Modeling Urban Growth Based on Transport and Accessibility Changes in Kurunegala

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MODELING URBAN GROWTH BASED ON TRANSPORT AND ACCESSIBILITY CHANGES IN KURUNEGALA

ABSTRACT - This research uses spatial modeling techniques to assess how urbanization is affected by transportation and accessibility in Kurunegala. It has been built on an approach to simulate urban growth patterns by examining a wide range of variables, such as land use, excluded areas from development, slope, and road network. The findings indicate that improvements in transportation and ease of access have a major bearing on urban development, especially in regions with higher population density and economic activity. The level of urbanization considering road influence is 6.78%, and when it is not considered it is 13.13%. The study used a CA model for comparing and contrasting the simulated results with the Agent-based (Net Logo) modeling outputs. The results generated from the CA-Python simulation, the level of urbanization was obtained as 11.12% and the results are quite similar when it is not considering the road-influenced growth. Accordingly, when road influence growth is considered, less urban dissemination can be observed and the results can be emphasized using the CA model. The model validation of the derived results was done using the urbanization level and the comparison of the level of urban area expansion. The validation of the CA-Python results was done using the same model itself.

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1. INTRODUCTION

This approach, using an agent-based modeling framework, checked how road-influenced urban growth would alter the normal urban growth process. The main objective of this research is to simulate the urban growth within Kurunegala with and without the influence of roads and compare the results generated with the CA model. Combining geospatial analysis, transportation modeling, and urban planning may simulate city expansion in response to alterations in transportation and accessibility [1] Policymakers are very interested in questions related to the scale, causes, velocity, and geographical pattern of urbanization. It has been stated that the three most important elements affecting modern modifications to land use are accessibility, neighborhood relationships, and spatial policies [2]. It is widely held that transportation infrastructure may encourage and direct urban expansion by increasing convenience [3]. It is a well-known fact that urbanization tends to happen close to already-established urban centers. This can be seen in the way cities grow outward from their centers or in the way suburbs form around large cities [4]. Most studies that look at the long-term effects of transportation infrastructure use growth and urbanization as a measure of population change. The spread of rail networks has changed the way people live and helped more people move to cities, though the effect has been different in different places and at different times [4]. Thus, the contemporary literature reveals the following research gaps. The first one is, there is a significant knowledge gap when it comes to studying the impact of road accessibility on urban expansion across a variety of urban growth scenarios. [3] The second one is the use of sophisticated modeling approaches to examine the interconnected dynamics of road availability and urban expansion [4]. Finally, further studies are required to provide evidence-based insights into the
correlation between road accessibility and urban growth [4].

Urban expansion is a complex phenomenon influenced by several causes, with transit infrastructure and accessibility being particularly important. In Kurunegala, a vibrant city located in the center of Sri Lanka, comprehending the impact of road networks on urban growth is not only an academic pursuit, but rather has significant consequences for sustainable development and urban planning. With the rapid increase in urbanization worldwide, especially in developing countries such as Sri Lanka, the patterns of urban expansion become more intricate and interrelated. This project aims to investigate the complex link between transit developments and the geographical development of Kurunegala. The central focus of this project is using a cutting-edge agent-based modelling framework, which is a tool that can effectively reveal the intricate relationship between transport infrastructure and urban development patterns. This project aims to gain useful insights into how transport networks impact the spatial design of cities by modelling scenarios of urban growth with and without the presence of roads. The project aims to understand how urban growth changes in response to changes in accessibility by using ideas from geospatial analysis, transportation modelling, and urban planning. This method not only enhances our theoretical comprehension of the processes of urbanization, but also provides policymakers with practical information to guide urban growth towards sustainability and resilience.

The importance of this study is emphasized by the increasing interest among policymakers in understanding the magnitude, reasons, speed, and spatial distribution of urbanization. As metropolitan centers such as Kurunegala struggle with the intricacies of rapid urban expansion, it becomes crucial to examine the factors that are propelling this change. As the importance of accessibility, neighborhood linkages, and spatial policy in influencing land use changes becomes more evident, there is a growing demand for advanced modelling methods. This study seeks to address current research deficiencies by examining the complex interplay between road accessibility and urban growth, revealing hitherto undiscovered aspects of this mutually dependent connection. This project aims to investigate numerous crucial problems that have not yet been thoroughly explored, in order to advance knowledge. This research aims to explore the complex relationship between road accessibility and urban growth in many circumstances. It also seeks to uncover the interwoven dynamics between transportation infrastructure and spatial development. By doing so, this study will contribute to advancing the discipline of urban studies. This study aims to educate stakeholders with the essential skills and information to negotiate the complexity of urbanization in the 21st century by giving evidence-based insights into the association between road accessibility and urban expansion.

An essential aspect of this study project is acknowledging the significance of Kurunegala’s place within the broader global framework of urbanization patterns. As cities throughout the globe struggle to handle the difficulties of housing growing populations while also protecting the environment and promoting social and economic fairness, it is crucial to comprehend the factors that drive urban expansion. Kurunegala, with its distinctive combination of historical importance and modern vitality, exemplifies the worldwide tendencies of urbanization. By concentrating on this lively metropolis, the research not only provides significant observations into the dynamics of
the local urban environment but also enhances our comprehension of urbanization processes occurring in many settings. Furthermore, the use of agent-based modelling is an innovative method in urban studies that provides a detailed view of the intricate relationships between transport networks and urban structure. Agent-based modelling allows researchers to accurately represent the complexity and spontaneous behaviour seen in urban systems, which is typically lacking in conventional modelling methods. This research aims to reveal the complex feedback loops and non-linear interactions that influence urban development patterns by modelling the decision-making processes of individual agents in a dynamic spatial setting. Hence, the research not only enhances theoretical understanding but also introduces a novel methodology that has substantial implications for future investigations in the domain.

Moreover, the study design integrates a multi-disciplinary framework, using knowledge from geospatial analysis, transportation planning, and urban governance. This multidisciplinary approach recognizes the interrelated nature of urban systems, where modifications in transit infrastructure have ripple effects on spatial, social, and economic aspects. The study seeks to provide a comprehensive knowledge of the intricate forces that shape the urban development of Kurunegala by combining various viewpoints and research approaches. An integrated approach is crucial for developing successful policy interventions that support sustainable urban development while meeting the varied demands and desires of urban populations. Furthermore, the research has practical implications for urban policymakers, planners, and practitioners, in addition to its scholarly contributions. The study provides stakeholders with essential tools for informed decision-making by producing evidence-based insights into the link between road accessibility and urban expansion. The results of this research may provide valuable insights for guiding Kurunegala's urban growth towards resilience, inclusiveness, and sustainability. These findings can be used to shape transport policy, define land-use rules, and allocate infrastructure expenditures. Therefore, the study goes beyond the scope of academic investigation to serve as a catalyst for promoting positive transformation in urban government and planning practice.

2. Literature review

The study of urban development modelling, specifically focusing on the impact of transportation and accessibility modifications, has received considerable interest in the field of urban studies and planning literature. Researchers have used many methods and theoretical frameworks to comprehend the intricate dynamics that influence the shape and structure of cities. This literature review summarizes important results from relevant research, emphasizing the intricacies of urban development processes and the crucial significance of transportation infrastructure.

The correlation between transport infrastructure and urban growth has been a central focus of urban studies for many years. Kuby and Barranda (2007) emphasize the crucial significance of transport networks in promoting spatial development, underscoring the impact of road accessibility on land use patterns and population distribution. Handy and Niemeier (1997) contend that transport investments influence the development of cities by changing the ease of reaching different locations and the expenses associated with travel. These studies highlight the interdependence between transport networks and urban structure, emphasizing the need of integrated planning...
methods to encourage sustainable development. Agent-based modelling is a methodology used to simulate complex systems by representing individual agents and their interactions.

Agent-based modelling has become a potent tool for replicating the processes of urban expansion and investigating the effects of transportation modifications. Batty et al. (2003) illustrate the effectiveness of agent-based models in capturing the intricate interactions between agents (individual actors) and their environment. This enables researchers to replicate emergent phenomena, such as urban expansion and land use change. Clarke et al. (2007) use an agent-based modelling framework to study how transport policies impact urban development patterns. They emphasize the significance of include behavioral dynamics and spatial interactions in modelling exercises. Geospatial analysis refers to the examination and interpretation of data related to geographic locations. It is a valuable tool in urban planning, which involves the development and organization of cities and towns. Geospatial analysis is essential for comprehending the spatial aspects of urban expansion and evaluating the effects of transportation measures. Zhang and Zhang (2013) use geographic information systems (GIS) to examine the spatial arrangement of urban development in relation to transport enhancements, uncovering the influence of road networks on the growth of urban regions. Wang et al. (2018) use spatial analytics approaches to detect geographical clusters of urban growth and evaluate the impact of transportation accessibility on development patterns. These studies emphasize the significance of geospatial technologies in providing factual information for making informed choices in urban planning.

The scholarly research on transport and urban expansion also highlights the policy ramifications of infrastructure investments for achieving sustainable development. Cervero and Murakami (2010) support the implementation of transit-oriented development (TOD) plans, which include creating compact and diverse urban areas around transit hubs. This approach aims to decrease dependence on cars and limit urban sprawl. In a similar vein, Bertolini et al. (2005) advocate for the incorporation of land use and transportation planning in order to develop urban landscapes that are more pedestrian-friendly and accessible to public transportation, hence promoting sustainable development. These studies emphasize the significance of harmonizing transport policy with wider sustainability objectives in order to promote resilient and habitable cities. Areas of research that have not yet been explored fully and potential paths for future investigation as follows. Although there have been notable progressions, there are still deficiencies in our comprehension of the intricate interconnections among transportation, accessibility, and urban expansion. There is a need for further empirical research that investigates the cause-and-effect connections between transport investments and urban growth in various settings, such as rising countries like Sri Lanka. Furthermore, next research might investigate the possibilities of new technologies like self-driving cars and ride-sharing platforms to transform urban transportation patterns and impact land use changes. Researchers may enhance the development of urban growth models that are tailored to particular contexts and provide valuable insights for sustainable planning and policy-making by addressing these shortcomings.

To summarize, the literature on urban growth modelling highlights the complex relationship between transportation infrastructure, changes in accessibility, and patterns of urban expansion. Scholars have used several research methods, including as agent-based modelling and geospatial
analysis, to get a better understanding of the intricate processes that influence the shape and structure of cities. To make progress, it is crucial to fill in the gaps in research and adopt multidisciplinary methods. This will help us get a better knowledge of how urban expansion occurs and enable us to promote cities that are sustainable and resilient.

3. Research design

The case study focuses on assessing the influence of highways and the resulting urban expansion on the development of urban regions. The process begins with a pivotal decision about the incorporation of roads and their impact into the urban development blueprint, examining two possible scenarios: one that includes roads and another that excludes them. Afterwards, the work progresses to determining coefficients that are crucial for modelling urban expansion. The spreading coefficient, slope coefficient, and 'Rg' coefficient are crucial factors in a cellular automata (CA) model. This model often functions on a grid that represents regions that are either undeveloped or developed. The coefficients in the model indicate the probability of cells transitioning from undeveloped to developed states. This probability is influenced by variables such as the proximity to current development or the slope of the terrain. After establishing the coefficients, the research continues to simulate urban expansion using the Cellular Automata (CA) model. This simulation consists of many time steps, each reflecting a progression in time. During
each time step, cells change from underdeveloped to developed states depending on specified coefficients.

Ultimately, the research juxtaposes the outcomes of the simulation with those derived from a Python model based on cellular automata (CA). This comparison is conducted as a benchmarking exercise to evaluate the precision and efficiency of the model that has been created. By examining differences and similarities in the outcomes, researchers may assess the dependability of their model in replicating urban expansion patterns, particularly in relation to the impact of roadways and the development they produce. The main focus of the case study is to examine the impact of roads and subsequent urban expansion on the growth of metropolitan areas. The inquiry begins with a crucial choice about the incorporation of highways and their consequences into the urban growth plan, considering two possible scenarios: one that includes roads and another that does not.

Afterwards, the research advances to the calculation of coefficients that are crucial for modelling urban growth. The spreading coefficient, slope coefficient, and 'Rg' coefficient are crucial factors in a cellular automata (CA) model. These factors have a significant impact on determining the likelihood of cells changing from an undeveloped to a developed condition inside a grid system that classifies areas as either underdeveloped or developed. The probability is affected by other factors, such as the distance to current infrastructure and the gradient of the terrain. After determining the coefficients, the study progresses to simulate urban growth using the Cellular Automata (CA) model. This simulation progresses through many time steps, each representing a distinct moment in time. During these rounds, cells experience changes from immature to mature states based on the stated coefficients. Ultimately, the research concludes with a comparison between the results of the simulation and those obtained from a Python-based model based on cellular automata (CA). This comparative evaluation is a benchmarking effort designed to evaluate the correctness and effectiveness of the produced model. By carefully analyzing differences and similarities in the results, researchers may assess the dependability of their model in reproducing patterns of urban growth, especially in relation to the impact of roads and the resulting development they promote.

4. Results and discussion

![Figure 1. Without road influence](image1.png)  ![Figure 2. Considering road influence](image2.png)
4.2. Comparison with CA Python model –without considering the road-influenced growth

The analysis two urban growth modelling scenarios, one including the effect of roads and the other without it, indicates a significant disparity in the rate of development. When the modelling framework does not include road effect, the simulation advances much quicker compared to situations where road influence is considered. The rapid increase in urban development may be ascribed to several causes, such as the lack of limitations imposed by transportation networks and the efficient spread of urban areas into vacant places. When road effect is not taken into account, the simulation gives greater importance to criteria like land use, slope, and accessibility to facilities. This leads to a faster more unrestricted pattern of urban growth. On the other hand, when the impact of roads is included into the process of modelling urban expansion, the rate of development decreases significantly. The main cause of this decrease in speed is the complex interaction between road networks and the dynamics of urban growth. Roads bring forth further intricacies and factors to the simulation, such as the impact of transit accessibility on the distribution of urban activities. As a result, the simulation becomes increasingly complex and time-consuming as it tries to accurately represent the detailed relationships between highways, land use patterns, and urban development dynamics.

Moreover, including the impact of roads into the modelling framework results in a more widely spread dispersion of urban activity throughout the road networks. When road effect is taken into account, urban growth is more evenly distributed along transportation arteries, unlike in cases where road influence is ignored and urbanization may be concentrated in certain locations due to other considerations. This phenomena demonstrates the central significance of roads in influencing the spatial arrangement of urban development and emphasizes the need of including transportation infrastructure in urban growth modelling endeavors. To summarize, the comparison of several scenarios for modelling urban expansion demonstrates the substantial effect of roads on the speed and pattern of urban development. Simulations that do not include the impact of roads show quicker rates of development. However, simulations that take road effect into account provide a more thorough insight of the intricate factors driving urban expansion dynamics. Simulations that
take into account the effect of roads on land use and urban expansion help to improve decision-making in urban planning and development by revealing the complex relationships between these factors.

The discrepancy in the rate of urban expansion modelling between scenarios that take into account road effect and those that do not arises from many underlying factors that are deeply ingrained in the dynamics of urban development. Initially, when the impact of roads is removed from the modelling framework, the simulation tends to advance more rapidly since there are no limitations imposed by road networks. The simulation largely emphasizes inherent criteria such as land use appropriateness, topography features, and accessibility to facilities, without taking into account road infrastructure. This efficient strategy enables quick growth into accessible areas without the need to manage intricate transportation systems. On the other hand, including the impact of roads into the modelling process adds a level of intricacy that naturally reduces the speed of the simulation. Roads have a crucial impact on the formation of urban development patterns by affecting how easily places can be reached, how well they are connected, and the choices made about how land is used. Therefore, while simulating road networks, it is necessary to take into consideration the complex interaction between transportation infrastructure and urban growth dynamics. The simulation must take into account several factors, including road capacity, traffic flow patterns, and the geographical distribution of road networks. This adds complexity and processing cost to the modelling process. Furthermore, taking into account the impact of roads in urban development modelling results in a more widespread dispersion of urban activity along transportation routes. In contrast to situations where the impact of roads is ignored, urban growth may be concentrated in certain places exclusively based on internal reasons. However, when roads are taken into account, development is more evenly distributed along transportation corridors. This phenomena demonstrates the essential function of roads as accelerators for urbanization, as they provide access to resources, markets, and job opportunities, so impacting the geographical spread of development.

Moreover, while including road impact into urban development modelling, it is essential to take into account supplementary elements such as transit accessibility and mobility patterns. To address this issue, it is necessary to gather and analyze more extensive data. Additionally, advanced modelling approaches should be used to accurately represent the intricate relationships between roadways, land use, and urban development patterns. As a result, the process of modelling becomes more complex and time-consuming, which leads to a slower speed in simulations that take into account the effect of roads. The differences in the rate of urban expansion modelling between scenarios with and without road effect are mostly caused by the inherent challenges of including transport infrastructure into the simulation. Although eliminating the impact of roads allows for quicker simulation durations, including roads into the modelling framework offers a more detailed comprehension of the elements that determine urban growth patterns. Simulations that take into account the effect of roads help to better understand how urbanization is shaped. This, in turn, leads to more informed decision-making in urban planning and development.
5. Conclusion

Ultimately, the analysis of different urban growth modelling scenarios, taking into account or disregarding the impact of roads, provides valuable insights into the complex factors that shape urban development. The discrepancy in the rate of simulation underscores the significant influence of transportation infrastructure on patterns of urbanization. Simulations that do not include the impact of roads advance more quickly because they use simpler modelling parameters. However, simulations that include roads provide a more thorough picture of the many factors involved in urban expansion. The incorporation of road impact reveals the crucial function of transport networks in affecting the spatial arrangement of development and emphasizes the need for advanced modelling techniques to adequately capture these dynamics. Simulations that take into account the effect of roads on land use and urban expansion help to enhance decision-making in urban planning and development by revealing the complex relationships between these factors. As cities progress and grow, it is essential to comprehend the relationship between transport infrastructure and urban growth in order to promote sustainable and resilient urban ecosystems.

6. References