Evaluation of the Trans-Texas Corridor Proposal: Application and Enhancements of the RUBMRIO Model [1]

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ABSTRACT

The Trans-Texas Corridor (TTC) projects a vision of 4000 centerline miles of new roadways and railways, intended to provide a faster, safer and more reliable means of transport for people and freight, while fostering economic growth of Texas's rural regions. This work enhances and then applies a Random-Utility-Based Multiregional Input-Output (RUBMRIO) model to assess project impacts on trade, production, and worker locations. Driven by foreign exports and domestic demands, the enhanced model endogenously generates monetary trade flows for 18 economic sectors across Texas' 254 counties, equilibrating explicit labor and land markets, along with capacity-constrained networks.

The model predicts a slight redistribution of economic activities, increasing the supremacy of counties located closer to export zones, and an 8% reduction in the traffic volumes on existing highways . It also suggests a greater diversification of economic activity/production and moderate changes in the distribution of wages, floorspace rents and population, following the production trends. These effects are most noticeable in counties traversed by the TTC, especially in those previously inadequately connected to the State's transportation network.

CE Database subject headings: Economic Models, Land Usage, Transportation, Transportation Corridors, Transportation Systems, Transportation Models, Transportation Networks.

1. INTRODUCTION

The Trans-Texas Corridor (TTC) project involves the construction of a new multi-use, statewide transportation corridor. Envisioned to have 4000 centerline miles of new tolled roadways, it is to be accompanied by freight railways and pipelines. TTC highways will be designed to include 3 to 5 lanes per direction, with a possibility to separate freight vehicles and passenger cars flows if the observed demand levels are high enough. The corridor also may provide high-speed rail (HSR) lines between Dallas, Houston, and San Antonio.

The purpose of this paper is to provide some intuition about the type, magnitude and direction of the trade, travel, land use and other impacts that TTC construction is likely to generate. The new facilities are intended to provide a faster, safer and more reliable means of transport for people and freight, while supporting economic growth in rural areas (Texas DOT

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2004). The TTC undoubtedly will affect the performance of Texas' transportation system, which will be reflected in household and firm location choices, production levels, and trade patterns.

The fundamental interdependence of transportation system operations and economic activity demands an integrated modeling approach for projects as significant in scope as the TTC. The Random-Utility-Based Multiregional Input-Output (RUBMRIO) model aims to capture these interactions. Its enhanced capabilities make it a suitable tool to appraise the possible effects of the TTC on the Texas economy and personal and freight travel behaviors.

2. THE RUBMRIO MODEL

2.1 Literature Review

Integrated modeling of transportation-land use interactions aims to enhance planning, policy and investment decisions. Transportation system features affect household and firm location choices, production levels, and trade patterns. And these choices manifest themselves in various forms of travel demand, impacting the operational performance of the transportation system.

Input-Output (IO) models (Leontief 1963) have been widely used to simulate the linkages between industries and between producers and consumers. These models are demand-driven, in the sense that production levels are adjusted to meet both final and intermediate demands. Traditional IO models have been extended to incorporate social accounts, spatial disaggregation and even variable technical coefficients (Rose 1984). Oregon's Statewide Transport-Land Use Model (Hunt et al. 2001) and Hunt and Abraham's Production, Exchange and Consumption Allocation System-PECAS (Hunt and Abraham 2002) incorporate production factor demand elasticities through variable technical coefficients, although calibration of the parameters that govern these coefficients has not yet been accomplished. Spatial disaggregation in IO models is often achieved via logit models for location choice based on random utility principles, as in MEPLAN (Echenique 1985, Hunt and Echenique 1993, Hunt and Simmonds 1993, Abraham and Hunt 1999), TRANUS (de la Barra 1995) and others (see, e.g., Kim 1989, and Ham et al. 2000).Extended IO models, linked in various ways to econometric and transportation models (as exemplified in Rey and Dev 1999), give rise to very powerful operational integrated models, of which Southworth (1995) makes a fairly extensive (though somewhat dated now) review. However, data acquisition for calibration and estimation of some of these models can be very challenging.

Computable general equilibrium (CGE) also can be used to predict the economic impacts of transport system changes. For example, Kim et al. (2002) used a CGE model to predict the impacts of modifications to South Korea's transportation system, and Ivanova (2002) studied how transportation improvements reduced trade barriers between regions. CGE models simulate many inter-industry linkages using an IO process and a matrix of technical coefficients. But unlike IO models, they explicitly model production factors and intermediate input supply using a large number of econometric equations. (See, e.g., Shoven and Whalley 1984, Janvry and Sadoulet 2002, and Broker 1998.) These typically include self- and cross-elasticity parameters, which are difficult to estimate reliably due to data scarcity (e.g., data on prices, input purchases and sales volumes). Solving CGE models involves finding the relative prices that equilibrate production factors and commodity markets. The large number of equations necessitated by such models greatly limits the number of zones and economic sectors that can be and have been modeled. Moreover, spatial relationships are rarely considered. Some CGE models incorporate transportation costs in a simplified way (e.g., Broker 1998, Miyaigi 2002, and Buckley 1992). However, Ivanova (2002), Izard (1998), Anas (1997) and Logfren and Robinson (1999) are examples of models that attempt to explicitly account for transportation costs and system performance. Kim et al. (2002) linked a CGE model to an external transportation model that provides a single performance measure for use in the CGE's system of equations(Please, refer to Ruiz Juri (2004) for a more detailed literature review).

This work's improvements to the RUBMRIO model introduce certain CGE model features (for land and labor markets) while continuing to rely greatly on extended IO models for most economic interactions (including random utility principles for trade's spatial distribution). This combination makes it possible to achieve a reasonable degree of both spatial and sectoral detail, while generating land and labor prices through a market equilibration process. It also results in fairly low data requirements, which are limited to publicly available data sources in the present model. Although the approach requires some simplifying assumptions, the model structure is flexible, and can rather easily incorporate future refinements.

2.2 Model Specification and Data Sources

The RUBMRIO model derives from Input/Output-type productive dependencies across economic and social sectors, and logit models of input origin and transportation mode choice. Its trade equilibration module relies on an iterative algorithm (Zhao and Kockelman 2004) for solution of trade flows among zones and production within zones. It applies random utility theory for input purchase decisions, which requires computing the disutility of acquiring commodity *m* from every possible provider zone *i*, by transporting the commodity via rail, highway, and any other permitted modes. The current version of the model comprises 254 zones, and 21 economic sectors. The RUBMRIO model also incorporates two key factors of production (land and labor), market equilibration modules for these, plus an internal trip generation and equilibration module. Figure 1 illustrates the linkages and mutual feedbacks among different model components. For further detail on the trade equilibration modeling assumptions, including model equations and data sources, please refer to Kockelman et al. (2004). More information regarding the vehicle generation procedure and domestic demand incorporation can be found in Ruiz Juri and Kockelman (2004).

The model is driven by ***final demands,*** encompassing foreign export demands from 18 foreign export ports, and domestic demands by 50 U.S. states (plus the District of Columbia) as provided by the Commodity Flow Survey (CFS) data set (BTS 1997). Domestic demands amount to $129 billion, and they represent just over half (52%) of the total final demand that drives the Texas economy in this model application.

The ***trade equilibration*** module of the RUBMRIO algorithm begins by assuming/initializing sales prices across production zones and commodity types (typically at $0). As Figure 1 suggests, it distributes export demand (existing at export zones) and domestic demands (by other U.S. states) across production zones, according to relative trade (dis)utilities, comprised of transport costs and production zone sales prices. Production to meet this export demand plus any intermediate demands arising from such production (in other sectors and counties) is computed for each region/county. Intermediate consumption also is distributed across counties and the networks that unite them, using relative trade utilities. Average intermediate input prices (in units of utility) are computed as purchase-weighted averages of trade utilities across counties. When coupled with IO technical coefficients, these input prices provide average output sales prices (in units of utility). These newly computed sales prices are first evaluated for model convergence (i.e., compatibility between assumed and predicted prices), and then, if needed, fed back in order to initialize a new iteration.

The trade ***disutility*** is a function of transport distance (as a proxy for travel cost) plus commodity sales price (at the commodity's origin/place of production). For the first sixteen sectors, Kockelman et al. (2004) calibrated mode- and origin-choice parameters by industry, using a nested logit model of the 1997 Commodity Flow Survey data (BTS 2001), based on inter-state trade and inter-state distances.

For labor (industry/sector 17), a logit model for choice of input origin choice was calibrated, using the Census 2000 County-to-County Worker Flow Files and household data (U.S. Census Bureau 2003). In this model, employers choose their workers (or at least choose the counties from which they draw their workers), much like any other input to production. The model's explanatory variables are inter-county distances (as a measure of commute cost) and origin-county population (thus using labor-market size as the "attraction"). County average wages across industries were expected to be an explanatory variable for this choice model, but they were not estimated to be statistically significant, probably as a consequence of the low variation in this variable among counties. Only the highway mode is permitted for worker commutes (rather than railway, as for other inputs to production). While the State's freight railway is not a realistic option for Texas commuters, transit and other modes of travel may be added, particularly for intra-county travel choices. (The automobile mode dominates personal travel in Texas, however, claiming 96% of such commutes, according to the 2000 Census.)

Allocation of household consumption across counties, is done via a logit model calibrated based on Austin Travel Survey (ATS) shop-trip data. The Government sector's consumption is assumed to be strictly local.

Personal vehicle trips are generated from dollar trade flows. Truck trips, work trips and household shopping trips are computed separately (as total daily trips among zones), and then are combined to generate a representative single hour of total trip demand via fixed percentages.

Commodity trips to be loaded on the roadway network derive from the percentage of annual trade between counties, by industry sector, that relies on highways (computed based on the original model's nested logit's mode and origin choice parameters, as calibrated by Kockelman et al. 2004). The mining sector (commodity group 2), receives special treatment here, since it is dominated by shipments of crude petroleum and natural gas, which are mostly transported by pipeline, rather than highway or railway.

Given the proportion of freight conveyed by highway, a truck conversion factor (TCF) is used to transform the dollar flows into tons, tons into trucks and annual flows into daily flows. Even though all sectors generate some form of travel, some of them, such as Finance, Insurance and Real State (FIRE) are absent in the data used to compute the TCFs (1997 CFS and VIUS 2000). Thus, they are assumed to generate negligible truck trips here. They can and do generate work and shop trips, however.

Work trips are a consequence of the demand for labor by different industries. They are obtained via a labor market equilibration algorithm, as the ratio of payroll expenditure flows by sector to the corresponding industry-specific wage rates.

*S**hop trip*** patterns are estimated based on households' consumption of various goods among various counties, as provided by the trade-equilibration algorithm. Assuming an average purchase value per shop trip, uniform trip-making rates over the year, and a single available mode (highway), the trips are obtained by simple division, similarly to work trips.

In order to consider the ***impacts of roadway congestion*** on trade-patterns, an iterative feedback with TransCAD's (Caliper Corp. 2002) network user equilibrium commands was performed after each wage/trade equilibration cycle. This update relies on "distance updating factors" to effectively increase shortest path distances between zones to reflect congestion levels (relative to free-flow travel times). Thus, this factor is the ratio of the shortest congested/actual travel time between zones (after trip assignment) to the shortest free-flow travel time. *Intra*zonal travel times (t_{ii}) are obtained as a percentage of the average of travel times to three bordering zones. Dummy connectors without capacity constraints were created to link ports and county and state centroids to the Texas network. The highway network used for the model's TransCAD applications is the National Highway Planning Network (NHPN V2.2), supplied by the Federal Highway Administration.

The RUBMRIO model makes monetary prices explicit for two factor markets: floorspace and labor. Market equilibration (so that demand equals supply) is achieved by adjusting appropriate wages and floorspace rents. The production factor demands are computed taking advantage of the dollar formulation of the IO table in the RUBMRIO model. Assuming constant returns to scale (CRTS), which is a common assumption, according to Saito (1971), these IO coefficients can be interpreted as the exponents of a CRTS Cobb-Douglas production function (Klein, 1952, and Saito, 1971), which yields fixed expenditure shares for intermediate inputs.

Given this, and isolation of payroll and rent sectors as labor and land "industries" or sectors, the ***wage equilibration algorithm*** starts by assuming initial (annual) wage rates (per full-time worker), and computing labor demand as the ratio of payroll expenditures to average wage (Eq. 1).

$$Wrk_j^n = \frac{Payroll_j^n}{Wage_j^n} \qquad [1]$$

Then, it determines the wage rate that will equilibrate labor supply (which is a function of wage rates across counties, as explained below) and demand, and iteratively adjusts county average wages (increasing them if demand exceeds supply, and reducing them otherwise) until convergence. Subsequently, new estimates of population by county are calculated based on labor supply, and fed back into the trade equilibration model (Eq. 2 and 3).

$$Pop_i = \frac{\sum_j \left(\sum_n WrkTrip_j^n \cdot \frac{\exp(V_{i,j}^{17})}{\sum_k \exp(V_{k,j}^{17})} \right)}{WrkRate} \qquad [2]$$

$$V_{ij}^{17} = \gamma_{pop} \cdot Pop_j + \gamma_{dist} \cdot d_{ij} \qquad [3]$$

The computed *wage* rate is the average (across economic sectors) annual payment received by the workers employed in each county (Eq. 4).

$$AvWage_j = \frac{TotalPayroll_j}{LabSupply_j} \qquad [4]$$

$$LabSupply_j = \frac{\exp(UWrk_j)}{\sum_j \exp(UWrk_j)} \cdot TotalPop \cdot WrkRate \quad [5]$$

$$UWrk_j = AvWage_j \cdot \beta_{LOC} + p_j^{17} \quad [6]$$

$$p_j^{17} = \sum_m (a_j^{mn} \times HHc_j^m) \quad [7]$$

$$TotalPayroll_j = \sum_n \frac{Payroll_j^n}{(1 + IndDev^n)} \quad [8]$$

$$Payroll_j^n = X_j^n \cdot a_j^{17,n} \quad [9]$$

$$IndDev^n = \frac{AvWage_j - Wage_j^n}{AvWage_j} \quad [10]$$

Wage and employment data from the Bureau of Labor Statistics (BLS 2000) suggest that average wage rates vary considerably across industries, although the relationships among wages in different sectors remain fairly constant over time. To account for the wage rate variation across industries, appropriate "deviation" factors were computed (Eq. 10), which, when applied to each county's average wage, yield estimates of industry- and county-specific wage rates. (Kim [2002] and Logfren [2002] took a similar approach.)

Labor supply is a function of population by county (a fixed rate of 0.44 workers per inhabitant was assumed, based on Census 2000 data). Since the current RUBMRIO model does not predict population growth, labor supply by county is obtained by distributing 2000's total State population, as provided by the U.S. Census 2000via a logit model. This model was calibrated using BLS data on the number of workers and average wage per county and U.S. Census 2000's population counts by county. The employees choose the county in which they work based on a comparison of average wages, as well as average "prices" (in units of utility) of the average household consumption bundle for that county. This bundle represents the cost of living in that zone.

The model also specifies a ***floorspace market***, where parcels of real estate (land plus improvements) are dedicated to specific uses and owned by households and industries. ***Floorspace rents*** are the fees paid by industries and households for use of floorspace, including annualized costs of floorspace ownership (Wheaton, 1992). The ***floorspace rent equilibration*** algorithm applies at the county level, given that floorspace supply is immobile. As a consequence, rents are obtained in a single step (Eq. 13), based on floorspace rent expenditures incurred by all sectors in that county and a floorspace supply/availability equation. The model can accommodate various floorspace supply equations, corresponding to different assumptions. These include fixed supply (as a short-term case) or flexible supply, as a function of rents and other variables. A fixed supply is assumed for purposes of the TTC application pursued here, since this component of the model has not yet been calibrated.

$$RentPay_j^n = X_j^n \cdot (a_j^{18,n} + a_j^{19,n}) \quad [10]$$

$$IndustryXPay_j = \sum_n \left(RentPay_j^n \cdot PercentUse_n^Y\right) \quad [12]$$

$$RentIndustryX_j = \frac{IndustrXPay_j}{UseSupply_j^Y} \quad [13]$$

The proportion of the floorspace expenditures of sector *n* assigned to floorspace use type *Y* used in Eq. 12 were computed based on data about the number of employees in each occupation (by sector) as provided by the Occupational Employment Statistics Survey-OES (BLS, 2000), assigning each occupation to a specific floorspace type, and assuming fixed ratios between rent rates of different floorspace types, based on Hunt et al. (2002) findings.

Floorspace supply may be perfectly elastic in the long term. In the short term, however, the proportions of developed land and built floorspace that enter into the market are likely to depend on the market rents. At low rent values, owners might decide not to rent all available floorspace; low rents may not pay off maintenance and other costs, and owners may anticipate future higher rent rates. However, given the scarcity of real estate transaction data, this model application assumes fixed industrial and residential floorspace supply. (The model structure is rather flexible, however, and can incorporate supply elasticities, if such data becomes available.)

Due to the insufficiency of readily available floorspace supply data, a simplified estimation procedure (based on suggestions by Abraham and Hunt (2004)) was employed. It consists on applying an industry-specific floorspace requirement factor to the number of workers in each industry (and in each county), as suggested by the Quarterly Census of Employment and Wages (QCEW) provided by the BLS (2000). This factor was obtained by multiplying the proportion of workers in each occupation, by industry (from the BLS's OES Survey), and fixed ratios industrial floorspace requirements per employee in each occupation (Thompson 1997). The type of floorspace required by each occupation type (as defined in the OES Survey) was decided based on the occupation characteristics. The OES's retail and office floorspace requirements were combined as urban floorspace demands in this application. Residential floorspace supply, measured in housing units, was obtained from the U.S. Census 2000 housing count. Agricultural land supply (agriculture land requirements are defined here as "floorspace") was provided by the Oak Ridge Energy Crop county level database (ORNL, 1996).

Residential and industrial *land use intensities*, per county, are defined as the ratio of households or workers (as computed by the trade equilibration algorithm) to the associated equilibrium floorspace supply levels (from Eqs. 13 and 14). As a consequence of the model specification, in which there is no current limit on any county's production levels, the resulting land use intensities can be unrealistically high. A feedback process, involving maximum residential and industrial land-use densities (as estimated by Krishnamurthy and Kockelman (2002)), iteratively adjusts the prices of all commodities, by county, in order to reduce production levels when necessary, and achieve reasonable residential and industrial densities. The adjustment is performed by decreasing by one unit the utility of transporting commodities from the overloaded counties to every other location. This has an impact similar to increasing the corresponding prices, and was found to be more effective in terms of convergence and precision. The final price adjustment factors (after convergence) are fed into the wage/trade equilibration algorithm, and the solution process is repeated until consistent/compatible wages, trade-flows and floorspace rents are found.

$$IndDensity_j = \frac{Pop_j \cdot WrkRate}{\sum_{Y2,Y3} UseSupply_j^Y} \leq maxdensity \qquad [14]$$

$$HHDensity = \frac{Pop_j \cdot WrkRate \cdot HHWrkRate}{UseSupply_j^{Y1}} \leq 1 \qquad [15]$$

In these equations, Y2 and Y3 stand for urban and agricultural floorspace uses respectively, while Y1 represents residential land use.

The enhanced version of the RUBMRIO model described in this section offers a flexible framework to incorporate more realistic industrial and household's behavior. The next section describes an application of this extended model, using some simplifying assumptions for those parameters that have not yet been calibrated.

3. MODEL APPLICATION

The TTC's impacts were assessed using the new RUBMRIO model essentially by performing a with/without comparative analysis. Model results for the current Texas highway network were compared to outcomes obtained after incorporating the TTC's links.

3.1 Description of Scenarios

A number of different scenarios were modeled, recognizing that the completion of the entire system could take as many as 50 years. The different system components are expected to be built in stages, starting with truck lanes and commuter/freight railway lines during the first 20 to 35 years, and with passenger car lanes during the next 15 years. HSR lines would connect key cities (Austin, Dallas, San Antonio and Houston) only in the last stage of development.

This application exercise involves two different time horizons. In the first one, set in the year 2035, the TTC links include two trucking lanes per direction, plus rail lines. The second time horizon is set in 2050, and includes 3 passenger car lanes per direction (5 lanes total) in each corridor). The current RUBMRIO code and network do not recognize HSR or pipeline modes, so these were not modeled here. Exclusive use of trucking lanes by freight vehicles was not modeled either; it is not expected to strongly affect the results, given that most model-predicted inter-county trips (which are the trips effectively loaded into the network) are by truck. In addition to this, the TTC lanes are expected to convey mixed traffic if the demand levels do not become great enough to justify flows separation, and this is likely to be the case under the modeled conditions.

Three scenarios were modeled for each of these two points in time: one in which the TTC is not present (Base or original case [O]), one that includes only the priority corridors (P) (Figure 2), and one embracing the complete system (C). Each modeled scenario relies on rough estimates of future population (based on Texas Water Development Board numbers), as well as foreign and domestic final demands (based on Texas' Business and Industry Data Center projections and CFS numbers). It is necessary to note that most, if not all, TTC highway links are expected to be tolled. This is not accounted for in the current traffic assignment procedure, since the current mode and origin choice models are based on CFS data, which do not include information on any tolls paid for freight transport. Thus, the model has no toll term (only distances). However, future model refinements certainly could modify these choice models and apply appropriate tolls in the corresponding corridors. Finally, it is important to note that the current model does not account for congestion in the railway model. Consequently, the railway network improvements impacts are limited to reductions in the average inter-county distances by rail (these reductions can be large for some county pairs).

3.2 Results

This section describes and compares the model outcomes for various scenarios, in terms of production levels and their distribution, land rents, wages and commute patterns. Most of the discussion is based on comparing the complete implementation of the TTC in year 2050 versus the base case in the same year. For a full comparison among scenarios, please refer to Ruiz Juri (2004).

The comparison of 2050 scenario's production levels shows a slight re-distribution of production, involving a reduction in the number of counties with high production levels, an increase in the number of counties with medium/low production levels, and the concentration of a large portion of the total production in a few counties with extremely high production levels. What the model is suggesting is that those counties that benefit from proximity to points of final demand (i.e., export ports and Texas border points) will retain their supremacy. Moreover, the TTC's enhanced connectivity will allow them to improve upon their current position, and to obtain less expensive intermediate inputs from other counties, thanks to lowered transportation costs. Also, counties that formerly had intermediate/high production levels, thanks to their proximity to top producers, will lose their advantage. This results in more pronounced regional disparities, which may not be desirable. Of course, these results are to some extent affected by the assumption of unlimited production capacity by county, and by the distribution of final demands based mainly on transportation costs. Given that most of the associated costs in meeting final demands from other states involve reaching Texas' borders, the TTC's construction has little impact in the final demand distribution pattern, explaining the increased predominance of the same counties when intra-Texas transport costs are reduced. Model enhancements may rein in certain behaviors.

Positive and negative percentage changes in production levels (relative to the base case) are predicted across Texas, and the greatest impacts can be noted in counties nearest the new corridors; and, among these, particularly in those that originally had lower production levels and poorer access to the Texas network. The distribution of the top counties in terms of expected changes in wage rate and population follows a similar pattern to the one identified for production levels. The model predicts small wage variations (most are around +/-10%) in both directions. The predicted population redistribution effects of the TTC range from a 50% decrease to increases of more than ten times the base case population. These are likely to be over-estimated, as a consequence of the simplified population distribution model implemented in the current application.

The (flow-weighted) average highway travel distances in the 2050-C scenario are moderately higher than the corresponding base case for those sectors exhibiting lower sensitivity to transportation costs/distance (The enumeration and calibration of transport-cost sensitivity by sector can be found in Ling et al's 2004). This suggests that they respond to the diminution of congestion costs (brought about by the TTC) by increasing their trade flows with counties located further away. A roughly 20% reduction in the average percent of intrazonal trade for these sectors supports this belief. Unexpectedly, the commodity-specific flow-weighted average highway travel distance for the 2050-C scenario is about 5% to 60% less than the associated base cases for the remaining industries. Even though a small portion of this reduction is generated by the better connectivity brought about by the TTC construction, the diminution appears to contradict the prediction of increased proportions of inter-county trade in approximately 70% of Texas counties. However, these findings are actually reflecting the model suggestions of very strong regional disparities. The concentration of production in a few dominant counties exhibiting high levels of intrazonal trade explains the coexistence of an overall increase in inter-county trade flows, and the general reduction in the flow-weighted average traveled distances.

The percentages of *intra*zonal commuting do not vary much across scenarios, a result of using a relatively coarse, county-level zoning system, most likely.

Another effect of the reduction in transport cost is the increase in industrial diversification. This follows from the fact that, thanks to the lowered transport costs, some counties will experience higher demands for various commodities (even if they are not directly related to their satisfaction of final demands). In the context of the present model, counties trade mostly internally, given that the transport costs tend to compensate any technological competitive advantage that other counties might have. However, if these costs are reduced, counties which do not have a convenient production technology for certain commodities demanded from them might choose to import those from counties located further away. In the 2050-C scenario, more than 20 counties have economies based on 5 or more industries (which individually account for between 5% and 10% of total production), compared to four counties in the 2050-O scenario.

The model suggests slight changes in floorspace rents. Given that the floorspace supply was considered fixed, rent increases indicate increasing demand, with respect to supply, suggesting that one can expect higher rates of land development in the future, in order to accommodate the increases in production (due primarily to future increases in final demand)

It is noticeable that, in the priority corridor scenarios (P), which account for 49% of the TTC's total projected highway lane-mileage, the production re-allocation effects are more noticeable. This may be an outcome of the scale of the full system, which traverses/touches almost half of the State's 254 counties, thus diminishing the comparative advantages of being located near the TTC.

4. CONCLUSIONS

The TTC's 4000 centerline miles of highways and railways will undoubtedly affect Texas' economy and its residents' travel choices. The literature suggests that household and business location decisions also will be affected (Luton, 1980, Horst and Moore, 2003); economic activity and trade will redistribute, particularly in areas presently poorly connected to the transportation network (Luton, 1980); industrial production will diversify within each zone (Horst and Moore, 2003); and commercial markets will expand (Luton, 1980). The enhanced version of the RUBMRIO model, described in section 2, can capture many of these effects. Adding the TTC to the State's current highway and railway networks generates interesting and consistent results.

The model predicts small changes in production, suggesting stronger differentiation in top-producing counties located near points of final demand, and more noticeable impacts in counties traversed by (or located close to) the TTC . These effects are less noticeable in the long-term (2050) scenarios, which incorporate the complete TTC system, connecting 52% of Texas' 254 counties and thereby diminishing the competitive advantage of being located near the corridor.

The production concentration in a small number of counties is likely to be overestimated, as a consequence of the limitations of the final demand allocation model, which uses distance as the main decision variable. Given that most of the associated costs in meeting final demands from other states involve reaching Texas' borders, the TTC's construction has little impact in the final demand distribution pattern, explaining the increased predominance of the same counties when intra-Texas transport costs are reduced. Improved results can be expected if more realistic limitations to the county- production levels are implemented. Moreover, the assumption of exogenous final demands is an important limitation of the present model. It is desirable to account for endogenous variation in such demands as a function of Texas' and other exporters', although this would require a strictly monetary price structure for the demanded commodities. Also, further sophistications in the final and intermediate demand allocation models, which currently use distance as the only significant origin-choice decision variable, are desirable. Moreover, buyers' sensitivity to distance has been calibrated using the state-level CFS data, which might result in an over-estimation of this parameter. The use of finer-level databases, such as Reebie's (http://www.reebie.com/) could improve the realism of the results (however, this type of information is usually not publicly available).

Model results following TTC incorporation also suggest higher levels of inter-county trade. The magnitude of this effect varies by commodity type, with longer-distance trading predictions for those industries less sensitive to transportation costs. Overall, 70% of Texas' counties are expected to trade more actively with one another. Average trade-weighted highway travel distances are expected to decrease substantially, by about 30%. However, this is likely to be a result of the predicted extreme production disparities among counties. Intuitively, the TTC construction is expected to generate transport costs reductions, decreasing a counties' need for self-sufficiency and encouraging inter-county trade. However, it is necessary to analyze more appropriated indicators of the transport costs change than the trade-weighted highway travel distance, such as changes in the flow-weighted average travel times.

The RUBMRIO model applications also suggest that the TTC will reduce traffic volumes on existing highways by 8%, by attracting roughly 10% of original volumes. However, TTC's tolls are not modeled in this application (due to scarcity of freight movement-with-transport cost data for sub-model calibration). It is likely that tolls will make the TTC less attractive and thus trade changes less impressive and travel distance reductions less significant.

The enhanced RUBMRIO model is specified to equilibrate explicit floorspace and labor markets, which are important for policymaking and comprehensive impact assessment, and which constrain production levels. However, this structural improvement should be complemented with more accurate and realistic estimates of population distribution and floorspace supply. It would be desirable to have a dynamic model, which recognizes population, production and floorspace changes as an evolution of the current situation. This could involve the incorporation of migration (and eventually in-migration) dynamic models based on economic indicators and previous population distribution, as well as models capturing the elasticity of floorspace supply and land development with respect to rents.

Recognition of imports and cross-Texas trade and travel also is needed to capture effects such as the TTC impacts on the transport occurring on IH35 and other current major NAFTA trade corridors and the attraction of interstate traffic that previously traveled through neighboring states or cross-Texas trades between Mexico and other U.S. states. In fact, such accommodation is one of the TTC's aims (TxDOT 2002). These trades involve external zone-to-external zone travel and are not modeled here. They should be modeled in future enhancements in order to appreciate the long-distance transport effects of the TTC system

In general, spatial aggregation at the level of counties is not optimal for the analysis of commute trips, floorspace supply, and within-county congestion. A finer zoning system could be implemented at these specific instances, without a significant increase in the computational capabilities requirements. Also, within-county models could prove practical.

The TTC corridor will impact Texas in a number of ways, not all of which can be captured by a single model. The RUBMRIO model is a valuable tool for predicting many of the most important effects of a project of this nature and magnitude, providing reasonable and optimistic results with relatively low data requirements. Like all states, Texas is moving toward an uncertain future, and any insights into future patterns of trade, travel and location are of use for planners, policymakers, transportation engineers, businesses, and the public at large.

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NOTATION

$a_j^{17,n}$	= Technical coefficient indicating the expenditures on labor per unit of output of industry *n* in zone *j*
d_{ij}	= Distance between counties *i* and *j*;
β_{LOC}	= Logit parameter for employees' sensitivity to wages;
γ_{dist} & γ_{pop}	= Input-origin-choice logit model parameter;
HHc_j^m	= Consumption by households of commodity *m* in zone j;
HHWrkRate	= Inverse of the number of workers per household;
$IndDev^n$	= Fixed deviation between wages in industry *n* and the county's average wage;
$IndustryXPay_i$	= Floorspace expenditures specific to industry *X* in zone *j;*
$LabSupply_j$	= Number of workers employed in zone *j;*
$UWrk_j$	= Systematic utility that employees perceive from working in zone *j;*
$V_{i,j}^{17}$	= Systematic utility that employers in *j* obtain if they obtain their labor input from *i.*
p_j^{17}	= Cost of living in zone *j;*
$Payroll_j^n$	= Payroll expenditures by industry *n* in zone *j;*
$PercentUse_n^Y$	= Proportion of sector *n's* floorspace expenditures assigned to floorspace type *Y*;
Pop_i	= Population in county *I;*
$\mathrm{Re}ntPay_j^n$	= Total expenditure on floorspace incurred by sector *n* in zone *j;*
TotalPop	= Texas' total population, which is an input parameter;
$UseSupply_j^Y$	= Fixed supply of floorspace type *Y;*
$Wage_j^n$	= Average wage rates by industry *n* in zone *j;*
Wrk_j^n	= Number of workers demanded by industry *n* in zone *j;*
WrkRate	= Average number of workers per inhabitant;
$WrkTrip_j^n$	= Number of work trips generated by industry *n* in county *j;*
X_j^n	= Total production of *n* in *j;*

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FIGURE 1. The RUBMRIO model structure

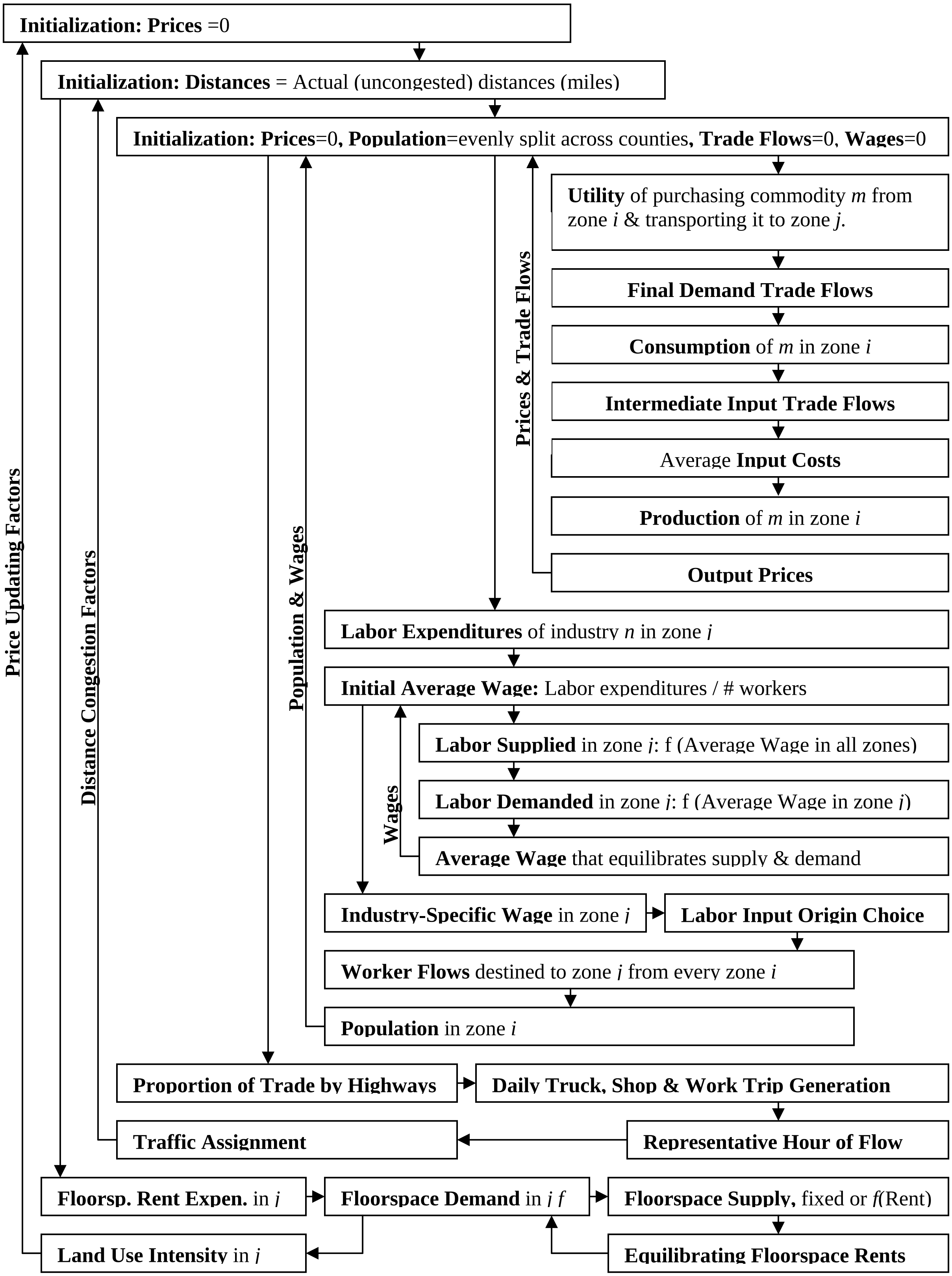

FIGURE 2. Proposed TTC layout, directly affected counties and priority corridors.