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学位記番号	博甲第130号
学位授与の要件	学位規則第4条第1項該当者
学位授与の年月日	平成30年9月28日
学位論文題目	Analysis on urban development using spatial modelling technique under data constraints in China
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論文内容の要旨

Global urbanization has brought changes in urban spatial morphology as well as URT network system, which deserves careful study for an effective management of urban system, as do the key factors affecting location choice of urban residents and economic entities. In developing countries, the spatially-resolved statistical data required by many models do not always exist, while recently a number of spatial data are accessible on a global scope. This thesis develops a spatial modelling technique incorporating remote sensing data and open data with neo-classical urban economic models and graph theory to evaluate urban development under data limitation.

Chapter 1: Introduction & contribution

This rapid urbanization accelerates the migration of population into urban areas and the development of URT network all around the globe. In most developing countries, rapid urbanization is often accompanied by the lag of socioeconomic surveys, which leads to inadequate understanding of how much impact urban strategies have on urban activities. The thesis contributes to providing a methodology to evaluate urban development using a modelling technique, particularly an urban economic model and a centrality-based model under data constraints.

Chapter 2: Literature review

Spatial modelling technique manages spatially-detailed information to develop model in order to elucidate the mechanism of urban development. This thesis evaluates urban development from two perspectives, an overall perspective of urban sprawl and a

perspective of URT network shape, to contribute to sustainable urban development in the future. A survey of existing literature, including the evolution of urban structure, urban development intensity, urban model, network centrality, and accessibility, finds that a significant advance in urban models and network analysis, but also poses the challenge of collecting data in developing countries.

Chapter 3: Application I: a monocentric urban economic urban model

In the view of urban system itself, this chapter seeks first to expand the classical AMM urban model to make it applicable to large-scale simulation in developing countries today, whose features include massive urbanization, population growth, building construction, and urban expansion. Also this chapter introduces a market for residential floor space and developers who provide this space. A dataset is prepared for building an extended AMM model that includes socioeconomic and spatial data derived from remote-sensing satellite data. A comparison between observed and simulated results for key urbanization indices in three Chinese cities is conducted to examine the applicability of the proposed urban model.

Chapter 4: Application II: the model of centrality-based index of a location

In the view of URT network shape, this chapter incorporates actual spatial distance into topological centrality properties of URT network aiming to amplify its impact in real-life space. An index reflected the importance of a location affected by URT network shape was proposed based on centrality. Potential accessibility is defined as the ease to economic activities by the means of URT & walking, whose attractiveness is determined by the values of nightlight time data. By integrating this two grid-based properties of a location, the decision of economic activities to locate in somewhere can be inferred. A case study is conducted in Beijing, and the result is validated in comparison with the observed distribution of commercial facility points.

Chapter 5: Exploration of two models for future possibility

The proposed monocentric urban model relies on several important assumptions, and one of which is that urban areas are monocentric structures with homogeneous households and uniform space. It allows us to neglect the effects due to the actual shapes of urban areas. But approximating polycentric cities by monocentric structures may deteriorate the simulation accuracy. Therefore, identifying where urban cores located in could be a solution for identification of urban structure whether monocentric or polycentric. As URT network plays an undoubtedly important role in forming urban

skeleton, combining the two methods proposed in chapter 3 and 4 could be beneficial for works related to polycentric urban model, especially in the context of limited availability of spatially-resolved statistical data in developing countries.

Chapter 6: Conclusion

The thesis uses a spatial modelling technique to develop models that incorporate remote sensing data and open data with neo-classical urban economic model and graph theory to evaluate urban developments under data limitation.

Two applications from two perspectives were carried out to analyze two types of urban development. One is an overall perspective from urban sprawl to evaluate urban expansion in 3 Chinese cities. The other is a perspective from URT network shape to evaluate the importance of a location affected by URT network in Beijing. Developing basic urban models by utilizing spatial modelling technique shows its practicability, validity and future possibility as a quick evaluation tool for urban planning under data constraints. It also provides a holistic understanding of urban planning and is flexible to be applied into different scenarios. Spatial modelling technique involving open spatial data is confident of widespread use in urban spatial analysis in the future.

審査結果の要旨

The defense committee examined the doctoral dissertation entitled “Analysis on urban development using spatial modelling technique under data constraints in China”, submitted by the above applicant for a doctoral degree. The aim of this study is to develop a spatial modelling technique for urban infrastructure investment policy evaluations incorporating remote sensing data and open data with neo-classical urban economic models and graph theory to evaluate urban development under data limitation.

The dissertation consists of 8 chapters as follows.

Chapter 1: I Introduction & contribution

This rapid urbanization accelerates the migration of population into urban areas and the development of URT network all around the globe. In most developing countries, rapid urbanization is often accompanied by the lag of socioeconomic surveys, which leads to inadequate understanding of how much impact urban strategies have on urban activities. The thesis contributes to providing a methodology to evaluate urban development using a modelling technique, particularly an urban economic model and a

centrality-based model under data constraints.

Chapter 2: Literature review

Spatial modelling technique manages spatially-detailed information to develop model in order to elucidate the mechanism of urban development. This thesis evaluates urban development from two perspectives, an overall perspective of urban itself and a perspective of URT network shape, to contribute to sustainable urban development in the future. A survey of existing literature, including the concept of urban development intensity, urban model, network centrality, and accessibility, finds that a significant advance in urban models and network analysis, but also poses the challenge of collecting data in developing countries.

Chapter 3: Application I: a monocentric urban economic urban model

In the view of urban system itself, this chapter seeks first to expand the classical AMM urban model to make it applicable to large-scale simulation in developing countries today, whose features include massive urbanization, population growth, building construction, and urban expansion. Also this chapter introduces a market for residential floor space and developers who provide this space. A dataset is prepared for building an extended AMM model that includes socioeconomic and spatial data derived from remote-sensing satellite data. A comparison between observed and simulated results for key urbanization indices in three Chinese cities is conducted to examine the applicability of the proposed urban model.

Chapter 4: Application II: the model of centrality-based index of a location

In the view of URT network shape, this chapter incorporates actual spatial distance into topological centrality properties of URT network aiming to amplify its impact in real-life space. An index reflected the importance of a location affected by URT network shape was proposed based on centrality. Potential accessibility is defined as the ease to economic activities whose attractiveness is determined by the values of nightlight time data. Integration of centrality-based index and potential accessibility offers a new investigation way to explore the concentration of economic activities from the viewpoint of URT shape. A case study is conducted in Beijing, whose result is validated in comparison with the observed distribution of commercial facility points.

Chapter 5: Exploration of two models for future possibility

The proposed monocentric urban model relies on several important assumptions, and

one of which is that urban areas are monocentric structures with homogeneous households and uniform space. It allows us to neglect the effects due to the actual shapes of urban areas. But approximating polycentric cities by monocentric structures may deteriorate the simulation accuracy. Therefore, identifying where urban cores located in could be a solution for identification of urban structure whether monocentric or polycentric. As URT network plays an undoubtedly important role in forming urban skeleton, combining the two methods proposed in this thesis could be beneficial for works related to polycentric urban model, especially in the context of limited availability of spatially-resolved statistical data in developing countries.

Chapter 6: Conclusion

The thesis uses a spatial modelling technique to develop models that incorporate remote sensing data and open data with neo-classical urban economic model and graph theory to evaluate urban developments under data limitation, by studying 3 Chinese cities from an overall perspective of their expansions, and the rail transit network in Beijing from the perspective of its shape. Two applications using spatial modelling technique to develop models showed practicability, validity and future possibility of the proposed method as a quick evaluation tool for urban plan under data constraints. The methods presented here can particularly be useful to urban/rail transit planners. Spatial modelling technique involving open spatial data is confident of widespread use in urban spatial analysis in the future.

The achievements presented in the dissertation were published in the following two journal papers as the first author and one journal paper as third author. All the publications were made during his doctoral period.

- [1] Zhenyu GAO, Masanobu KII, Atsuko NONOMURA, Kazuki NAKAMURA, “An analysis on urban expansion using remote sensing data —case of harbin, china—”, 土木学会論文集D3, 72巻5号, p.I_495-I_503, 2016
- [2] Zhenyu Gao, Masanobu Kii, Atsuko Nonomura, Kazuki Nakamura, “Urban expansion using remote-sensing data and a monocentric urban model”, *Computers, Environment and Urban Systems* (Accepted 20 May 2017).
- [3] 紀伊雅敦, 横田彩加, 高震宇, 中村一樹, “共有型完全自動運転車両の普及に関する基礎分析”, 土木学会論文集D3, 73巻5号, p.I_507-I_515, 2017.

最終試験結果の要旨

平成 30 年 7 月 26 日に公聴会ならびに最終試験を実施した。公聴会では、申請者が学位論文の内容に関する発表を行った（1 時間）。その後、口述試験として学位論文の内容にかかわる審査委員の質疑に的確に答えることを求め、更に学位論文に関連した分野の専門知識を確認することで最終試験とした（1 時間）。

最終試験における学位論文に対する質疑応答の概要は以下の通りであり、申請者は全て的確に回答した。

1) 土地利用分類で用いた教師付学習の方法は何か？

（回答）統計的方法による教師付分類学習で、的中率 90%程度である。

2) 床の供給関数はどのような関数か？

（回答）土地と資本を投入するコブダグラス型の床生産関数を仮定している。

3) Consumption は良く合っているが、Floor rent と Floor area の推計値と統計値が大きく違っている。その原因は何か？

（回答）モデルの問題と、統計値の調査手法と政策の問題があると考えている。モデルは全ての世帯が借家であることを仮定しているが、実際には異なり、統計とのずれの原因となる。一方、統計は実際の都市部の状況を反映していない可能性がある。また、住宅政策は補助金等もあるため、完全市場を想定する本モデルと前提が異なっている。

4) モデルと統計との相違が、社会の課題を見いだすことに役立つのではないか？

（回答）その可能性はある。前述のように統計が実態を反映していない可能性が示唆されるが、併せて住宅政策が社会的な非効率を生み出している可能性もある。今後十分な考察が必要である。

5) Monocentric モデルの仮定は中国では成立するか？

（回答）既往文献では成立するとするものもあった。ただし、成立するかどうかは適用の目的による。都市成長に関わるマクロな指標を得る上では Monocentric モデルでも有用だと考えるが、より詳細な都市内の活動空間分布などを分析するには Polycentric なモデルが必要である。

以上、本審査委員会は、学位論文、公聴会および最終試験における研究内容説明および質疑応答から判断して、申請者が提出した論文は、その新規性と学術的価値から博士（工学）の学位に値するものであり、また、申請者が専門領域に関する十分な学識と研究能力を有

すると判断した。よって、本最終試験の評価を合格とする。