roads and freeways outside C.B.D. zones in anticipating decentralized growth. Other experiments include full land release with minimum infrastructure development (piped water and unpaved roads) and advanced land purchase to strategically control development outside the five year boundary.

(2) Moderate aggregate growth, centralized. This scenario uses base case employment growth rates with policies designed to emphasize centralized development; this continues historical patterns to assess the impacts of land containment under moderate growth. Three spatial levels for containment are suggested. The base run of scenario (1) with C.B.D. maximum land release provides a stringent constraint. A more likely test constrains growth within the inner five zones and another allows maximum land release in zones 9, 11 and 12 to test "T" development.

Spatial restraint is sought by adjusting land zoned for permanently sited projects, shifting investment emphasis in transit networks and adjusting taxes to encourage central development. The new towns, government services complex and airport are developed at minimum scales when defined to be outside the central area with increased rates of public housing construction in C.B.D. zones; residential uses could be emphasized in multiple-purpose urban renewal projects downtown. The small metro system is retained since plan changes (i.e., shortened lines with lower fares and more convenient scheduling) seemed unlikely. Restrictions in ring road construction with capacity-increasing investments (fly-overs, street widening, etc.) in central zones are tested with lowered parking charges and graduated fares on buses.

(3) Government services, centralized. The sectoral scenarios emphasized policy re-design to accommodate specialized factor input and residiency requirements. The demand for professional-technical personnel and younger females for the secretarial labor force will increase demands for relatively centralized single and multi-family housing. Reductions in the average age of the labor force should reduce car ownership rates and increase public transit ridership (and/or car pooling). Advanced land purchase in zones 1-5 could allow for sustained government employment increases; this increases the leverage that government exerts over land use patterns that promote higher profits on metro and other public transit modes. Government employment densities should rise in central zones diverting manufacturing and lower-order services to non-central locations.

Tests emphasize centralized land development with housing and advance land purchase policies designed to provide for government’s own needs, control private development and retard land value increases in the region. Public housing is constructed at 3,000 units per annum in zones 1-5 and is designed for both low and moderate income groups. Land is required in these zones at rates which absorb government employment increases at 8% per annum maintaining historical densities for this sector. More comprehensive land-banking proposals may result from governmental growth; this could include large-scale purchase and more intensive infra-structure construction. Bus fare reductions to zones 1-5 with higher parking charges and petrol taxes encour-
age more efficient vehicular use in central zones; the government employee exemption from parking fees reduces the effectiveness of these changes, but is realistically maintained.

(4) Private services, decentralized. A high growth services scenario with spatial decentralization is complementary with national policies seeking a large industrial base. Spatial restrictions may have limited services' growth in Iran's central place causing rental increases discouraging this sector. Though services are best able to substitute high-price land for other factors, the services trade account has been historically in deficit and might develop more efficiently in the absence of spatial restrictions.

Differences to (3) above include a more cost-sensitive selection of building sites, more decentralized single family housing demand and a lower skill-mix of occupations. (Private sector salaries tend to be higher than in government for given experience-occupational categories, but only 7% of private services are professional-technical.) Housing construction of low density is constructed at 3,000 units per year in zones 5-10 for more moderate-income households. One experiment increases zoned land in the government complex at the expense of government, residential and open space. Another experiment increases rates of land release in zones close to the C.B.D. with increased zoning in new towns to encourage housing decentralization. Higher incomes reduce residential densities and increase car ownership rates so congestion may increase despite decentralization. High parking charges, increased petrol taxes and selected bus fare reductions to zones 1, 2 and 3 are combined to encourage higher public transit densities in the C.B.D.

(5) Private services/manufacturing, decentralized. A final scenario combines higher growth rates in both of the major private sectors to emphasize balanced private sector development in the region. An intra-regional causal relation between export (manufacturing) and service employment is allowed with Tehran assumed to be uninfluenced by locational criteria forcing a decentralization of private activity. Growth in the west-central industrial corridor and eastern manufacturing zones is added to high order services found in the C.B.D. and residential services that will follow decentralizing population growth within the region. Increased external trade suggests increased employment in the transportation sector in southern regional zones; housing construction is decentralized with transit policies accommodating more reverse commutation.

Policy tests seek to simultaneously accommodate both sectors. Alternative zoning for residential and industrial land are designed for the two major new towns. Higher rates of housing construction are allowed in the major (or contiguous) industrial zones 8, 11 and 12. A separate experiment increases industrial zoned land in western zones 7 and 8 with unconstrained services growth in zones 1 and 2. Selective bus fare reductions to zones 8, 11 and 12 are designed to assess the locational impact of residential changes that might occur under decentralized patterns of manufacturing employment growth.

*The distinction between business and residenatial-related services is not made in the model. Hence the attraction factors for services are a mix of high and low-density characteristics (e.g., central access to financial services and retailing attraction to rapidly growing suburban zones). This is a much-needed refinement in future work.
*Base case results* Though all six scenarios constitute the proposed development plan, the description of empirical results is confined to the base case. Figure 3 summarizes comparisons of benefits generated in the base case versus benefits with alternative policies. The units of the indicators vary between goals and a seven-interval code defined for all computer runs has been used for each column.  

*Land release tests* The four land tests concentrate new land release by zonal ring and when compared to base case moderate release throughout all zones, rental increases result in substantial land owner benefits in all comparisons. Travelers, on balance, also benefit from increased accessibility of trips taken within the region though benefit differences are small. Residents disbenefit from restrictions on land released outside zones 1 and 2, but benefit substantiably in the 25 year maximum release test. (As central rents have been high due to the restriction, preferences for residential land in zones contiguous to the C.B.D. are substantial.) The inner and outer ring tests also restrict land release centrally and provide land beyond the commuting range of most residents, so households experience reduced benefits compared to more even patterns of release in the base case.

The employment sectors suffer losses from the land release patterns summarized in Figure 3, but only minor changes occur with respect to the goal of decentralization. With the exception of agriculture, all employment sectors experience rental increases with the services sector suffering large negative benefits. In the C.B.D. test both population and service employment centralizes and since less C.B.D. land is available to release compared to other tests, most sectors suffer losses. The other tests restrict C.B.D. land and since a large part of services employment must be located centrally this sector absorbs the loss. Also, in the C.B.D. test industry decentralizes to zones outside of 1 and 2 whereas centralization of industry, government and services employment occurs in the 25-year maximum test, again reflecting preferences of households for non-central locations.

Population centralization occurs only in the C.B.D. maximum test and most indicators suggest an improvement in environmental quality. In the C.B.D. test central densities do become somewhat high, but shorter work trips tend to increase public transit ridership reducing traffic congestion, pollution and energy consumption. In the 25 year test C.B.D. activity levels are restricted compared to the base case, so the employment centralization that does occur is less than residential decentralization outside the C.B.D. On balance, densities are lowered and the environmental indicators improve. Minor household movements away from the C.B.D. occur in the inner and outer ring tests and environmental impacts are favorable.

The sharpest differences in indicators for the urban management goal are for capital costs. Little land is currently unutilized in central zones so infrastructural development costs are low. (These costs include site preparation, water supply and public land acquisition expenses for land used by these activities.) As the spatial area of the maximum-release zone increases lower density development occurs and total infra-structural costs increase. The inner

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*The coding format conforms to organizational guidelines on reporting computer results. There was a general reluctance to aggregate across activities and make strong commitments to precise numerical results. See [2, pp. 12-23] for an expanded version of these results.*
Figure 3. Goal Achievement for Base Case Alternative Policies
(source: adaptation of Figure 3, ref. 2, p. 24)
and outer ring tests have substantial negative benefits to residents and service employers in addition to high capital costs and are excluded as desirable policies.

Public housing The housing test doubles the rate of unit construction and places the additional units in zones 9 and 12, instead of 5, 7 and 8. This is still a small program so no major effects on employment sectors are found. Landowners suffer rental declines from tenants leaving private units and low-income families benefit from subsidized units. These households use public transit and since new units are located in employment zones 9 and 12 traffic congestion in the C.B.D. declines. Though insufficient to show on the scale, the eligible tenants were drawn from low-income C.B.D. zones but the rent declines were insufficient to attract significant amounts of new employment to the downtown areas.

High parking charges Higher parking charges in central zones tend to decentralize households, industry and government raising rents in peripheral locations relative to the affected zones. (The alternative policy doubled the base case parking charge with 50% of the auto trips to zones 1, 2 and 4 assumed to be influenced.) Small net losses are absorbed by households, landowners and travelers through net rental reductions and lower accessibility of households to employment locations; landowners do not receive enough increased rental revenue in dispersed locations to offset reduced rents from service firms in the C.B.D. The distribution of income effects for households and travelers are favorable in the sense that benefit reductions are concentrated in higher income classes. Due to decentralization, revenues from parking charges decline.

High petrol taxes Raising the cost of petrol may promote a centralization of activity as households try to shorten trip-lengths to work or decide to use public modes. Total daily car trips fall by 6% and trip lengths decline with some households moving toward central zones and profits increasing on metro and bus. Both pollution and energy consumption decline, but congestion is not significantly affected; the reduction in auto use appears to have offset the effects of higher central densities. Landowners receive slightly higher rental revenue with increased rents in central zones attributable to industry and services more than compensating for the net decline in benefits to households. Though some households do respond by making residential changes, most remain in decentralized zones to benefit from a small rent reduction. Transit revenues increase reflecting the inelastic price elasticity of demand for auto use.

Graduated fares A final experiment in Figure 3 contrasts a per kilometer charge to the current system of flat bus fares which would increase bus trip costs for rides in excess of about six kilometers. Total bus trips fall, but bus revenues increase due to a concentration of trips at more profitable, shorter distances. Some household and employment centralization occurs so that net rent increases accrue to landowners at the expense of residents and industrial employers. Travelers disbenefit to the extent that they do not own an auto and must still take longer trips; these negative benefits are less than fully offset by less congestion encountered for longer trips and increased accessibility to auto owners. The distribution of income effects are unfavorable due to rent increases to low income households and net increases in out-of-pocket costs of travel.
These experiments are suggestive of the approximate magnitude of changes expected from increased rates of land development outside of Tehran's central zones. Though we may be skeptical of the land use impacts of "reversible" policy alternatives and the exact amount of benefits generated, these are promising first estimates of policies proposed in the region. It is likely that rates of land development near to those in the base case and 25 year maximum test provide the greatest net benefits to regional residents over the 10-year planning period.

Conclusion
The framework for strategic development planning suggested here can be readily applied in any urbanized region which has a comprehensive land use/transportation model. In Tehran's case, the model analyses summarized above have led to a series of long run development guidelines presented to regional policy makers.\(^{10}\) The most important includes increasing developed land in the 5-25 year boundary and discouraging massive new town development in the inner and outer ring zones. The land development is phased in accordance with computer tests which indicated eastward growth for 1978-81 and then a five year period of development west of Tehran. Zonal development is to be monitored by population and employment changes estimated for all computer zones with increased rates of housing construction and financial support for infra-structural investments. A study recommendation suggests a comprehensive land bank for financing land costs, home mortgages, possibly needed development subsidies and using public lands to retard land value increases in the region.

Finally, we note the generality of characteristics among urbanized regions that are capable of being analyzed within this planning framework. Many such regions in less developed countries are characterized by rapid population growth, manufacturing specialization, strong land use and employment locational controls coupled with an often singular urban node as the supporting center to other national sectors. Land use/transportation models offer the greatest generality in encompassing the alternative development patterns that seem possible in such regions; they are also an increasingly accurate and valuable educational tool in understanding the complexities of urban growth. Coupled with an organized framework for their use, they offer the best possibilities for long term strategic development planning.

REFERENCES


\(^{10}\)See [2, pp. 28-34] for an extended explanation of the strategic policy recommendations.