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Research article

A methodology to modify land uses in a transit oriented development scenario

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ABSTRACT

Developing nations are adopting transit oriented development (TOD) strategies to decongest their transportation systems. These strategies are often adopted after the preparation of land use plans. The goal of this study was to build a methodology to modify these land uses using soft computing. This can help to achieve alternate land use plans relevant to TOD. The methodology incorporates TOD characteristics and objectives. Global TOD parameters (density, diversity, and distance to transit) were studied. Expert opinions gave weights and ranges for the parameters in an Indian TOD scenario. Rules to allocate land use was developed. Objective functions were defined. Four objectives were used. First was to maximize employment density, residential density and percent of mix land use. Second was to shape density and diversity with respect to distance. Third was to minimize degree of land use change, and fourth was to increase compactness of the land use allocation. The methodology was applied to two sectors of Naya Raipur, the new planned administrative capital of the state of Chhattisgarh, India. The city has implemented TOD in the form of Bus rapid transit system (BRTS) over an existing land use. Thousand random plans were generated through the methodology. Top 30 plans were selected as parent population for modifications through genetic algorithm (GA). Alternate plans were generated at the end of GA cycle. The best alternate plan was compared with successful BRTS and TOD land uses for its merits and demerits. It was also compared with the initial land use plan for empirical validation.

1. Introduction

Developing nations are urbanizing rapidly. This leads to mobility and transportation issues like heavy traffic demand, congestion, and larger urban sprawls (Xu et al., 2017). Cities are leaning towards transit oriented development (TOD) strategies to combat these issues. TOD is defined as “a mixed-use community that encourages people to live near transit services, decreasing their dependence on driving” (Carlton, 2009). It was codified by Peter Calthorpe in late 1980's. TOD is a neighborhood centered on transit station or line. It contains sufficient people and activities to use the transit daily, within pedestrian friendly distances (MoUD, 2017; U.S.Department of transportation, 2005). It is characterized by high residential and commercial densities situated in mixed use structures (Calthorpe, 1993; Calthorpe Associates and Mintier & Associates, 1990). TOD has potential to attain sustainable urbanism as it shifts dependence from private to public transportation (Belzer and Autler, 2002; Cervero, 2010, 2006).

TOD can be implemented either using fixed rail systems (e.g. metros) or non-rail system. Bus rapid transit system or BRTS is a rubber-tired system. It is similar to a rail system integrating separate stations, corridors, and vehicles for transporting people. It has higher operational efficiency, and requires lower capital for implementation than rail systems. Additional benefits of BRTS are its flexibility, and passenger information system (Hossain, 2006; Polzin and Baltes, 2002; Wirasinghe et al., 2013). Cities such as Curitiba, Ottawa, and Brisbane, have shown land use benefits of BRTS. BRTS has potential to change land uses hence, land use planning for stations should be integrated as early as possible (Cervero, 2006; Levinson et al., 2002; Satiennam et al., 2006).

In India, five cities (Indore, Mysore, Hubli-Dharwad, Naya Raipur, and Pimpri-Chinchwad) are implementing BRTS under the government's sustainable urban transport project (SUTP) program. These schemes are often overlaid over existing land use plans. This creates a barrier for TOD strategies to work effectively because transportation and land use are linked coherently with each other (Waddell, 2011). Affecting one affects the other. Land use influences

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travel behavior (Sarkar and Mallikarjuna, 2013) while TOD influences land use and urban form (Ratner and Goetz, 2013). Therefore, cities are dependent on thoughtful land use planning for their effective development (Dutta, 2012). To achieve desired results, modification in existing land uses are required to create value (Salat and Ollivier, 2017). Land use can be modified through land use planning.

Land use planning is the allocation of land territories to different socio economic activities (Samper, 2012). It is a multi-objective decision making problem. Adding or changing objectives affects the solution. This makes the process complicated and time consuming. Time taking planning process and the inefficiency of its implementation are the reasons many Indian cities are facing challenges in planned growth and development. Decisions for implementation of mass rapid transit systems (MRT) are vital. If implemented after reaching a critical time stage, MRT will not bring expected impacts (Acharya and Morichi, 2007). Another barrier in structured progress is the preparation of a single draft plan which eventually gets finalize (Kumar and Pandit, 2013). This leaves no scope for comparison. A methodology that can help planners to generate alternative land use plans and evaluate them with ease is needed. It will reduce time to plan and can improve decisions. Many researchers have integrated multi objective optimization techniques with geographical information system (GIS) for land use planning (Datta et al., 2007; Stewart et al., 2004). Some of them have combined evolutionary algorithms, suited for multi objective optimization (Onseca and Fleming, 1994). Out of many evolutionary algorithms, genetic algorithms (GA) were found to be effective and appropriate for land use allocation problems (Cao et al., 2012; Stewart et al., 2004).

(Balling et al., 2000, 1999; Stewart et al., 2004; Xiang and Liu, 2015) have researched in modifications of land use through soft computation, GIS, and GA. Researches for an Indian TOD scenario is seldom present. This study tries to build a methodology to modify land uses using soft computing, GIS, and simple GA, applied to an Indian TOD scenario.

Genetic algorithm is a heuristic process of optimization based of natural selection and genetics. It uses objective functions to measure suitability (Sastry et al., 2014). This study defines objective functions based on TOD characteristics.

GA is called simple if selection, mutation and crossover are constant over the course of algorithm (Schmitt, 2001). A Simple GA has following steps – 1. Initialization, 2. Evaluation, 3. Selection, 4. Crossover, 5. Mutations and, 6. Replacement. Selection of parents can be done through roulette wheel selection or rank based selection schemes (Goldberg and Deb, 1991). There are many crossover techniques, one point crossover being the simplest and, commonly used (Gen and Cheng, 1997). Mutation is alteration of alleles in genes of the offspring. Crossover and mutation are controlled by their respective rates. This study uses rank based selections and one point crossover. An example of spatial one point crossover and mutations can be seen in Fig. 1.

2. Material and method

The methodology (see Fig. 2) was applied to the city of Naya Raipur, one of the demo cities under SUTP. The sectors of Naya Raipur that were relevant to the study were found out through site visits. Issues were identified through primary evaluation of the sectors. This is explained in sub section 2.1. After this, characteristics and parameters were identified from the literature, explained in sub section 2.2. Expert opinions are discussed in sub section 2.3. Attributes extracted through the opinions were used for land use allocation rules and objective functions (sub sections 2.4 and 2.5). Site was modelled in GIS using a 50 m × 50 m grid and spatial data

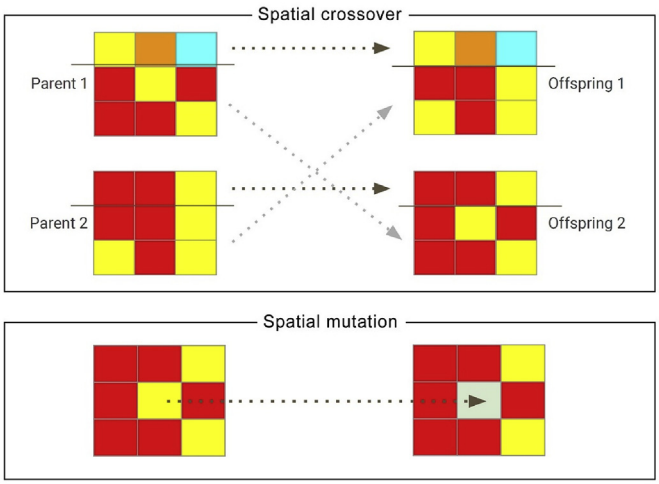

Fig. 1. Crossover and mutation example.

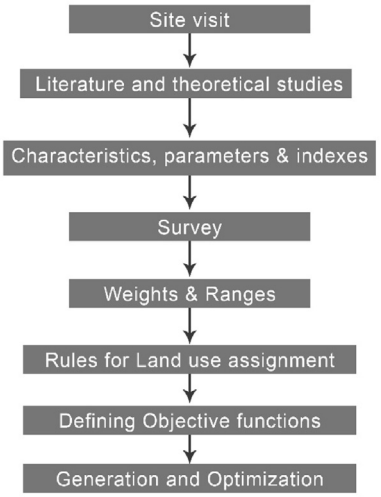

Fig. 2. Methodology for the study.

were added. The size 50 × 50 was suitable as it produced a workable number of land cells. The attributes were exported to MS Excel. Using Excel's visual basic scripts, objectives, parameters, and scripts were coded. The results are discussed in section 3.

2.1. Naya Raipur and land use issues

Naya Raipur was primarily developed to shift the administrative load from the old capital Raipur. It was also supposed to attract population from the adjacent cities and villages. The BRTS was operational at 5 stations during site visits, namely on sector 27, 29, Ekatm path, north block, and south block (see Fig. 3). The city was planned in grids. A typical residential grid is of 800 × 800 square meters to hold a population density of 16000 residents (NRDA, 2014). Excluding the capitol complex (main administrative hub), major development has happened in sector 27, and 29. Rest of the city is under development. The development in sectors 27, and 29, can be broadly classified into low and medium densities, with abundance of single storied houses, and a few apartments. Naya Raipur development plan 2031 suggests permissibility of shopping center, banks, and retail shops in residential land uses, but are rarely present in sectors 27, and 29. BRTS was implemented after

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