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An integrated framework to evaluate the equity of urban public facilities using spatial multi-criteria analysis

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ABSTRACT

Spatial equity is an important component of sustainable urban planning. We introduce an Integrated Spatial Equity Evaluation (ISEE) framework based on spatial multi-criteria analysis to assess spatial equity. This framework measures the balance between demands generated by residential areas and supply offered by urban services at various spatial scales. It considers the balance between different types of services at one spatial scale, and the balance between the same type of services across different spatial scales, applying an absolute measure of spatial equity at parcel level based on geographic analysis and Spatial Multi-Criteria Analysis (SMCA) methods. Its application is demonstrated in a case study area in Tehran, Iran by evaluating equitable access to several basic services used mostly by children. The results show that overall the case study area has an oversupply of educational services and an undersupply of recreational services, while some parts of the case study area have insufficient access to these services within a reasonable distance. The ISEE outputs can be readily visualised and interpreted providing urban planners with parcel level information to aid their decisions on how to equitably balance demand and supply for urban facilities and services.

Introduction

In developing countries, especially in metropolitan areas, rapid urban growth vastly exceeds the capacity of municipalities to provide basic infrastructure and services for their citizens (Cohen, 2006). Consequently, there are insufficient service locations that may also be inappropriately distributed over space, contributing to spatial inequity in service provision.

Spatial equity is understood as the degree to which services are distributed spatially in an equal way over different areas corresponding to the spatial variation of 'need' for that services (Omer, 2006). The evaluation of spatial equity is useful for urban planners and policymakers to identify areas of under-provision, to assess the effectiveness of existing urban services-provision policies and to advice on how to allocate scarce public facilities (Smoyer-Tomic, Hewko, & Hodgson, 2004).

Quantitative evaluation of spatial equity is often based on spatial accessibility measures. Tsou, Hung, and Chang (2005) defined accessibility as the relative nearness or the proximity of one place to another. Spatial accessibility methods play an essential role in equity studies, because the availability and spatial distribution of services along street networks is a significant factor for spatial equity assessment.

Recent efforts to evaluate equitable access to urban facilities have concentrated on assessing access to one type of facility, for example health care (Rosero-Bixby, 2004), schools and public playgrounds (Chin & Foong, 2006; Singleton, Longley, Allen, & O'Brien, 2011), urban parks and green space (Comber, Brunsdon, & Green, 2008; Oh & Jeong, 2007), and neighbourhood facilities (Lotfi & Koohsari, 2009). Only a few studies so far have considered a systematic approach for assessing equitable access to various and related urban facilities, the comparison of these varying equity values, and an aggregation into an integrated equity measure (Chang & Liao, 2011; Tsou et al., 2005). These existing approaches for integrating the effects of different facilities and evaluating equity for a range of urban public facilities provide a good starting point, but various improvements are required:

(i) Although, from a planning point of view it is useful to have an integrated measurement of spatial inequalities within a municipality, it makes little sense to simply aggregate equity measures related to various urban opportunities in the manner proposed by Tsou et al. (2005) as each type of urban

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opportunity has its own characteristics and satisfies particular needs (Chang & Liao, 2011). This diversity should be addressed during the integration process based on the goal of urban planners for equity evaluation.

(ii) Tsou et al. (2005) show the spatial distribution of relative inequity regarding access to urban facilities, irrespective of the absolute levels of access (Comber et al., 2008). More researchers have tried to show the level of inequality in access to certain facilities spatially, but they rarely looked into the (in-)adequacy of supply. While spatial equity considers the spatial distribution of facilities with respect to the spatial distribution of demand, adequacy of supply is an aggregated measure that considers total supply with respect to total demand. It is therefore possible that the supply is adequate but inequitable or inadequate but equitable.

(iii) Recent researches utilised GIS analysis tools to better present the results of spatial equity evaluation (Oh & Jeong, 2007; Yang, Robert Goerge, & Mullner, 2006); however, they have rarely integrated GIS and Spatial Multi-Criteria Analysis (SMCA) to evaluate spatial equity. SMCA is concerned with structuring and solving spatial decision and planning problems using multiple criteria. In this case, the aim of SMCA is to classify residential parcels based on the level of their equitable access to various urban opportunities. Residential parcels are considered as options and the criteria that reflect the values associated with the consequences of each option represent the accessibility of each option (parcel) to various urban opportunities (services). As a result we have several values for each parcel related to several urban opportunities that present a multi-criteria analysis problem. Each option (parcel) has a unique situation with respect to the different opportunities. Each parcels' accessibility may be good for some opportunities but poor for others. Compensatory MCA techniques, such as Analytical Hierarchy Process (AHP), are therefore needed, since low scores of one criterion may be compensated by high scores of another. Decision makers should determine acceptable trade-offs between different criteria. Finally an aggregation method is necessary to combine weights and scores for each of the options to derive an overall equity value.

(iv) Spatial resolution, ranging from macro to micro (Waddell & Ulfarsson, 2004, chap. 13), is an essential issue in equity evaluation. Some urban models rely on a macro-level zonal system that assumes that all attributes are uniformly distributed throughout a zone (Wegener, 2001). This approach ignores the actual connectivity and topological relationships between land uses based on mobility networks and the special characteristics of different land uses, such as service levels, linkages with others, compatibility, and functions (Moeckel, Spiekermann, Schürmann, & Wegener, 2003). Liao, Chang, and Tsou (2009, p. 137) mentioned that the "use of aggregate data for the evaluation of spatial equity entails methodological problems. The scale effect of the associated modifiable areal unit problem (MAUP) is also important for the analysis of spatial equity". Development of finer grained micro-level spatial planning models with smaller analysis units (parcel or building) allows a detailed investigation of spatial equity in relation to planning norms. This approach also aligns well with the trend towards disaggregated accessibility measures (Geurs & Wee, 2004).

Improved methods for analysing spatial equity are needed. Hence the objective of the paper is to develop a multifunctional/multi-scale equity evaluation framework at parcel level that addresses the above issues. This framework relies on the use of GIS based MCA methods. The paper begins with a literature review on measuring spatial equity, focusing on the linkages between various urban land uses and questions how to model such linkages. Then useful criteria for modelling equity are defined by applying the concept of minimum service standards. Next the steps for modelling spatial equity at various scales and with various functions are presented. Finally, the framework is applied and tested in a case study of the 7th Metropolitan Division in central Tehran, Iran. The focus of the case is on common facilities for children, such as schools, parks and recreations opportunities, but it can also be applied to other facilities and other user groups.

Spatial equity and linkages between land uses

Since urban areas consist of multiple land uses with specific, interconnected functions, there are several relationships between the various land use categories. For instance residential units are dependent upon other public and private land uses such as schools, shops, and parks for their required services. As these are distributed in space around any given residential parcel, not all locations are equally serviced. Equity values would show the severity of the imbalance between demands generated by the residential areas and supply offered by urban facilities. Demand is the expression of a population's needs for services. Supply is the expression of the availability and capacity of opportunities. Distances of residents to needed service opportunities and land per capita measures are commonly used to quantify supply.

Urban residents also have different demands for facilities (service land uses) at various scales (local, district, regional, city). This issue is a major challenge in modelling trade-offs between different facilities at different spatial scales in equity evaluation. For example, a single household may require schooling at preschool, primary and secondary levels, or health services for primary care or for high-cost inpatient care at a general or specialised hospital. Furthermore, available support for a service at a higher or lower scale may or may not be considered as a compensatory measure for other scales. For instance, if we accept that a clinic (as a district-level medical opportunity) offers primary health services, that are normally considered as local-level medical opportunities, then we can assume that a shortcoming in local-level medical services is compensated by district-level medical land uses such as clinics. On the other hand, the lack of local-level education services (primary school) cannot be compensated with higher level academic facilities such as universities. As a result, we should mention that trade-offs are relevant for some types of facilities (e.g. medical services, shopping), but not for others (e.g. education), because they cannot be compensated.

Evaluation of minimum service standards as the basis for equity modelling

Planning standards for service location provide a consistent basis for planning for community needs and measuring programmatic success (Kaiser, Godschalk, & Chapin, 1995). They provide useful goals of what to achieve in urban planning. The norms presented in minimum service standards were defined by urban planners considering the lack of sufficient resources and funding to provide all the services needed by the citizens. Therefore in a top-down urban planning approach, where the community was excluded and decisions were made solely by the government, planning standards can be interpreted as an optimum value. Most standards have been set by experts who determine how many libraries, police offices, bus stops, etc. they believe a community requires. A problem here is that these kinds of standards are often general and