A LOOSELY-COUPLED PLANNING SUPPORT SYSTEM FOR TRANSPORTATION SKETCH PLANNING

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Abstract: This paper describes the use of two loosely-coupled commercially-available GIS-based planning support systems to provide a scenario-based sketch transportation planning tool for a medium-sized city in Brazil. The application first used *What if? 2.0* and available GIS data for São Carlos, Brazil, to project the city's land use, population and employment patterns in 2020 by traffic analysis zone (TAZ). The TAZ-level population and employment forecasts were then loaded into *TransCAD* to calibrate current trip patterns and forecast peak hour trips by auto and bus modes. The analysis indicated that the central area currently contains the most heavily loaded links, for both car and bus trips, primarily along a north/south axis. The projected city growth by 2020 doubles these loads for bus trips and triples them for car trips. These increases are expected, since the population and employment are expected to increase by roughly 50% and 100%, respectively, by the year 2020. This application demonstrates the value of loosely linking commercially available GIS-based planning support system to provide an understandable, relatively low cost, and easily implemented land use-transportation analysis tool for areas that cannot utilize more comprehensive integrated urban models, like most developing countries cities.

Keywords: transportation planning, sketch planning, planning support systems

1. INTRODUCTION

Large cities in Brazil and throughout the so-called "developing world" are currently experiencing substantial population growth rates. This growth is causing significant development problems, particularly as they relate to transportation and mobility. These problems are exacerbated by a lack of accessible, affordable, and understandable planning tools that can be used to analyze the complex and interdependent relationships between transportation and land use.

Planners have long recognized the intimate connection between urban land use patterns and transportation demand (Harris, 1985; Klosterman, 1994). This recognition provided the foundation for the earliest large-scale urban models and is integral to today's generation of integrated land-use transportation models (Hunt *et al.*, 2005; Wegener, 2005). However, the currently available "state of the art" models for considering land use-transportation interaction are generally too large, complex, and data-intensive to be applicable in smaller jurisdictions in the developed world or in most of the developing world (Schrank, 2004).

Transportation models have been developed that attempt to incorporate simpler approaches and easily accessible data. However, even the simplest models often rely on more sophisticated methods such as the activity-based approaches and traditional regression methods (Anderson *et al.*, 2006; Eom, 2007). In addition, most of these models are concerned primarily with the accuracy of the input data and the statistical validity of the results and neglect other aspects such as the presentation and visualization of the results that make them more informative and useful for nonexperts.

This paper describes the use of two loosely-coupled commercially-available GIS-based analysis tools to provide a scenario-based transportation planning tool that incorporates the conventional four-step travel demand model. The tools were applied to a medium-sized city in Brazil, for which is difficult to apply more complex urban and transportation planning tools. For other attempts to develop loosely-coupled urban models see Clarke *et al.*, 1998; and Klosterman and Xie, 1997. The application first used *TransCAD* (http://www.caliper.com/tcovu.htm) to collect and analyze the available geo-referenced data for São Carlos, Brazil. *TransCAD* has been used extensively for transportation planning tasks, such as traffic assignment in small and medium-sized cities but has not been integrated with an urban growth model (Han *et al.*, 2007). The spatial data for São Carlos were transferred to *What if? 2.0* (Klosterman, 2001; Klosterman, 2008; http://www.whatifinc.biz/) and used to project the most important variables influencing trip generation (Hensher, 2004): land use, population and employment patterns in 2020, by traffic analysis zone (TAZ).

The future land use, population and employment scenarios developed in *What if?* were then transferred back to *TransCAD* and used to perform the trip distribution, the mode choice and the traffic assignment modeling phases and project future traffic patterns by automobile and by bus. This approach recognizes that using a combination of packages based on a GIS interface is not only promising as a modeling tool, but also provides a useful tool for analysis and visualization (Johnston and de la Barra, 2000). This approach is particularly useful for cities in developing countries that can benefit from the application of GIS for urban transportation planning and management in many other ways (Khan *et al.*, 2007).

The application used readily available data from official sources, with special attention to the data collected for the city's Master Plan. Brazilian federal law required cities above a certain population size to prepare master plans. As a result, municipalities throughout Brazil are currently developing these plans. Unfortunately, many of these cities do not view this exercise as an opportunity to implement useful planning tools and procedures. This paper attempts to demonstrate how the data that are collected in preparing the Master Plan can be used to provide an effective planning tool, allowing planners to view the activities in which they are currently involved in a different way. This objective provided the motivation for the study described in this paper.

The paper begins by describing the data that were used in the study, on the assumption that data availability is often a critical problem in conducting land use/transportation studies. It then describes briefly the procedures that were used in *What if?* and *TransCAD* to provide a GIS-based system for transportation sketch planning. The paper concludes by summarizing the study results and conclusions, considering both the specific case study results and the application's operational aspects.

2. DATA

The spatial data for the city of São Carlos and the surrounding area were obtained from the city's Master Plan, which was prepared in 2002. These data included the current land use for the city's 60,000 land parcels. The land use for each parcel was classified into the following categories: residential, commercial, industrial, institutional, and leisure. The parcel-level data were aggregated to the blocks by assigning each block with its predominate land use, as shown in Figure 1. Vacant areas outside the urbanized area were divided into one hectare cells, which is roughly the same size as the blocks within the city. The limitations of available land use data required that this approach be used instead of more detailed land use classifications that consider mixed land uses and subdivide zones according to their population densities or activities (see, for example, Smith and Saito, 2001).

The Master Plan also provided information on the suitability of different locations for accommodating urban development, considering factors such as soil characteristics, relief, and sensitivity to harmful environmental impacts. Four different suitability categories were considered: developed, suitable, partially suitable, and unsuitable, as shown in Figure 2.

The Master Plan was also used to define a growth axis which assumed that future development would occur primarily in the currently vacant areas to the northwest of the city center. The growth axis indicated in the Master Plan was complemented by information of the development that has taken place after the plan was prepared. The result is a map that indicates the city's expected growth pattern, as shown in Figure 3. Another GIS layer was prepared showing the boundaries for the 250 census tracts or traffic analysis zones (TAZs) in São Carlos.

Additional data were obtained from other official sources, including the Brazilian Institute of Geography and Statistics (IBGE) and the State of São Paulo Data and Analysis Foundation (SEADE). IBGE, the national census bureau, provided population data by census tract for 2000 and the annual population estimates for the city until the present. The SEADE Foundation provided employment data by employment sector for 2000.

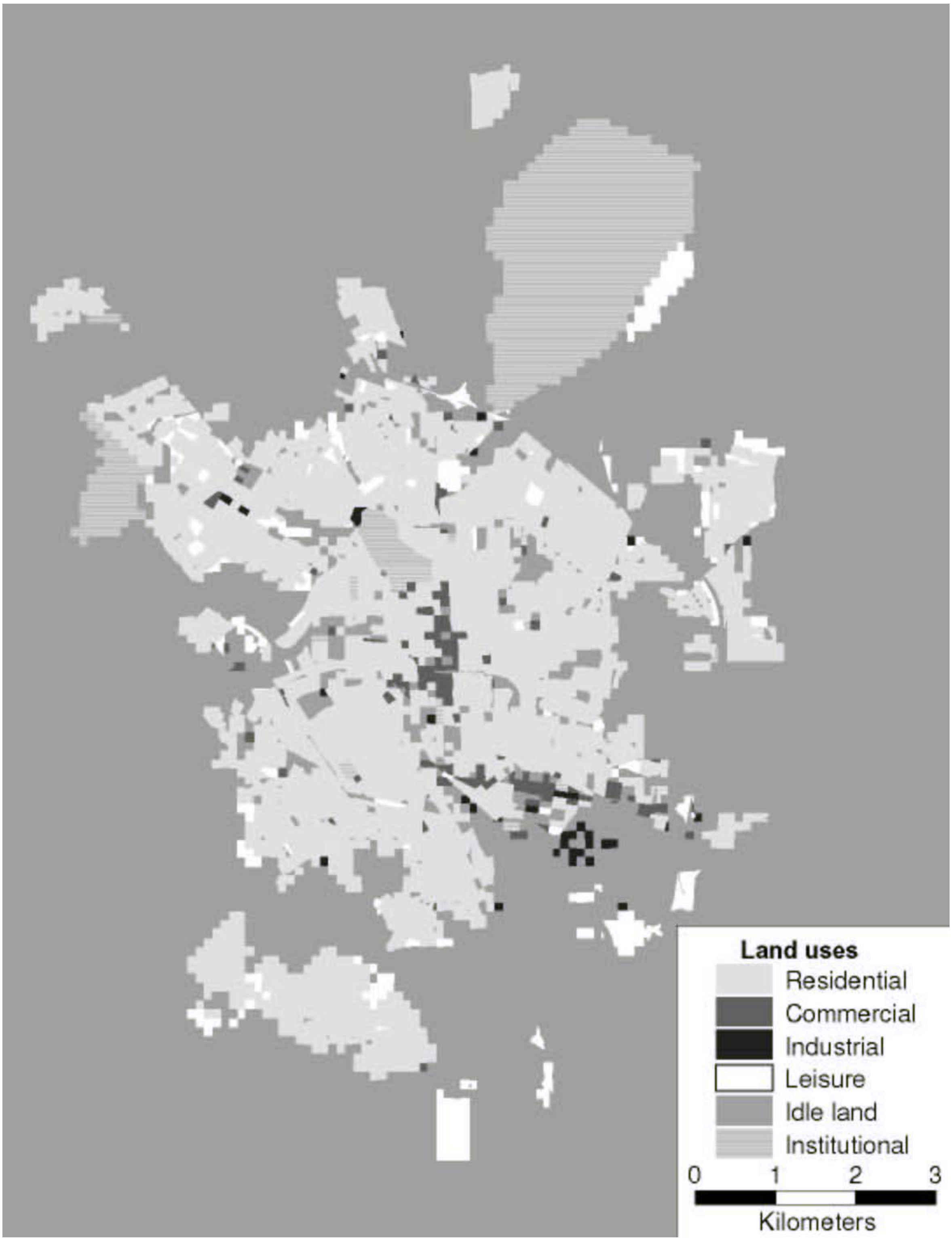


Figure 1 Land Use by Block for São Carlos, 2000

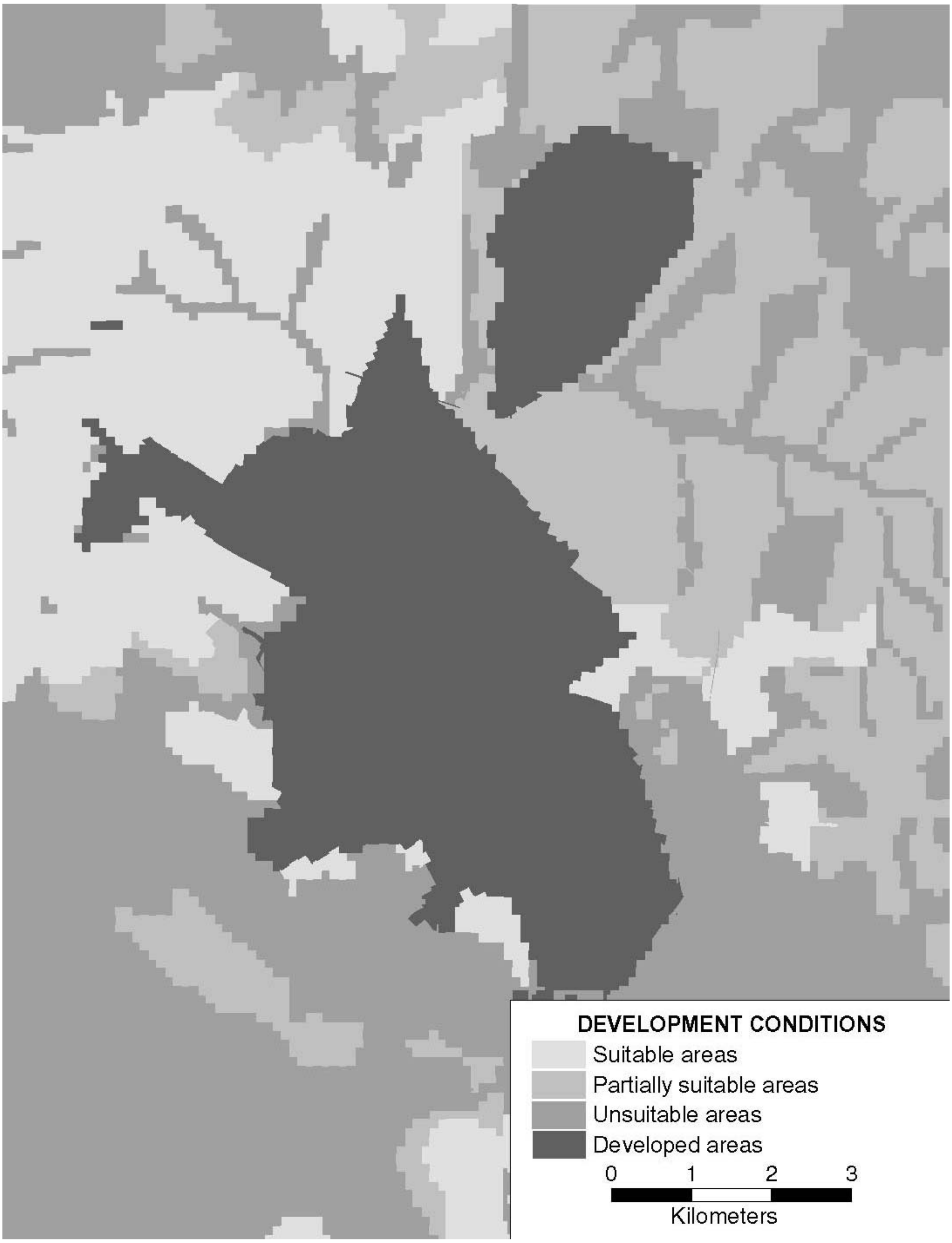


Figure 2 Suitability for Urban Development for São Carlos

Figure 3 Anticipated Growth Patterns for São Carlos

3. PROJECTING LAND USE PATTERNS

The GIS layers were geo-referenced in *TransCAD* and saved as shapefiles that were loaded into *What if? 2.0.* The *What if?* Suitability option was used to prepare suitability scenarios expressing the user's assumptions about which areas would and would not be developed, given the suitability analysis conducted for the city' Master Plan. The *What if?* Growth option was then used with assumed population and employment trends for five-year increments from 2000 to 2020 to project future land use demands. The official population and employment growth projections prepared by the IBGE and SEADE were modified to determine what would happen if the more rapid growth that has been observed over the last few years continued into the future.

The growth projections assumed that the city's population would grow by 46% and its employment would more than double over the next twenty years.

The *What if?* suitability and demand scenarios were then combined to project the future land use patterns in each projection year, as shown in Figure 4. As Figure 4 indicates, the city's future residential growth is projected to occur primarily north and west of the current urban core. Particularly noteworthy is the large expansion of industrial and commercial development in areas well outside the current urban center. The implications that these growth patterns will have on the city's transportation network were investigated with *TransCAD*. The projected land uses generated by *What if?* were required for the next steps of the application that used *TransCAD* to model the future trip flows.

4. PROJECTING AUTOMOBILE AND BUS TRIPS

The *What if?* outputs included shapefiles reporting the projected land uses, residential population, and employment in each projection year for São Carlos's 250 traffic analysis zones. These data were directly imported into *TransCAD* to prepare matrices representing the projected travel demand between different parts of the city. This was done by using a gravity model which assumes that the number of trips between zones is related to the projected residential population in the originating zone and the projected employment in the destination zone. Origin-Destination (O-D) matrices for 2000 (the base year) and 2020 were derived from the resulting trip vectors.

Two types of trips were considered: auto trips and bus trips. The mode share information came from an O-D survey conducted by the Department of Transportation of the São Carlos School of Engineering in 2007/2008. Two analyses were then conducted for the trip assignment phase, using the all-or-nothing method: one with the entire network of streets, for the auto trips; and other with a network formed by the streets in which buses operate, for the transit trips. The outputs of both analyses were displayed in thematic maps, in which the network links with high flows are thicker than the links with low volumes, as shown in Figure 5. In order to make the analysis results easily understandable for practitioners and the public, all maps were displayed in the same scale. Although this is apparently an obvious procedure, it has not always been done (see for instance, Han, 2008).

The analysis indicated that the central area currently contains the most heavily loaded links, for both car and bus trips, primarily along a north/south axis. The projected city growth by 2020 doubles these loads for bus trips and triples them for car trips. These increases are expected given the substantial population and employment growths that are assumed to occur by the year 2020. However, because the growth is projected to occur mainly in the northwest part of the city, routes that had low traffic loads in 2000 become some of the most heavily traveled ones by the year 2020. The traffic projections indicate that the city's transportation system must be redesigned to cope with the projected expansion in the demand for automobile and bus trips. Without that, the road network would not be able to accommodate the projected traffic flows, which could exceed ten times the current loads in some links, and would certainly overload the city's current transportation network.

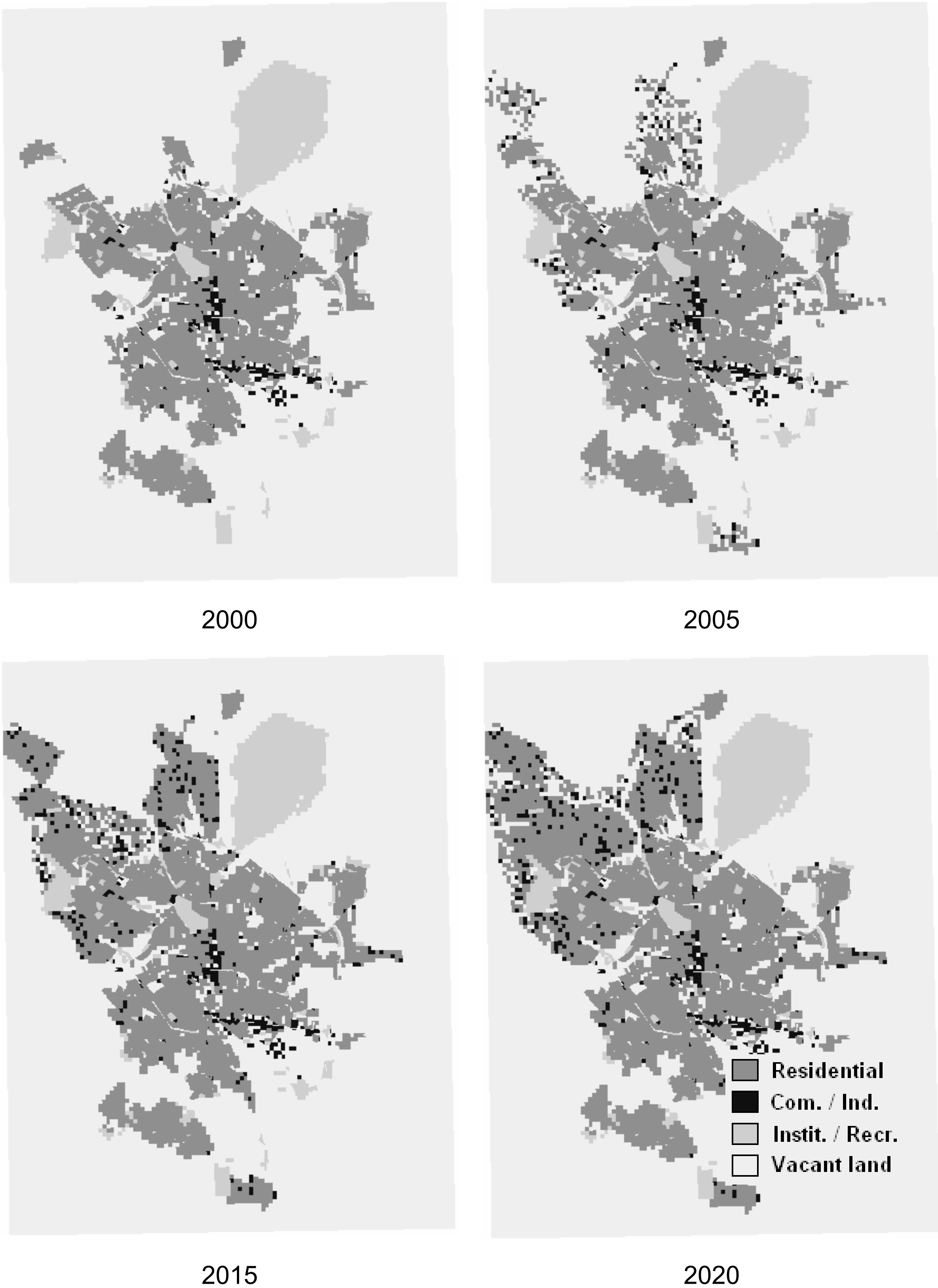
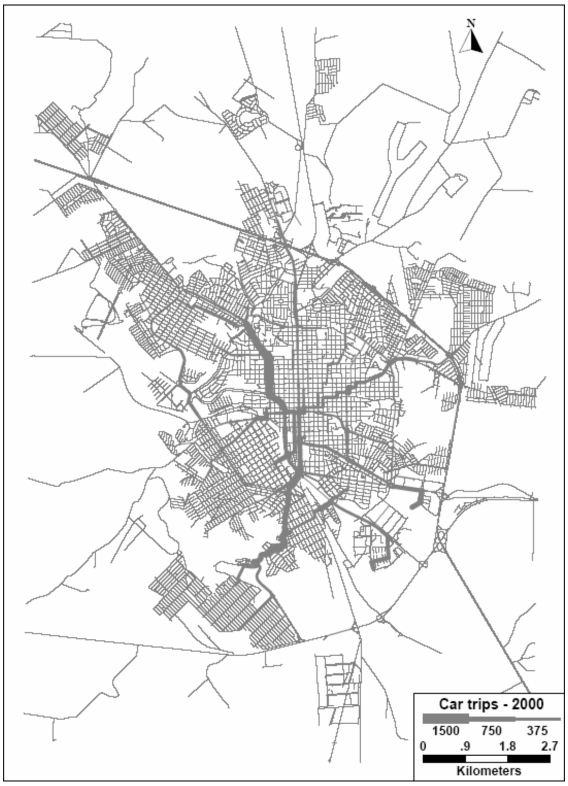


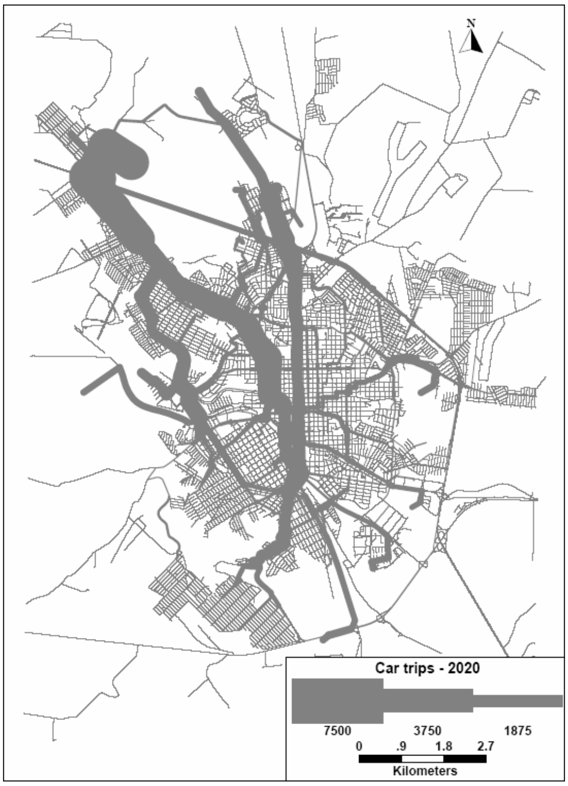
Figure 4 Projected Land Uses for São Carlos, 2000 to 2020

Bus trips - 2000

Bus trips - 2020



Car trips - 2000



Car trips - 2020

Figure 5 Projected Auto and Bus Trips for the City of São Carlos, 2000 and 2020

It is important to point out that the only action needed to transfer that data from *TransCAD* to *What if?* and then back to *TransCAD* was to save the required GIS layers as shapefiles. Once this was done, transferring the data between the two packages was a straightforward process. It is also appropriate to mention that projections were not made for additional leisure or institutional uses. However, that should not affect the results of the transportation analysis because the trips produced by those activities are usually not concentrated in the peak periods.

5. CONCLUSIONS

The study demonstrates that it was possible to use data that are readily available in Brazil and other countries to produce easily understandable land use and transportation scenarios. The study also demonstrated that it was easy to use two commercially available GIS-based systems to provide analyses that neither package could provide on their own. The fact that both packages used common file formats, shapefiles, made an integrated analysis possible.

Two insights about the future of the city of São Carlos were obtained from the study. First, if the Master Plan is implemented and the study assumptions are correct, the city can expect a large increase of the traffic flows towards the northwest part of the city. And, second, if the bus trips follow the pattern found in the application, there is room for a significant change in the transit system, moving from a radial system to a trunk-feeder system.

The difficulty of getting accurate data that required the use of relatively simple off-the shelf commercial packages suggests at that the projected traffic patterns are not precise, even though the study was conducted in a medium-sized city which reduces forecasting errors (Anderson, 2002). Nevertheless, the relative ease of conducting the research and the highly visual nature of the analysis results suggests that the uncertainty of the results will not affect the planning process substantially. As a result, given the limited number of publications demonstrating the practical applications of simple land use-transportation models, this work may provide an important reference for practitioners and decision-makers in small- and medium-sized cities of developing countries. This may be particularly true because the impacts of urban growth on transportation systems (and the reverse) are often neglected in these cities due to the lack of appropriate planning methods and tools.

In summary, this study demonstrates the value of loosely linking commercially available GIS-based planning support systems to provide an understandable, relatively low cost, and easily implemented land use-transportation analysis tool that can be used in areas that cannot utilize more comprehensive integrated urban models.

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