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Dissertation

IN SEARCH OF SPATIAL PATTERNS:
HOW ROAD INFRASTRUCTURE IMPACTS LAND DEVELOPMENT

Candidate: MSc. Rron Beqiri, TU Wien
Supervisor: Associate Prof. Dipl.-Ing. Dr. Thomas Dillinger, TU Wien

Faculty for Architecture and Planning
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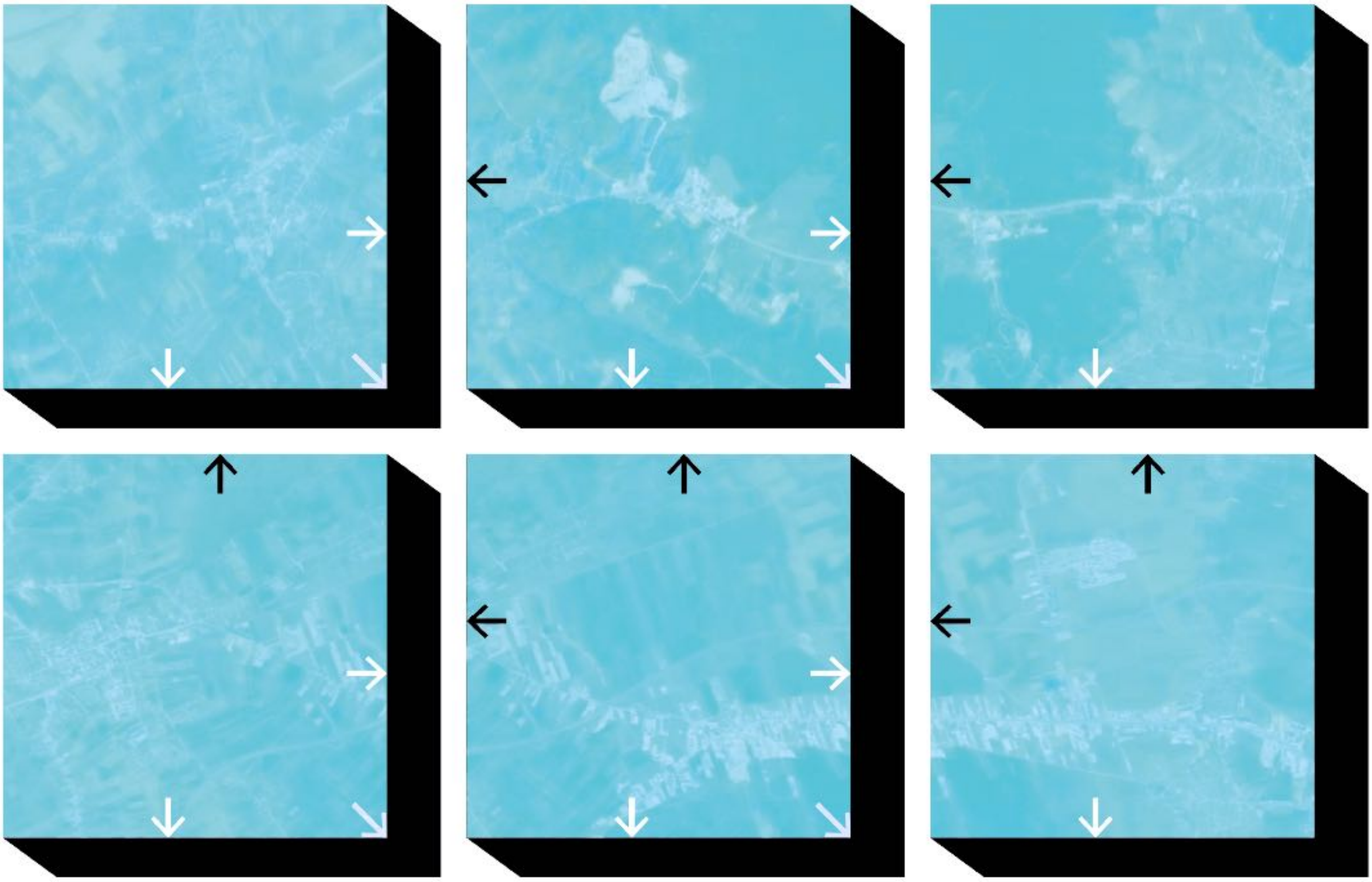

D I S S E R T A T I O N

In Search of Spatial Patterns: How Road Infrastructure Impacts Land Development

Ausgefürt zum Zwecke der Erlangung des akademischen Grades eines
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Begutachtung durch

Ao.Univ.Prof. Dipl.-Ing. Dr.techn. Andreas Voigt

Prof.Asoc.Dr. Florina Jerliu, Eng.Arch.

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von

Rron Beqiri

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ABSTRACT

The construction and development of road infrastructure is critical in the shaping and development of land. When it is not recognized as an essential component of the very early stages of planning, and when it is treated as a background step from the planning process, it has the potential to be detrimental to the implementation and long-term viability of existing plans in a particular region. Additionally, land-use is subject to changes influenced by road infrastructure, and when policies, regulations, and/or physical barriers are not in place to prevent these changes from occurring, these changes are bound to occur in a particular fashion.

Despite the fact that the function of road infrastructure in determining land development is well established, there is a clear element of subjectivity in the decision-making process when it comes to the design and planning of new road infrastructure. The construction of road infrastructure is often based and dependent on non-public investments and political decisions, which repeatedly tend to disregard the planning phase and long-term effect on the spatial development of the region.

The aim of this dissertation is to analyze and understand the role and influence road infrastructure has on spatial development, with the attempt of identifying patterns of Land-Use change and development intensity. Ultimately, the goal of this dissertation is to construct a model that can be used to anticipate the possibility of land development in specific sections of a road under consideration, a model that can be used as a technological tool in the formulation of spatial planning policies and actions.

Kosovo is used as a study case, as is a country where investment and development, particularly in road infrastructure, have occurred in a very short period of time with little to no control, management, or supervision over how this development is being formed. This provides a more uncontaminated window through which observations can be made on how land-use changes and development are shaped in a 'natural' manner, without the interference of the state or the government.

A number of case studies of different road types have been used and tested with the model to understand the growth and development pattern they will likely have, without intervention. For each individual case study, intervention actions are proposed to tackle issues that arise and are identified by the model and its outputs.

Finally, one of the most important goals that this dissertation seeks to achieve is to introduce the concept of using technological tools, data, and urban analytics in the field of spatial planning into the professional and technical discussion in the field of spatial planning.

KURZFASSUNG

Die Entwicklung und der Bau der Straßeninfrastruktur ist entscheidend für die Bildung und Entwicklung von Land. Es könnte der Umsetzung und dem langfristigen Erfolg von Plänen in einem bestimmten Bereich schaden, wenn es nicht von Anfang an als wichtiger Teil der Planung angesehen und als Hintergrundschritt behandelt wird. Zusätzlich, die Landnutzung unterliegt Änderungen, die von der Straßeninfrastruktur beeinflusst werden, und wenn Richtlinien, Vorschriften und/oder physische Barrieren nicht vorhanden sind, um das Auftreten dieser Änderungen zu verhindern, werden diese Änderungen zwangsläufig in besonderer Weise auftreten.

Trotz der Tatsache, dass die Funktion der Straßeninfrastruktur bei der Bestimmung der Landentwicklung gut etabliert ist, gibt es ein klares Element der Subjektivität im Entscheidungsprozess, wenn es um die Gestaltung und Planung neuer Straßeninfrastruktur geht. Der Bau von Straßeninfrastruktur basiert und ist oft abhängig von Investitionen, die nicht vom Staat kommen, sowie von politischen Entscheidungen, die immer wieder dazu tendieren, die Planungsphase und die langfristige Wirkung auf die räumliche Entwicklung der Region außer Acht zu lassen.

Das Ziel dieser Dissertation ist es, die Rolle und den Einfluss der Straßeninfrastruktur auf die räumliche Entwicklung zu analysieren und zu verstehen, mit dem Versuch, Muster der Landnutzungsänderung und der Entwicklungsintensität zu identifizieren. Letztendlich ist das Ziel dieser Dissertation, ein Modell zu konstruieren, das verwendet werden kann, um die Möglichkeit der Landentwicklung in bestimmten Abschnitten einer betrachteten Straße zu antizipieren. Dieses Modell kann als technologisches Werkzeug bei der Formulierung von Raumplanungsstrategien und -maßnahmen verwendet werden.

Das Kosovo wird als Fallstudie herangezogen, weil es ein Land ist, in dem Investitionen und Entwicklung, insbesondere in die Straßeninfrastruktur, in sehr kurzer Zeit stattgefunden haben, ohne dass es zu einer Kontrolle, Verwaltung oder Aufsicht darüber gekommen ist, wie diese Entwicklung entsteht. Dies bietet eine unverfälschtere Linse, durch die beobachtet werden kann, wie Landnutzungsänderungen und -entwicklung auf „natürliche“ Weise geformt werden, ohne Einmischung durch den Staat oder die Regierung.

Eine Reihe von Fallstudien verschiedener Straßentypen wurden verwendet und mit dem Modell getestet, um das Wachstums- und Entwicklungsmuster zu verstehen, das sie wahrscheinlich ohne Intervention haben werden. Für jede einzelne Fallstudie werden Interventionsmaßnahmen vorgeschlagen, um Probleme anzugehen, die auftreten und durch das Modell und seine Ergebnisse identifiziert werden. Schließlich ist eines der wichtigsten Ziele dieser Dissertation, das Konzept der Nutzung von technologischen Werkzeugen, Daten und Urban Analytics im Bereich der Raumplanung in die fachliche und technische Diskussion auf dem Gebiet der Raumplanung einzuführen.

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This dissertation would not have been possible without the guidance and the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

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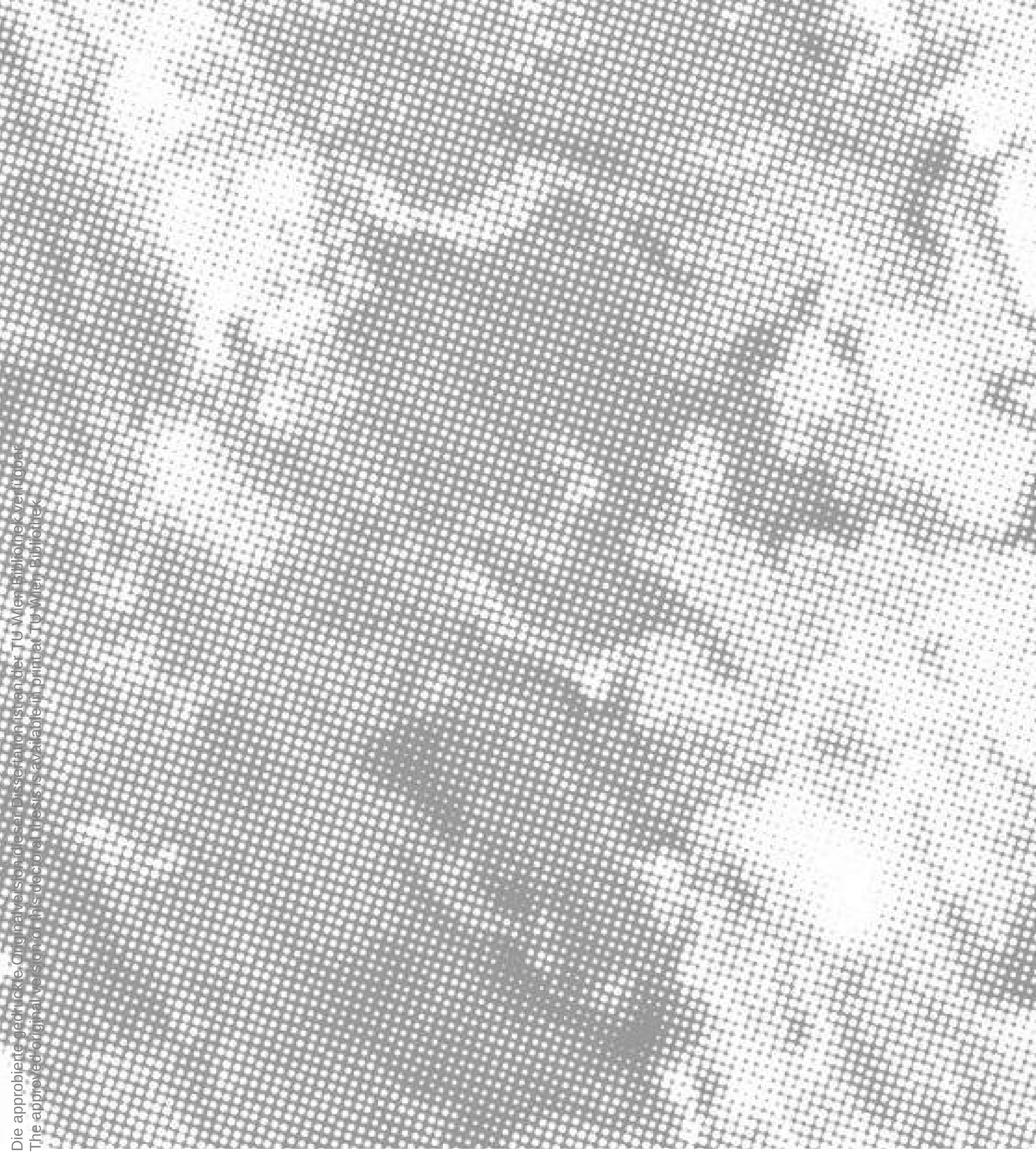
ABBREVIATIONS

MESP	The Ministry of Environment and Spatial Planning
MESPI	The Ministry of Environment, Spatial Planning and Infrastructure
UNMIK	United Nations Mission in Kosovo
SPK	Spatial Plan for Kosovo
SPSA	Spatial plan for Special Area
MDP	Municipal Development Plan
UDP	Urban Development Plan
URP	Urban Regulatory Plan
ZMK	Zoning Map of Kosovo
SPSZ	Spatial Plan for Special Zones
MDP	Municipal Development Plan
MZM	Municipal Zoning Map
DRP	Detailed Regulatory Plan
ABM	Agent-Based Modelling
CA	Cellular Automata
GIS	Global Information System(s)
ESDP	European Spatial Development Perspective



CHAPTER 1
INTRODUCTION

The first chapter contains general background information about the topic, problem statement as well as the methodology that is to be used. Additionally, this chapter covers the reasoning for picking Kosovo as the main general case study, whereupon further case studies o road samples have been picked. Furthermore, this chapter covers the contributions as well as the limits of the dissertation as well as it lays out the structure of the dissertation.

1. INTRODUCTION

By its very nature, road infrastructure and transportation are linked to economic development. It is the duty of road infrastructure to provide mobility, which goes on to provide economic activity, which goes further to provide development of land and influencing changes in land-use. Planning and careful outlining of road infrastructure can serve as a useful and powerful tool to enhance regional growth, as well as a tool to deliberately redirect growth to reduce regional inequality in terms of developed land.

The impact of road infrastructure in land development and growth has also been an important part in political discourse during the last few decades. This discussion has happened for different spatial levels, such as urban – in terms of congestion, but especially the regional level – in terms of using road infrastructure as an instrument to stimulate as well as control and redirect growth and development.

Recently, it has also attracted much attention in many countries where national governments understand the fundamental role that road infrastructure plays in the competitiveness of national economies. This role is also evident within nations themselves where road infrastructure has always been regarded as a significant trait of growth and development for cities and regions, due to the effect it has on reducing transport and commute cost as well as increasing accessibility.

Additionally, road infrastructure has commonly been seen as a responsibility of the public sector, especially in lesser-developed countries where it plays a major role in often being one of the main priorities of the national government. This has made process of planning and investment on road infrastructure shift from being based on data and science, towards something that is dependent on the political climate that is current at the time. This means that road infrastructure is constructed in regions that are more prone to provide political support, rather than in regions where the impact of having road infrastructure could be positive. Such is the case with the discussion of the ‘Dukagjini’ motorway in Kosovo, becoming one of the main pillars of that time’s government’s coalition agreement.

The aim of this research is to analyze and understand the role and influence road infrastructure has on spatial development, with the attempt of identifying patterns of Land-Use change and development intensity. Ultimately, the purpose of this research is to develop a model that serves the function of predicting the likelihood of land development, in certain parts of an analyzed road. In exploring these questions through making use of the model, there will be a clearer understanding on how different types of road infrastructure shape the development. In addition, it will help to lessen the effect of political decision on the planning and construction of roads. Furthermore, the model can assist in understanding what types of limitations should be put in place to better manage the development.

1.1. Background

The relation between public infrastructure and economic growth is quite evident and has been long observed by researchers and planners. Planners have continually emphasized the far-reaching effects that accessibility has on the development of land. The more accessible an area is to the various activities in a community, the greater its growth potential.[1]

Certainly, the effect of road infrastructure in shaping land-use and affecting the economy has been known to be present for a long time. Many efforts have been made to measure and quantify this effect, especially in exploring the effects of road infrastructure on urban growth and expansion. Research for measuring the effects of road infrastructure on land-use differs a lot depending on the context of the analysis, i.e. development in USA reacts differently to that in Europe, and Asia.

Much of the research that covers this topic, has been focused on measuring of the phenomenon of suburbanization, this being one of the more apparent ways of exhibiting the effect of road infrastructure on development. According to Baum-Snow, in the US motorways passing through central cities are responsible for reducing its population by 18 percent,[2] indicating that road infrastructure has been one of the main causes of the phenomenon of suburbanization. Garcia-López came to similar results in showing the effect of motorway and road infrastructure in Spain. The results from this research show that road infrastructure originating from central cities caused a decline in central city population of up to 9%.[3] This proves that in Europe as well as in the US, road infrastructure plays a crucial role in expanding cities outward, especially in a linear manner.

In light of the literature review on impact of road infrastructure, it could be determined that research that has pursued to measure spatial effects of road infrastructure on land-use, rely on simple spatial weight matrixes, with a more focused look towards the effect on the economy of the region. However, whereas much of the research has been focused on identifying the impact of road infrastructure, with cities in the center of the analysis, as indicated in the introduction section, the originality of this research lays in analyzing the patterns in land development between cities/settlements.

[1] Hansen, W. G. (1959). How accessibility shapes land use. Journal of the American Institute of planners, 25(2), 73-76.

[2] Baum-Snow, N. (2007). Did motorways cause suburbanization?. The quarterly journal of economics, 122(2), 775-805.

[3] Garcia-López, M. À., Holl, A., & Viladecans-Marsal, E. (2015). Suburbanization and motorways in Spain when the Romans and the Bourbons still shape its cities. Journal of Urban Economics, 85, 52-67.

The relevancy of this research work in terms of how it will serve, lies in providing a scientific, data-driven basis upon which political, economic, and environmental decisions can be based in regard to planning and investing in road infrastructure. The results from the model can be used and enhanced upon by planners, when designing and deciding on new road infrastructure development. The final product of the research will be a tool for simulating the effects of infrastructure on land-use change. Additionally, the conclusion and recommendations of this dissertation will give a set of rules on how to plan road infrastructure, especially as an integrated part of the planning process.

1.2. Why Kosovo?

Detailed explanations of the primary reasons why Kosovo was chosen as a study case are provided in the following section of the chapter, which includes political, geographical, and economic considerations. This part also elaborates four various facets of this argument while maintaining the underlying subject of road infrastructure-driven development.

The Background of the Level of Development – What did we inherit?

During the 20th century, the urbanization project of Kosovo remained unfinished and undeveloped. Furthermore, since the Second World War, there has been no proper development of road infrastructure in Kosovo, with the exception of the motorways connecting the former republics of Yugoslavia. This form of general development has failed to adequately address the need to connect settlements to the road network in a genuine way, and as a result, rural settlements - with the exception of those located close to the perimeter of cities - have remained isolated from the rest of the world. As a result, the reason why Kosovo was chosen is precisely the fact that the road network in Kosovo was unfinished - until about the beginning of the 21st century.

The Pace of Development in the Eve of 21st Century – The Approach

Based on the previous statement, this study attempts to determine whether the new road network: a) was constructed in accordance with the "traditional" concept of the last century (as a means of completing modern development), or b) is being constructed in accordance with the new concepts of the twenty-first century, which take into consideration new principles.

What is known is that in Kosovo, we have a window that dates back to 2000 and was constructed without the involvement of the government. This window serves as a good example for me because it is not a pure form of development and does not require external intervention. Consequently, the reason why Kosovo was chosen as an example in this study is to determine whether the government's approach to investing in road infrastructure is genuine and is done in accordance with the principles of "development driven" - that is, whether they responded to requests from all developers who requested the greatest amount of access possible.

To demonstrate the critical importance of road infrastructure for Kosovo's development, consider the 2019 budget for the country's ministries. According to the Ministry of Finance's budget report, the Ministry of Infrastructure has the largest budget, accounting for 17 percent of the state budget. The majority of this amount is dedicated to the construction of highways (75 million), road rehabilitation (112 million), and other road construction (27 million), not including maintenance costs.[4]

New State, New Opportunities – to place correct format of development

As discussed in Point 2, the question of whether Kosovo has failed or not is relevant in terms of the approach that has been taken so far. Kosovo is a new state whose entire economic and political development is predicated on the construction of new infrastructure on existing roads, as previously stated by alt. In contrast, Kosovo aspires to become a part of the larger regional road network, in which case it will benefit not only from the possibility of efficient transportation, but also from the increased opportunity for economic exchange that comes with it.

In this regard, when the Pan-European Corridor VIII was designed, Kosovo was not included.[5] This is another reason why the more balanced the access to road distribution and in support of settlements of specific categories are, the better off everyone is. – not only for Kosovo, but the region as well. The greater the number of roads in a region, the greater the opportunities for networking and self-development within that region and beyond. Thus, the Pan-European Corridor VIII, based on this kind of elevated understanding - needs to be corrected. In this context, Kosovo needs to do most of its work, which means being able to predict how its road system will develop and what opportunities and capacities it offers to the future Corridor VIII.

The introduction of a new technological tool to achieve a predicted, balanced and sustainable future development

Kosovo possesses the political will and, more recently, the best capacity for putting laws and principles into effect. Assuming that the theoretical model infused in this dissertation is effective in addressing all of the problems raised in the first three points, then the final reason why Kosovo was chosen for this dissertation is to promote the model that connects good practices, local capacity, and the affinity of a calibrated model in order to achieve results more quickly than would be possible by using only

[4] Ministry of Finance. Law No. 06/L -133 on Budget Allocations for the Budget of the Republic of Kosovo for 2019. Source: https://mf.rks-gov.net/desk/inc/media/4CEFBA4C-4397-4901-AB93-2AA37F43A9F7.pdf (retrieved: June 2022)
[5] South-East Europe Transport Observatory (SEETO). (2018) "THE CORE TRANSPORT NETWORK"

policies and practices based on good examples in the conventional way. Consequently, a model is added, which also provides the capability of forecasting and calibration of required attributes, allowing for the development of more rapid and sustainable spatial development solutions through road infrastructure.

1.3. Problem Statement

This study demonstrates that Kosovo, given its developmental topicality, has potential and opportunities, as well as, most likely, the appropriate political context in which to implement a model that is being introduced to this topic for the first time.

This study proposes a model that can be used to convert the observed phenomena of the empirical study into a quantified system, allowing for more accurate measurement of the observed phenomena in the future. Modeling the observed qualities into attributes allows them to be adjusted and calibrated to generate the desired results. This is accomplished by assigning them a value and a specific weight to each attribute.

These qualities, which are transformed into model attributes, are derived from observations made during the empirical study, as well as from theoretical considerations and assumptions. Based on what has been said thus far, the three phases of the approach to road development in Kosovo beginning in 2000 can be divided as follows:

Table 1 Road Infrastructure Development Phases in Kosovo

Phase	**Phase Name**	**Description**
Phase 1	Undriven Development	Transitional Phase – the first decade before independence. Most of the development happening in this phase was market driven, and without any particular control from any instance
Phase 2	Politically-Driven Development	After the independence of 2008, there was a political push for investment in transportation. As can be seen by the budget reports mentioned earlier, road infrastructure became one of the pillars of the political sphere.

Phase 3	Data-Driven Development	The aim is to transform into a data-driven way of developing road infrastructure. Such is the aim of this dissertation, by providing an example of how scientific methods can be used to deter investments in road infrastructure.

For one, if planning and implementation of road infrastructure continues to be reliant on political decisions instead of being based on data and science, it will produce long term consequences that will harm the region. By this logic, the regions with a weaker political force will be disfavored when it comes to constructing road infrastructure, and thus will end up having a reduced accessibility with other regions.

To tackle this issue, Kosovo is used as a study case as it is a country where investment and development, especially in road infrastructure has happened in a very concentrated period of time,[6] with little-to-no control, management or supervision of how this development is being shaped. This gives us a more uncontaminated window to observe how land-use changes and development are shaped in a 'natural' manner, without much state/governmental interference.

On the other hand, if road infrastructure has no significant accessibility, it most likely will not have any impact on land-use, because accessibility is the mechanism by which land use changes are affected. Even if commuting is observed and measured, it may not reflect enough of a change in accessibility to promote changes in land-use. Accessibility is important since it has been proven that foreign investors evaluate potential sites based on hard factors (e.g. transport connection, space availability, employment market, energy supply, local and national taxes).[7] (This offers new development perspectives, in particular for regions which are well-connected within the country itself but also cross-nationally as investors often decide against capital city locations. This means that the better connected a country is, the bigger the chance for finding investors that can contribute to development.

By having a model that can to some accuracy predict patterns of land-use, we will have a better understanding of how changes in land-use occur when there are no

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[6] Ministry of Finance. Law No. 06/L -133 on Budget Allocations for the Budget of the Republic of Kosovo for 2019. Source: https://mf.rks-gov.net/desk/inc/media/4CEFBA4C-4397-4901-AB93-2AA37F43A9F7.pdf (retrieved: June 2022)

[7] Haselsberger, B. (2014). Decoding borders. Appreciating border impacts on space and people. Planning Theory & Practice, 15(4), 505-526.

policies in place. It becomes easier to help create more coherent policies, measures, and plans once we have a clearer understanding of how these patterns are created, to the extent that the model can predict them. As a result, the model serves as a mediator, assisting us not only in better understanding how land develops when we invest in infrastructure in Kosovo in the manners that have occurred thus far, but also in more effectively linking - integrating policies, plans, and institutions.

Based on what has been said thus far, the study proposes the following research questions for further investigation:

- **Research Question 1:** What is the impact of road infrastructure on land development and settlement growth, and is it a balanced impact?

- **Research Question 2:** How to understand the spatial patterns that result from development guided by road infrastructure?

- **Research Question 3:** Can an urban model be devised which can quantify spatial patterns, in order to measure current and future development?

- **Research Question 4:** Is it possible to use this model to promote intervention packages that spread across a broad range of issues and that can be used as a tool to better align and foster coherence among spatial planning, legal, planning, and institutional frameworks?

The manner in which the research questions are addressed, is as follows:

Research question 1 is addressed in Chapters 2 and 3. The second research question is addressed in Chapter 3 and 4. Chapters 5, 6, and 7 are devoted to answering research question 3. While research question 4 is addressed in chapter 8.

1.4. Methodology

The research begins with the process of observing and analyzing changes in land use, which are accomplished through the visualization of data acquired from the Corine Land Cover Survey (CLC). It is presented in five different time periods, namely 2000, 2006, 2012, 2018, and 2022, in order to identify changes in land use along the analyzed road. For the sake of simplicity and ease of analysis, the Land-Use has only been divided into two categories: built and unbuilt, regardless of the specific function performed on the land.

Using the acquired data, a quantified analysis is conducted, and a model is built in order to forecast patterns of development and changes in land use as a result of a given type of road infrastructure being implemented. The influence of infrastructure is also assessed by evaluating the evolution of places where no infrastructure has been built in the absence of infrastructure construction. In accordance with the national hierarchy of roads, different tiers of roads have been chosen for use as case studies.

Several types and categories of roads are discussed and analyzed to best understand how their hierarchy, connectivity, accessibility, length as well as the configuration/contents at both ends of the road, influence the different intensities and shapes of development. The main dataset for this research consists solely of changes and developments in land-use along road infrastructure. Roads are subdivided into shorter parts in order to make the analytic process more straightforward, with settlements functioning as breakpoints.

As part of the process of determining the influence of road infrastructure on land use, the acquired data is transferred onto maps, which are then converted into diagrams that serve as a quantification tool, which in turn supplies the input values for the model. It is through this procedure that data may be structured and made more understandable, which is particularly useful for building up the 'rules' (protocol) of the model.

The Model it is designed to require inputs (Model Attributes) and produce outputs (Model Cells). Model Attributes are selected and derived from observations in study cases to form the basis of the models. Those attributes are the primary 'input' into the model, and they are what ultimately determines what the outcomes will be (Model Cells). Some attributes have already been identified and proposed; however, there are many more that will be studied, added, and possibly even eliminated from the list. Model Cells serve as an ‘output’ and all measuring and quantification is presented through these Cells. The road samples are then subdivided into equal portions, which are referred to as Cells, in order to have a better understanding of and more accuracy in predicting where land development is likely to occur. Each road sample has a number of cells that is reflective of the length of the road in kilometers, as measured by the sampler.

The outcomes of the model's analysis are checked and tested against the data from the case study investigation. If the findings of the model do not match the results of the case studies analysis, the input can be evaluated and calibrated in order to get a more accurate match between the two. When results from the model match those from the case study data, on the other hand, we can move on with applying the model to future analysis (predictions). We deal more with present state analysis in order to improve our model in part one of this research, but in part two of this research, we may use our now-established model to make predictions about how development will form in the next several years.

An outline or map of a proposed road project can be created once the model has been run and development estimates for future road projects have been made. If the results is not sufficient, calibrations (adjustments) might be made in order to achieve a result that is more appropriate for the situation. Adding or removing Model Attributes, as well as developing policies that influence the development in the appropriate manner, can be used to make these alterations. Those in charge of planning will be the ones who will come up with the adjustments and calibrations.

The final phase in this dissertation is to use the model and the findings of the model to design a set of policies and measures that can be offered in order to improve the outcome in terms of development in the future. These policies will cover a wide variety of topics, from legal to planning to institutional framework, and will be comparatively tested against the practices of interventions and real development that has taken place.

1.5. Contribution and Limitations of the Dissertation

The contribution of this dissertation rests in the fact that, when it comes to planning and approving new developments, there is still a lack of effort put forward to make effective data-driven decisions. The model suggested in this dissertation aspires to close this gap by giving quantitative outcomes that may be used to guide future decision-making.

Anticipated contribution in terms of urban modelling

Against this backdrop, this research may be able to add to the international discourse by exposing a methodology for contextual urban modeling. As a result of this dissertation' empirical and contextual dimensions, we may gain a better knowledge not only of Kosovo's attitude toward the components of modeling, but also the applicability of these methods in a broader context.

Despite the fact that the proposed model is constrained by a context that is typical and characteristic of Kosovo's setting, many of its features and elements can be transferable to other parts of the region, and perhaps to other parts of the world with similar context and level of development. Further investigation into this component of the dissertation, which concerns the adaptability and applicability of the model outside of the limits of Kosovo's setting, is something that can be pursued in future research.

Anticipated contribution in terms of data gathering and producing

Kosovo is frequently depicted as a blank island on many regional and international maps that display data of various kinds, with the rationale being that there is insufficient or no data available for the country.

The goal of this dissertation is to additionally develop some spatial and urban data that is currently lacking in terms of information that can be made available to the public. It is possible to generate more data on probable future developments through the usage of the model, which may then be used as input for further research in disciplines that are related to this subject.

Additionally, the contribution of this dissertation is in establishing a discussion point on the significance of data collection, production, and analysis, which has not previously been subject to spatial planning and development policies and laws. The subject of spatial and urban analytics is currently underdeveloped in Kosovo, and this study can serve as an example, or a starting point, in the process of the development of this discipline along with the methodological frameworks of urban analytics in Kosovo.

Anticipated contribution in terms of Spatial Planning practices in Kosovo

This dissertation tries to make a contribution towards filling a void of the usage of data and scientific results in the decision making practices in the field of spatial planning in Kosovo. In this context, this research, once it has been published for the internal public, may contribute to the initiation of an internal discourse on spatial planning and road infrastructure that is consistent with the international discourse on spatial planning and road infrastructure, which is currently non-existent. A more direct contribution of this research is that it serves as an intermediary between planning practices and road infrastructure, or, in other words, it provides a scenario for the implementation of a more integrated approach to planning with road infrastructure in mind, which the Kosovo planning community is already aware of and should take into consideration in the future.

Limitations

Because the suggested model is restricted to the setting of Kosovo, and because it is most accurate in predicting outcomes for this particular context, the dissertation's primary constraints are as follows: It will almost certainly require further tuning as well as additional research in order to be relevant in different geographical areas. Also, accuracy of the model's output is based on the accuracy and quality of the inputs that are provided by the user (planners). As a result, the quality of the data can vary, resulting in less-than-desirable outcomes in terms of the accuracy of the mode.

Secondly, Kosovo must sooner or later acquire the technological tools and products, as well as the established systems of data collection, processing, and usage, in order to be able to assist in decision-making in the system of spatial planning. This indicates that the Kosovo government would have to calibrate necessary policy and legislation papers in order to integrate spatial and urban analytics features as an important instrument applicable to all parts of management and development in spatial planning. In a sense, the validity of the ideas resulting from this research is limited to the point at which the government recognizes that this is the best course of action, which means that political will is required to include these aspects and tools in future spatial planning practices.

Lastly, it is possible that if this research is successful in understanding and implementing a new attitude toward land development through the implementation of road infrastructure policies - in the future, in the case of Kosovo, it will be used to determine whether the model could be compatible with railway infrastructure, which would be a more sustainable and overall better alternative to road infrastructure Because of Kosovo's reliance on road infrastructure and the absence of a functional rail network, which is essentially non-existent, this is a secondary, but not less significant, purpose of this research. If road infrastructure is not included as a vital component of data-driven and scientific planning, the consequences could be long-term and indirect ramifications for land development, exacerbating already existing inequities across different regions.

1.6. Structure of Dissertation

The dissertation is divided into nine chapters, and the organization of the chapters reflects the steps of the analysis in the following logic / format:

The first chapter serves as the introduction, whereas the Chapter 2 will give an overall explanation of the legal, planning as well as the institutional framework in Kosovo, and their impact on road infrastructure. The aspects of background and development theory that arise as a result of road infrastructure, as well as the aspect of urban modeling, are discussed in detail in Chapters 3-4 of this dissertation. The main focus of this dissertation is on Chapters 5-7, which deal with the proposal and methodology for implementing the urban model proposed in this dissertation. Chapters 5-7 deal with the methodology for implementing the urban model proposed in this dissertation. However, the main product is located in chapters 8 and 9 where provisions are given for the application of the model in decision-making processes in the context of spatial planning, management and implementation of spatial plans. Whereas, chapter 10 serves as a conclusion and includes the opening of a discussion about the results obtained in the previous chapters. The detailed contents of each chapter are as follows:

Chapter 1 contains general background information about the topic, problem statement as well as the methodology that is to be used. Additionally, this chapter covers the reasoning for picking Kosovo as the main general case study, whereupon further case studies o road samples have been picked. Furthermore, this chapter covers the contributions as well as the limits of the dissertation as well as it lays out the structure of the dissertation.

Chapter 2 covers a context analysis of Spatial Planning in Kosovo, including the Legal, Planning as well as the Institutional Framework. In this chapter the argument that Road Infrastructure has been the main driver for development is explored by analyzing the impact each legal document has on road infrastructure.

The majority of **Chapter 3** is dedicated to developing a reasoning for how land use behaves when it is influenced by road infrastructure. This chapter will primarily investigate and examine existent cases and occurrences based on theoretical considerations and a review of the literature. Furthermore, a brief history of urban modelling is presented, beginning with the simple models of the 1950's and 60's, until what is currently being developed.

Chapter 4 demonstrates how information gathered from site visits, as well as cartographic data, is transformed into diagrams and, ultimately, into numeric values that may be used by the suggested model to make decisions. It is shown visually in the form of maps and diagrams how data obtained and processed through empirical study is presented in this chapter.

Chapter 5 provides an in-depth discussion of the reasons for the creation and use of the model, as well as a full explanation of the model's structure, characteristics, and intended use. The values and weights of model attributes as well as the techniques of calculation will be thoroughly studied in addition to the model attributes themselves.

Chapter 6 discusses how the model's outputs are calculated and how attributes are quantified to produce exact results. As a result, this chapter discusses the creation of the first generation of model predictions, as well as the development of future generations, which include forecasts for future development.

In **Chapter 7** includes all the results that derive from chapter 5 and 6, and improves upon them by proposing a calibration loop. Furthermore, in this chapter future perspectives are analyzed in regards to thinking about how to use the model results as spatial planners, to improve the future outcomes. This includes changing policies, legal frameworks, or any other tool in the arsenal of a spatial planner.

Chapter 8 covers three different case studies that are tested with the model, in order to see the potential future of development in those cases. As a result of the outcomes these case studies, intervention actions are also proposed.

Chapter 9 contains the recommendations and conclusions of the dissertation.

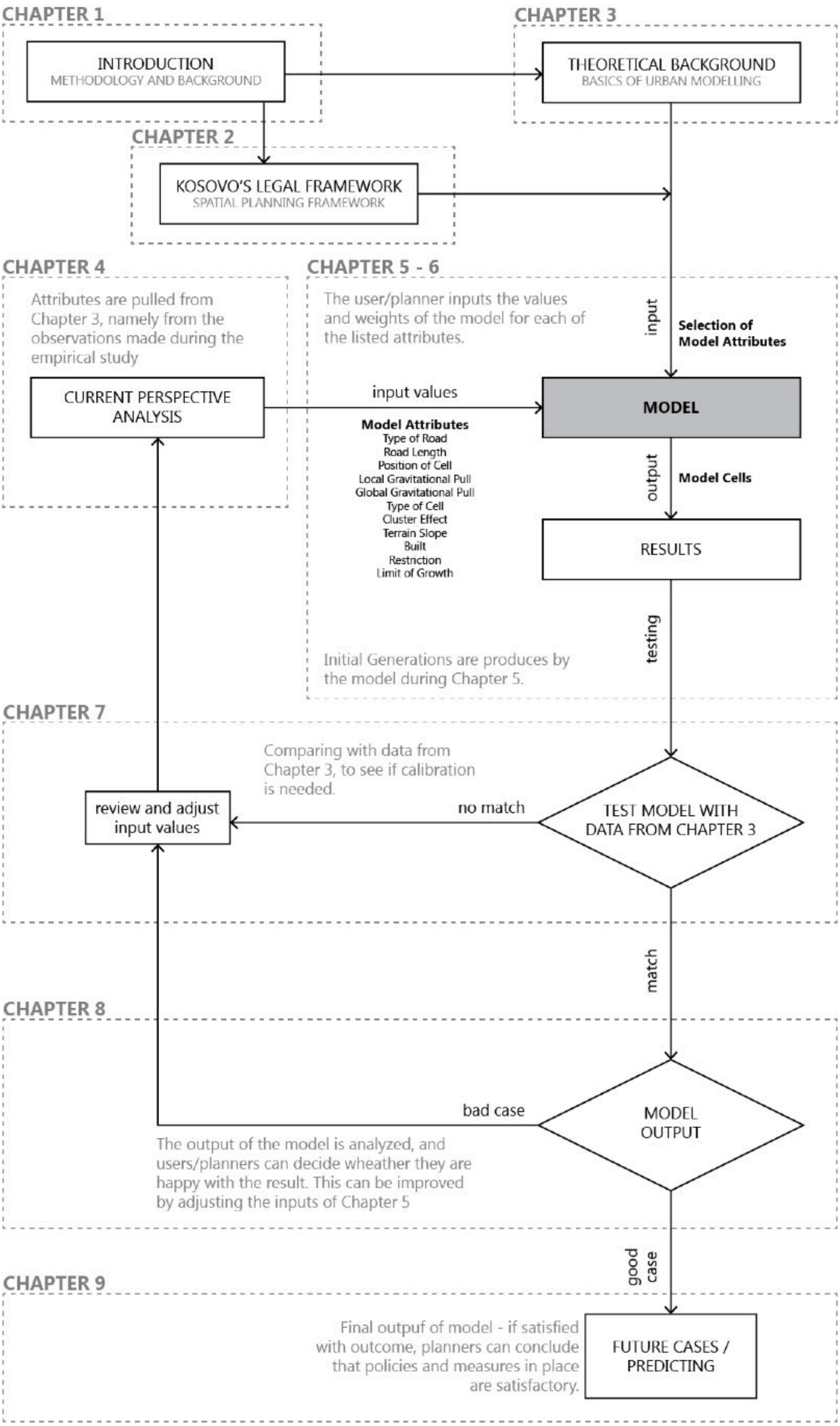

Figure 1 Structure of Dissertation

CHAPTER 2

CONTEXT ANALYSIS: KOSOVO'S LEGAL, PLANNING AND INSTITUTIONAL FRAMEWORK

The Legal, Planning and Institutional framework of Kosovo is presented here, that will serve as the backdrop in establishing the arguments needed for chapters 8 and 9. Furthermore, this chapter also analyzes the manner in which each of these frameworks affects road infrastructure development.

2. CONTEXT ANALYSIS: KOSOVO'S LEGAL, PLANNING AND INSTITUTIONAL FRAMEWORK

The following chapter will provide an overview of the Spatial Planning Laws, Plans, Institutions, and Practices in Kosovo, as well as their historical development. This is done in order to have a better knowledge of how each of these frameworks affects the development of road infrastructure.

In order to establish a foundation for further discussion, this chapter will argue for and analyze the assumption that road infrastructure has been the most important aspect in the development of Kosovo. A large portion of the new development that has occurred since 1999 has taken place along existing and newly constructed road infrastructure, with little or no interference from any level of government or other institution in the process. Following the expansion of road infrastructure, it is vital to comprehend the intricacies of regulatory framework that will influence future land development as a result of the expansion and development road infrastructure.

Just as it has been the case in many Eastern European countries, Kosovo has had a diverse range of legal frameworks, plans with varying levels of hierarchy, and institutions that have molded the country in a variety of ways. In order to obtain a better understanding of the context in which the Planning, and Institutional Frameworks are set to operate, this chapter delves into the topic of the spatial planning legislation, as well as planning and institutional framework in depth.

2.1. Legal Framework

In order to keep up with the rapid developments that have affected the subject of spatial planning, the legal framework for spatial planning in Kosovo has undergone two rounds of reform during the last two decades of the multiple transitions, which have characterized Kosovo after the war of 1999 and the deployment of international community in Kosovo. During the first of the two reforms, which took place under the supervision of the United Nations Mission in Kosovo (UNMIK), the first Law on Spatial Planning was drafted, whereas the second reform took place after Kosovo gained independence with the introduction of the updated (revised) Law on Spatial Planning by the Ministry of Environment and Spatial Planning (MESP).

As stated, the first reform began under UNMIK, whereupon the MESP was first established in 2002 as part of the process of building Kosovo's institutional structure, responsible for environmental and spatial planning issues in the country. In this phase, the Law on Spatial Planning No. 2003/14[8] was prepared in accordance with Regulation No. 2001/9 of May 15, 2001, on the Constitutional Framework for Provisional Measures, which was promulgated shortly after the establishment of the MESP. Prior to that, Kosovo's Legal framework in general and concerning Spatial Planning in specific, was part of the legal system of ex-Yugoslavia.

As part of the democratization and institutional development processes of Kosovo that took place during the second decade of transition, the Government of Kosovo decided to reform a number of laws, including the law on spatial planning. Through this process, in 2013 the new law on spatial planning, No. 04 / L-174 was adopted. Together with the new reform on the law, came a few significant changes that impacted the planning system.

The previous system that derived from Law no. 2003/14 instructed and obliged the central level with the drafting of Spatial Plan of Kosovo (SPK) and Spatial Plans for Special Areas (SPSA) while the local level with drafting of the Municipal Development Plan (MDP), Urban Development Plan (UDP) and Urban Regulatory Plans (URPs). The new law No. 04 / L-174 adopted in 2013, intended to simplify the planning process by introducing the Kosovo Zoning Map (KZM) and Municipal Zoning Map (MZM) (see table below).

Table 2 Spatial planning legislation framework: comparison of the system of planning as presented during reform 1 and 2

Reform 1: 2003—2013 Applicable Law on Spatial planning No. 2003 / 14		**Reform 2: 2013—onwards Applicable Law on Spatial planning No. 04 / L-174[9]**	
Central Level	Spatial Plan of Kosovo Spatial Plans for Special Areas	*Central Level*	Spatial Plan of Kosovo Zoning Map of Kosovo Spatial Plans for Special Zones
Local Level	Municipal Development Plan Urban Development Plan Urban Regulatory Plans	*Local Level*	Municipal Development Plan Municipal Zoning Map Detailed Regulatory Plans

[8] Law on Spatial Planning No. 2003/14 https://gzk.rks-gov.net/ActDetail.aspx?ActID=8865 (retrieved: March 2022)
[9] Law on Spatial Planning No. 04 / L-174 https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8865 (retrieved: March 2022)

To better grasp specificities of each phase and comprehend the development structure of the legal instrument on spatial planning in Kosovo, the two above-mentioned phases are analyzed in more depth

2.1.1. Legal Framework under UNMIK, from 2003—2013

Developed under the supervision of United Nations, as United Nations Mission in Kosovo (UNMIK), and as specified in the body of the Law on Spatial Planning adopted in 2003, this law (No. 2003/14) was drafted with the goal of ensuring rational spatial planning and development, achieving a balance between development and preservation of open space and environmental protection, as well as with the aim of bringing the spatial planning regime of Kosovo, in conformity with European and international standards. In addition, the law defined and contained key concepts and approaches that were in accordance with EU and international standards, such as the recognition of the public as key stakeholders in the decision-making process; the role of local authorities; the development of public spaces; and the identification of protective zones, among other things. According to previous analysis of spatial planning laws applicable in Kosovo, the Law of 2003 contained all relevant concepts and was tailored to the new political and economic context of Kosovo, recognizing the MESP as the primary authority for the implementation of the law, which was not the case with legal provisions applicable for Kosovo during the ex-Yugoslav regime.

In terms of institutional responsibilities (Article 5)[10], MESP is in charge of central planning and is responsible for drafting such documents as the Kosovo Spatial Plan (KSP) and Spatial Plans for Special Areas (SPSA). Municipalities (Article 13[11]) are responsible for local planning and are required to create documents such as the Municipal Development Plan (MDP), Urban Development Plan (UDP), and Urban Regulatory Plans (URP) for their territories. The following table summarizes the content of these plans.

There were no clear definitions of the functions and responsibilities of the planning institutional bodies at either, the local or the central levels, as will be explained in the forthcoming subchapter on the topic of institutional framework. Additionally, the 2003 Law did not provide clear instructions on how to go about amending and changing plans, which was a source and cause of many problems in the process of amending plans.

During the preparation of the first generation of plans, which spanned the time period from 2003 to 2013, it became apparent that there were difficulties in putting the system

[10] Law on Spatial Planning No. 2003/14 https://gzk.rks-gov.net/ActDetail.aspx?ActID=8865 (retrieved: March 2022)
[11] Ibid

into operation. Some of the issues that were identified with this legal framework included finding means of financing and funding the drafting of plans. Among deficiencies in this respect was also the implementation of the legal provision which allows for joint planning (Article 13.5)[12]; despite the fact that the law provided for two or more municipalities to prepare a joint MDP, which would have reduced municipalities' planning expenditures while also providing the opportunity to use human capacity (particularly in municipalities where there is a shortage of experts in the field of urban planning), this opportunity was not taken advantage of by any municipalities. Financial restrictions, which in many cases can be traced back to the inability to incorporate planned projects in plans with a medium-term financial framework, have also remained a source of concern for plan execution. These are among the most common issues that have arisen in recent years. This issue will also be further elaborated under the subchapter of the institutional framework. The 2003 Law on Spatial Planning also touches upon the issues of infrastructure, but in a more general manner. Road infrastructure is mentioned in passing, with obligations delegated to other laws and legal instruments. Below is a summary of points when infrastructure and transportation are discussed in the 2003 Law on Spatial Planning. The words infrastructure and transportation, are mentioned four times each in the 2003 Law on Spatial Planning.

Table 3 Mentioning and Instruction for Infrastructure and Transport on Law on Spatial Planning No. 2003/14[13]

Instruction	**Mentioning**
Road infrastructure Shall be dealt through the "Infrastructure Plan"	**Article: 2:** *"Infrastructure plan means a plan presentation of the installations and existing buildings and planned underground and above-ground installations in the field of: transport, electrical installations, gas pipelines, oil pipelines, water supply and sewage systems, telecommunications and other installations;"*[14]
Road infrastructure shall be taken into consideration during urban development	**Article 17:** "*17.3 The construction of buildings may be planned outside of construction zones for the needs of: Transport and other infrastructure;"*[15]

[12] Law on Spatial Planning No. 2003/14 https://gzk.rks-gov.net/ActDetail.aspx?ActID=8865 (retrieved: March 2022)
[13] Ibid
[14] Ibid. Article 2
[15] Ibid. Article 17

Small changes to infrastructure are not considered changes to the detailer urban plan	**Article 22:** *"22.2 Within the meaning of the present law, the change of individual construction plot boundaries, the change of the dimensions of individual apartment buildings and their position, slight shifts of the right-of-way in a traffic street and wires of infrastructure, as well as other similar harmonization of the plan by means of which we manage to rationally apply it, shall not be considered changes and supplements to the detailed urban plan. These changes are applied in the determination procedure on the conditions for spatial regulation."*
Location conditions consider infrastructure connections	**Article 23:** *"23.2 Location conditions shall address:* *(d) the methods of connecting buildings with the necessary infrastructure;"*[16]
Spatial Plan of Kosovo is a multi-sectorial plan that addresses among other things can treat infrastructure as a separate sector	**Article 11:** *"11.1 The Ministry shall be responsible for preparing a draft Spatial Plan of Kosovo. The Ministry may delegate tasks related to preparation of the Plan to the Institute, municipalities, and other government agencies and experts:* *(e) Take into account development strategies of different sectors, including finance, higher education and studies, telecommunications, transport systems, mining, energy production, natural resources, most qualitative land, sports, and recreation;"*[17]

[16] Law on Spatial Planning No. 2003/14. Article 23. https://gzk.rks-gov.net/ActDetail.aspx?ActID=8865 (retrieved: March 2022)
[17] Ibid. Article 11

2.1.2. Legal Framework under MESP, from 2013—ongoing

As previously noted, the Law on Spatial Planning was amended in 2012 in response to requests for simplified procedures for obtaining construction permits in order to stimulate development through domestic and international investments. The Law on Construction served as a forerunner to the Law on Spatial Planning, which proved to be influential, albeit not always in a positive way, and at times even proved to be an impediment in the development of actual planning.[18]

This reform also affected the planning system. As opposed to the previous planning system of 2003, which determined at the central level the drafting of the Spatial Plan of Kosovo (SPK) and Spatial Plans for Special Areas (PHZV), and at the local level, the Municipal Development Plan (MDP), Plan Urban Development Plan (UDP) and Urban Regulatory Plans (URPs), the new law introduces the Zonal Map of Kosovo and the Municipal Zoning Map (MZM) - a new planning instrument or tool, which was thought to reduce the time of the planning process. In the redefined planning system there is no UDP, which treated the urban area in particular, while Regulatory Plans are not mandatory

The new planning system eliminates the planning instrument that dealt specifically with the urban region, namely the Urban Regulatory Plan, and Regulatory Plans are deemed no longer a requirement.

The construction conditions are subject to treatment with the Zoning Map of Kosovo (ZMK), the Municipal Zoning Map (MZM), the Spatial Plan for Special Zones (SPSZ), and eventually the Detailed Regulatory Plan (DRP), should Municipal Development Plans (MDP) and Municipal Zoning Maps (MZM) determine that their drafting is required.

One of the main purposes for amending the Law on Spatial Planning was the clarification of the role and responsibilities of the various planning entities, and putting a spatial emphasis on agricultural land preservation, consultation procedures and public hearings of all processes related spatial and urban plans and maps.

The new law mandates that the Assembly of Kosovo (for central level plans) and Municipal Assemblies (for local level plans) review the Annual Reports for monitoring and implementation of the goals and objectives stated in the planning documents, but it makes no determination as to who is responsible for monitoring and preparing these reports, or how to monitor and evaluate the implementation of one type of plan when

[18] Law on Spatial Planning No. 04 / L-174 https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8865 (retrieved: March 2022)

it is known that the other type of plan is being implemented, or how to monitor and evaluate the implementation of one type of plan when it is known that the other.

As opposed to the 2003 Law on Spatial Planning, the 2013 Law refers to transport on 4 different occasions, while it refers to Infrastructure on 24 different occasions, especially when tasking different plans with the responsibility of treating and managing of infrastructure (both physical and social).

Besides the two versions of the Law on Spatial Planning, there is a variety of other laws and legal documents that also affect infrastructure in some way. The table below is includes all significant laws that have an impact on road infrastructure in one way or another. The table consists of laws that are valid at the time of writing of this dissertation.

Table 4 Spatial Planning Legal Framework of Kosovo

List of relevant Laws	**Purpose & Scope in relation to Road Infrastructure**
Law No.04/L-174 on Spatial Planning	*"This Law determines the basic principles of spatial planning, methodology and regulations, types, procedures, contents as well as the responsibilities of the administrative entities at central and local level towards drafting and implementation of spatial planning documents, administrative supervision for enforcement of this Law, and related activities undertaken in spatial planning and territorial regulation in the Republic of Kosovo."*[19] The law on spatial planning is the main law regulating the responsibilities of relevant authorities in the decision making process related to planning and fund allocation for road infrastructure development. Through this law, strategic documents shall be drafted determining the future infrastructure development and road networks that will contribute to achieving strategic goals and objectives set by said documents.
Law no.04/L-179 on Road Transport	*"The purpose of this law is to regulate and develop the sector of road transport of passengers and goods, an open and non-discriminatory access to market, provision of services in the market of the road transport of passengers and goods sector as well as to establish driving and resting regime.'*[20]

[19] Law on Spatial Planning No. 04 / L-174. Article 2. https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8865 (retrieved: March 2022)
[20] Law no.04/L-179 on Road Transport. Article 1. https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8688 (retrieved: July 2022)

	In terms of Road Infrastructure the law on road transport complements the law on spatial planning, especially with two key aspects which are usage maintenance of roads. The law on road transport helps increase national mobility through ensuring safe and secure transportation. This law dictates responsibilities of institutions for drafting and designating rules pertaining to the operation of motor vehicle services.
Law No.03/L-025 on Environmental Protection	*"The purpose of this law is to promote the establishment of healthy environment for population of Kosovo by bringing gradually the standards for environment of European Union. It shall harmonize economic development and social welfare with basic principles for environmental protection according to the concept of sustainable development."*[21] It supports rational use of natural recourses and limitation of pollution discharge on environment, prevention of damage, rehabilitation and improvement of defective environment; improvement of environmental conditions in correlation with life quality and protection of human health; saving and maintenance of natural recourses, those renewable and un renewable as well as its sustainable management; coordination of national activities for fulfilling of request concerning to environmental protection; regional and international coordination in the field of environment; stimulation and public participation on activities related to environmental protection; ensure that Kosovo development is sustainable in order to protect the soil, air, water, living sources in favor of the coming generations. The law defines institutional responsibilities and respective mechanisms for administering environmental protection, defines policy and other regulatory instruments for planning and managing environmental protection, protection measures from hazardous matters, monitoring and environment information system, funding mechanisms for environmental protection and punitive provisions, administrative and inspective supervision measures. In terms of Road Infrastructure, the law on environment protection may influence the decision for road construction overruling the plan/decision for investment in a particular area. In addition, this law and its administrative instruction documents, policies and other relevant documents identify potential risks, challenges and/or benefits of infrastructure works in specific areas. It may

[21] Law No.03/L-025 on Environmental Protection. Article 1.
https://gzk.rks-gov.net/ActDetail.aspx?ActID=2631 (retrieved: July 2022)

	also impose special conditions to road infrastructure development decisions in order to preserve the environment (flora and fauna) of a region.
Law No.04/L-010 on Inter-Municipal Cooperation	*"The aim of this Law is to regulate inter-municipal cooperation and cooperation of municipalities of Republic of Kosovo with other municipalities and institutions of local governing outside the Republic of Kosovo, in compliance with the Constitution of Republic of Kosovo, the applicable law as well as with the European Charter for Self-Governing of the European Council."*[22] The law sets key principles, procedures and forms for initiating and establishing inter-municipal cooperation at the national and international level. Through this law, municipalities have the opportunity to develop joint plans and initiate infrastructure projects that are co-funded and serve all parties in particular as well as have an importance in the road network development at the national level.
Law No.03/L-040 on Local Self Government	This law establishes the legal basis for a sustainable local self-government system in Kosovo. It defines the legal status of municipalities, their competencies and general principles of municipal finances, organization and functioning of the municipal bodies, the intra-municipal arrangements and the inter-municipal cooperation including the cross-border cooperation and the relationship between municipalities and central government."[23] The law lists environmental protection and related areas such as economic development, spatial planning and territorial management, public services, primary healthcare etc. among own municipal competencies. This law provides municipalities with decision making powers and responsibilities for self-governance. In terms of Road Infrastructure, municipalities are responsible for researching, strategizing and deciding on the investments towards infrastructure development within the municipality or with other municipalities. All decisions should be approved by the designated authorities within the municipality and should be in line with national plans and strategies.

[22] Law No.04/L-010 on Inter-Municipal Cooperation. Article 1-2. https://gzk.rks-gov.net/ActDetail.aspx?ActID=2749 (retrieved: July 2022)
[23] Law No.03/L-040 on Local Self Government. Article 1-2. https://gzk.rks-gov.net/ActDetail.aspx?ActID=2530 (retrieved: July 2022)

Law No.2003/11 on Roads; *Law No.03/L-120 for amending and supplementing The Law No. 2003/11 On Roads;*	*"This law regulates the legal status of public roads; construction and maintenance of public roads; measures for protection of roads and circulation; governance; financing and supervision of public roads."*[24] [25] In terms of Road Infrastructure, the Law on roads defines and explains the types of roads and what they consist of. In addition, this law determines the reconstruction works for the purpose of improvement of road elements and for enhancing the level of services in the roads. It regulates the conditions, processes and responsibilities of relevant authorities.
Administrative Instruction MESP-No.08/2017 on Spatial Planning Technical Norms	*""The spatial planning technical norms set a regulatory framework to ensure the implementation of the law on spatial planning, drafting and implementation of Spatial Planning documents in Kosovo."*[26] In terms of Road Infrastructure, this administrative instruction document includes a dedicated chapter to transport infrastructure, setting minimal norms for planning and designing the road, railway and air transport infrastructure including vehicular space, buffer zones and parking space. The Spatial Planning Technical Norms also propose the development of special acts dedicated to road and railway terminals, respectively dedicated spaces to passenger and freight transport, including spaces for loading and unloading goods, etc.
Administrative instructions I No.02/2014 for the Granting of Consent for Connection and Access to the National and Regional Roads	*"The purpose of this administrative instruction is to determine the conditions and procedures for granting consent for access, installations and land-use in national and regional roads."*[27] In terms of Road Infrastructure, this administrative instructions document determines the conditions that need to be fulfilled by the investor (being local or national level) in order to link a newly constructed road with the existing infrastructure. The conditions determined and the procedures that need to be followed, play an important role in offering safety and security as well as maintaining the appropriate standards of construction.

[24] Law No.2003/11 on Roads. Article 1. https://gzk.rks-gov.net/ActDetail.aspx?ActID=2467 (retrieved: July 2022)
[25] Law No.03/L-120 for amending and supplementing The Law No. 2003/11 On Roads. https://gzk.rks-gov.net/ActDetail.aspx?ActID=2467 (retrieved: July 2022)
[26] Administrative Instruction MESP-No.08/2017 on Spatial Planning Technical Norms. Article 1. https://gzk.rks-gov.net/ActDetail.aspx?ActID=14822 (retrieved: July 2022)
[27] Administrative instructions I No.02/2014 for the Granting of Consent for Connection and Access to the National and Regional Roads. Article 1. https://gzk.rks-gov.net/ActDetail.aspx?ActID=10276 (retrieved: July 2022)

	Additionally, this administrative instruction allows the decision making authority (the ministry) to refuse linking or using of any existing road that could in any way jeopardize the well-functioning of the road or damage the original purpose of a road across the territory.
Administrative Instructions No.09/2015 for Connection, Installations through the road land, and land use of National and Regional Roads	*"The purpose of this Administrative Instruction is to define the conditions and procedures for design and construction of: connections, installation and use of land in national and regional roads."*[28] In terms of Road Infrastructure, this administrative instructions document determines the conditions and procedures for design that need to be fulfilled by the investor in order to permit the construction of roads. The conditions determined and the procedures that need to be followed, play an important role in maintaining the appropriate standards of construction for all roads across the territory. Additionally, this administrative instruction allows the decision making authority (the ministry) to refuse the design and deny the construction, if all the conditions have not been met.

2.2. Planning Framework

The origins of spatial planning in Kosovo can be traced back to the first plans of the early 20th century maps and drawings. These maps, drawings, monographies and other archeological and anthropological studies, are the primary sources of information in mapping of Kosovo of the previous century.

Within the years 1912-1937, while still a part of the old Yugoslavia, Kosovo begins to implement regulatory plans for settlements throughout the region. While the urbanization process in Kosovo does not begin until after 1945, it is primarily characterized by the development of general urban design plans and strategies for major urban centers in the region.[29]

For the first time, the Socialist Autonomous Province of Kosovo received approval for its spatial plan in 1973. During this time period, under the supervision of the Kosovo Assembly, a large amount of action in the field of spatial planning has been carried

[28] Administrative Instructions No.09/2015 for Connection, Installations through the road land, and land use of National and Regional Roads. Article 1, https://gzk.rks-gov.net/ActDetail.aspx?ActID=15016 (retrieved: July 2022)
[29] Jerliu, F., & Navakazi, V. (2018). Socialist Modernization Of Prishtina: Interrogating Types Of Urban And Architectural Contributions To The City. Mesto a dejiny, 2(7), 55-74.

out. Funds for regional spatial plans were approved as part of the provincial budget, and certain resources were set aside for research and studies across all sectors and sub-sectors as part of the provincial budget.

The Spatial Plan of Kosovo was developed between 1990 and 1995, while maintaining the territorial integrity under that of Serbia. During this time period, new laws on spatial planning were enacted, which stipulated that these specific designs must include, among other things, the following instruments:

- General Plans for settlements,
- Detail Urban Plans and
- Framework of urban regulation for rural zones.
- Spatial Plan for SR Serbia,
- Regional Spatial Plan,
- Spatial Plan for the territory of special importance and
- Spatial Plan for infrastructure network, territory and buildings with special functions.
- General Urban Plans,
- General Regional Plans,
- General Plans for Infrastructure Network and
- Regulatory Plans.

Until 1999, various General Urban Plans for cities and specific settlements were drafted in accordance with the laws on spatial planning of 1995; some regulatory plans were also drafted.

After 1999, and up until the year 2003, these operations in this area were only deemed to be endeavors, not accomplishments. A number of important urban plans, as well as urban plans and detailed urban plans for specific settlements, were developed in accordance with Kosovo's applicable laws and regulations, though not many were put into effect. Following the year 2003, several actions in the field of spatial planning were carried out using a new methodology – namely, the movement from conventional planning to strategic planning. The strategic plans were thought to be followed by more technical and detailed plans.

The establishment of a legal framework for spatial planning was a significant step forward. The first draft of the Kosovo Spatial Plan 2005-2015+ was created as a result of this endeavor.

The process of creating municipal and urban development plans, as well as some urban regulatory plans and initiatives in the drafting of spatial plans for special areas, began during this period.

2.2.1. Planning Framework under UNMIK, from 2003—2013

As previously stated, there are two laws governing spatial planning in Kosovo, each of which has its own set of plans that serve as the primary means of implementing the laws. In this regard, the most significant issue remains that many plans and planning instruments did not have accompanying paperwork or administrative instructions on how they should be prepared when the new law was in effect.

Therefore, many municipalities throughout the country have continued to work on plans under the old law, which was no longer in effect, while other municipalities have prepared municipal zoning maps, some of which were done without the assistance of administrative instructions.

Under UN law, there are two levels of planning: central and local; each level has a number of plans or levels of planning in and of themselves.

Central level planning for the entire territory of Kosovo through spatial planning documents, such as:

- Spatial Plan of Kosovo;
- Spatial Plans for Special Zones.

Local level planning for the entire territory of municipalities through spatial planning documents, such as:

- Municipal Development Plan;
- Urban Development Plan
- Urban Regulatory Plans

Table 5 Levels of Planning according to the Law on Spatial Planning No. 2003/14

Central Level	Local Level
Central level planning for the entire territory of Kosovo through spatial planning documents	Local level planning for the entire territory of municipalities through spatial planning documents
• Spatial Plan of Kosovo • Spatial Plans for Special Zones	• Municipal Development Plan • Urban Development Plan • Urban Regulatory Plans

The purposes and scopes of the relevant planning documents for the period of 2003 – 2013 are listed below. However, as some municipalities are yet to develop Municipal

Zoning Maps for example, they often refer to these older legal documents even though they are not applicable as of 2013.

- *"Spatial Plan of Kosovo is a multi-sectoral strategic plan developed with public input. Spatial Plan of Kosovo establishes the principles and long-term aims of spatial planning over a ten-year period, as well as implementation schedules and costs. SPK promotes better living conditions, economic equality, environmental conservation, and natural, cultural, and archaeological heritage. It's based on spatial planning, sustainable development, and good governance to meet European standards. It is based on reports from relevant government ministries and the Ministry of Environment and Spatial Planning, and describes the potential cultural, social, economic, and environmental consequences of its implementation."*[30]
- *"Areas identified in the Kosovo Spatial Plan as having special characteristics requiring a special regime of organization, development, use, and protection are designated as SPSZ. National parks, special natural, economic, agricultural, cultural, or historical value areas. Special Spatial Plans for Special Areas must align with the Kosovo Spatial Plan's principles and long-term goals and be drafted for at least 10 years."*[31]
- *"Municipal Development Plan (MDP) is a multi-sectoral strategic plan with 5-year economic, social, and spatial goals. This plan covers municipal land. MDP must follow PH. Multiple municipalities could create an MDP."*[32]
- *"Urban Development Plan (UDP) is a multi-sectoral plan with 5-year goals for urban development and management. The plan includes the city's territory. UDPs can be part of MDPs or separate documents."*[33]
- *"Urban Regulatory Plans (URP) define the conditions for regulating space and locating buildings and land plots. These plans define construction areas, regulation and construction lines, technical urban norms, and other conditions on urban land parcels."*[34]

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30 Law No. 2003/14 Law On Spatial Planning. Article 11.
https://gzk.rks-gov.net/ActDetail.aspx?ActID=8865 (retrieved: July 2022)
31 Ibid. Article 12
32 Ibid. Article 13
33 Ibid. Article 14
34 Ibid. Article 15

2.2.2. Planning Framework under MESP, from 2013—ongoing

As with the former Law, according to the new Law, two levels of Planning and Spatial Planning Documents were foreseen: central and local level. According to the 2013 Law on Spatial Planning, Zoning Maps for both levels are added as a more technical tool in spatial organization.

Central level planning for the entire territory of Kosovo through spatial planning documents, such as:

- Spatial Plan of Kosovo;
- Zoning Map of Kosovo; and
- Spatial Plans for Special Zones.

Local level planning for the entire territory of municipalities through spatial planning documents, such as:

- Municipal Development Plan;
- Municipal Zoning Map; and
- Detailed Regulatory Plans.

Table 6 Levels of Planning according to the Law on Spatial Planning No. 04/L-174

Central Level	Local Level
Central level planning for the entire territory of Kosovo through spatial planning documents	Local level planning for the entire territory of municipalities through spatial planning documents
• Spatial Plan of Kosovo • Zoning Map of Kosovo • Spatial Plans for Special Zones	• Municipal Development Plan • Municipal Zoning Map • Detailed Regulatory Plans

The following table contains the Planning Framework, with all important plans (from the 2013 onwards) that affect the road infrastructure.

Table 7 Important plans (from the 2013 onwards) that affect the road infrastructure.

List of relevant Planning Documents **2013—Ongoing**	**Purpose & Scope in relation to Road Infrastructure**
Spatial Plan of Kosovo (SPK)	*"is a multi-sectoral document which identifies in spatial terms social, economic and environmental development policies in order to create sustainable and balanced development throughout the territory of Kosovo. SPK reviews and evaluates the existing situation for the spatial planning sectors, determines the vision, principles, objectives and priorities of strategic development on which the drafting of the Zonal Map of Kosovo is based. The objectives of the SPK are based on the objectives of the strategic development plans of the various sectors of the Government. The SPK is drafted by the MESP and reviewed and approved by the Government of Kosovo prior to final approval by the Assembly of Kosovo."*[35] In terms of Road Infrastructure, the Kosovo Spatial plan document provides guidelines that define the strategic objectives concerning the expansion, investments and development of roads in order to achieve the overall goals of the Plan that contribute to improve the lives of citizens.
Zoning Map of Kosovo (ZMK)	*"is a multi-sectoral document that through graphs, maps and text defines in detail the type, destination, planned use of space and action measures which are based on the duration and achievable projections of public and private investments for the entire territory of Kosovo, for a period of at least eight (8) years; ZMK determines the areas and measures for the development of spatial planning sectors, is based on the statement of vision, principles and sectoral goals of strategic development and the creation of good living conditions, equal economic opportunities and environmental protection and natural and cultural heritage. and archeological. ZMK must contain construction conditions that are conditions that serve as a basis for drafting construction documentation for each cadastral parcel. ZMK is drafted by MESP based on SPK and reviewed and approved by the Government of Kosovo."*[36]

[35] Law on Spatial Planning No. 04 / L-174. Article 12. https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8865 (retrieved: March 2022)
[36] Ibid. Article 13

	In terms of Road Infrastructure, Zoning Map designates surfaces and measures for development, including improvement of a central level public infrastructure.
Spatial Plans for Special Zones (SPSZ)	"*SPSZs are prepared for the areas identified in the SPK that have special characteristics and require a special organizational, developmental, user and protection regime. Such areas may include national parks and other areas of unique natural, economic, mineral, agricultural and cultural heritage value. SPSZ must be in accordance with SPK and ZMK and is drafted for a period of at least 8 years. SPSZ must contain the construction conditions for that area.*"[37] In terms of Road Infrastructure, SPSZ affects the infrastructure network as it limits its expansion in support of protection of the environment as well as natural and cultural heritage sites. However, identification of special zones, i.e. cultural heritage sites, may influence the construction of roads in order to secure proper access and suitable infrastructure that contributes to other aspects such as tourism or economic development.
Municipal Development Plan (MDP)	"*is a multi-sectoral strategic plan which sets long-term goals of economic, social and spatial development. The MDP should include a plan for the development of urban and rural areas for a period of at least 8 years. MDP reviews and evaluates the existing situation of the spatial planning sectors, determines the vision, principles, objectives and strategic priorities for the overall economic, social and spatial development of the country or municipality on which the drafting of the Municipal Zoning Map is based. The MDP is drafted by the Municipal Authority for Spatial Planning and approved by the Municipal Assembly after obtaining the prior consent of the MESP for compliance with central and sectoral strategic level documents of the Government.*"[38] In terms of Road Infrastructure Municipal Development Plan reviews and evaluates the existing conditions and resources in relation to the objectives of governmental and municipal strategic development plans that affect future municipal investments and fund allocation for infrastructure.

[37] Law on Spatial Planning No. 04 / L-174. Article 14. https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8865 (retrieved: March 2022)
[38] Ibid. Article 15

Municipal Zoning Map (MZM)	*"is a multi-sectoral document that through graphs, photographs, maps and text defines in detail the type, destination, planned use of space and action measures which are based on achievable duration and projections of public investments and private for the entire territory of the Municipality, for a period of at least eight (8) years. MZM is drafted by the Municipal Spatial Planning Authority based on ZMK, MDP and Technical Spatial Planning Norms (NTPH) and approved by the Municipal Assembly after approval by MESP. MZMs covers a period of at least 8 years and are subject to a review after 4 years in case less than 40% of the measures envisaged for this period have been implemented."*[39] In terms of Road Infrastructure, the Municipal Zoning Map directs municipal funds and strategic investments on roads and defines the connectivity within the municipal territory while taking into consideration strategies at national level as well as between municipalities.
Detailed Regulatory Plan (DRP)	*"set out the conditions for the regulation of premises and construction conditions for urban or rural areas as defined in the MDP and ZMK. Municipalities, depending on the needs for spatial development can prepare DRP for all or for any of the areas defined by the MDP and KZK. DRPs are approved by the Municipal Assembly. The DRP covers a period of at least 8 years and is subject to a review / change every 5 years."*[40] In terms of Road Infrastructure, DRP mainly affects local roads and can be used to define and determine detailed specifications concerning the development of local road infrastructure providing the Municipality with a plan that would secure proper implementation while taking into consideration all relevant aspects. The DRP is also subject of approval by the Municipal Assembly.

[39] Law on Spatial Planning No. 04 / L-174. Article 16. https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8865 (retrieved: March 2022)
[40] Ibid. Article 17

Table 8 Process of Municipal Development Plans and Zoning Maps for all municipalities[41]

No.	**Municipality**	**Municipal Development Plan**			**Municipal Zoning Map**	
		Existing MDP	MDP in Process	MDP Approved	MZM in Process	MZM Approved
1	Prishtina	✓				
2	Fushë Kosova	✓	✓			✓
3	Graçanicë	✓	✓			
4	Lipljani	✓	✓			✓
5	Shtime	✓	✓		✓	
6	Gllogovc	✓		✓		
7	Podujeva	✓		✓		✓
8	Obiliq	✓				
9	Mitrovicë e Jugut	✓		✓		
10	Mitrovicë e Veriut	✓	✓			
11	Vushtrri	✓		✓	✓	
12	Skenderaj			✓		✓
13	Leposaviq		✓			
14	Zubin Potok		✓			
15	Zveçan		✓			
16	Pejë	✓		✓	✓	
17	Istog	✓		✓	✓	
18	Klinë	✓	✓			✓
19	Gjakovë	✓		✓	✓	
20	Rahovec	✓				
21	Malishevë			✓		
22	Deçan	✓				
23	Juniku	✓				
24	Gjilan	✓		✓	✓	
25	Kamenicë	✓			✓	
26	Hani I Elezit	✓	✓			
27	Viti	✓	✓			
28	Kllokot	✓	✓			
29	Novo Bërd	✓				
30	Ranilluk	✓				
31	Partesh			✓		
32	Ferizaj	✓		✓		
33	Kaçanik	✓			✓	
34	Shtërpce	✓				
35	Prizren	✓				✓
36	Mamusha	✓				
37	Suhareka			✓	✓	
38	Dragash	✓	✓		✓	

[41] Information based on interviews with representatives from Ministry of Environment, Spatial Planning and Infrastructure (MESPI). (retrieved: March 2022)

2.3. Institutional Framework

This section describes the allocation of competencies, responsibilities, and obligations among the institutions operating in or influencing the field of spatial planning in Kosovo. The Ministry of Environment and Spatial Planning, which recently acquired the Department of Infrastructure as MESPI, is the primary entity that operates and has authority over all other substances.

MESP was supported by the international donors in the drafting of this legislative framework in order to develop a suitable document that is applicable in the entire territory of Kosovo and is compatible with EU and international legislative requirements on spatial planning.

The support from the donor community did not only involve the engagement of relevant experts but it also provided the technical assistance in building institutional capacities and enhancing the knowledge of local staff on best practices and policies relevant to spatial planning. For this purpose, the Institute for Spatial Planning and regional offices were established. The mandate of these institutions was to train the ministry staff on the proper implementation of the law and respectively monitor the work of the staff in municipalities, provide training and mentorship to municipal officials and transfer the knowledge related to the adequate application of all relevant rules and regulations deriving from this legislative framework.

This period marked a significant advancement of Kosovo Institutions towards establishing the needed legislative and administrative infrastructure in the field of spatial planning. However, being a new country came with political instability causing frequent changes in government and consequently with significant changes in MESP leadership. This led to new challenges in the implementation of the new planning system, which was more evident during the drafting of the first plans.

The spatial planning system in Kosovo consists of central and local level, as determined by the legal framework in place.

Central Level

In accordance with the Law on Spatial Planning, the Ministry of Environment, Spatial Planning, (MESP) is responsible for the coordination of spatial planning in Kosovo as well as the formulation of spatial development policy proposals in the field of spatial planning and infrastructure development. Furthermore, MESP is in charge of the creation of pertinent documents and reports on spatial planning, as well as the assessment and monitoring of all planning documents throughout the territory.

Aside from these duties, MESP is also responsible for the review, monitoring, and harmonization of the planning process at the municipal level, as well as ensuring compliance with planning procedures, providing advice and assistance to municipalities in the preparation of municipal and urban development plans as well as urban regulatory plans, among other things.

According to the law on spatial planning, the Ministry of Environment and Spatial Planning (MESP) is responsible for the following tasks:

- spatial planning coordination for the entire country;
- formulation of Kosovo's spatial development policies;
- preparation of relevant planning documents and reports;
- review of planning documents for the entire country; and
- monitoring of planning documents.

The Spatial Planning Sector, which is comprised of the Department of Spatial Planning and the Institute for Spatial Planning, both of which are located within the MESP, represents the central level of government. Due to the ambiguity of legal responsibilities, there is frequently overlap between the work of these two bodies:

Department of Spatial Planning - responsible for drafting and implementing of the existing legal framework and

Institute for Spatial Planning - responsible for preparing the Spatial Plan of Kosovo and undertaking other professional tasks that are authorized by Administrative Decision.[42]

Along with the institutions, departments, and offices stated above, the Kosovo legal framework establishes and recognizes the council for spatial planning. The council for spatial planning is a consultative body of the Kosovo government that ensures a sustainable and equitable spatial development in Kosovo, as well as scientific and professional support for spatial planning documentation and other related documentation. Duties and responsibilities of this council include:

- Consult on, make proposals for, and make comments on the document of territorial planning (the spatial plan of Kosovo and plans for specific areas) and on other documents defined by the law of territorial planning and issued by the Government and Assembly of Kosovo in the field of territorial planning;
- At each point when there is a lack of coordination between the development strategies of different sectors that are vital for spatial planning, revise and suggest a suitable alternative;

[42] Institute for spatial planning mission, vision and obligations. MESPI. https://mmphi.rks-gov.net/departamentet/286/misionivizioni-dhe-detyrat-inst (retrieved: March 2022)

- Monitor and follow up on for the procedures that must be followed in order to implement the spatial planning documents that have been approved by the Government and Assembly of Kosovo in accordance with the Law on Spatial Planning
- Completion of various works that are a result of legal acts passed by the government in the field of spatial planning.

The current organizational and functional structure of the above-mentioned units is ambiguous at times, which frequently results in a situation where overlapping responsibilities are experienced. As a result, additional documents that clarify these roles would be beneficial in clarifying roles and responsibilities.

Local Level

The local (municipal) level consists of various planning and urban management departments. The local level is often faced with a lack of human resources which are not ready and able to deal with more complex issues related to the requirements and needs of spatial planning.

The municipal level lacked capacities in drafting of plans, managing processes but also in quality control. The work was outsourced from local private companies who, at that time, were inexperienced and untrained. Therefore, the quality of documents produced was fairly poor and not compatible with the approach of the drafted Law. Even in the cases when the quality of produced plans was acceptable, there was not sufficient personnel trained to implement them.

However, municipalities, as the fundamental territorial unit of local government, are responsible for carrying out activities related to urban and rural planning within their respective jurisdictional boundaries. Cities and towns are in charge of putting together development plans (both municipal and urban) and regulatory plans for urban areas. Although it is worth noting that cities are not specified as such in the Legal and Planning Framework, whereas the capital city is defined in the Legal Framework. As a result, cities will continue to be referred to as "settlements" throughout this dissertation.

Municipal spatial development is overseen by the Planning and Urban Management Directorates, which are tasked with this responsibility. The current state of urban planning and management in Kosovo's municipalities is that there is no one official name for these directorates, nor is there a single official makeup of these directorates. The size of the municipality, the availability of human resources, and the general organizational structure of municipal administration all play a role in determining this. Planning and urban management departments are dealing with a variety of issues at the moment, the most serious of which is a lack of qualified personnel, which has a direct impact on the ability of departments to carry out their essential activities and responsibilities. In order to complete the professional work in the process of developing municipal spatial plans and urban plans, as well as to provide support in the process of putting these plans into effect, the Municipal Assembly shall appoint a Committee of planning experts, which will be appointed by the Municipal Assembly.

Other Actors

In addition to the core governmental agencies, there are a number of other actors in Kosovo who contribute to the field of spatial planning. It is also vital to acknowledge their contributions to the development of planning processes, which are significant.

- **Civil Society**

Kosovo has a long and illustrious history of collaboration with civil society, which has frequently assisted in closing various gaps in legislation or even other forms of government. It goes without saying that there are many different actors involved in the development of the spatial planning sector, particularly in the production of recommendation documents and in the submission of legislative intervention proposals. This category of players primarily takes a reactive strategy and is concerned with putting an end to negative behaviors (for example, environmental protection), rather than taking a very proactive approach, as would have been suggested by other visionary writings.

- **Private Sector Developers**

Developers, in addition to road infrastructure, are the primary drivers of development in the country of Kosovo. Due to the fact that construction is one of the most influential businesses in the country, developers frequently exert influence over both the market and spatial planning laws, and unfortunately, they are often not impacted by the law and the state. For example, according to the Kosovo Energy Regulator Office, based on the number of new electrical grid connections, it appears that around 20,000 new housing units are built each year in the entire country.[43]

- **International Institutions**

The fact that Kosovo has a relatively small budget, particularly when it comes to investments in capital projects such as infrastructure, means that the country is reliant on a variety of projects sponsored by international organizations such as the European Union, the World Bank, the United Nations, and other international actors whose primary goal is to improve the lives of citizens through investments in capital and development projects.

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43 Zyra e Rregullatorit Elektronik. Numri I konsumatorit familjar. http://www.ero-ks.org/zrre/sites/default/files/Publikimet/T%C3%AB%20dhena/Numri%20i%20konsumator%C3%ABve%20familjar%20p%C3%ABr%20distrikt.xlsx (retrieved: June 2022)

Issues / Barriers:

Since Kosovo is a young state, it has had little opportunity to gain valuable expertise and become familiar with the different obstacles that could potentially impede a successful planning process. Some of these barriers that may be a cause for the overall threatening of the planning process are as follows:

- **Legal / Legislative / Political barriers**

Kosovo has gone through a dynamic period of state formation in the past 20 years and has been drafting and approving a large number of laws, regulations and policies for all sectors which have mainly been adapted to the Kosovo context. However, there have been many cases where laws contradict and are not in harmony with each other, causing unclear situations. This has often led to halting of specific procedures that would be crucial to move works forward, especially in spatial planning, infrastructure and construction. The ambiguity related to the legislative framework has been often caused by the frequent changes in government.

The unstable political situation has also been a barrier impacting the proper drafting and implementation of laws and regulations due to changes that have been constantly initiated in this regard. The organizational changes recently introduced by governments in regards to restructuring and merging of Ministries, is one of the major issues that has impacted the administrative and logistical capacities, causing an unclear transfer of responsibilities. In addition, governments have often promised, planned and initiated major infrastructure projects that were later interrupted, changed or halted altogether due to changes in leadership.

These issues have impaired the spatial planning process in Kosovo and have also affected the foreign investments in this field. To date, institutions face similar challenges in harmonization of work plans between respective/relevant ministries and agencies competent for securing the proper implementation of laws.

- **Organizational / Cultural barriers**

One of the most difficult problems to solve throughout the planning process is the misunderstanding surrounding the competencies and responsibilities of different institutions, departments and sectors. The lack of specificity in the Law on Spatial Planning is the primary reason for this overlapping of obligations, which frequently results in inactivity since one party believes that the other party should address a certain issue.

Even though this is not clearly defined by the legal framework, decent communication between all of these parties should be sufficient in clarifying these roles and responsibilities.

That said, communication between the central and local levels of planning is not sufficient, and there is currently little space for improvement in this area of the organization. Major factor influencing such a situation is the large amount of work (large portfolio) carried out by municipal departments for planning and urban management in the vast majority of cases. In addition to providing services to citizens, the primary activities of these departments have an impact on their ability to deal with issues relating to spatial planning and development. This is clearly reflected in the planning process for Municipal Development Plans (MDP) and Municipal Zoning Maps (MZM), in which the departments for planning are primarily observers rather than active participants, as is the case in the majority of municipalities.

Communication across different sectors at the central level is also extremely important to the success of the organization. Inter-sectoral disputes frequently result as a result of a lack of communication across these sectors, which prevents harmonized initiatives from having a positive impact on the ground.

In spite of recommendations that the spatial planning sector serve as coordinator of spatial developments in the country, this does not appear to be happening. Many significant sectors of government are developing their activities without consulting the spatial planning sector, or, at the very least, the communications are merely formal, according to the situation.

Additionally, Kosovo has cultural barriers that date all the way back to before the 1999 war. While Kosovo was a part of the former Yugoslavia, due to the political and socioeconomic context at the time, there is a widespread perception in Kosovo that everything that is common or communal belongs to the regime at the time (sometimes derisively referred to as 'država,' a Serbian word meaning 'state'). Even after Kosovo's independence and establishment of its institutions, this mentality persists, with many public, municipal, and governmental possessions viewed as 'nobody's' rather than 'common'. This leads to a lack of seriousness with which capital projects such as road infrastructure are treated.

- **Financial barriers**

Insufficient funds remain one of the main barriers affecting spatial planning. Investments in this sector usually are quite large and require proper research, adequate planning and undergo through several layers of approval therefore, take a longer period for implementation. This means that funds dedicated for realizing major infrastructure projects could have vast financial implications for the country. The consequences of such investments sometimes outweigh the benefits and bring the country into economic stagnation.

Kosovo being a small country with very limited financial capabilities and recovering from a post war period, had to compromise when it came to large infrastructure investments that contributed directly to spatial development. One of the largest infrastructure investments was the construction of the first motorway which was nearly a one year’s budget worth.

At the local level, considering that municipalities are responsible for carrying out activities related to urban and rural planning within their respective jurisdictional boundaries, they are also responsible for financing these activities from their own funds within the municipal budget. Based on small financial revenues and limited budget that municipalities have at disposal, the investments in infrastructure are quite limited. Municipalities also depend on large capital investments coming from the central government or large projects that are financed by international donors.

- **Technical knowledge barriers**

One of the main issues in the public institutions, are the relatively low wages for spatial planners, compared to those of the industry and especially of other NGOs. This usually results in state institutions hiring candidates that are sub-par and that are not very qualified in their respected fields.

Another issue that arises as a result of Kosovo's youth is the fact that multiple generations of education have not yet been completed, particularly in specialized fields like architecture and spatial and urban planning. In the majority of situations, architects and planners in Kosovo are only the second generation to be educated in their families, which suggests that there is always room for development in terms of gaining knowledge.

Taking into consideration the current situation in the spatial planning sector, both at the national and primarily at the local level, spatial planning work is generally carried out by architects and urban planners, which may lack sufficient professional qualifications.

Municipal departments for planning and urban development are currently engaged in the provision of urban services, which is the primary function of practically all municipal departments. As a result, the shortage of qualified professionals is the most significant difficulty facing the planning and urban management sector. The majority of municipal planning departments are either understaffed with professional staff.

Kosovo is quickly building new capacities however, with up to date knowledge of contemporary concepts and practices in the field of spatial planning.

The following table contains the Institutional Framework, with all important institutions that in one form affect the road infrastructure.

Table 9 List of Institutions relevant to Spatial Planning

List of relevant Institutions	**Purpose & Scope in relation to Road Infrastructure**
Ministry of Environment, Spatial Planning and Infrastructure (MESPI)	*"As defined by the Law No. 04/L-174 on Spatial Planning, the Ministry of Environment, Spatial Planning and Infrastructure is the authority responsible for spatial planning and management. MESPI is one of the main responsible entities that exercises functions, powers and responsibilities that are based on the current legislation and are related to matters concerning spatial planning that include but are not limited to:* • *preparation of policies for the scope of the spatial planning* • *drafting and coordination of legal framework of spatial planning* • *preparation of proposal-decisions, drafting and coordination for the drafting of Spatial Plan of Kosovo and Zoning Map of Kosovo, and Spatial Plans for Special Zones, and for their revision.* • *coordination of spatial and territorial planning objectives of central authorities* • *encouragement and to ensure that public participation is involved in the drafting and implementation of spatial planning documents, etc."*[44] In terms of Road Infrastructure the Ministry provides the government with technical and financial support in order to research, plan and facilitate the development of roads that are crucial for national and regional connectivity and have a substantial role in the development of the infrastructure.
Institute for Spatial Planning	The Ministry of Environment, Spatial Planning and Infrastructure, through a sub-legal act has established the Institute for Spatial Planning and defined the scope and responsibilities of the Institute through the Administrative Instruction No. 03/2017. *"This document has established the scope of the Institute which is to contribute to coordination of objectives of the central authorities for territorial and spatial planning through the preparation of relevant spatial planning documents The responsibilities of the Institute consist of:* • *provision of support in drafting and revision of documents* • *provision of assistance upon request from the Ministry or Department for Spatial Planning*

[44] Law on Spatial Planning No. 04 / L-174. Article 9. https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8865 (retrieved: July 2022)

	• *provision of technical assistance to support the municipal authority in charge of spatial planning.* • *other responsibilities as described by the law and administrative instruction, etc."*[45] In terms of Road Infrastructure, the Institute for Spatial planning plays an important role in the process of drafting of strategies and other relevant documents determining the road infrastructure development. Through the provision of technical support, the institute provides the relevant authorities with professional resources and capacities to develop such documents, supporting the institutions with research, collection of data and maintenance of databases.
Government of Kosovo	In accordance with the Law on Spatial Planning, the Government of Kosovo, among other things, is responsible for allocation of funds for: • drafting of Spatial Plan of Kosovo; Zoning Map of Kosovo; • development of Spatial Plan for Special Zones; • implementation of goals and objectives as determined in the Spatial Plan of Kosovo, etc.[46] The Spatial Plan of Kosovo, Zoning Map of Kosovo and other relevant documents should be reviewed and approved by the Government of Kosovo prior to the submission for approval in the Assembly of Kosovo. In terms of Road Infrastructure, the Government of Kosovo plays an important role in determining and defining the road infrastructure development through the national strategies, policies and budget allocations that shall be approved by the Assembly. The Government of Kosovo through regular coordination and harmonization of policies and sectoral strategies of the relevant Ministries, facilitates and supports the implementation of activities deriving from strategies that also impact road infrastructure.
Assembly of Kosovo	As stated by the Law on Spatial Planning, the Assembly of Kosovo is the highest authority for approval of laws and administrative instructions and funds allocated for Spatial Planning and infrastructure. The Assembly of Kosovo is responsible for final approval of:

[45] Administrative Instruction MESP - No.03/2017 On The Scope And Responsibilities Of The Institute For Spatial Planning. Article 4. https://gzk.rks-gov.net/ActDetail.aspx?ActID=14818 (retrieved: July 2022)
[46] Law on Spatial Planning No. 04 / L-174. Article 8. https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8865 (retrieved: July 2022)

	• proposals for decisions on drafting Spatial Plan of Kosovo, and Spatial Plans for Special Zones after they are approved by the Government of Kosovo; • Spatial Plan of Kosovo, after its approval by the Government of Kosovo; • Zoning map of Kosovo after it is approved by the Government of Kosovo; • Spatial Plans for Special Zones after their approval by the Government of Kosovo; etc. The Assembly of Kosovo reviews the Monitoring Report on Implementation of goals and objectives stated in the Spatial Plan of Kosovo, Zoning Map of Kosovo and Spatial Plans for Special Zones prepared by the Government.[47] In terms of Road Infrastructure, the Assembly has the final say on investments and strategic developments through the official approvals and endorsements.
Municipal Department of Planning	Municipal Department of Planning, is known and recognized by the Law on Spatial Planning as the Municipal authority responsible for spatial planning and management. *"The Municipal Department of Planning is the main authority within the local government responsible for the spatial planning and in accordance with the Law on Spatial Planning is responsible for:* • *Spatial development, through design and implementation of goals and objectives stated in spatial planning documents;* • *Development of spatial planning documents in full compliance with the Spatial Plan of Kosovo, Zoning Map of Kosovo and Spatial Planning Standards;* • *Preparation of proposal-decisions on drafting the Municipal Development Plan and Municipal Zoning Map and Spatial Plans for Special Zones, and for their revision* • *Coordination of sector directorates and human resources within the municipality for drafting the Municipal Development Plan* • *Drafting of Detailed Regulatory Plans, in accordance with the Municipal Zoning Map, Spatial Planning Standards* • *revision of the Zoning Map of Municipality* • *submission and presentation of the Municipal Development Plan and Municipal Zoning Map to the Ministry, to verify compliance with the Spatial Plan of Kosovo, Zoning Map of Kosovo and Spatial Planning Standards*

[47] Law on Spatial Planning No. 04 / L-174. Article 7. https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8865 (retrieved: July 2022)

	• *reviewing and monitoring the implementation of the objectives set out in spatial planning documents in the entire territory of the municipality, etc."*[48] In terms of the road infrastructure, it is the responsibility of the municipality to write pertinent documents and strategic plans for the development of infrastructure that are in line with the strategies employed at the national level. In addition, it is the obligation of the municipality to provide the necessary finances for the building of roads, which contribute to shaping the spatial form of the city on both a large and a local scale. The Municipal Assembly is the approval authority. Municipalities are directly involved in the process of implementing national roads and highways that touch the territory of the municipality and influence the long-term viability, inclusivity, efficiency, and economic growth of cities and the surrounding area.
Municipal Assembly	"*The Municipal Assembly is the main municipal authority in charge of approving the funds allocated for the implementation of the Law on Spatial Planning. Municipal Assembly is responsible for:* • *approval of proposal of decision for drafting as well as approval of the drafted of the Municipal Development Plan, Municipal Zoning Map, and the Detailed Regulatory Plans;* • *approval of Detailed Regulatory Plans, after approval from sector directorates of the municipality;* • *revision of the Zoning Map of Kosovo, after approval by the sector Directorates of the municipality;* • *revision of Detailed Regulatory Plans, after approval from the sector directorates of the municipality;* • *other documents stipulated by the law on spatial planning."*[49] The Municipal Assembly on an annual basis reviews the Monitoring Report of the Implementation of the goals and objectives stated in the Municipal Development Plan and Municipal Zoning Map, and the Detailed Regulatory Plans prepared by sector directorates of the municipality. In terms of Road Infrastructure, the Municipal Assembly provides its approval to any documents that will determine the development of the road infrastructure as well as any decisions linked to the distribution of funds for this purpose.

[48] Law on Spatial Planning No. 04 / L-174. Article 11. https://gzk.rks-gov.net/ActDocumentDetail.aspx?ActID=8865 (retrieved: July 2022)
[49] Ibid. Article 10

2.4. Summary

This chapter serves as the purpose to summarize Kosovo's spatial planning laws, plans, institutions, and practices, as well as their historical evolution. This is done in order to have a better understanding of how each of these frameworks affects road infrastructure development. To lay the groundwork for future discussion, this chapter argues for and assess the hypothesis that road infrastructure has been the most critical part of Kosovo's development.

Since 1999, the majority of new development has occurred along existing and newly constructed road infrastructure, with little or no intervention from any level of government or other organization. Following road infrastructure expansion, it is critical to understand the complexities of the regulatory framework that will affect future land development as a result of road infrastructure expansion and development.

Kosovo, like many Eastern European countries, has a broad range of legal frameworks, hierarchical systems, and institutions that have shaped the country in a variety of ways. To gain a better grasp of the context within which the Planning and Institutional Frameworks will operate, this chapter looks deeply into the subject of spatial planning legislation, as well as the planning and institutional frameworks. Regulatory Framework To keep pace with the rapid changes affecting the subject of spatial planning, Kosovo's legal framework for spatial planning has undergone two rounds of reform over the last two decades of multiple transitions that have characterized the country following the 1999 war and the deployment of the international community.

The frameworks analyzed have not produced the best practices, as can be viewed by the study cases of this dissertation, however they are plentiful in serving as means of controlling development.

The Legal, Planning and Institutional Frameworks presented in this chapter, show that they can serve as a large variety of tools that can be used to better plan and control development along road infrastructure. Additionally, the frameworks presented here, will serve as the basis of chapter 4, whereupon some of the attributes of the model are devised.

CHAPTER 3

THEORETICAL BACKGROUND: ROADS, LAND AND PATTERNS

This chapter covers the theoretical background and basics of land-use development patterns in relation to road infrastructure. Furthermore, a brief history of urban modelling is presented, beginning with the simple models of the 1950's and 60's, until what is currently being developed.

3. THEORETICAL BACKGROUND: ROADS, LAND AND PATTERNS

People, and consequently communities, have a natural tendency to form dense settlements as a cost-effective manner of consuming a variety of services, land, and activities in nature. According to general principles, the establishment or expansion of communities is dependent on the long-term benefits that the location provides to its inhabitants. Another adjacent settlement, which turns out to be more unstable in terms of developmental characteristics, has a proclivity to join / merge with another settlement or to dissolve entirely. This is a common occurrence in the case of settlements that are close to one another in terms of distance.

Historically, roads have been used to connect towns, and they have been classified according to the amount of traffic that passes through them from one place to the other. The points in between are defined as settlements that must be passed, giving them the character of a transit zone. Consider the following example: by connecting the largest port, Thessaloniki with the largest market of the Balkan Peninsula, Belgrade, there appeared the need for smaller supporting settlements that can serve as stops for resupplying, refueling and exchange. This is where settlements like the capital of Kosovo, Prishtina appeared, which is almost hallway between Thessaloniki and Belgrade.

The road - which was built to connect two settlements, or two vital centers of commerce, for example - has occasionally resulted in the formation of new settlements along its course. As a result, according to this scenario, the road serves as a catalyst for new land development.

According to the other modern scenario, the road has helped small settlements avoid extinction while encouraging their development in order to preserve their core, precisely because they have access to the services of large settlements without having to relocate - from this comes the concept of the commuter.

For commuters, proximity is an important consideration because the trend is always to maintain one's original place of residence while making work, services, and activities accessible at a fair time / distance. By introducing road infrastructure, this time/proximity element is transformed. By stretching space, time is affected, whereupon proximity is altered.

Understanding the generation of proximity and revisiting the fundamental concepts of settlement-road conditioning is the method that has been taken in this chapter to demonstrate and simplify the relationship between road-land development and development of the road network.

To comprehend the interdependence of ideas and directions for motorway construction with the land on which they are situated, but also in the context of land development plans, it is necessary to develop methods for comprehending - that is, for comprehending distances and distance measurements between settlements that we wish to connect or that are connected by road - through the motorway system.

3.1. ROADS: Understanding the Relation of Road Infrastructure and Land Development

For the purpose of building spatial/location models, the measurement of distance or closeness is critical. Because it is considerably faster to compute, and it is often more convenient when reducing complex events, Euclidean geometry is commonly used to depict and measure distance. Reality, on the other hand, is significantly more complicated. Any distance traveled is outside of Euclid's realm, thus a margin of error should be expected while performing mathematical computations. This method of representation and measurement, on the other hand, is chosen because it allows for a more straightforward and direct manner of translating observations into understandable systems and explanations that can then be developed further.

For the purpose of gaining a better understanding of why commuters tend to move towards the settlement center and vice versa, this research will begin by presenting simplified versions of settlements, first without the concept of infrastructures introduced, and then with the concept of infrastructure introduced. The first 3 cases (1, 2a and 2b) present settlements without road infrastructure, whereas in the last case (3) road infrastructure is introduced in order to illustrate the impact it has on the settlements.

One Settlement (Case 1)

In the first case, with the assumption is made that all citizens want to be as close as possible to the center of the settlement. This is the simplest example that shows the relation between distance and cost. The further citizens are from the settlement center, the less expensive it is for them to live there and vice-versa. The costs for being away from the settlement center are equal to the Euclidean distance from the settlement center, where ($\bar{x}_A$; $\tilde{y}_A$) represent the center of settlement A:

$$c(x;y) = -[(x-\bar{x}_A)^2 + (y-\tilde{y}_A)^2]^{1/2}$$

In this example, the highest density is found in the settlement's center, with density decreasing as the distance from the settlement's center increases. This means that the greater the distance between the center and the settlement, the lower the density of the settlement. However, for the purposes of this example, all density is assumed to be the same, regardless of distance from the settlement's center. [50] [51]

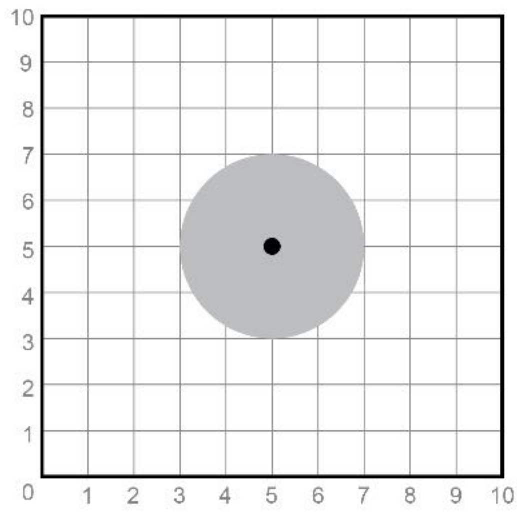

Figure 2 One settlement, where $\bar{x}A = 5$ and $\tilde{y}A = 5$.

Such is the case of earlier (especially ancient) settlements, which tended to have this sort of development, as it was difficult and impractical to have neighboring settlements, where their forces could be combined into one compact form. Road infrastructure was used more rarely, mostly for trading purposes.[52]

Two Settlements

When two neighboring settlements are forced to compete for the same level of development, the scene alters dramatically. A pair of scenarios are presented in the next section: one (2a) illustrating the Euclidian distance, and the other (2b) illustrating the Log of Euclidian distance.

- **Euclidean Distance** (Case 2a)

In the case of two neighboring settlements, all citizens want to be as close as possible to both settlement centers. The costs for being away from a settlement center are equal to the Euclidean distance from the settlement center – the further away, the higher the cost of access. Since there are two settlement centers the costs become:

$$c(x;y) = -[(x-\bar{x}_A)^2 + (y-\tilde{y}_A)^2]^{1/2} -[(x-\bar{x}_B)^2 + (y-\tilde{y}_B)^2]^{1/2}$$

Where $(\bar{x}_A; \tilde{y}_A)$ represent the center of settlement A.

[50] Baum-Snow, N. (2007). Suburbanization and transportation in the monocentric model. Journal of Urban Economics, 62(3), 405-423.
[51] Batty, M. (2008). The size, scale, and shape of cities. science, 319(5864), 769-771.
[52] Morris, A. E. J. (2013). History of urban form before the industrial revolution. Routledge.

This cost structure may be appropriate if we think that it is crucial to be as close as possible to both settlement centers. This would be the case if the different settlement centers offer activities that are exclusive to that settlement center. In such a case, the individual is happier if she is, say 5 km away from each center rather than living in the center of one settlement and being 10 km away from the other.

The following cost structure may be appropriate if the belief is that it is critical to be as close to both settlement centers as possible. This would be the situation if the two different settlement centers each offered activities that were only available at that particular settlement center. In such a case, the individual is happier if she is, say 5 km away from each center rather than living in the center of one settlement and being 10 km away from the other.

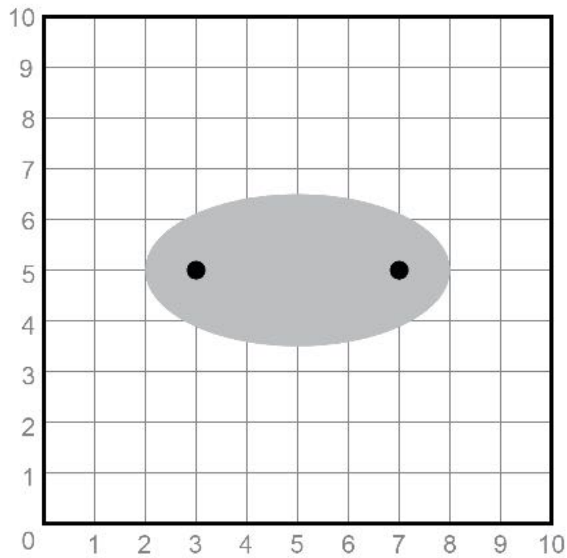

Figure 3 Two Settlements – Case 1, where $\bar{x}A = 3$, $\tilde{y}A = 5$ and $\bar{x}B = 7$ and $\tilde{y}B = 5$

Because the individual is neither too close nor too far away from either settlement center, he or she will be able to take advantage of the services of both settlements while minimizing travel time and distance. This will come at a cost in terms of travel time and distance, because in order to be as close to both settlements as feasible, the individual will have to lose proximity to both. This implies that the ideal position for the person is somewhere in the middle of the two settlements.

The scenario provided here assumes that both settlements are of comparable size and, as a result, have the same gravitational pull toward development. If one of them becomes larger, the gravitational pull will shift in favor of the larger settlement, drawing development away from it to the point of absorbing it entirely.

To better illustrate this position, the case of the settlements of Prishtina and Fushë Kosovë is take. These two settlements are positioned quite closely together, and have to some degree a different nature of services they provide. Prishtina is the capital and serves as an administrative and commercial center, whereas Fushë Kosovë, which is smaller in size, has more of an industrial and commercial/trade nature.

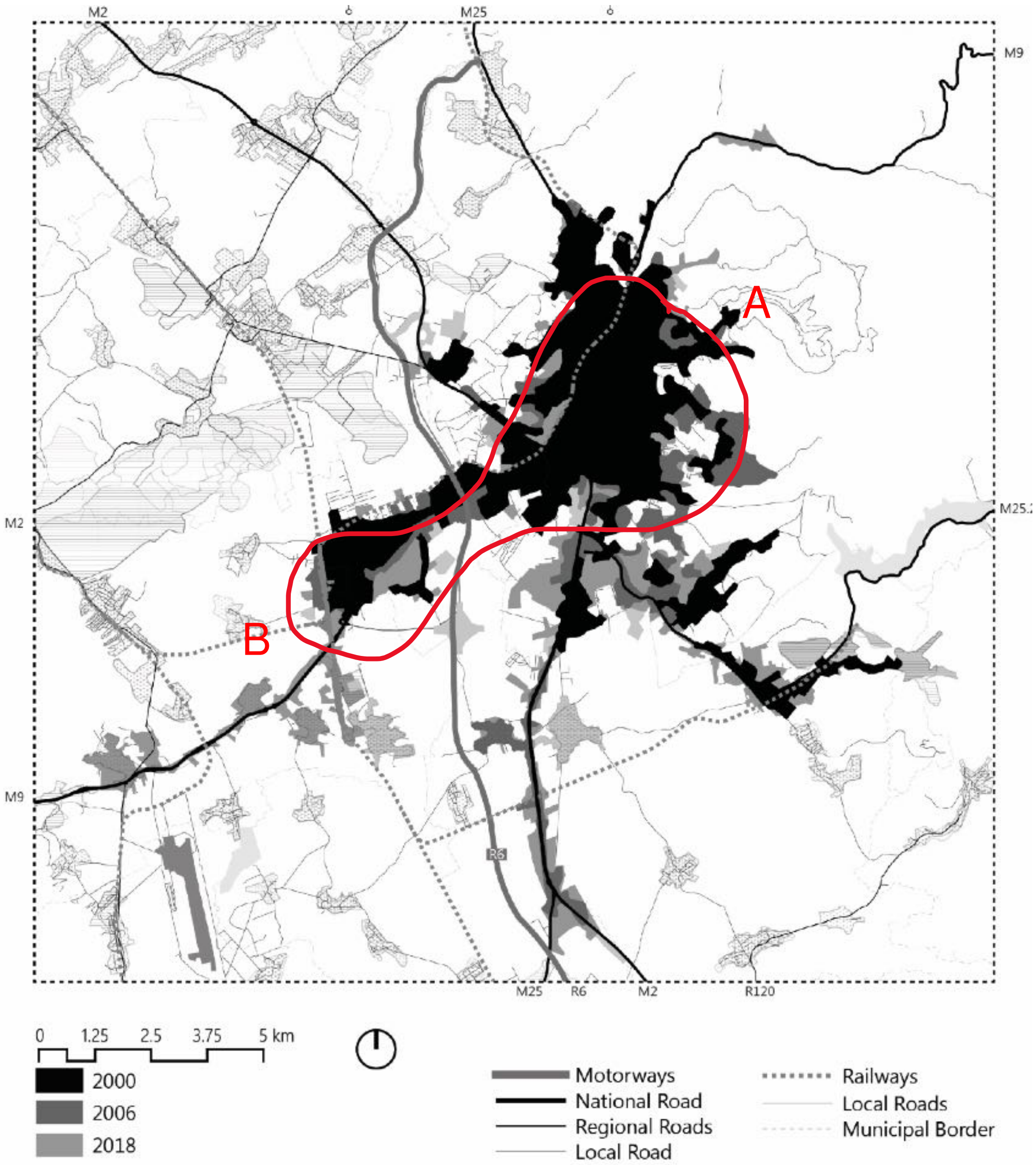

Figure 4 Prishtina (A) and Fushë Kosovë (B) and their proximity

Individuals are interested in having access to both settlements' services, indicating that development has occurred between the two settlements. Because of the lower cost of living, many of them live in Fushë Kosovë and commute daily to Prishtina for employment and other services. Individuals who live in the capital of Prishtina, on the other hand, have access to the services of Fushë Kosovë, which is primarily engaged in industrial and agricultural production in nature. This is more convenient for them because the expense of having them delivered to Prishtina is less expensive in this manner. In this trade, the ability to access both settlements is advantageous to both the seller and the buyer, as it eliminates the need for additional expenditures associated with logistics and shipping.

- **Log of Euclidean Distance** (Case 2b)

In the case of two neighboring settlements, all citizens want to be as close as possible to both settlement centers. The costs for being away from a settlement center are equal to the log of the Euclidean distance from the settlement center. Since there are two settlement centers the costs become:

$$c(x;y) = -\log\{[(x-x_A)^2 + (y-\tilde{y}_A)_2]^{1/2}\} -\log\{[(x-x_B)^2 + (y-\tilde{y}_B)^2]^{1/2} \}$$

Where ($\bar{x}_A$; $\tilde{y}_A$) represent the center of settlement A and ($\bar{x}_B$; $\tilde{y}_B$) represent the center of settlement B.

This cost structure may be appropriate if the assumption is made that, as the distance from a settlement center increases, the "personal costs" of individuals keep on increasing, but in shrinking increments.

This would be the case if activities from one settlement can to some extent be counterbalanced by activities from the neighboring settlement. In such a case, if the individual is offered to live in the center of one settlement while the other settlement is 10 km away, versus living 5 km away from the center of either settlement, the individual would prefer the former.

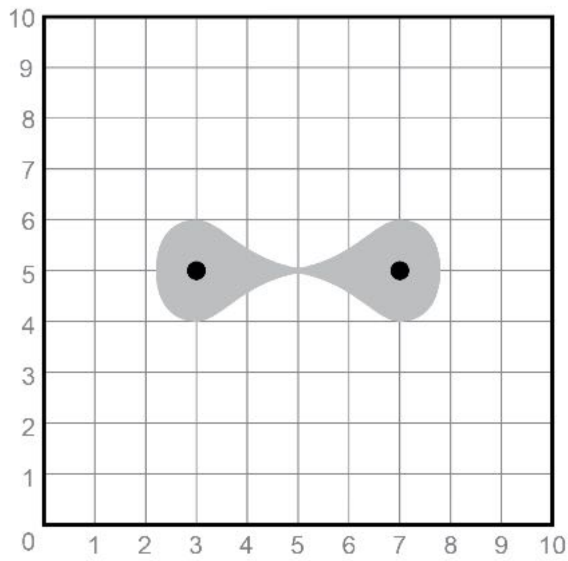

Figure 5 Two Settlements - Case 2, where $\bar{x}A = 3$, $\tilde{y}A= 5$ and $\bar{x}B = 7$ and $\tilde{y}B= 5$

In this case, without any linking infrastructure, the two similarly sized and equipped settlements, will have difficulty to stay connected and attract development away from the neighboring settlement. The gravitational pulls of both settlements are too strong to allow for development in-between them. Here too, if one of the settlements is larger than its neighbor, it will pull development away from it, shrinking and possibly absorbing it entirely. If both settlements are of similar size, development will remain more balanced.

This effect can be viewed in the connection between the two settlements Lipjan and Shtime, both of which are similar in size and population. As some services can be obtained in-between the two settlements, most are present closer to each of the two settlements.

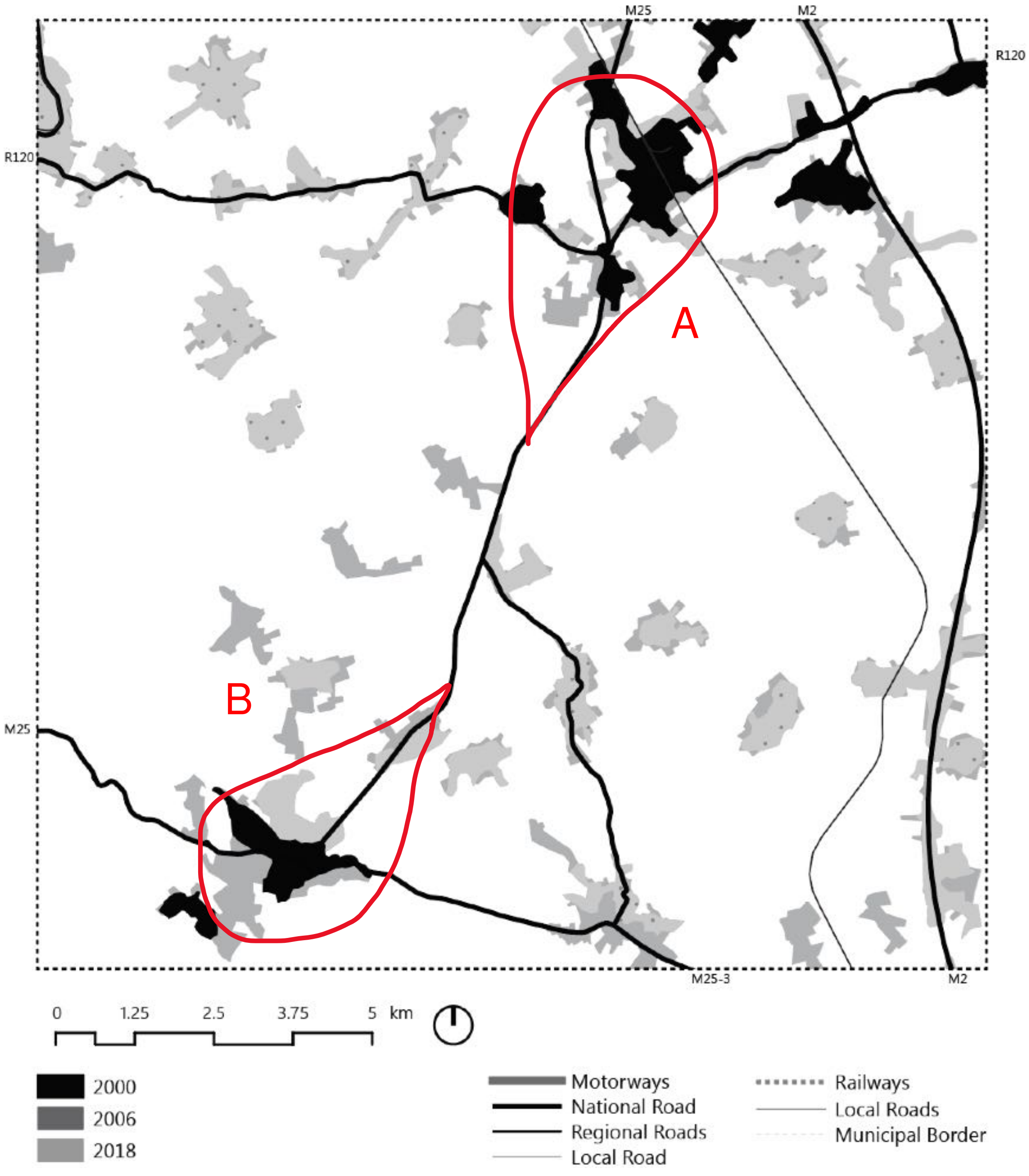

Figure 6 Lipjan (A) and Shtime (B) and their proximity

Introducing Road Infrastructure (Case c)

This study now analyzes the effects of introducing a road infrastructure that connects the two settlements. On the graph below the settlements are denoted by black circles while the infrastructure is denoted by the black line.

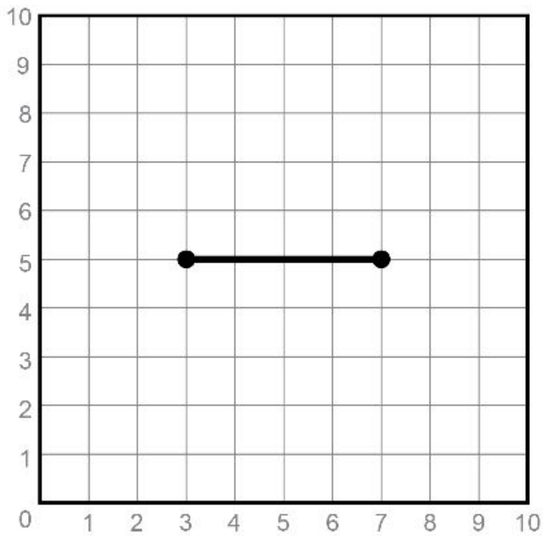

Figure 7 Introducing road infrastructure – the road is denoted by the black line, the city centers are denoted by the black dots.

The assumption is that if the individual reaches the road, the costs of traveling on the road are multiplied by < 1. That is, traveling on the road is less costly. Once more the assumption is made that the costs are equal to the Euclidean distance. The graph below plots how the individuals would have positioned around the cities, without (left) and with the road infrastructure (right).

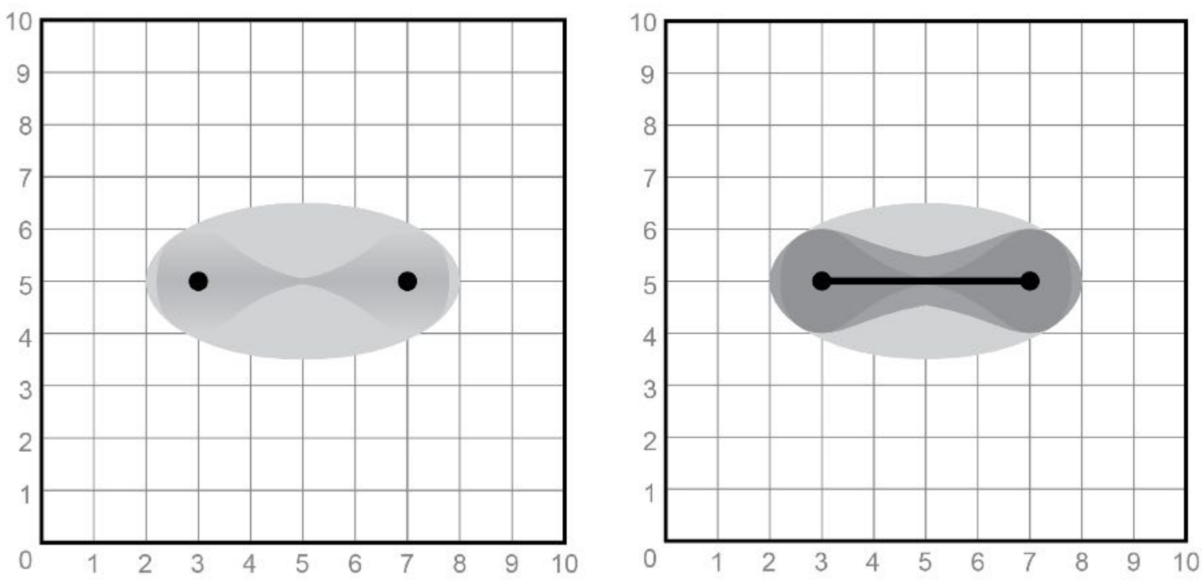

Figure 8 Two Settlements - without road infrastructure connection (left), with road infrastructure connection (right)

The previous figure is plotted with K = 0:75, that is, under the assumption that road infrastructure decreases traveling costs by 25%. As can be seen, the presence of the road infrastructure decreases the vertical spread and increases the horizontal spread.

The plot on the right showing the new distribution is composed of different shades of gray. The light grey color represents all the individuals that would not make use of the road infrastructure, although it is present. The dark grey color represents all the individuals that would make use of the road infrastructure for traveling to at least one of the settlements. In particular, only individuals within the center of the dark grey part, make use of the road infrastructure to travel to both settlements.

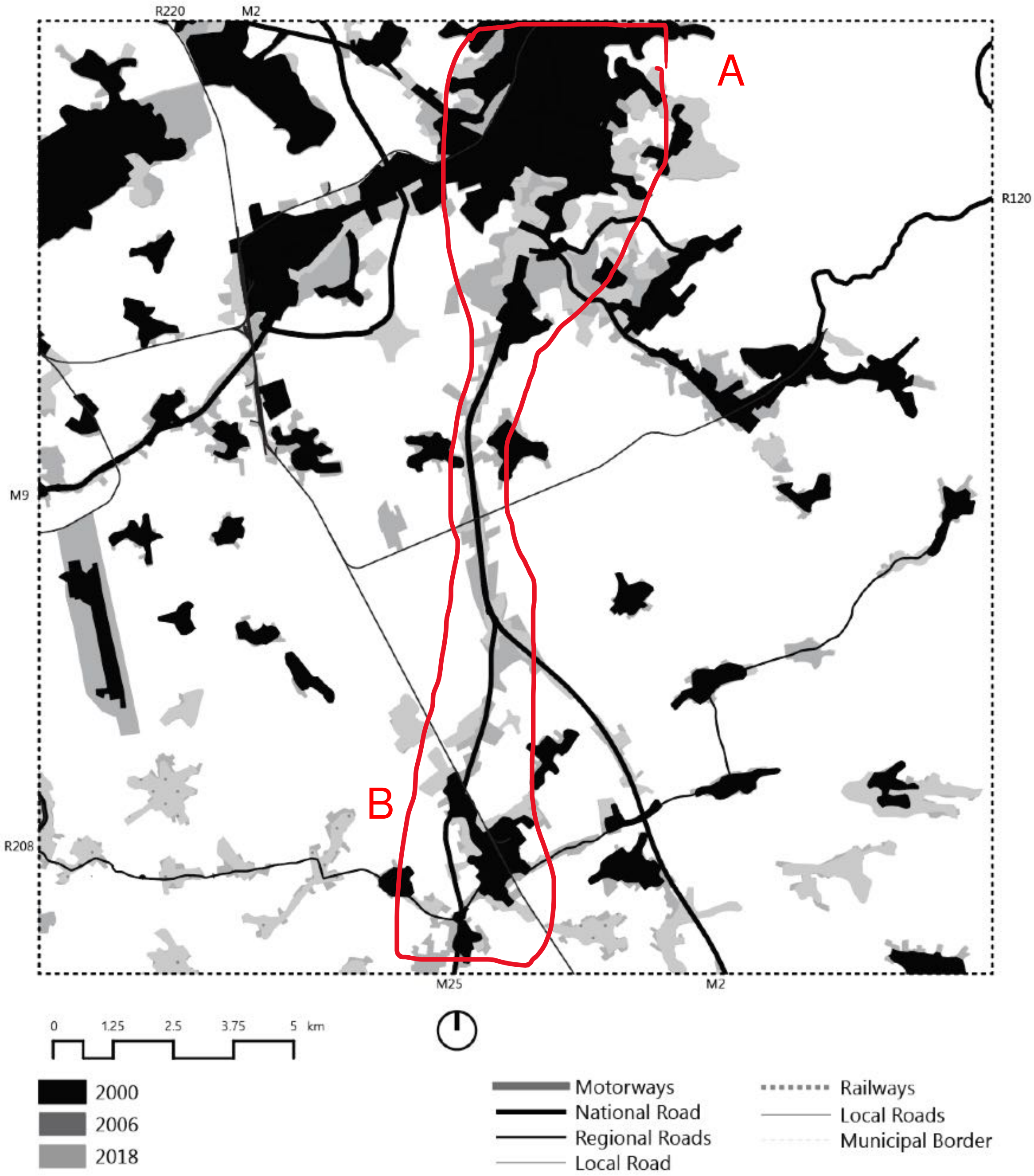

Figure 9 Prishtina (A) and Lipjan (B) and their proximity

One observation that can be pulled, is that building a road infrastructure that connects settlement A with settlement B can lead to a wider horizontal spread. This will in one sense fight the densification of the cities, and possibly lead to various forms of sprawl developing on the outskirts of settlements, along road infrastructure in particular.

This might not be the case and these predictions may change considerably if sprawl is bounded by land development restrictions as seen in many cases around the world. The discussion might be about the extent to which constructing road infrastructure will continue to reshape settlements, and how road infrastructure essentially is promoting sprawl by reducing the cost of transportation and commuting.

This accounts for the linear development that has become a characteristic of development in Kosovo's cities and settlements, and that will be explored in the next chapter.

3.2. LAND: Road Infrastructure and Urban Growth

Urbanization is a demographic and spatial phenomenon that refers to the city as a population concentration center in the economy and society. In general, urbanization and population increase are relatively similar underlying causes, and most examples cannot be distinguished.[53] In this circumstance, vigilance is needed to prevent uncontrolled urban growth. The process, pattern, and outcomes of urban growth determine its quality.

By this point, it is reasonable to conclude that, if left unchecked, road infrastructure has the potential to function as a major attractor of development outside of urban areas. In order to promote urban expansion in a variety of ways, road infrastructure must be properly designed and constructed. It is typically the major driver of urban growth, but it can also be used to manage and aid in smart growth when done properly.

The main idea is that the growth of a place should take occur in a series of sequential steps wherever possible. Initial investments are made in infrastructure, which is subsequently built and developed, serving as the foundation for all future advances.

Because of the increased opportunities for exchange and trade that result from the development of infrastructure, the country's economic development is enabled and facilitated. In the wake of economic development, as well as the creation and expansion of purchasing power opportunities, socio-cultural development happens, which is the primary goal of in improving the quality of life for all citizens. These three

[53] M. M. Aburas, Y. M. Ho, M. F. Ramli, and Z. H. Ash'aari, "Improving the capability of an integrated CA-Markov model to simulate spatio-temporal urban growth trends using an Analytical Hierarchy Process and Frequency Ratio," Int. J. Appl. Earth Obs. Geoinf., 59, 65–78, 2017.

steps can also be thought of as three growth components, namely Geography representing Infrastructure, Economy and the Social component.

In this section, with the help of examples, the findings of this study provide a comprehensive understanding of the consequences of road infrastructure on sustainable development, especially in terms of geography, economy and society.

Growth component 1: Geography

The purpose of this section is to present the correlation between road infrastructure and urban growth. To do this, a few case studies will be presented that demonstrate urban growth as impacted by road infrastructure.

Aside from the positive aspects of urban growth that result from increased connectivity and accessibility as a result of improved road infrastructure, urban growth typically manifests itself in the form of sprawl and suburbanization in the geographical dimension, as the impact is greatest when the population density of settlement centers is reduced, resulting in outer urban growth.

The effect of sprawl and suburbanization as a result of road infrastructure has been studied by Baum-snow, whereupon his findings show that despite a 72 percent rise in metropolitan areas, the population of core cities in the United States declined by 17% between 1950 and 1990. Baum-Snow investigates the impact of new limited-access motorways on population loss in central cities. According to empirical estimations, one additional interstate motorway crossing through a city reduces its population by 18%. The population of central city would have grown by 8% if the interstate motorway system had not been constructed.[54]

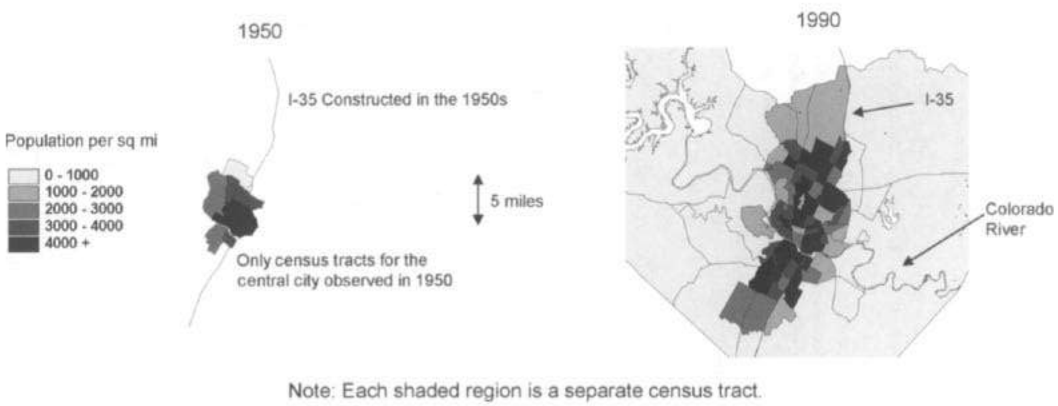

Figure 10 Development Patterns in Austin, TX (source: Baum-Snow, N, 2007)[55]

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[54] Baum-Snow, N. (2007). Did motorways cause suburbanization?. The quarterly journal of economics, 122(2), 775-805.
[55] Ibid

Additional studies on the topic of sprawl and suburbanization caused by rod infrastructure have been carried by Garcia-López, Holl, and Viladecans-Marsal, specifically the impact of motorways on Spanish city suburbanization.

The authors examine Spain's historical roadways because of the endogeneity of motorway provision. For starters, their findings show that between 1960 and 2011, each motorway that originated in a major city, caused a drop in central city population by 8–9%. Second finding shows that each motorway ray increased the population of suburban areas by 20%, particularly in towns and municipalities with ramp infrastructure. Finally, this study confirms that motorways are having an increasing impact on urban form: every kilometer closer to a motorway ramp increased city density growth by 8%.[56]

Growth component 2: Economy

One of the easiest measures of the impact of road infrastructure on overall growth, is the economical side of it, and other aspects related to economy that might indicate growth, such as employment and job locations.

It is important to conduct these studies because they provide information on how cities develop and grow, since they provide a more solid empirical basis for versatile theoretical models of settlements and cities, and because they provide guidance to policymakers who must plan road infrastructure and other complementary public infrastructure.

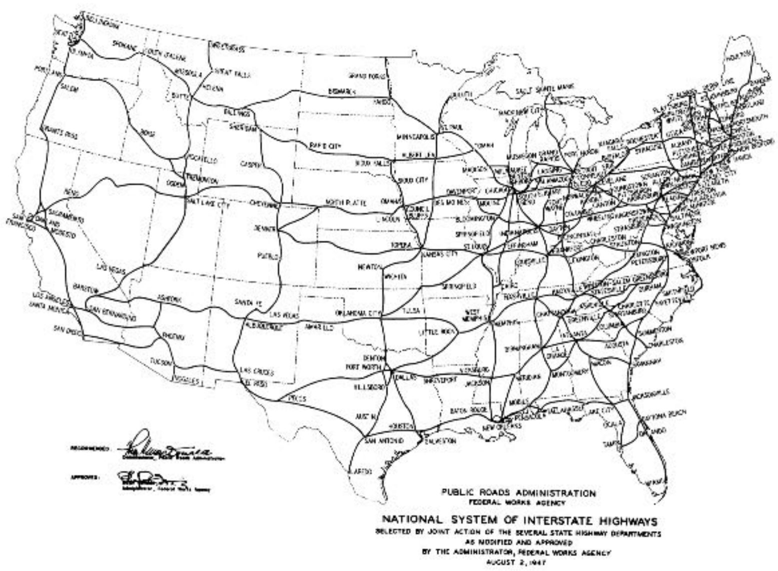

Figure 11 United States' National System of Interstate Motorways and city density

[56] Garcia-López, M. À., Holl, A., & Viladecans-Marsal, E. (2015). Suburbanization and motorways in Spain when the Romans and the Bourbons still shape its cities. Journal of Urban Economics, 85, 52-67.

Duranton and Turner assess the impact of interstate motorways on US city growth from 1983 to 2003. Their findings show that a 10% increase in a city's initial roadway stock results in a 15% increase in employment over a 20-year period. The motorways of 1983 are based on a 1947 plan of the interstate motorway system, an 1898 railroad map, and early US exploration maps.[57]

In exploring and investigating the economic benefits and implications of motorways in China, one of Baum-Snow and his colleagues' main findings is that roads that improve market access have little or no effect on the economic activity or population of the prefecture. These averages obscure an obvious winner-loser trend. Meaning that a better regional motorway network benefits the region's economic output and population at the expense of the prefectures in the hinterland. As can be viewed by the following figure, as travel time and distance drops, GDP and population size tends to rise.

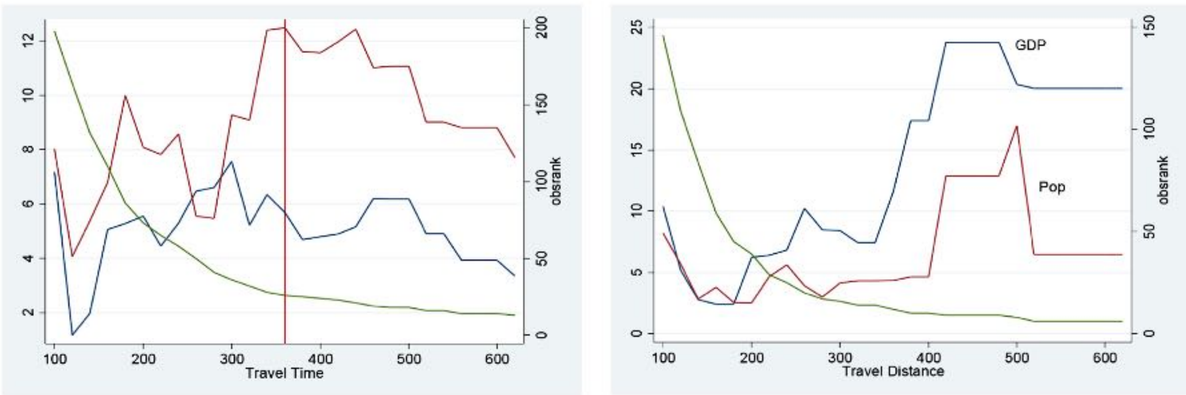

Figure 12 Determining the Number of Regional Primate Cities - Travel Time Based (left), Distance Based (right) (Source: Baum-Snow, N. 2020)

Soundly, the authors of the paper find that specialization patterns are influenced by motorways, in that the better regional motorways allow regional economies to focus on manufacturing and services, while rural areas benefit from increased agricultural production. Better access to international ports enhances population, GDP, and private sector wages, benefits that probably outweigh the downsides of primate prefectures. Investing in local transportation infrastructure to encourage the growth of hinterland prefectures has the reverse effect, resulting in increasing agricultural specialization and a loss of economic activity.[58]

In many cases in China and other Asian countries, there is ample proof that road infrastructure is improving and promoting economic growth, as has been

[57] Duranton, G., & Turner, M. A. (2012). Urban growth and transportation. Review of Economic Studies, 79(4), 1407-1440.

[58] Baum-Snow, N., Henderson, J. V., Turner, M. A., Zhang, Q., & Brandt, L. (2020). Does investment in national motorways help or hurt hinterland city growth?. Journal of Urban Economics, 115, 103124.

demonstrated in many studies and papers.[59] [60] [61] In spite of this, the scope and intensity with which those interventions (particularly in China) were carried out make them unsuitable for comparison with the European setting under consideration in this study.

Growth component 3: Social

Being a well-connected settlement with high accessibility has many advantages, and is the basis for a growing population. Road infrastructure affects jobs, accessibility, as well as lifestyle. Failures in this area can therefore harm a city's economy, functionality, and ecology, as well as create and alienate suburban communities.

Automobile dependency has risen dramatically since after the second World War boom, impacting municipal land use planning. Fast-growing cities and settlements have increased commuting times and distances for suburbanites wanting a metropolitan lifestyle. The growth necessitates an endless cycle of road building to stop it.

For example, Baum-Snow shows that US cities have decentralized to the point where most working residents have no contact with their major metropolises.[62] Motorway construction has played a major part in the rise of suburbs and decline of cities, both as residential and commercial areas.[63] This study by Baum-Snow found that motorways predominantly led within-central city commuters to become within-suburb commuters. If the urban motorway systems had not been developed, the number of commutes within cities would have doubled while commutes within suburbs would have been cut in half. According to the author this reallocation would make these two categories account for 0.31 and 0.30 of total commutes, respectively.

Additionally, findings by Duranton and Turner on their US study, also shed insight on how cities are allotted road infrastructure. They show that cities get road infrastructure in reaction to negative population shocks, meaning that when populations start to drop, road infrastructure is invested in. This shows that roads are built where land and manpower are cheap rather than where they are most needed. This is unlikely to be the best use of infrastructure funds. The structural model presented by the authors allows to assess the social benefits of different transportation plans. This study

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[59] Banerjee, A., Duflo, E., & Qian, N. (2020). On the road: Access to transportation infrastructure and economic growth in China. Journal of Development Economics, 145, 102442.
[60] Yu, N., De Jong, M., Storm, S., & Mi, J. (2012). Transport infrastructure, spatial clusters and regional economic growth in China. Transport Reviews, 32(1), 3-28.
[61] Mohmand, Y. T., Wang, A., & Saeed, A. (2017). The impact of transportation infrastructure on economic growth: empirical evidence from Pakistan. Transportation Letters, 9(2), 63-69.
[62] Baum-Snow, N. (2010). Changes in transportation infrastructure and commuting patterns in US metropolitan areas, 1960-2000. American Economic Review, 100(2), 378-82.
[63] Duranton, G., & Turner, M. A. (2012). Urban growth and transportation. Review of Economic Studies, 79(4), 1407-1440.

concludes that a continuation of the existing expansion rate of their case studies would likely result in more road infrastructure being built than is socially optimal.[64]

Batty (2022) has developed a model that predicts the population distribution along a linear city. The authors of this paper argue that Linear cities want to be accessible to their neighbors and the countryside. These city forms are popular among architects and planners when imagining perfect cities, but they're difficult to implement because they limit development and ignore human behavior relating to where individuals live and how they travel. Authors cover the history of these ideas and the latest proposal to build a 170 km metropolis called Neom in northeastern Saudi Arabia, which has garnered criticism for ignoring how actual cities grow and spread. In this study, authors develop equilibrium conditions that show how a hypothetical city on a line might progressively adapt without controls. First, authors draw a line through the city to show how its population balances out. Expanding the two-dimensional space, the original line crossing over the grid evolves as populations maximize their accessibility. In this 2-D universe, authors simulate forms that show the destructive potential of centralizing and decentralizing forces. This method informs how idealized future cities can depart from linear city-imposed formal designs. [65]

Sustainable growth, which is the desired outcome for most planners, should be achieved by a balanced development of the three components discussed above:; Geography, Economy and Social.

3.3. PATTERNS: Urban Modelling

Throughout history, there have been various forms of urban growth, all of which have some characteristics in common based on the time period, geographical location, or even socio-economic situation. The Mesopotamians, for example, built their cities in a more organic manner, whereas the Egyptians used a grid design to organize theirs[66]. Identifiable patterns can be found in all of these peoples' settlements, and once understood, they make it easier to study and (possibly) predict the form of new settlements by these peoples in the future.

Similarly to what was discussed in the previous chapter, depending on the circumstances, settlements generally have a pattern to the way they grow and evolve. It is critical to identify who is the primary driver of development, as well as the characteristics of that driver, in order to make informed decisions. Furthermore, it must

[64] Duranton, G., & Turner, M. A. (2012). Urban growth and transportation. Review of Economic Studies, 79(4), 1407-1440.
[65] Batty, M. (2022). The Linear City: illustrating the logic of spatial equilibrium. Computational Urban Science, 2(1), 1-17.
[66] Morris, A. E. J. (2013). History of urban form before the industrial revolution. Routledge.

be determined whether or not these qualities are editable, and if so, how they can be modified through the use of alternative values and weights.

The four growth types that determine the probability of a cell becoming urbanized are termed: Spontaneous growth, New Spreading Center, Edge growth Road Influenced growth.[67] There is a meta level of growth rules called 'self-modification' rules, which help to avoid linear and exponential urban growth in the model.[68] The urban growth dynamic implemented in the Urban Growth Model (UGM) contains four types of growth, namely:

Table 10 Types of Growth

Growth Order	**Growth Rule**	**Summary Description**
1	Spontaneous Growth	defines the occurrence of random urbanization of land
2	New Spreading Centers	determines whether any of the new, spontaneously urbanized cells will become new urban spreading centers.
3	Edge Growth	defines the part of the growth that stems from existing spreading centers.
4	Road-Influenced Growth	agents take a road trip along a transportation infrastructure and look for suitable space for urbanization.

Specifically, the goal of this part is to go over some examples of how scientist and urbanists have been able to recognize and predict certain development trends, which are mostly observed through urban modeling.

A Brief history of Urban Modeling

As part of the state-of-art study, this section of the dissertation contains both a chronological and conceptual history of the urban land use-transportation models movement. Urban models are computer-based simulations that are used to test theories concerning the spatial distribution, changes in land uses and the interaction between them and other activities such as transportation, commuting, jobs, etc. These digital simulations allow planners to explore the effects of planning rules and policies on the future layout of settlements in a virtual environment.

67 Clarke, K. C., & Gaydos, L. J. (1998). Loose-coupling a cellular automaton model and GIS: long-term urban growth prediction for San Francisco and Washington/Baltimore. International journal of geographical information science, 12(7), 699-714.
68 Silva, E. A., & Clarke, K. C. (2002). Calibration of the SLEUTH urban growth model for Lisbon and Porto, Portugal. Computers, environment and urban systems, 26(6), 525-552.

Urban Models arose as a result of two interrelated forces: the development of digital computing, which allowed for large-scale simulation to be performed, and the need for policymakers to test the effects of large-scale public investments on cities. Such models is thought to have first appeared in the 1950s in North America, meaning that the first large-scale land-use-transport studies started taking place in major US cities, as did the first generation of urban models.

Among the main contributors to this field are, in instance, Lowry[69], Harris[70], Kilbridge, O'Block and Teplitz)[71], and Brown, Ginn, James, Kain and Straszheim[72] as well as many others, who all gave good assessments of the modelling experience.

Continuedly improved computer hardware and software, combined with a strengthened understanding of how complex systems such as cities grow from the ground up, have resulted in a shift away from theories and structures that define and se land-use and movement (commuting) in aggregate static terms, and toward more dynamic models of individual behavior (often referred to as agent-based) from which spatial structure emerges.[73]

Models have evolved from parsimonious models, in which the number of processes and variables is constrained, to considerably richer structures such as agent-based and cellular automata models, which cannot be verified in the conventional manner.

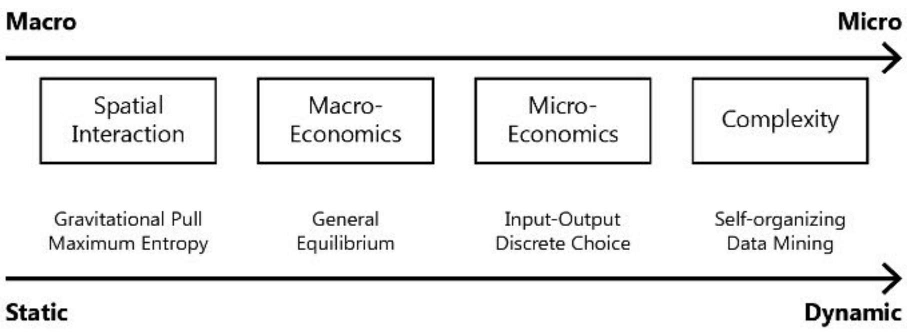

Figure 13 Evolution of Urban Growth Models – From Static to Dynamic

69 Lowry IS (1964) Model of Metropolis. Memorandum RM-4035-RC, Rand Corporation, Santa Monica, CA

70 Harris B (1965) Urban Development Models: A New Tool for Planners. Journal of the American Institute of Planners 31: 90-95

71 Kilbridge, M. D., O'Block, R. P., & Teplitz, P. V. (1969). A conceptual framework for urban planning models. Management Science, 15(6), B-246.

72 Brown, H. J., Ginn, J. R., James, F. J., Kain, J. F., & Straszheim, M. R. (1972). Front Matter to" Empirical Models of Urban Land Use: Suggestions on Research Objectives and Organization". In Empirical Models of Urban Land Use: Suggestions on Research Objectives and Organization (pp. 17-0). NBER.

73 Batty, M. (2009). Urban modeling. International encyclopedia of human geography. Elsevier, Oxford.

Despite the fact that their foundations are built on theoretical conceptions that reach back to the roots of modern social science and with a heavy influence of physics and mathematics, the thinking behind the drafting and design of models is primarily dictated by planning and policies. Even though this field has been around for a relatively brief time, there have been a lot of changes in viewpoints. Furthermore, there have also been changes even to how the city and settlement is modelled including which attributes are used and how they are modelled.[74]

Three particular types of models are explored in the following examples, including the SLEUTH model, the Urban Growth Model (UGM) as well as the Land-Use Transportation Interaction Model (LUTI). Additionally, their theoretical origins and practical applications are explored as well.

In the following section, three examples representing each of the three types of models will be explored, as the proposed model in this dissertation, will be borrowing features from each of these examples explored here. Ultimately, the focus of this section is to demonstrate that urban models are a tool that can be used to better understand and predict the consequences of plans, policies, and measures implemented by planners on the settlement and city under consideration.

Table 11 Summary of three typical groups of urban growth models

Group	**LAND-USE / TRANSPORTATION**	**AGENT BASED MODELLING**	**CELLULAR AUTOMATA**
Target	Socio-economic Activities	Socio-economic Activities & Land-Use	Land-Use
Unit	Zones	Zones and Grids	Grids
Theory	Economics	Economics & Sociology	Self-Organization
Scale & Inputs	Local; Detailed Datasets	Local; Detailed Datasets	Regional; General Datasets

As cities, settlements and flows of people are very complex phenomena, it is impossible for a urban model to be entirely successful in predicting all outcomes, therefore it is important for planners to review the data generated in order to make better decisions.

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[74] Albeverio, S., Andrey, D., Giordano, P., & Vancheri, A. (Eds.). (2007). The dynamics of complex urban systems: An interdisciplinary approach. Springer Science & Business Media.

Example 1: Land-Use / Transportation Model - The SLEUTH Model

SLEUTH is an urban growth and land use change simulation model that was originally developed by Keith Clarke in the early 1990s, in order to model urban growth and land use change.[75] The SLEUTH model is a cellular automata based computer simulation model that utilizes historical land-use, slope, road, and hill shade information to calibrate and simulate the land use/land cover change and urban growth.

The name is an acronym that originates from GIS input data images, namely: Slope, Land-use, Excluded (where development can't happen), Urban, Transportation and Hill shade. The SLEUTH model was first applied to the San Francisco Bay area between 1993 and 1997, and it has since been applied to more than 100 cities and metropolitan zones throughout the world.[76]

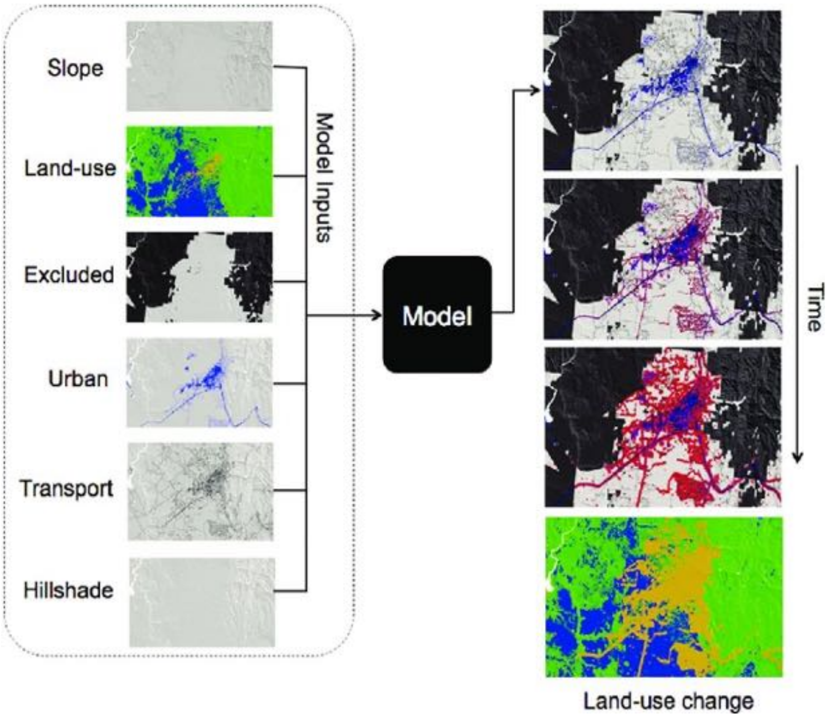

Figure 14 A basic SLEUTH-type model based on growth rules as defined by Clarke (Author: Andrew Crooks)

The model has contributed to a better understanding of urban growth and its consequences for planning strategies in a variety of places, and it is one of the most commonly used Cellular Automata based urban growth simulation models that focuses on urban growth and development, according to the authors.[77] SLEUTH implementation has two stages. The first phase is called calibration, and the second

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[75] Clarke, K. C. (2008). Mapping and modelling land use change: an application of the SLEUTH model. In Landscape analysis and visualisation (pp. 353-366). Springer, Berlin, Heidelberg.
[76] Ibid
[77] Jantz, C. A., Goetz, S. J., Donato, D., & Claggett, P. (2010). Designing and implementing a regional urban modeling system using the SLEUTH cellular urban model. Computers, Environment and Urban Systems, 34(1), 1-16.

is called prediction, in which SLEUTH is trained to predict how things will go in the future based on how things have gone before.[78]

In this model, each cell can be used for either urban or nonurban things. People, land use, transportation, and slopes and hillsides as a background are all GIS-based inputs in this SLEUTH model. All of the rows and columns in the input layer must be the same number of rows and columns, have the correct geo-reference, and be very exact.

There should be at least four time periods in which urban levels can be used to calibrate the model statistics. The figure below shows what data the SLEUTH model needs in terms of Input Layers, ways of preparation and format. Much of this data is prepared in rasters in GIS, that can be overlayed on top of each-other. When the SLEUTH model is used in developing countries, where resources are limited, high-end technology is needed to process the many datasets that are needed to make the model work. [79]

Table 12 Data requirement for the SLEUTH Model[80]

Input Layer	Prepared Through	Format
Urban Extension	Supervised Classification of Satellite Image	Raster
Transportation network	On-Screen digitization from satellite image	Raster
Slope	Derived from DEM (digital elevation model)	Raster
Hill shade	Derived from DEM (digital elevation model)	Raster
Excluded area	Rasterized from vector	Raster

The SLEUTH Model is illustrated in the graphic below as an example. The model, which was created in NetLogo, depicts the impact of road infrastructure on urban growth and the development of new land. There are inputs and layers required for a

[78] N. Bihamta, A. Soffianian, S. Fakheran, and M. Gholamalifard, "Using the SLEUTH urban growth model to simulate future urban expansion of the Isfahan Metropolitan Area, Iran," J. Indian Soc. Remote Sens., 43(2), 407–414, 2015.
[79] Ibid
[80] A. A. A. Al-sharif and B. Pradhan, "Monitoring and predicting landuse change in Tripoli Metropolitan City using an integrated Markov chain and cellular automata models in GIS," Arab. J. Geosci., 7(10), 4291–4301, 2014.

model of this type on the left side of the screen. The software generates a variety of outputs based on the changes made to the inputs.

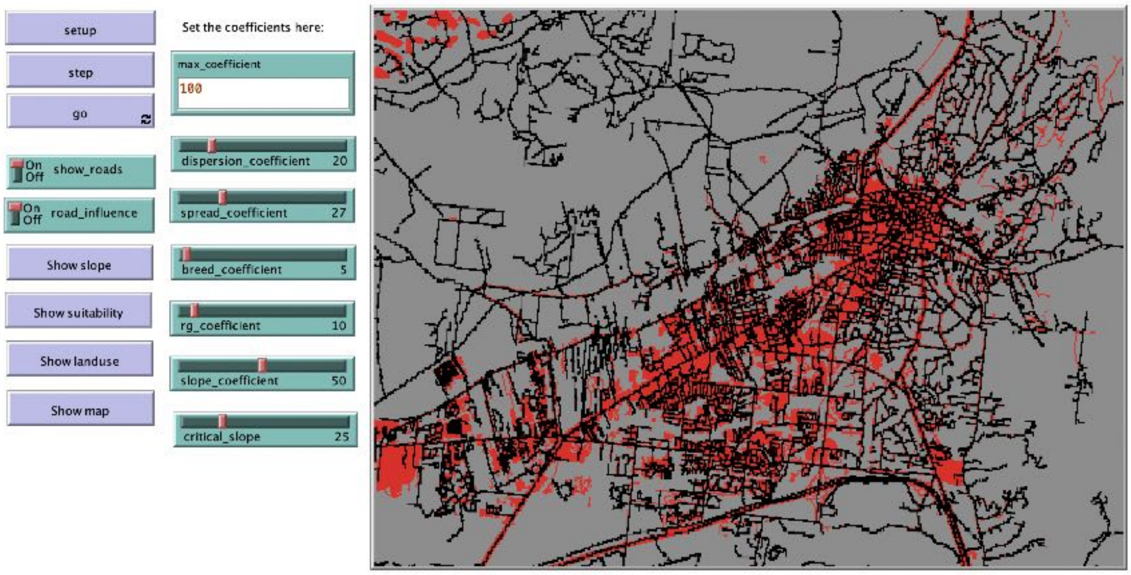

Figure 15 Urban Growth Model of Santa-Fe, with data obtained from the National Map[81], developed with NetLogo

Example 2: Agent-Based Modelling (ABM)

Agent-based modelling (ABM) is another type of models that is gaining traction. This type of model is a computational study that simulates the activities and interactions of autonomous agents (individuals or collective entities like organizations or groups) to better understand system behavior and results. These models depict the actions and behaviors of individuals (or agents) in space.

This particular type of model has been used in architecture and urban planning to analyze design and simulate pedestrian flow in urban environments,[82] as well as in the examination of public policy implications to land-use.[83] The discipline of socio-economic impact analysis of infrastructure investment, which makes use of ABM's ability to discover systemic consequences upon a socio-economic network, is likewise rising in importance.[84]

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[81] Clarke, K. C, Gaydos, L., and Hoppen, S., A self-modifying cellular automaton model of historical urbanization in the San Francisco Bay area. Environment and Planning B 24: 247-261

[82] Aschwanden, G.D.P.A; Wullschleger, Tobias; Müller, Hanspeter; Schmitt, Gerhard (2009). "Evaluation of 3D city models using automatic placed urban agents". Automation in Construction. 22: 81–89.

[83] Brown, Daniel G.; Page, Scott E.; Zellner, Moira; Rand, William (2005). "Path dependence and the validation of agent-based spatial models of land use". International Journal of Geographical Information Science. 19 (2): 153–174.

[84] Smetanin, P., & Stiff, D. (2016). Investing in Ontario's public infrastructure: a prosperity at risk perspective, with an analysis of the greater Toronto and Hamilton area. The Canadian Centre for

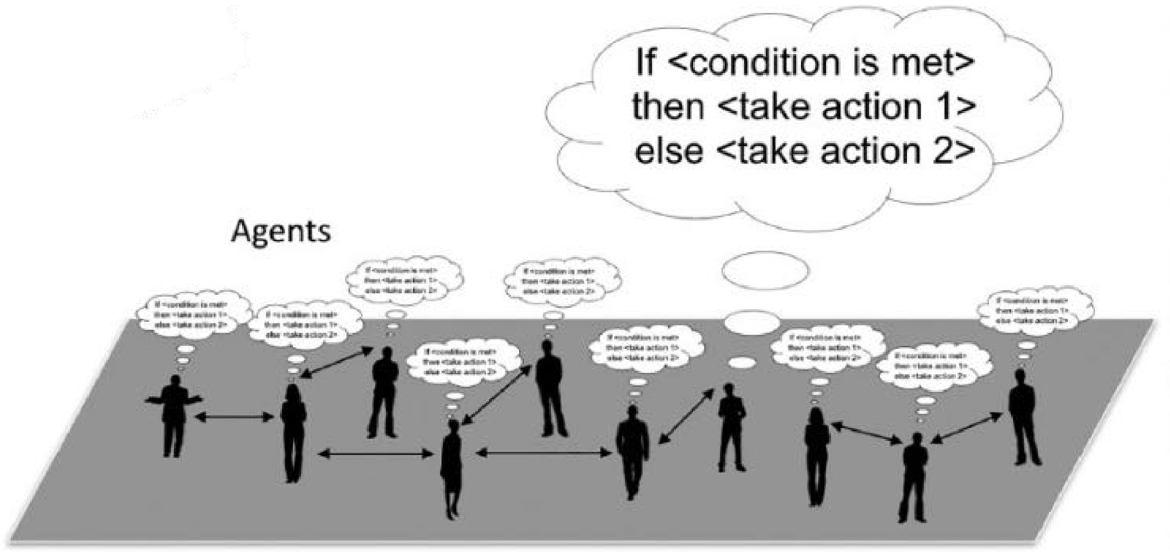

Figure 16 Conceptualization of an agent-based model where people are connected to each other and take actions when a specific condition is met[85]

There is a lot of research on specific issues in urban systems. They are used in urban land use, residential segregation, commodity or resource flows, risk analysis in emergencies, and policy consequences. One of the most famous applications of ABM is in depicting Schelling's Segregation model.[86]

For example, increasing the preference for the percentage of agents who are similar to themselves would lead to the formation of more pronounced patterns of segregation, as illustrated in the figure below. This means that using this type of model, it is possible to investigate the underlying causes of segregation in greater depth.[87] While it is possible to measure the degree of segregation inside neighborhoods, it is difficult do so across neighborhoods. Attempting to prevent such a process or phenomenon becomes difficult in the absence of the knowledge obtained from such tools as this model..

Economic Analysis, 2015. Investing in Ontario's Infrastructure: A Prosperity at Risk Perspective, with an analysis of the Greater Toronto and Hamilton Area Page, 2, 4.

[85] Crooks, A. (2015). Agent-based modeling and geographical information systems. Geocomputation: A practical primer, 63-77.

[86] Crooks, A. T. (2010). Constructing and implementing an agent-based model of residential segregation through vector GIS. International Journal of Geographical Information Science, 24(5), 661-675.

[87] Reardon, S. F., & O'Sullivan, D. (2004). Measures of spatial segregation. Sociological methodology, 34(1), 121-162.

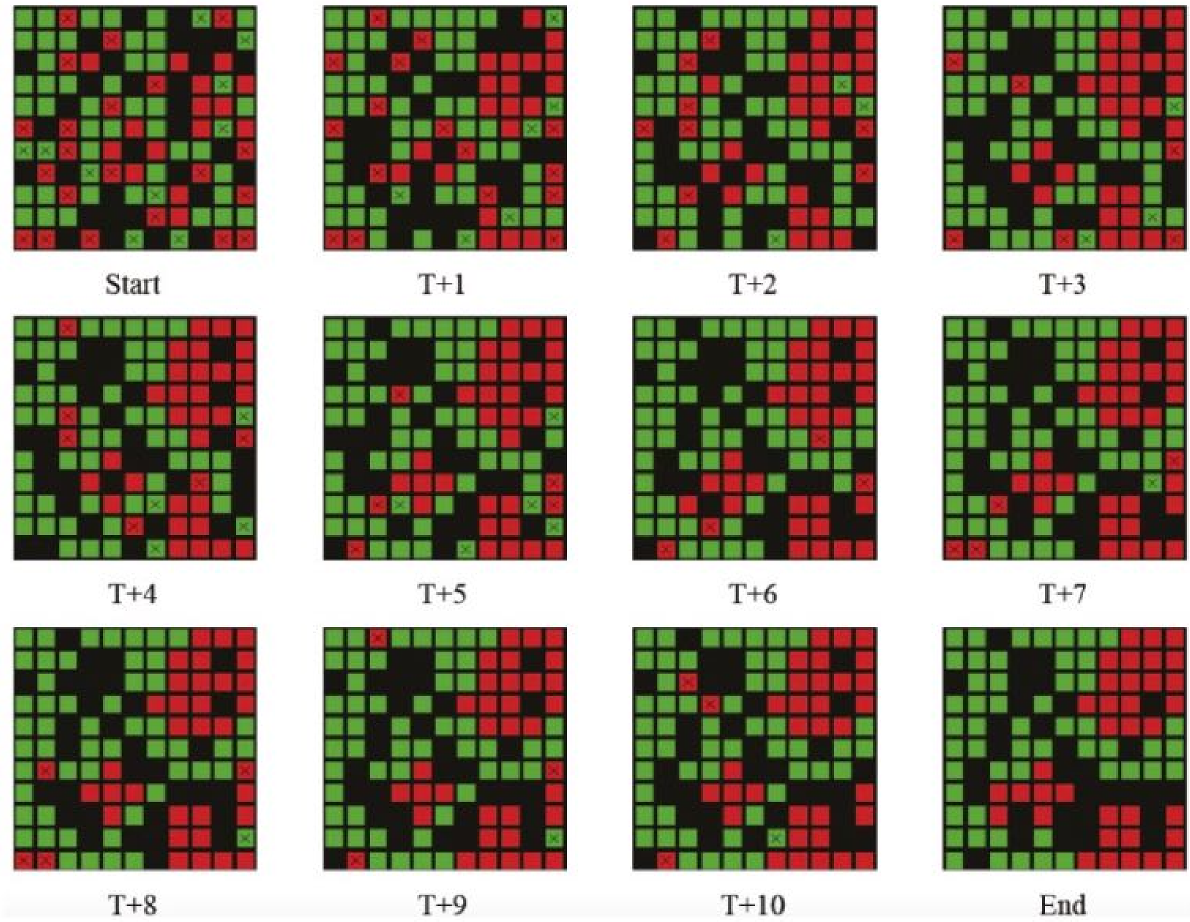

Figure 17 Progression of segregation over time: agents want to live in a neighborhood where 40% are of the same color[88]

Various precursor models, such as Chapin and Weiss's North Carolina housing market models[89] and Ingram, Kain, and Ginn's housing market models[90], were built around individuals, market processes, and developer decisions, meaning that there are many applications of agent-based models. However, the main focus of agent-based models is micro-level traffic simulation.[91]

Agent-Based Modelling (ABM) is widely used in conjunction with other modeling methodologies, owing to the fact that it is primarily a modeling framework rather than a single piece of software or platform. For example, agent-based models have been coupled with Geographic Information Systems (GIS) in some cases. In this case, the

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[88] Crooks, A. (2015). Agent-based modeling and geographical information systems. Geocomputation: A practical primer, 63-77.
[89] Chapin Jr, F. S., & Weiss, S. F. (1968). A probabilistic model for residential growth. Transportation research, 2(4), 375-390.
[90] Ingram, G. K., Kain, J. F., & Ginn, J. R. (1972). Front matter, the Detroit prototype of the NBER urban simulation model. In The Detroit Prototype of the NBER Urban Simulation Model (pp. 28-0). NBER.
[91] Castle, C. J., & Crooks, A. T. (2006). Principles and concepts of agent-based modelling for developing geospatial simulations.

ABM acts as a process model, and the GIS system can function as a pattern model, which is a valuable combination.[92]

A big advantage to agent-based modeling is that it can quickly build "realistic" agents by getting information from a lot of different sources. There are also important constraints that the researcher needs to be aware of, such as whether the model's purpose is to predict, or whether the inputs and attributes of the model are correct.

Furthermore, It is critical to verify that the model has been thoroughly inspected, including all values such as inputs and weights, etc. It is still a significant task to evaluate agent-based models. Additionally, the model has to know what is being examined, such as a measure, pattern, or process – as well as its size or magnitude. When creating an agent-based model, one should consider how the model will be calibrated and validated as well.

Example 3: Cellular Automata Models (CA)

The most widely known empirical but rarely used policy-making model is based on cellular automata, where agents are cells that modify their land use cell state. There are many applications, but few are utilized to test urban policy because transportation is handled poorly or even excluded in this type of model.[93] The main focus is on urban growth, which nowadays is sometimes referred to as sprawl, with these models being more suggestive than predictive. Other issues with such models include their physicalist focus, which ignores spatial economy characteristics like property prices, wage rates, and transportation expenses.

The state of each cell is similar to that of an agent in an agent-based model, in that it can contain a wide range of characteristics. CA-based models have been widely used for a long time because of their simplicity, flexibility, and intuitiveness. Their origins can be traced back to the early days of computer science and fractal theory [66], and they are still in use today.

$$S_{ij}^{t+1} = f\left(S^{t}_{ij}, \Omega^{t}_{ij}, T \right)$$

where S_{ij}^{t+1} is the state of cell (i, j) at time t + 1, which is closely related to the current state of cell S^{t}_{ij} ; the impact of its neighborhood Ω^{t}_{ij} and the transition rules T by a particular linkage of T. In other words, the future state of the analyzed cell, in entirely dependent on the current state that same cell, as well as the current state of its

[92] Zhang, J., Tong, L., Lamberson, P. J., Durazo-Arvizu, R. A., Luke, A., & Shoham, D. A. (2015). Leveraging social influence to address overweight and obesity using agent-based models: the role of adolescent social networks. Social science & medicine, 125, 203-213.
[93] Batty, M. (2005). Agents, cells, and cities: new representational models for simulating multiscale urban dynamics. Environment and Planning A, 37(8), 1373-1394.

neighbors. The neighborhood rules and transition rules are considered to be two key components in CA- based models.

An example that can illustrate the manner in which CA-based models work is Conway's Game of Life, which is a very straightforward model that operates on a rectangular lattice. A cell has a single property and can exist in one of two states: 'dead' or 'living'. The model's rules are also straightforward. Each cell evaluates its own state and the states of the eight cells in its Moore neighborhood (see chapter 6) and, based on the statuses of these cells, the cell either stays alive, or dies.

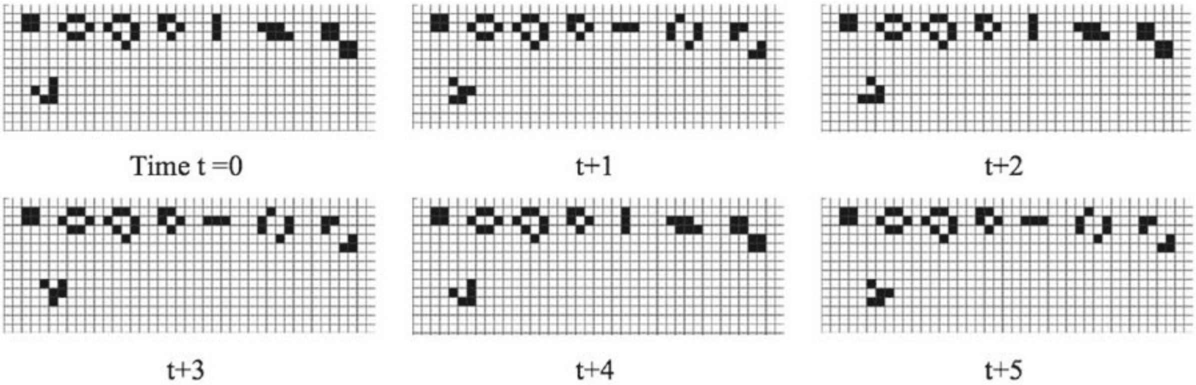

Figure 18 Example of cells changing state from dead (white) to alive (black) over time depending on the states of their neighboring cells[94]

This indicates that complex patterns can arise from simple, well-defined rules over a long period of time and space, meaning that different levels of complexity can emerge based on transition rules and cell state.

From a geographical standpoint, the first prominent application of a cellular automaton was for the purpose of urban growth and land use planning and allocation (e.g. Tobler, 1979)[95]. Because of its relative simplicity in implementation, cellular automaton modeling continues to be a popular choice for simulating large-scale urban phenomena such as urban sprawl, for example the previously mentioned SLEUTH model possesses some aspects of Cellular Automata.

3.4. Summary

Road infrastructure is an important factor that can determine the direction and intensity of urban growth. In developing countries, road infrastructure is frequently seen as the most important tool for promoting the ongoing growth of the economy and society. However, with this in mind, poor planning is frequently undertaken, perhaps on

[94] Wilensky, U., & Rand, W. (2015). An introduction to agent-based modeling: modeling natural, social, and engineered complex systems with NetLogo. Mit Press.
[95] Tobler, W. R. (1979). Cellular geography. In Philosophy in geography (pp. 379-386). Springer, Dordrecht.

purpose, with disastrous consequences manifested in the form of sprawl and unplanned growth. As a result, great attention needs to be paid when planning such infrastructure. Furthermore,

Road infrastructure is also crucial in the urban planning of communities since it allows for the movement of people. Some may see a decline, while others may experience an increase, and some may experience a complete disappearance. It is also possible that, in some exceptional circumstances, road infrastructure can be used to retain the shape and size of settlements while also providing people with access to other amenities that are not necessarily available in the settlement itself.

Upon understanding the theoretical aspect of urban growth, it is also worth noting that urban models span both theory and practice and that their rationale depends on developing new theory as well as their use in policy-making and planning. The rise of more micro-dynamic CA models and ABMs are being applied, as a tool to tend to concern more particular processes in cities such as segregation, housing market policies, pedestrian movement and related behaviors. What has happened however is a broadening of styles and model types.

Urban Models can be extremely useful tools for bridging the gap between theory and practice, as well as the policy-making and planning sides of the equation when it comes to understanding the impact of transportation infrastructure on land development.

CHAPTER 4

ROAD INFRASTRUCTURE AND ITS IMPACT ON LAND-USE: CURRENT PERSPECTIVE ANALYSIS

In this chapter, data gathered and processed through empirical research is presented in the form of maps and diagrams. This chapter shows how the information from site visits as well as cartographic information is translated into diagrams and then into quantitative values, to be used by the proposed model.

4. ROAD INFRASTRUCTURE AND ITS IMPACT ON LAND-USE: CURRENT PERSPECTIVE ANALYSIS

A qualitative review of the empirical study is carried out in this chapter, which provides information about the actual situation on-the-ground as well as the state of urban development and growth in conjunction with road infrastructure, as observed in reality.

It has been demonstrated that the dependency of the road with the growth or development of the land has a quantitative measuring indicator - which was stated before, i.e. through proximity - that can be used to quantify the relationship. The addition of the qualitative dimension provides a clearer picture of the development of the patterns of settlement and urban growth, under discussion in the context of a number of selected case studies.

However, bringing maps that illustrate the manner of expansion, without prejudging the qualitative type of growth, is the first stage in data analysis that provides a first view of how cities in Kosovo are developing and so provides the first impression of how cities in Kosovo are developing.

It is necessary to physically examine several diagrams or maps of Kosovo settlements such as Prishtina, Mitrovica, Ferizaj, Gjilan, Gjakova and Peja in order to comprehend the volume and intensity of growth and development that has occurred. Each settlement has its own distinct pattern of growth and development, and it is worthwhile to investigate the factors that have contributed to this pattern of growth and development in order to better understand it.

This qualitative aspect of research will be contributed through the examination of these case studies of some of the largest settlements in Kosovo, as well as the explanations for why and how this growth or development is taking place in conjunction with the construction of road infrastructure.

Further on in this chapter, the explanation and development of the case studies will be provided, including how they were selected, what data was used, and how they will be addressed in the context of this study. Furthermore, the graphic presentation, as well as the database that will be used for this study, will be discussed in further detail.

Finally, a number of case studies from each type of road will be investigated and studied, and these will be used as case studies in evaluating the model suggested in the following chapter of this study, which will be discussed further below.

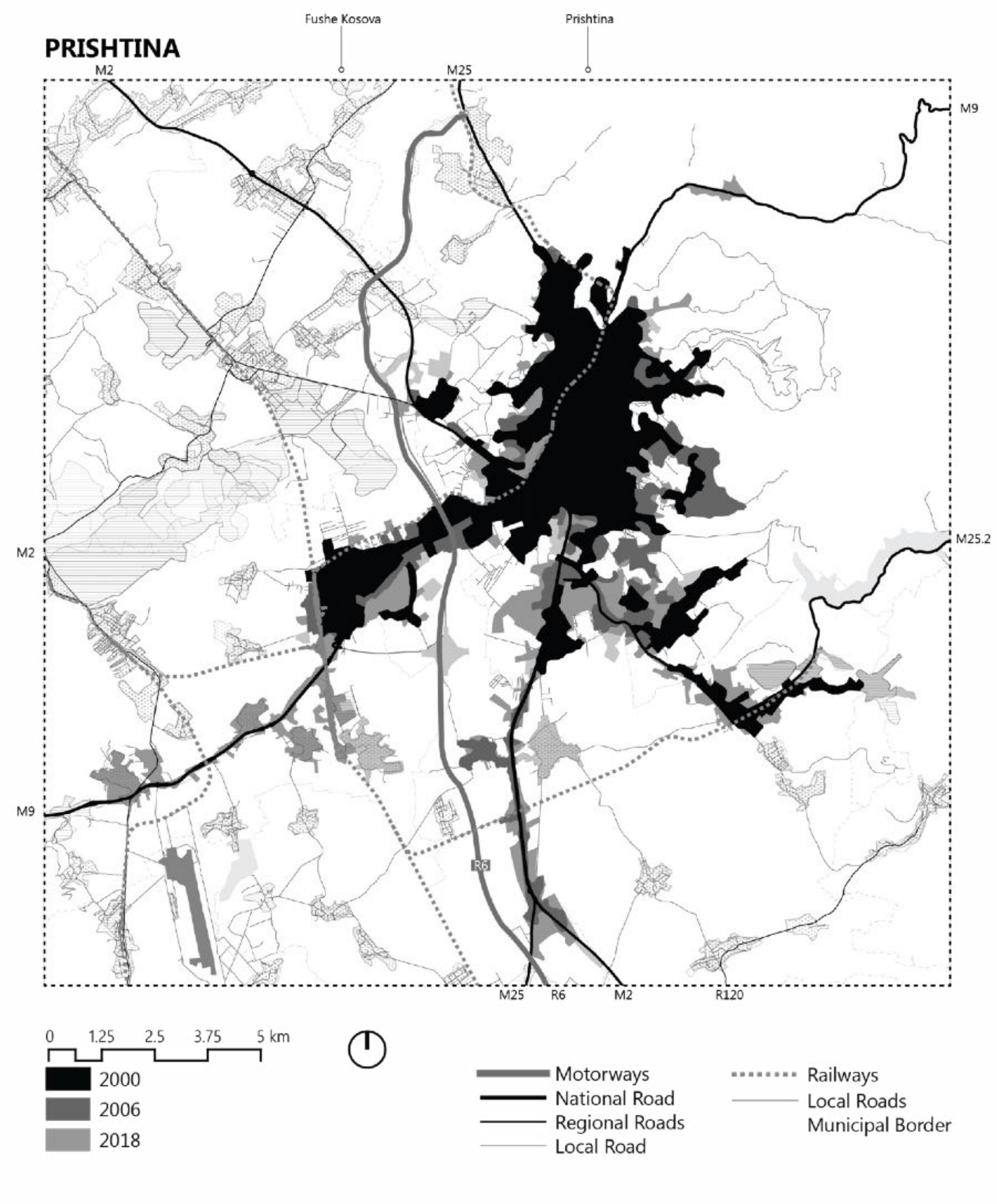

Figure 19 New Land Development in Prishtina

The expansion diagram for Prishtina demonstrates that new developments (shown in gray color) have appeared in significant numbers along the city's road infrastructure. The primary arteries are the M2 national level road, which runs south of the capital and links to Lipjan; from the west, the M9 road runs through Fushë Kosova and continues west. Additionally, there is the road M2, also a national level road, which runs north-westerly toward the settlements of Vushtrri and Mitrovica.

Along the western section of the M9 motorway, the settlement of Fushë Kosova has been almost entirely absorbed into the capital, thanks to the road infrastructure. Although Fushë Kosova provides adequate services to remain sustainable, the road's character, which is primarily commercial with some industrial services, has pushed this settlement toward the city. Additionally, the relatively short distance between these two settlements has aided in the acceleration of this absorption.

Figure 20 Prishtina - Fushë Kosova (M9 road)[96]

The opposite route, particularly the M2 road to Lipjan, has a slightly different form of development, as it is not as compact as the previous scenario, but rather sporadic and sprawled along the road. This is owing to the larger distance between the two settlements, as well as the road's nature, which contains more separately organized business or industrial units. These units are also accessible mainly by car, and therefore bear some typical characteristics of sprawl (see the figure below).

Figure 21 Prishtina - Lipjan (M2 Road)[97]

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[96] Prishtina Insight. Kosovo Struggles with Long-Term Illegal Building Boom. (2016) https://prishtinainsight.com/kosovo-struggles-long-term-illegal-building-boom/ (retrieved: February 2022)

[97] Mapio.net https://mapio.net/pic/p-77570144/ (retrieved: February 2022)

As the M25 Road leading to Podujeva is more mountainous and windy, it has a fewer number of new developments. The characteristics of the geography and terrain, namely slopes, did not allow for the type of sprawled development to occur as with all three previous cases presented here.

Figure 22 Prishtina - Podujeve (M25 Road)[98]

Simillarily to the M2 in the south direction, the M2 road, leading to the settlements of Vushtrri and Mitrovice, also has development that is essentially spwarl in character. Much of the new developments have been possition along the road infrastructure, despite the fact that this particular road has been under construction for a long period of time. This road too has a character that mainly houses bursinesses and small to medium industrial shops and werehouses.

Figure 23 Prishtina - Mitrovica (M2 Road)[99]

[98] Llapi.info. Magjistralja Prishtine – Podujeve. (https://www.llapi.info/banoret-kerkojne-nga-veliu-parking-per-xhematin-te-xhamia-e-vjeter-ne-podujeve/magjistralja-prishtine-podujeve/ (retrieved: February 2022)

[99] Dailymotion.com. Rruga M2 Prishtine - Mitrovice, 31 Tetor 2015. (2015). https://www.dailymotion.com/video/x3btcgh (retrieved: February 2022)

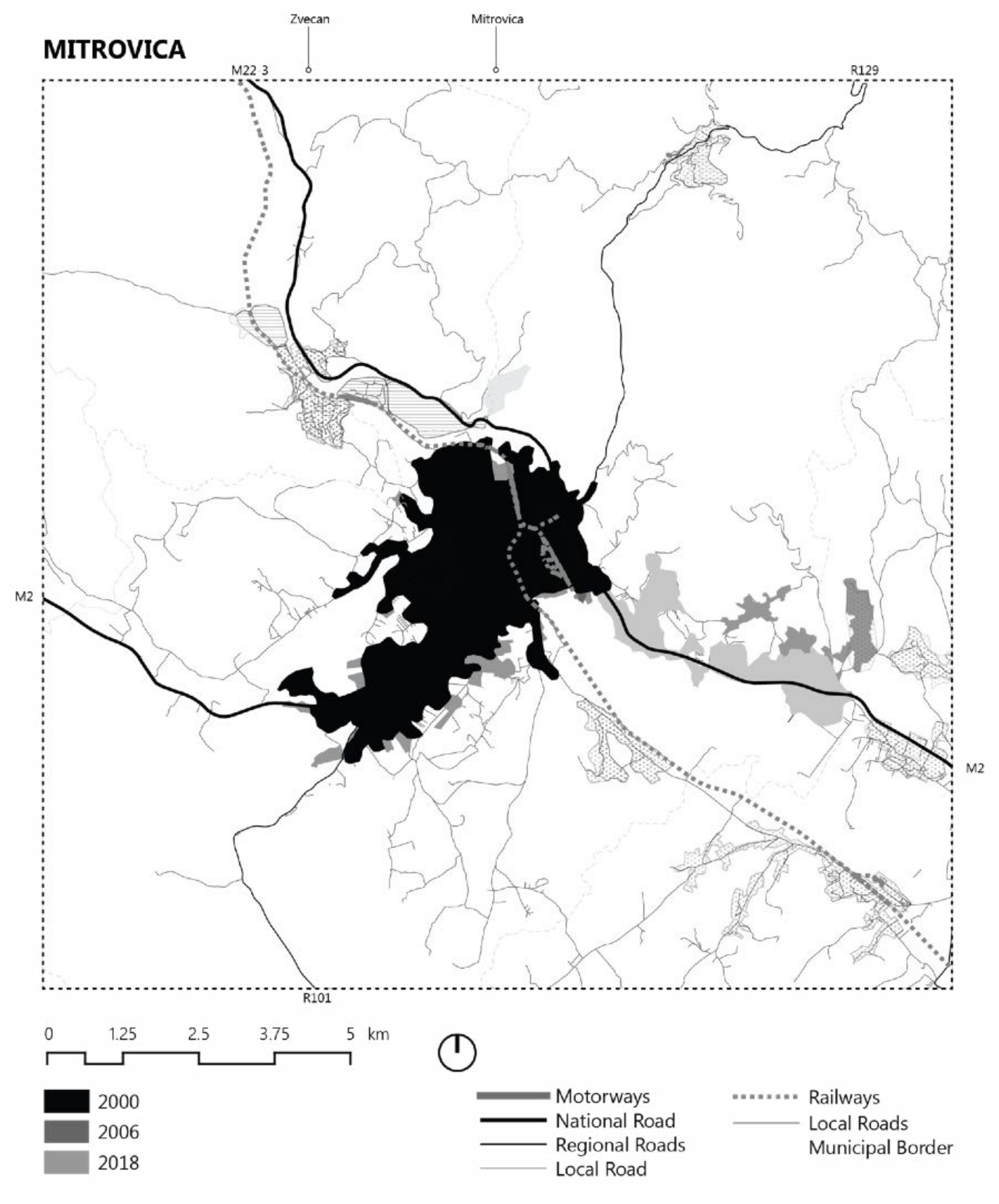

Figure 24 New Land Development in Mitrovica

The settlement of Mitrovica has had most of its development occur in the southern part, between and along the M2 National Road and the R101 Regional Road. Because of geo-political reasons, Mitrovica has struggled to stay connected to the northern part of the country, making the south the most attractive part for development. As is the practice in these cases, this new development (especially after the war of 1999) has happened along the road infrastructure, again in the form of parallel spawl.

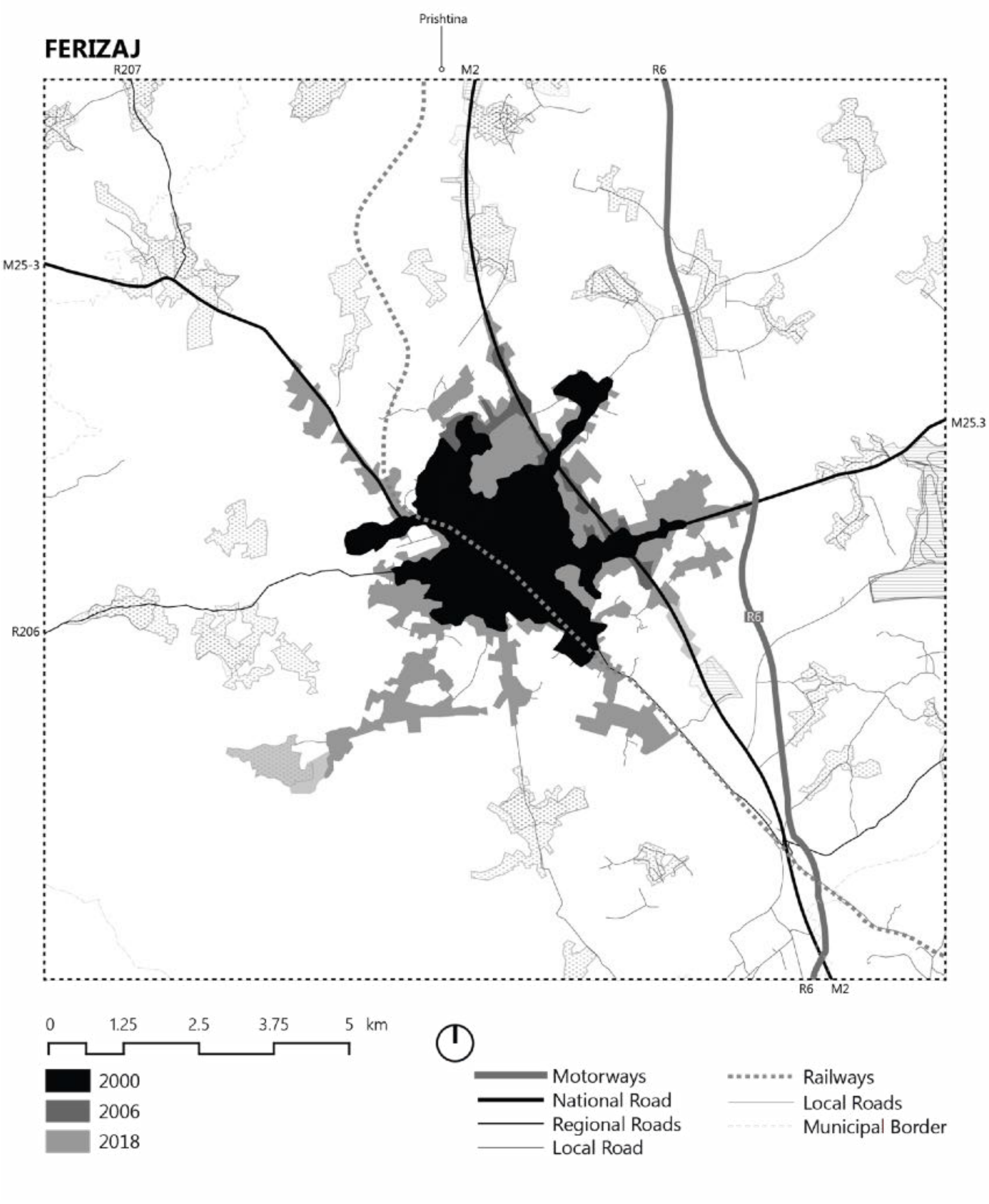

Figure 25 New Land Development in Ferizaj[100]

Ferizaj is relatively more compact in its form compared to the capital Prishtina, as it is a much smaller settlement. However, it, too, has demonstrated a proclivity for sprawl along road infrastructure, particularly to the north along the M2 National Road, as well as to the north-west along the M25-3 road, toward the settlement Shtime, which is the nearest settlement to this study case.

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[100] Data from CORINE Land Cover and the Kosovo GeoPortal (Illustration by Author)

Additionally, the road leading south to the border with Northern Macedonia is a vital connection to Ferizaj, as the capital Skopje is a significant business partner.

The M2 Road connecting the settlement to the capital is the most developed as the new developers seek to offer services to both the capital with its visitors, as well as to the settlement of Ferizaj itself. Again similarly to the road connecting Prishtina to Lipjan, this road too is mainly populated with small businesses and small workshops. Even though there is significant sprawl along this road, it shows tendencies that it can still be further developed in that manner, which is something that needs considering.

Figure 26 Ferizaj - Prishtina (M2 Road)[101] (Periskopi, 2018)

As the settlement of Shtime is very closely positioned to Ferizaj, a what can be considered natural growth has happened in the road connecting these two settlements. This, as explained in Chapter 3, is due to the fact that developers can benefit from being positioned between the two settlements, and because of the proximity, they can attract residents of both settlements.

Figure 27 Ferizaj - Shtime (M25-3 Road)[102] (YouTube, 2015)

[101] Periskopi.com. Magjistralja Prishtinë-Ferizaj. (2018). https://www.periskopi.com/reshje-te-medha-shiu-vershohet-magjistralja-prishtine-ferizaj-foto/ (retrieved: February 2022)
[102] Youtube.com. Rruga Ferizaj - Shtime (M25-3). (2015). https://www.youtube.com/watch?v=uX6ln8JhqTs (retrieved: February 2022)

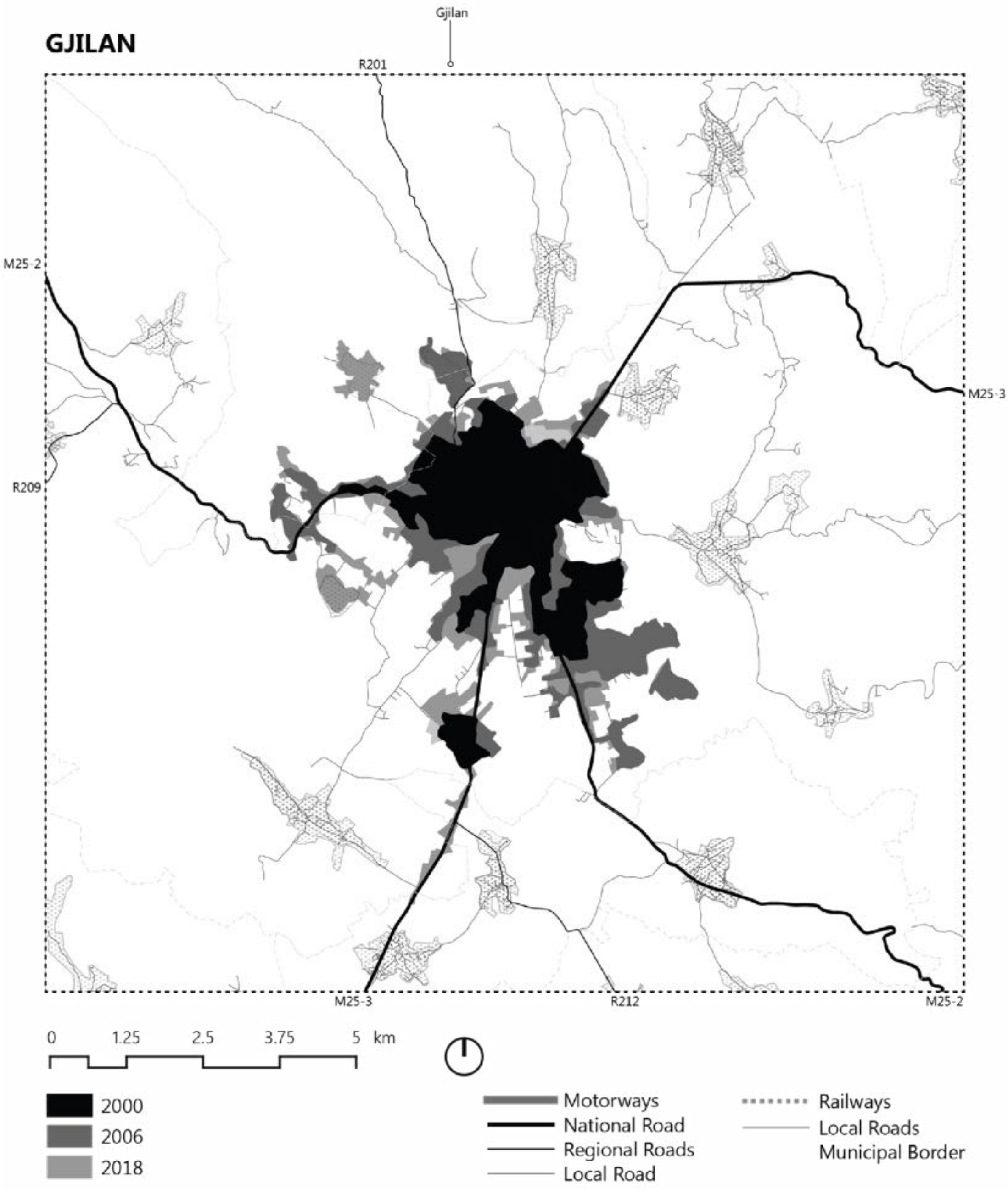


Figure 28 New Land Development in Gjilan[103]

Similarly to Ferizaj, Gjakova too is a more compact settlement then the other cases, however there is significant sprawling along the M25-2 route that leads to Preshevë, a settlement with a predominantly Albanian population, but located in the neighboring state of Serbia. This is due to the fact that the Preshevë, even though settlement of another country, regards Gjilan as one of the main points of contact, especially regarding trade and other services.

[103] Data from CORINE Land Cover and the Kosovo GeoPortal (Illustration by Author)

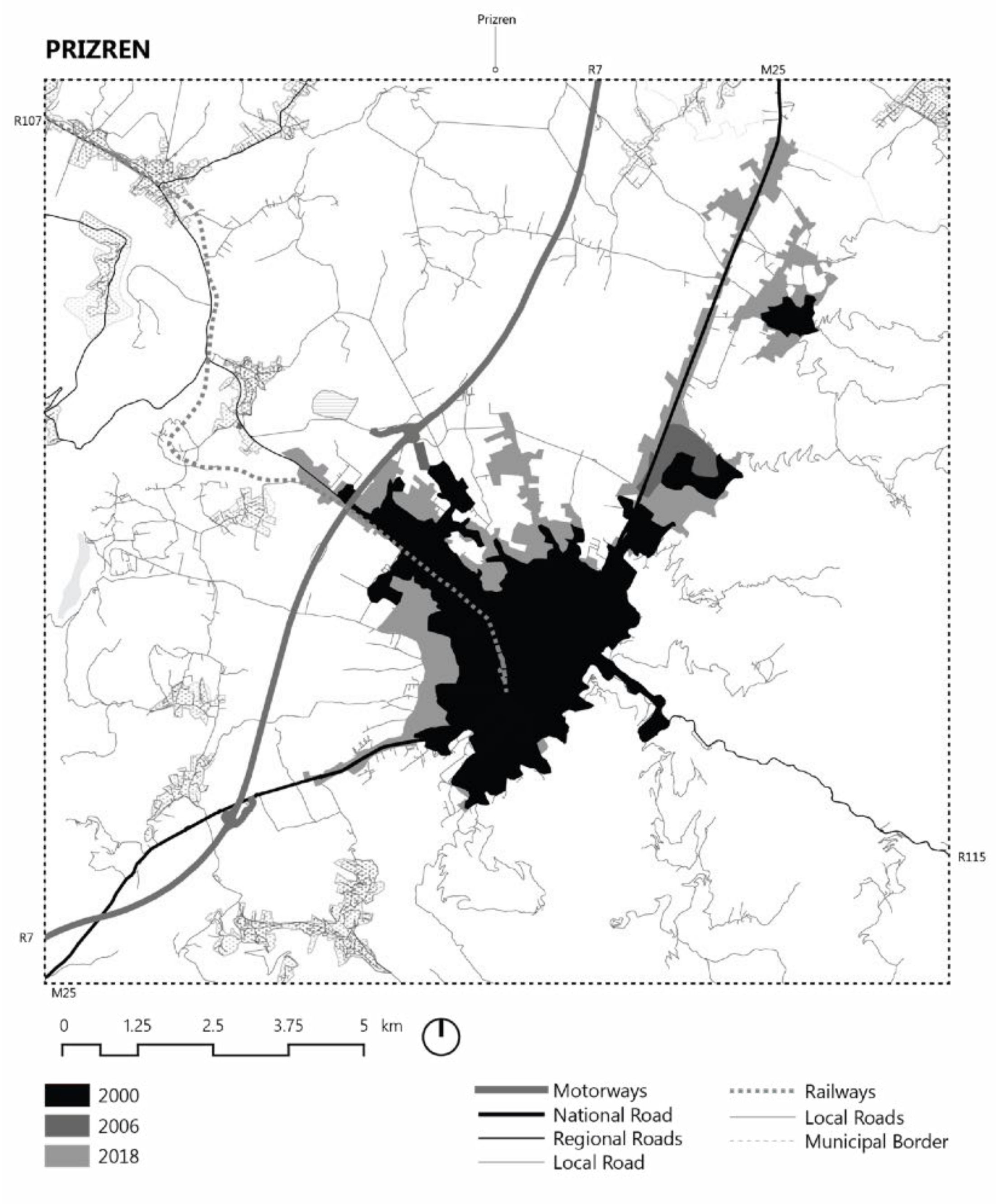


Figure 29 New Land Development in Prizren[104]

Prizren has had significant sprawl along three directions, along the M25 to the north and to the east, as well as to the north-west along the R107. There is no significant development to the south because of the terrain, as well as to the fact that most neighboring settlements are to the north. Prizren is the second largest settlement in Kosovo, and most development along road infrastructure is of individual units with business and industrial character.

[104] Data from CORINE Land Cover and the Kosovo GeoPortal (Illustration by Author)

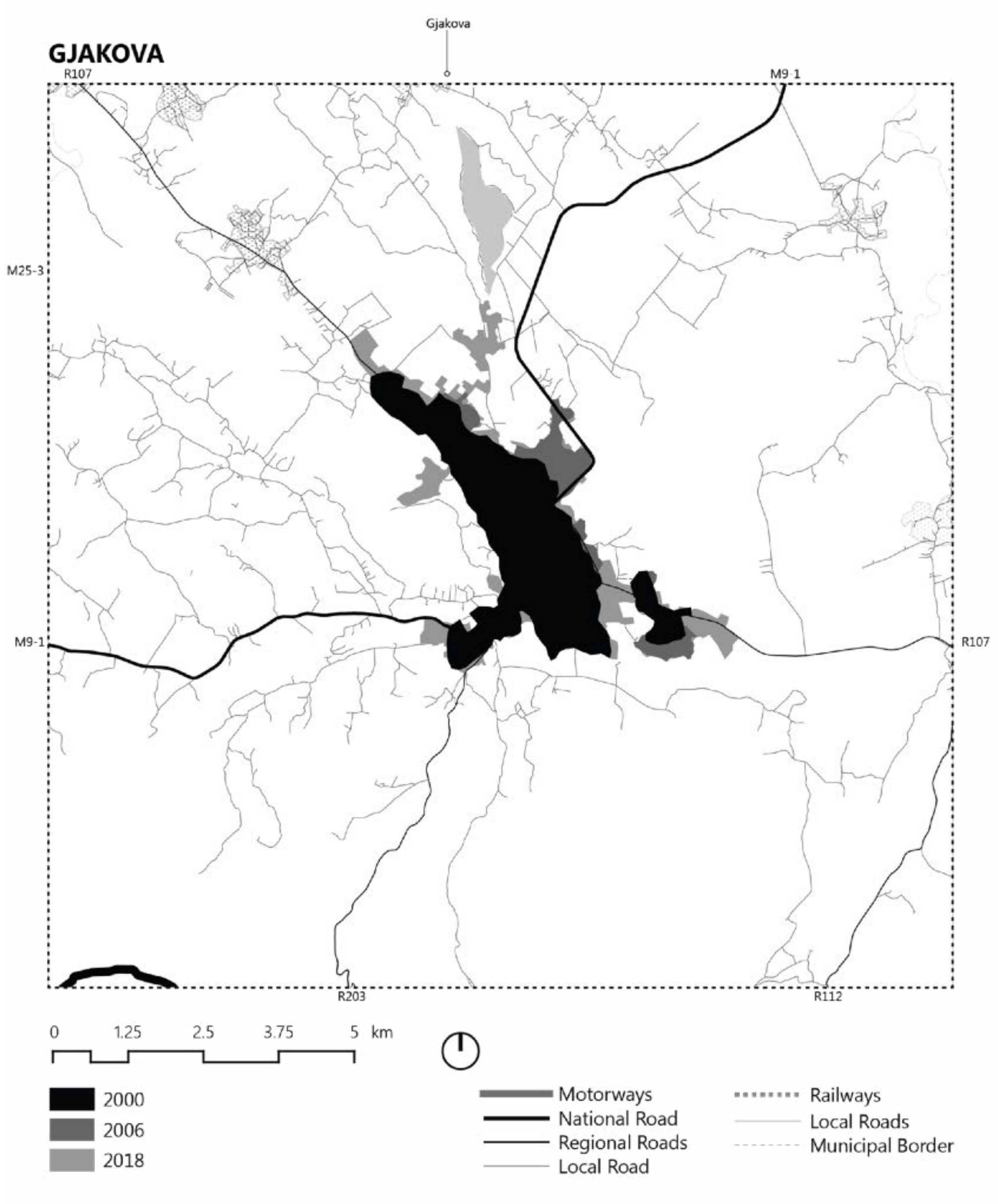


Figure 30 New Land Development in Gjakova[105]

Gjakova's linear expansion is the most pronounced of all settlements in the country. This linear growth happens primarily in the direction of the R107 Regional Road, which leads north to Decan and Peja. Additionally another identified linear growth of this sort is along the same Regional Road, heading east to Prizren, the second largest settlement of the country.

[105] Data from CORINE Land Cover and the Kosovo GeoPortal (Illustration by Author)

To the north there is the M9-1 National Road leading to Kline, which is a settlement that is positioned further away, suggesting that new development prefers proximity to the Type or level of road. This means that new development will rather be positioned in a lower ranking road, if it means being closer to two settlements, then to be along a higher ranking road such as National Road.

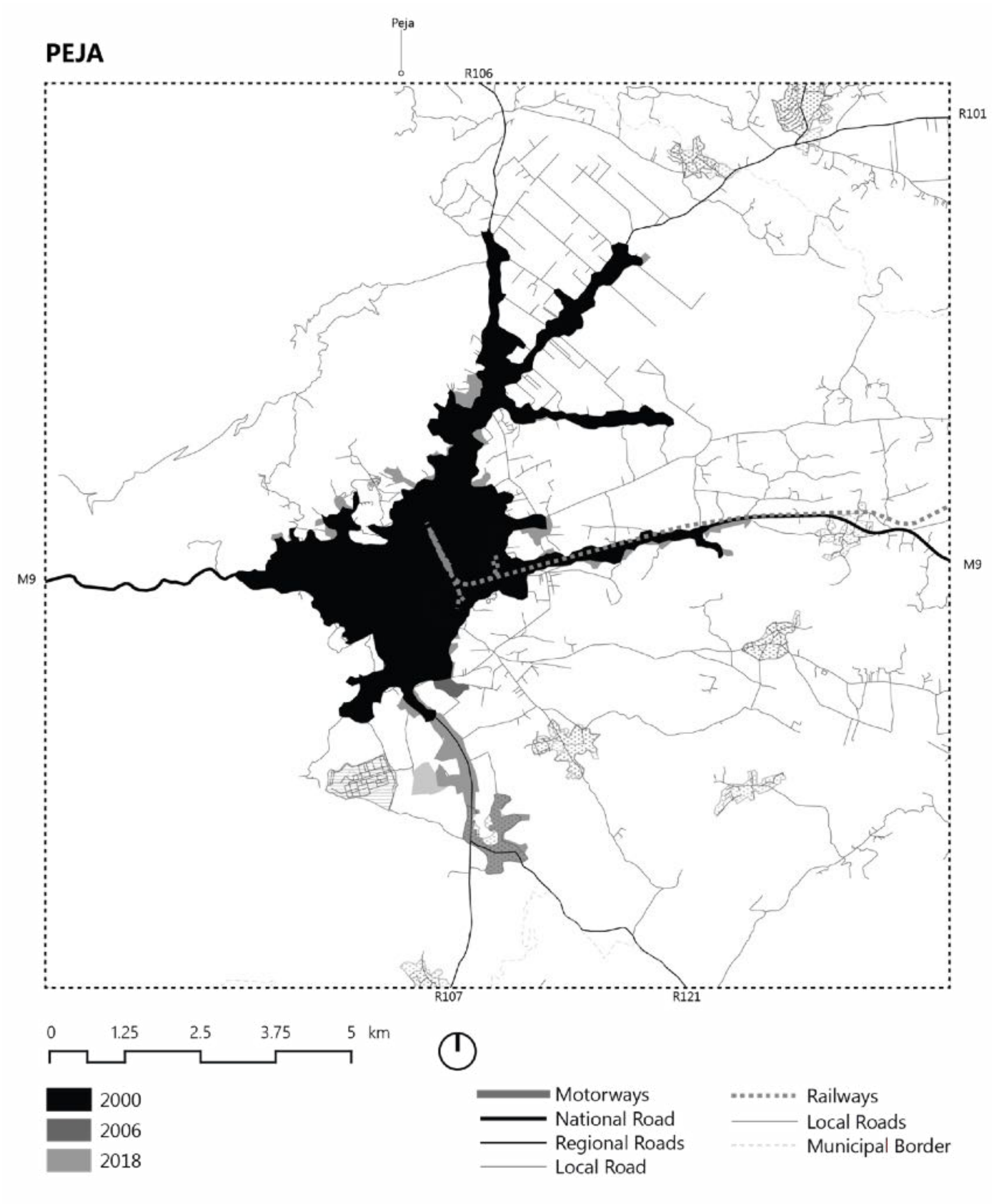


Figure 31 New Land Development in Peja[106]

[106] Data from CORINE Land Cover and the Kosovo GeoPortal (Illustration by Author)

Peja has a characteristic form of development, as it is the most extreme form of sprawl along road infrastructure found in the country. To the east it connects to the center of the country via the M9 National Road. That same road goes to the west into Montenegro, through very tough geography, hence the sprawl of that side is more compact. Furthermore, to the north and south, Peja has developed along the R106 Regional Road. The most significant connection is that to the south through the R106 to the neighboring settlement, Decan, which is halfway through the way to Gjakova.

Peja belongs to the Dukagjini region (often referred to as the Dukagjini Basin), which is arguably the only region of Kosovo still left without proper connection through National Road and Motorways. Only the National Road M9 connects the region to the east with the central part of the country.

An argument can be made that the lack of proper connection could have made it more feasible for new development to occur as close as possible to existing settlements, but along the already existing road infrastructure. This may have caused the star-shaped sprawl of land development that can be observed from the maps.

In general, all major settlements (cities) of Kosovo show some form of sprawl or development along infrastructure. As argued previously, here too it can be observed by practice and empirical study that road infrastructure indeed is seen as the most predictable and safest warrantor for new development.

4.1. State of Kosovo Road Infrastructure

Following Kosovo's independence, the state of the country's road infrastructure has greatly improved. As recognized by the legal framework of Kosovo, there are four different levels or types of road infrastructure: Motorway, National Roads, Regional Roads and Local Roads. There have been two significant road construction sprees in Kosovo in recent years, involving the construction of new motorways, the installation of modern signs, the planting of trees and other related greening projects on the country's principal state motorways. The construction of two motorways has been finished.

Figure 32 Hierarchy of road infrastructure

Motorways

Motorways are the highest level of road infrastructure, with the aim of connecting the larger region of the country. In recent years, the government of Kosovo has concentrated the majority of its investments on the development of multiple motorways, notably the R6, R7, and R7.1, which connect Kosovo with its neighboring nations and serve as a connector between the two countries.

National Roads

National Roads are the highest level of road that is not a motorway, with the aim of connecting the largest settlements (cities) in Kosovo. Additionally, Kosovo is connected to the rest of the region and to Europe by this type of road. The busiest national roads are the M2 and M9. These vital arteries for road traffic run parallel to the city of Prishtina in the settlement's outlying areas, respectively in the western and southwestern regions.

Figure 33 Map of Kosovo's Motorways and National Roads (National Roads in Blue, Motorways in Green)[107]

[107] Data retrieved from: Ministry of Infrastructure (2015), Sectorial Strategy and Multimodal Transport Action Plan, https://kryeministri.rks-gov.net/repository/docs/SECTORIAL_STRATEGY_AND_MULTIMODAL_TRANSPORT_2015-2025_AND_ACTION_PLAN_FOR_5_YEARS.pdf (retrieved: March 2022)

The M9 National Road begins at the eastern border with Serbia and continues via Pristina and Peja to the western border with Montenegro. This route is significant on a national level, as it connects Kosovo's two largest cities. The part leading to the Montenegrin border is being repaired at the moment, which will improve the link with Montenegro.

The M2 National Road connects Kosovo to Serbia in the north, North Macedonia in the south, and Prishtina to the European Corridor X in the south. M25 connects Kosovo to Serbia's northeastern border and Albania's southern border. This route, which travels through Prishtina and Prizren, is gaining importance in its southern section, as it connects Kosovo to Albania.

M 9.1, M 22.3, M 25.2, and M 25.3 are the primary supplementary routes that serve as their primary connection branches. The capital of Prishtina is the most connected settlement with this type (level of road), as it is the largest settlement of the country.

Table 13 National Roads in Kosovo

No of Road	**Settlements Covered**	**Length (km)**
M2	Hani i Elezit – Prishtinë – Vushtrri – Mitrovicë – Zubin Potok – Fsh. Banjë	133.5
M9	Prapashticë – Keçekollë – Prishtinë – Pejë – Buluhë	143.0
M9-1	Docll – Kramavik – Gjakovë – Ponoshec – Qafa e Morinës	53.2
M22-3	Mitrovicë – Leposaviq – Jarinje	53.6
M25	Merdar – Prishtinë – Shtime – Therandë – Prizren – Zhur – Vërmicë	117.4
M25-2	Prishtinë – Gjilan – Muçibabë	61.0
M-25-3	Shtime – Ferizaj – Gjilan – Konçul	68.7

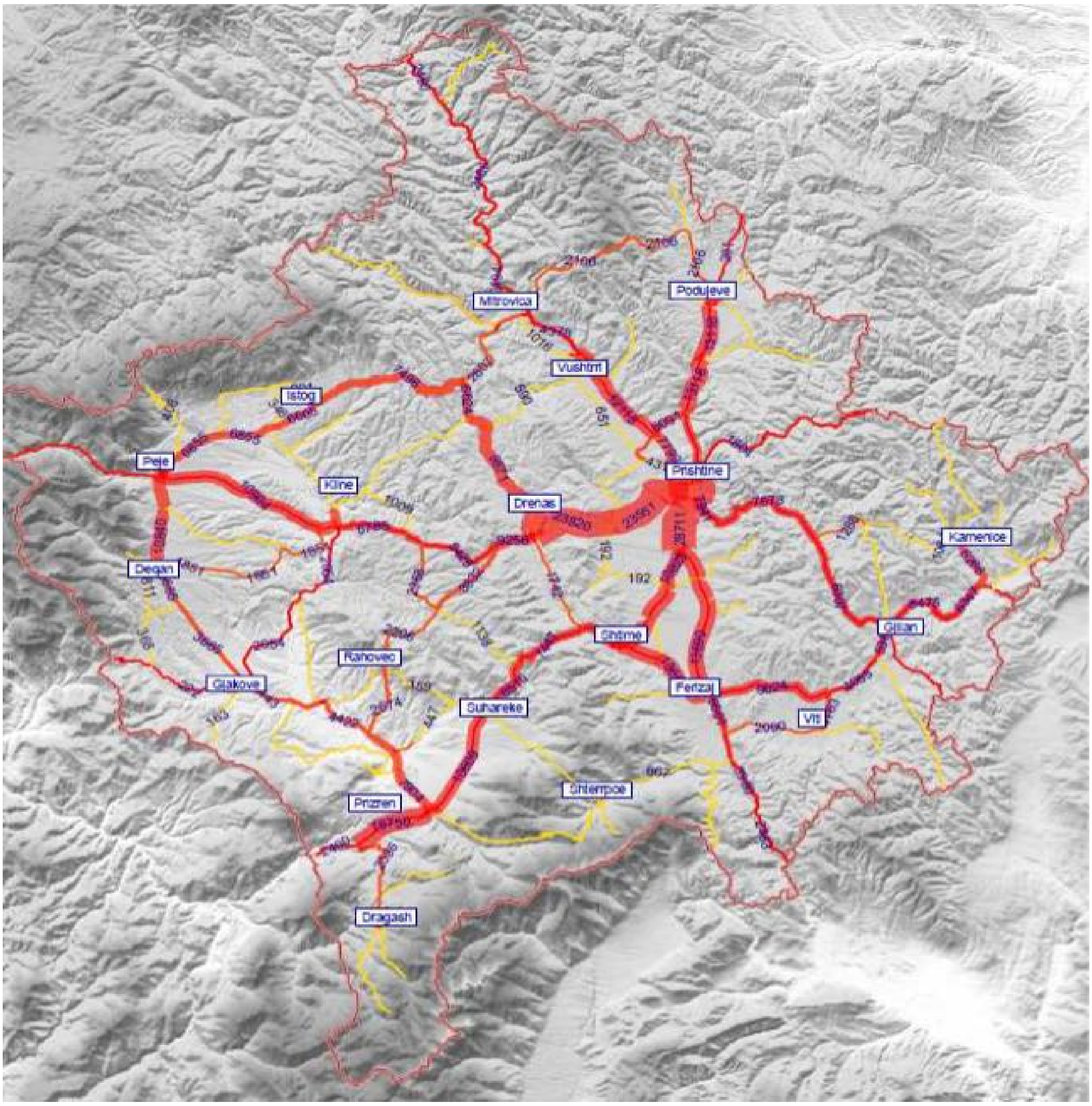


Figure 34 Daily traffic of private cars and of vehicles (Ministry of Infrastructure, 2011)[108]

In the figure above, the importance of national roads can be observed, as they are the main arteries used for travel and commuting by personal vehicles. Additionally, the importance of the capital as well as the roads connecting the capital to neighboring cities is clear in assessing development along this particular road infrastructure. Regional roads are however mainly used in the western part of the country, in the Dukagjini region, where there is a significant lack of National Roads and motorway connections.

[108] Ministry of Infrastructure (2015), Sectorial Strategy and Multimodal Transport Action Plan, https://kryeministri.rks-gov.net/repository/docs/SECTORIAL_STRATEGY_AND_MULTIMODAL_TRANSPORT_2015-2025_AND_ACTION_PLAN_FOR_5_YEARS.pdf (retrieved: March 2022)

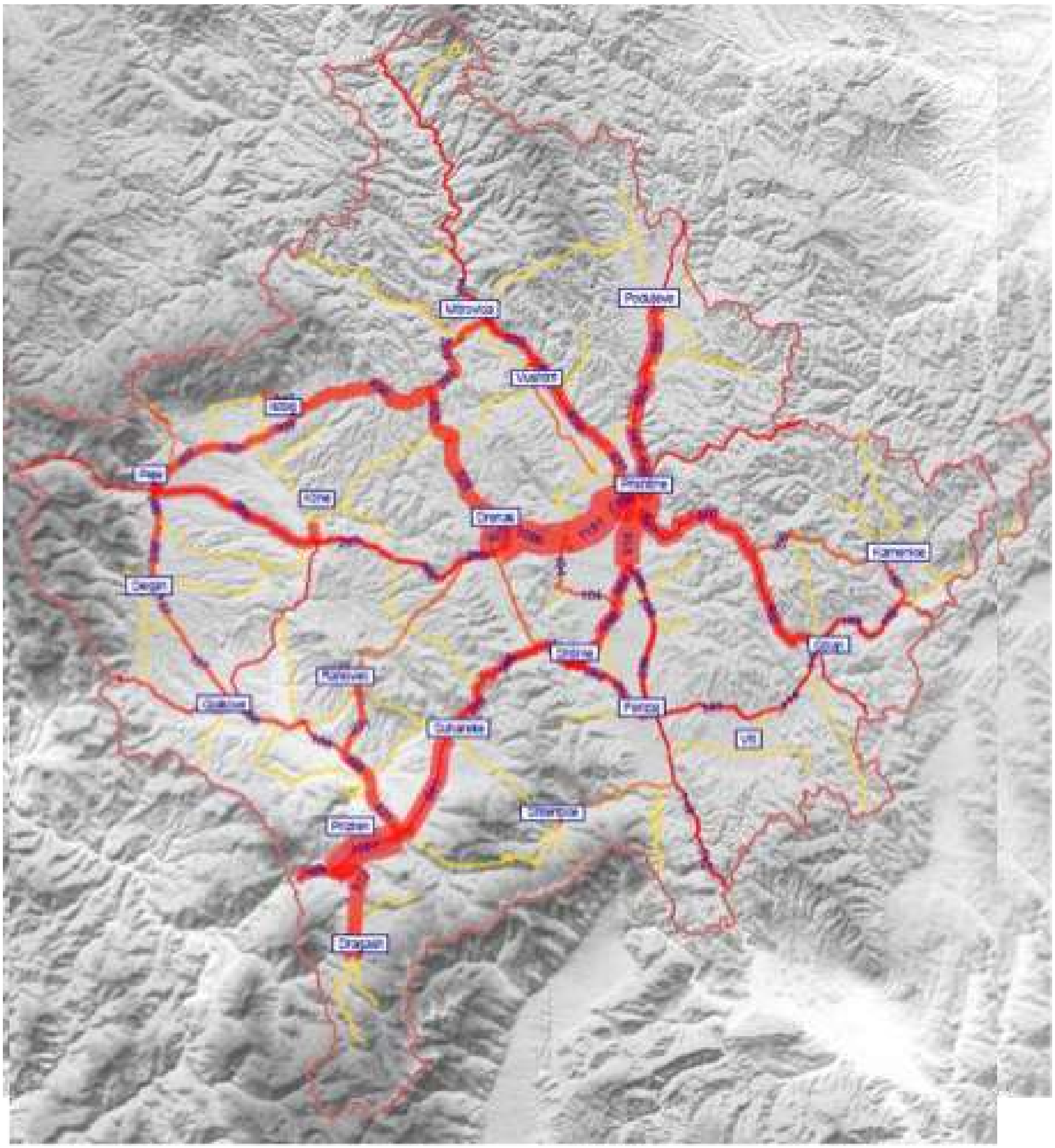


Figure 35 Daily traffic of Buses (Ministry of Infrastructure, 2011)[109]

Similar to the case with personal vehicles, National Roads also play an important role for commuting with buses, especially in connecting the southern settlements around Prizren, with the capital of Prishtina. Also, there is a significant importance in connecting the settlements west of Prishtina, Drenas, Fushë Kosovë, etc., with the capital. These routes are mainly used by daily workers that need to travel back and forth to Prishtina, as well as daily commutes of students, in surrounding settlements in the region of Prishtina.

[109] Ministry of Infrastructure (2015), Sectorial Strategy and Multimodal Transport Action Plan, https://kryeministri.rks-gov.net/repository/docs/SECTORIAL_STRATEGY_AND_MULTIMODAL_TRANSPORT_2015-2025_AND_ACTION_PLAN_FOR_5_YEARS.pdf (retrieved: March 2022)

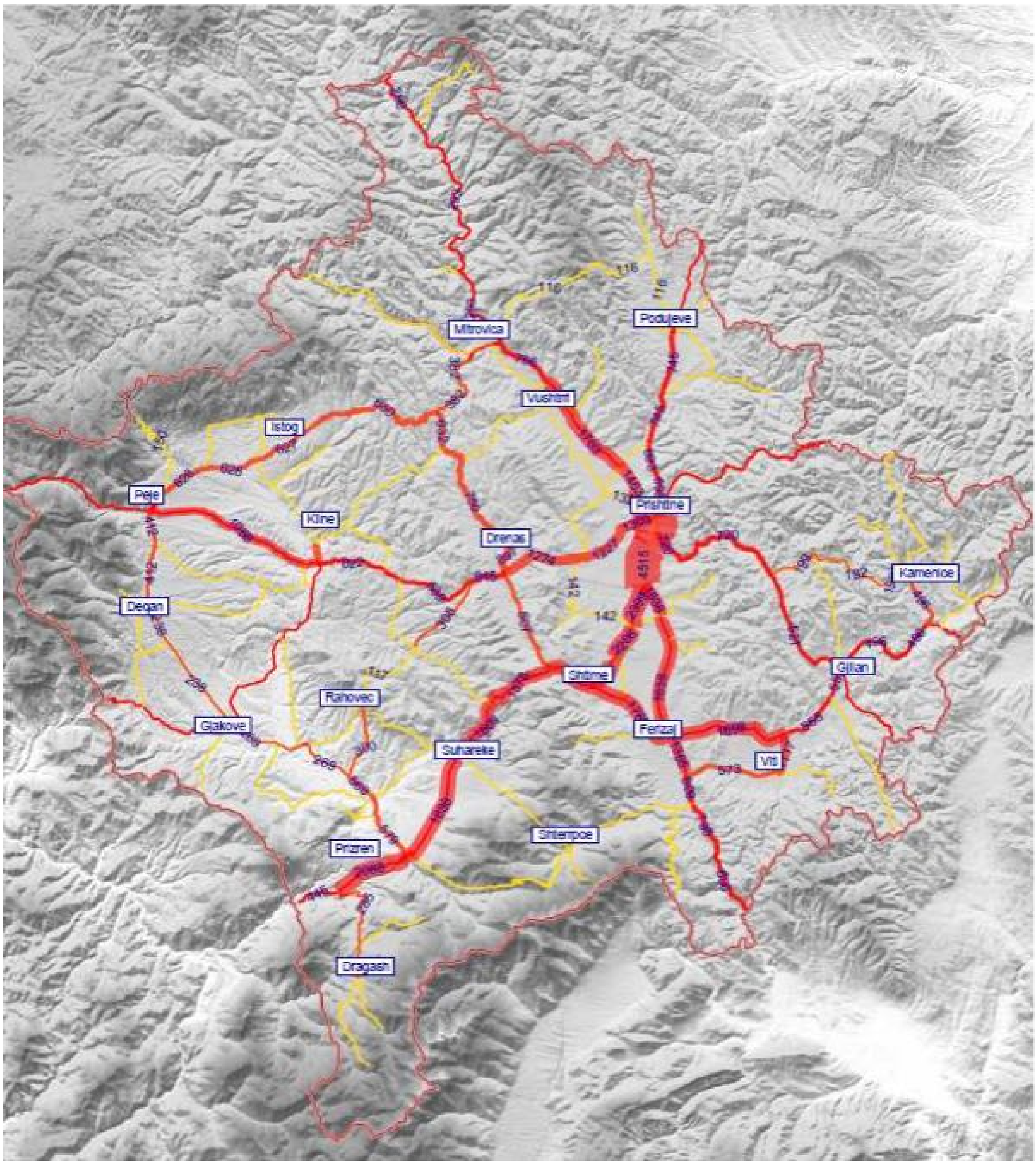


Figure 36 Daily traffic of Trucks (Ministry of Infrastructure, 2011)[110]

The roads primarily used by freight trucks are located south of Prishtina. This connection between the capital and southern settlements such as Lipjan, Ferizaj, Shtime, and Prizren is critical because the majority of them rely on this road infrastructure for commerce purposes, as Prishtina is substantially larger and more populous, and hence the region's largest market.

110 Ministry of Infrastructure (2015), Sectorial Strategy and Multimodal Transport Action Plan, https://kryeministri.rks-gov.net/repository/docs/SECTORIAL_STRATEGY_AND_MULTIMODAL_TRANSPORT_2015-2025_AND_ACTION_PLAN_FOR_5_YEARS.pdf (retrieved: March 2022)

Regional Roads

The purpose of Regional Roads, which is a lower level road, is to connect smaller settlements. There are different effects of this particular road infrastructure, namely in the way regional roads that contribute to the completion of the road network map by connecting the main axes and regions, or by connecting important settlements on a regional basis; and that are of limited national and even regional significance and connect small settlements to the main network. Part of this network remains to be entirely completed.

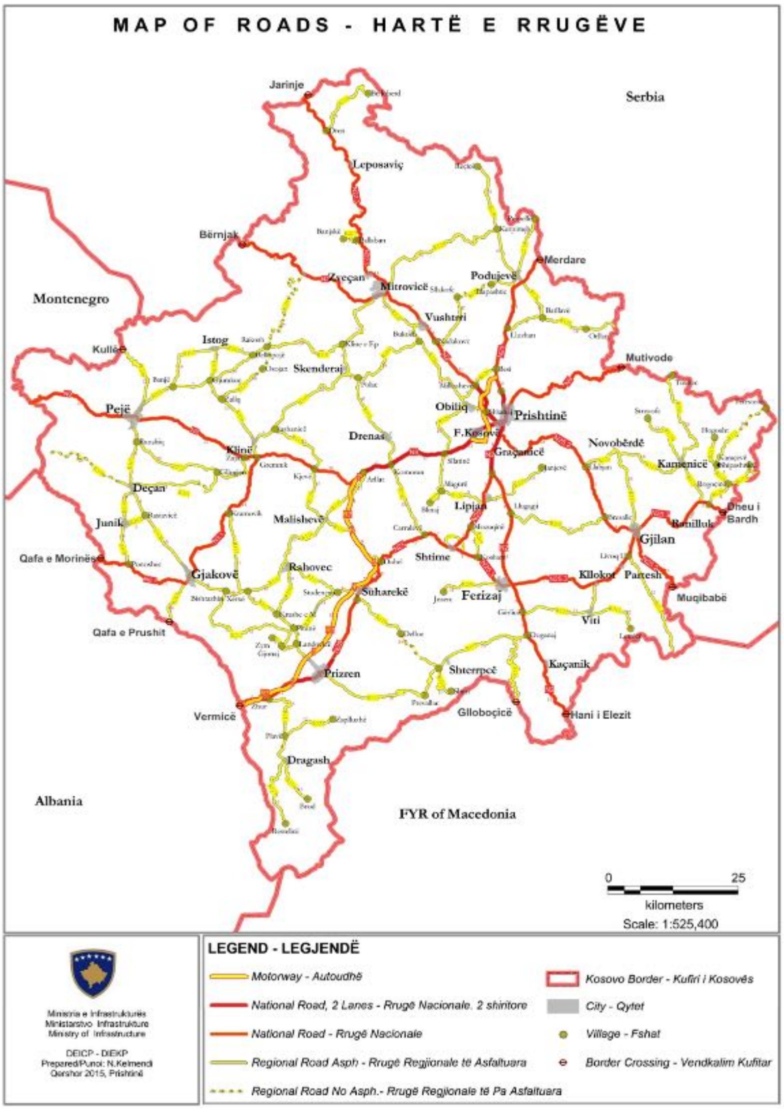


Figure 37 Kosovo Map of Roads, National Roads are depicted as Red lines, whereas Regional Roads as Yellow lines (Ministry of Infrastructure, 2015)[111]

[111] Ministry of Infrastructure (2015), Sectorial Strategy and Multimodal Transport Action Plan, https://kryeministri.rks-gov.net/repository/docs/SECTORIAL_STRATEGY_AND_MULTIMODAL_TRANSPORT_2015-2025_AND_ACTION_PLAN_FOR_5_YEARS.pdf (retrieved: March 2022)

Because of the cheaper cost and easier techniques of constructing, the list of Regional Roads is much larger than that of National Roads.

Local Roads

Local Roads are the lowest level or type of road, filling in the gaps left out by the regional roads. Regional roads are developed in accordance with former Yugoslavia requirements, therefore local roads are frequently designed in the same manner as regional roads, as there is no official standard. However, in many cases they can be narrower with a layer width of 3 m or less, mainly for unpaved roads. Kosovo municipalities are responsible for this type of road network's maintenance, operation, and development. Local roads are often poor shape, making crossing unsafe. This condition is attributed to a lack of proper finance, as they are deemed less important in terms of a larger context.

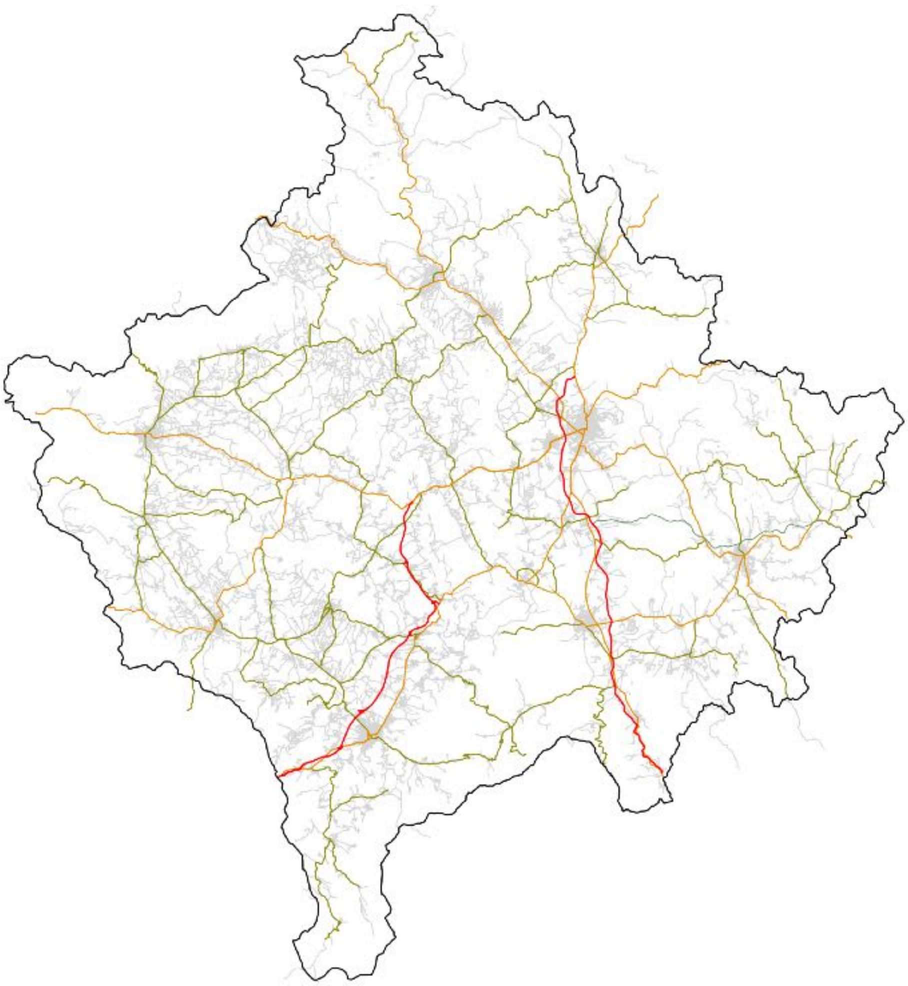


Figure 38 Kosovo Road Infrastructure - Local Roads are shown in Gray[112]

[112] Data retrieved by Kosovo GeoPortal. Kosovo Cadastral Agency. http://geoportal.rks-gov.net (retrieved: June 2020) (Illustration by Author)

4.2. CORINE Land Cover

The first step in the process of this research is the observation and analysis of changes in Land-Use throughout time, by visualizing data gathered from Corine Land Cover (CLC). CORINE's Land Cover (CLC) inventory began in 1985, and in 2000, 2006, 2012, and 2018, updates were published. It is an inventory of land cover classified into 44 classes. The time series are supplemented with change layers that emphasize changes in land cover at a five-hectare resolution.

Because of the period of inventorying, this data is presented in four different time periods, namely 2000, 2006, 2012 and 2018, identifying the changes in land-use along the analyzed road. For the purposes of this study, all classes of land cover will be simplified and divided into only built and not built, as the aim is to measure new development, regardless of specific class type, function and/or category..

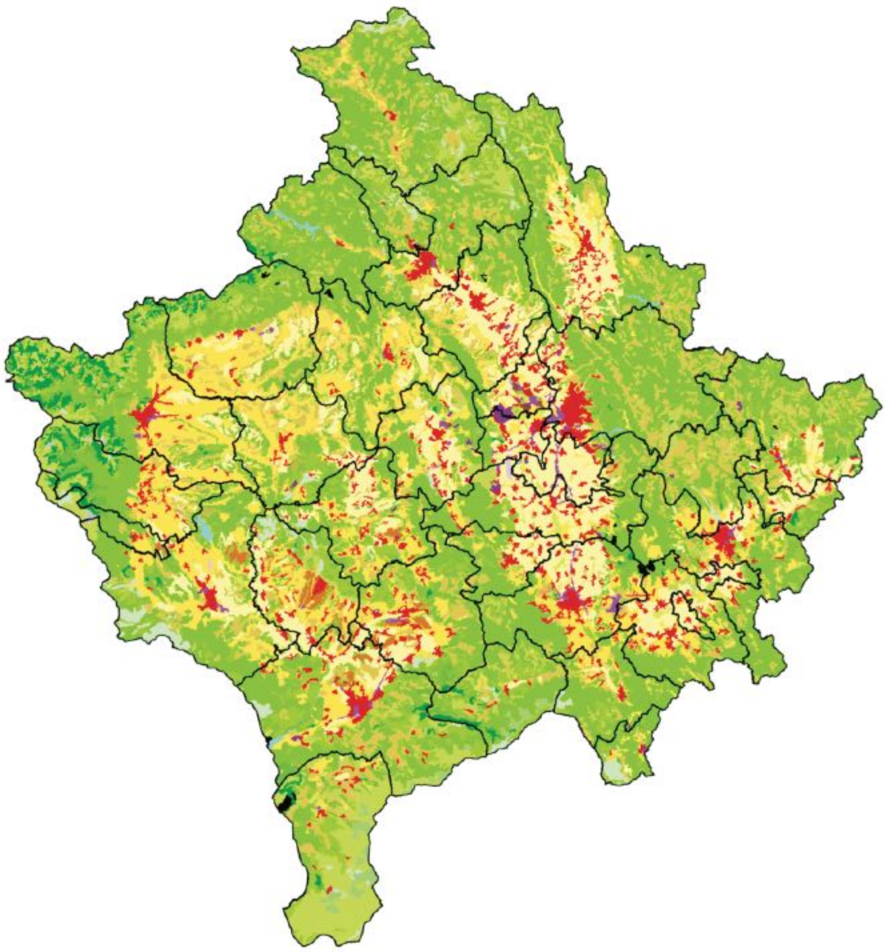


Figure 39 CORINE Land Cover – Kosovo, 2018[113]

[113] CORINE Land Cover — Copernicus Land Monitoring Service. https://land.copernicus.eu/pan-european/corine-land-cover (retrieved: June 2020)

For the purposes of this study, all classes of land cover will be simplified and divided into only built and not built, as the aim is to measure new development, regardless of specific class type, function and/or category.

As an example, the figure below shows only the built land of the year 2000 (in black) and 2018 (in red) overlayed with Kosovo's Transportation Infrastructure Network. In this depiction, the connection of all larger and smaller settlements connected with National and Regional roads can be observed, as well as the relation between them. The presentation of this data and the manner in which it will be used, will be discussed further on in this chapter.

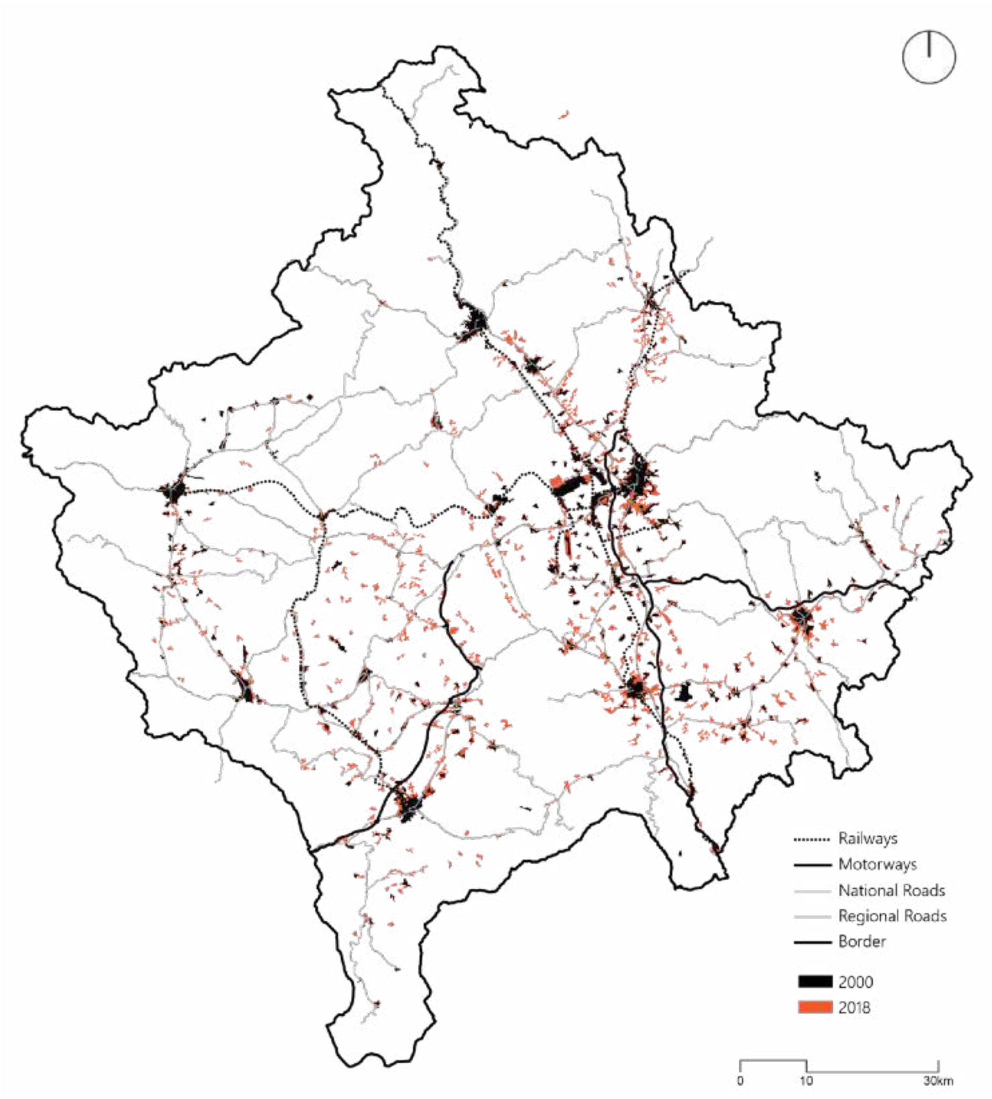


Figure 40 Kosovo Road Infrastructure and Developed Land[114]

[114] Data retrieved by Kosovo GeoPortal. Kosovo Cadastral Agency. http://geoportal.rks-gov.net and by CORINE Land Cover — Copernicus Land Monitoring Service. https://land.copernicus.eu/pan-european/corine-land-cover (retrieved: June 2020) (Illustration by Author)

4.3. Sample Selection and Hierarchy

Road Infrastructure is a complex network with many nodes, paths and directions. As a result, it is difficult to study this network as a single unit because it acts as a whole. In order to achieve a more effective and comprehensive analysis of roads, it is preferable to partition it into smaller segments that are more manageable.

Specifically, each road is separated into segments, with the settlements serving as separators and the road segment being the section of road that connects them both. Most roads do continue through settlements, so the segment of the road is cut and selected at the first point of contact with the settlement at either end.

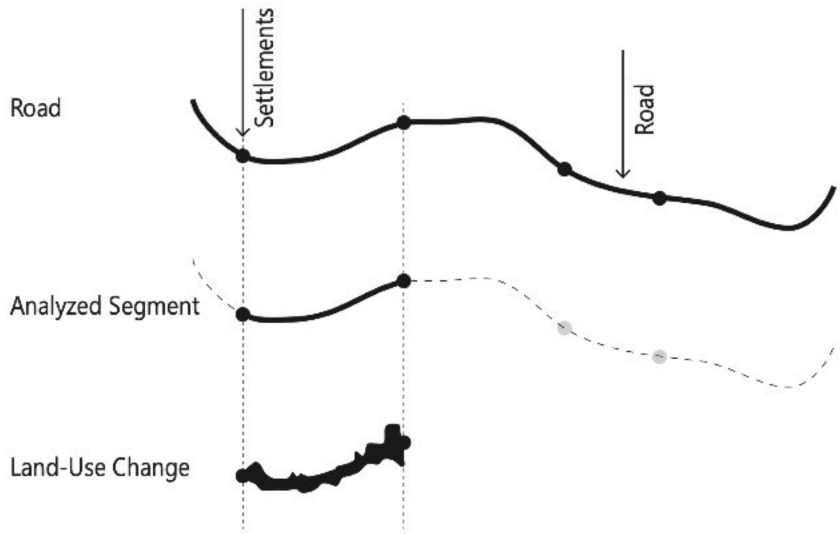


Figure 41 Example of Sample Selection

Additionally, changes along the analyzed segment will be considered and documented, in order to better understand the level and intensity of development. Land use that is not touched by the analyzed road infrastructure, will not be taken into consideration, as the argument is that the road might not have been the direct influencer of that particular development.

Furthermore, in order to account for the effect of other settlements as well as other road, attributes and other features have been designed into the model that will be covered in the following chapter.

4.4. Presentation of Data

As most of the data is in a map form, and the qualitative research also needs to be presented in a measurable form, diagrammatic maps will be developed to identify all land development. Since data from CORINE Land Cover has been inventoried in for different time periods (2000, 2006, 2012 and 2018), the representation of each of these periods will be done by a unique layer on the man, differentiated by color. The maps of these different time periods will be stacked, in order to better observe the changes from one period to the next (see the following figure as an example).

Besides the layers of CORINE Land Cover, an additional layer of the latest state of land development will be added, to show the changes for the year 2022. This is only done for the six case studies analyzed, including the three case studies to be treated by the model, in order to achieve a more accurate depiction of changes in land development.

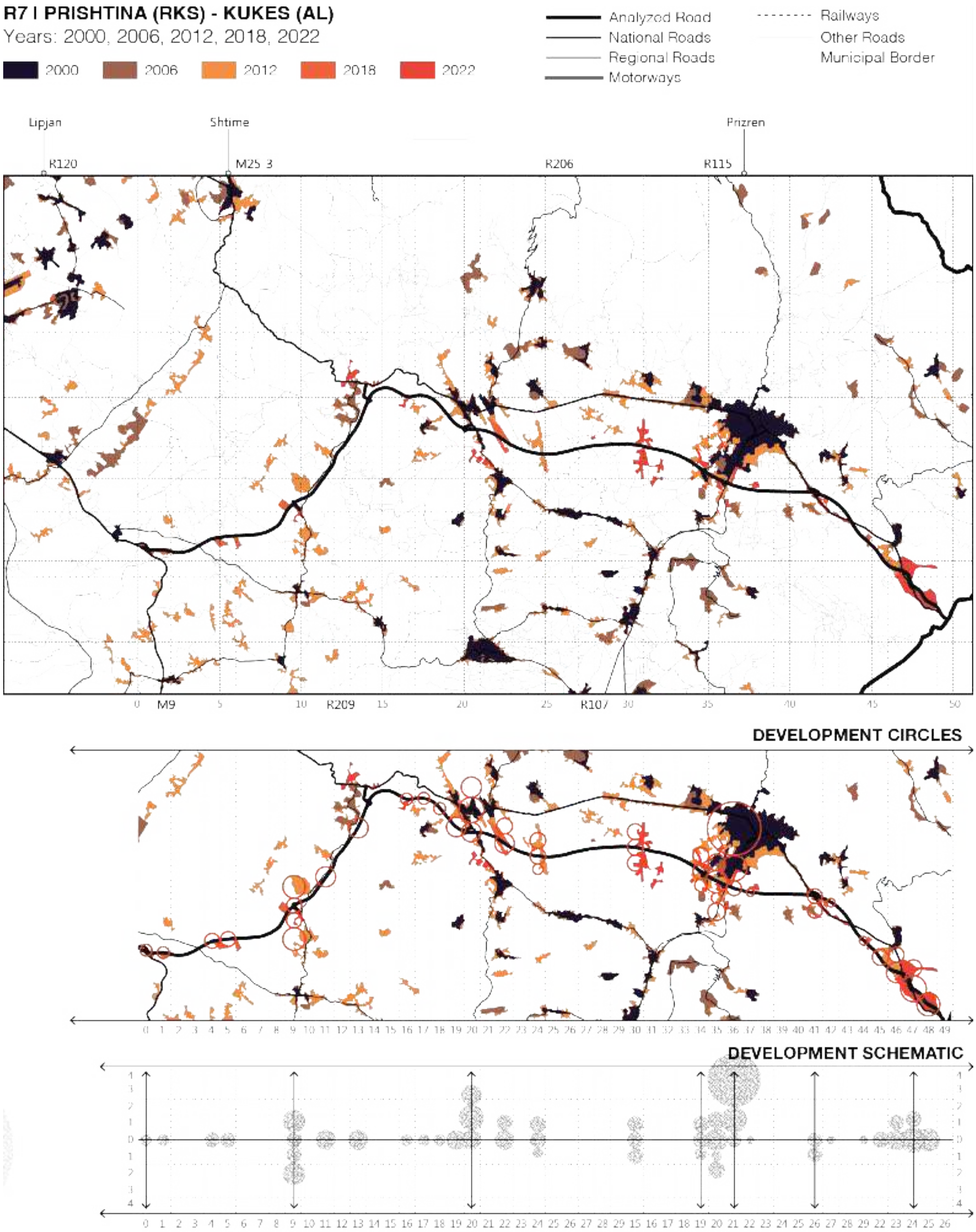


Figure 42 Maps depicting change in Land Use for four different time periods (example)

As can be seen in the example in the previous figure, the layout is is divided into three parts: The first part is the map depicting the development in 5 different periods. The second (middle) part depicts the development along with the ‘development circles’ which identify and define development along the road infrastructure. The third and last part is a diagram which simplifies the development into schematics that make it more easy to measure.

4.5. Case Studies

Several case studies have been selected for this study, with two from each type of road being chosen for consideration. This chapter's case studies will be examined separately in the following part, although only four of them (one from each type of road) will be used as case studies to evaluate the model and the recommended solutions. Throughout the next chapters, this evaluation will be carried out.

Motorways are the longest type of road that will be used in this study, as they span through the majority of the country's land area and are the most traveled. They are an exception in that they do not pass directly from one settlement to another; rather, they operate as a backbone, connecting as many settlements as they possibly can. As a result, they will be studied as a whole, rather than as specific sections.

National Roads is the easiest and most accurate analysis of a road, since they are much better defined and development along them is more easily observed and measured. When it comes to this type of road, the findings of the model should be regarded as much more accurate than the findings of the model for all other types of roads. Also noteworthy is that the findings and recommendations for this particular type of road should be applicable to other similar cases of the same type, because they act in a very similar manner.

Regional roads, as well as national roads, are easier to map, measure, and evaluate than national roads. This also is the case when testing them with the model devised in this dissertation. The results from Regional Roads can be considered to be fairly accurate, and they should be relevant to other samples or cases of the same type of road.

Local roads are the most difficult to measure since they are the lowest level in the type of road hierarchy and cover significantly shorter lengths than other types of roads. With regard to local roads, as it is difficult to come up with a solution that is universally applicable to all other roads of this type due to the fact that they differ significantly even though they are all classified as belonging to the same category of road infrastructure, they have not been selected as case studies.

As shown in the following table, the six case studies that were utilized for analysis considerations, as well as the three case studies that have been used for the model, will be presented.

Table 14 Case Studies selected for the study, with Roads, Population and Lengths

No.	Type of Road	Road No.	Settlement A	Settlement B	Population A	Population B	Length (km)
1	Motorway	R7	Prishtina	Vërmica	198,897	661	50
2		R6	Prishtina	Hani i Elezit	198,897	9,403	65
3	National Road	M2	Prishtina	Ferizaj	198,897	108,610	30
4		M2	Prishtina	Mitrovica	198,897	84,235	25
5	Regional Road	R107	Prizren	Gjakova	177,781	94,556	30
6		R107	Peja	Gjakova	96,450	3,803	14

Besides the eight main case studies used for this study, additional cases have been analyzed in order to enhance the reasoning and calibration of attribute values and weights of the model that will follow on the next chapter. All of these cases can be viewed in the appendix of the dissertation.

Table 15 Additional Case Studies, found in the Appendix of this dissertation

No.	Type of Road	Settlement A	Settlement B	Population A	Population B
1	National Road	Mitrovica	Fushë Banjë	84,235	n/a
2	National Road	Prishtina	Mitrovica	198,897	84,235
3	National Road	Prishtina	Ferizaj	198,897	108,610
4	National Road	Ferizaj	Hani i Elezit	108,610	9,403
5	National Road	Prishtina	Komoran	198,897	4,393
6	National Road	Komoran	Zajm	4,393	1,267
7	National Road	Peja	Zajm	96,450	1,267
8	National Road	Gjakova	Dollc	94,556	300
9	National Road	Ferizaj	Gjilan	108,610	90,178
10	National Road	Prishtina	Podujeva	198,897	88,499
11	National Road	Prishtina	Shtime	198,897	27,324

Type of Road

The road level is one of the most important properties that influences how development occurs in tandem with road infrastructure. This is especially noticeable on motorways, which serve more as transportation corridors and cannot be developed parallel to the road as Regional Roads and National Roads do due to road profile (speed, width, access, etc.). Furthermore, development and construction parallel to this level of the road are controlled (read: restricted) by legal documents, that address road infrastructure and development along it. For this level of road, development occurs primarily at junctions, particularly along secondary roads that connect to these junctions.

Gravitational Pulls

Because there is no other orientation of the pull of development, internal (local) and external (global) gravitational pulls have the greatest effect at this level of road. This means that this level of road is primarily used for transportation in a transit manner, rather than as a space for development. The main attractions in this case study are in the direction of the capital, Prishtina, and the area near the border with Albania.

Accessibility

Secondary road infrastructure near motorway junctions seem to have the potential to attract more development. This is because they have the advantage of proximity to the motorway along with the accessibility, and they do not face the same legal and physical obstacles as motorways when it comes to having development parallel to the road infrastructure. According to this case study, secondary roads located near motorways attract far more development than other roads that lack access to (or vicinity to) motorways.

Agglomerations

Exiting development attracts further development in this case study just as well. As the distances in this level of road are far greater, it is even more beneficial for development to cluster together.

Restrictions

In this particular case study, as well as with the other motorway case study, restrictions occur all along the road infrastructure, except around junctions. These restrictions are not of the natural/geographical kind, rather they are policies and other obstructions that are defined by various legal documents in Kosovo.

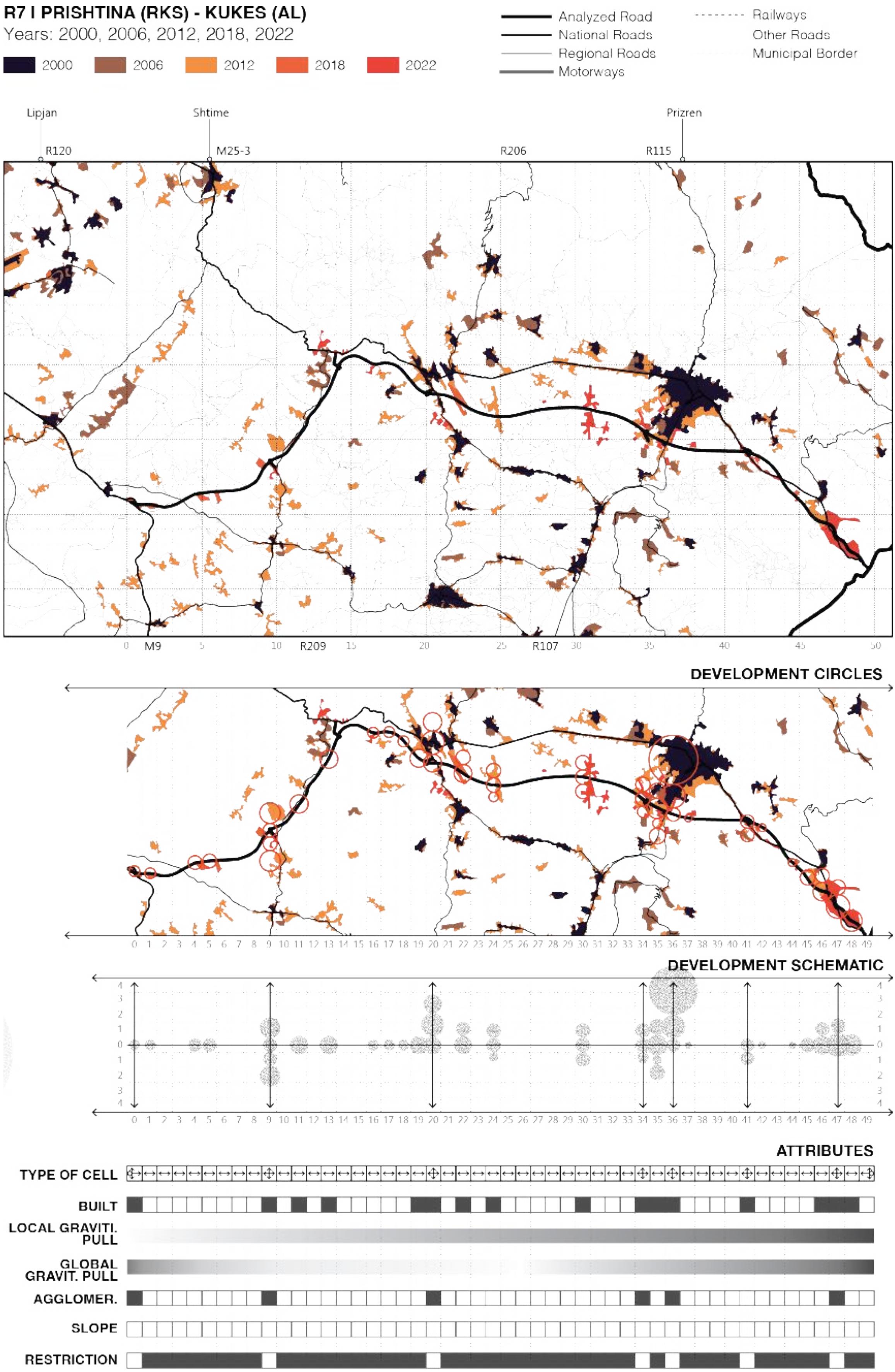


Figure 43 Study Case 3 - Motorway: Prishtina (RKS) - Kukës (AL)

Type of Road

The previous case study of motorway has a trajectory that covers the middle part of the country, and still has opportunity to help develop that part of land. In this particular case, the motorway stretches from the capital of Prishtina, past two major and well established commercial and industrial settlements (Lipjan and Ferizaj), all the way to the border with Northern Macedonia. The capital of Skopje is very close and poses as a significant pull of development. The fact that this motorway passes existing islands development and settlements, it has a greater chance of influencing further development, especially in the form of growing agglomerations. As with the other case study, development along the road infrastructure is restricted by legal documents, and secondary road infrastructure connecting to junctions poses the highest chance for development.

Gravitational Pulls

There is significant pulling towards both capitals (Prishtina and Skopje), as well as towards the larger settlements along the way (such as Lipjan and Ferizaj) that have established economies. This means that locally, the gravitational pulls of this motorway will be in the direction of Prishtina and Ferizaj, and globally, the gravitational pulls will be in the direction of Skopje too. This means that this motorway too is primarily used for transportation in a transit manner, rather than as a space for development.

Accessibility

Secondary roads near motorway intersections could spur growth. They benefit from proximity to motorways and accessibility, and do not face the same legal and physical restrictions as motorways when it comes to development parallel to road infrastructure. According to this case study, secondary roads near motorways attract significantly more development than secondary roads not near motorways.

Agglomerations

Exiting development attracts further development in this case study just as well. As the distances in this level of road are far greater, it is even more beneficial for development to cluster together.

Restrictions

In this case study too, restrictions occur all along the road infrastructure, except around junctions. These restrictions are not of the natural/geographical kind, rather they are policies and other obstructions that are defined by various legal documents in Kosovo.

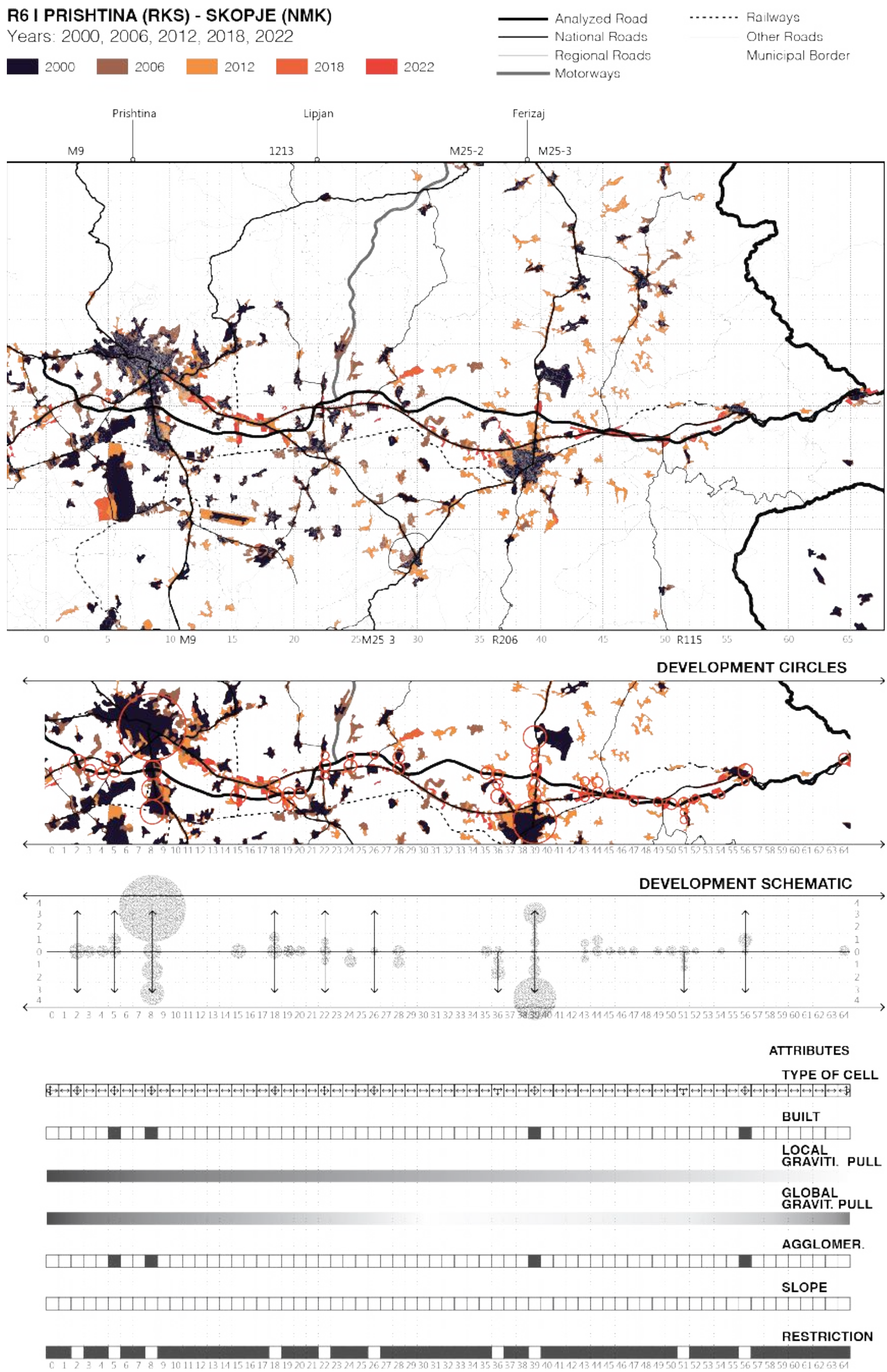


Figure 44 Study Case 4 - Motorway: Prishtina (RKS) - Skopje (NMK)

Type of Road

National Roads seem to be the best way to measure development along road infrastructure. This is due to the fact that they are both accessible at almost any point along the segment, as well as because they generally span across shorter distances compared to motorways. In this particular case study, development has occurred along almost the entirety of the road infrastructure, which when compared to the motorway, it can be seen that Type of Road has a significant effect on pulling and influencing new development.

Gravitational Pulls

As this case study connects two major and well established settlements of Prishtina and Mitrovica, as well as it passes through one other large settlement, Vushtrri, this road infrastructure is a highly developed segment. The capital of Prishtina is much larger than Mitrovica, both in size and population, and therefore it has a much higher gravitational pull of new development. As can be seen in the map of the case study much of the newer developments are closer to the larger settlement.

Accessibility

Access to road infrastructure represents a significant opportunity for development and is appealing to new development. As seen in this case study, whenever a secondary road connects to the main analyzed road, a much larger cluster of development occurs. This means that whenever development needs to be influenced in a specific region, the construction of new road infrastructure is a measure that can be taken, and vice versa.

Agglomerations

Because this case study has a settlement that is halfway between the two larger settlements, it also translates as a large agglomeration of development, which acts as a secondary gravitational pull. This is evident in the study, where development that is unable to access one of the main settlements will tend to default to a second-grade or smaller settlement that serves as an agglomeration. Furthermore, other small agglomerations act as gravitational pulls, albeit with a weaker force. Already built areas of the analyzed road will in turn influence further development close to them. This attribute too is featured in the proposed model of the following chapters.

Restrictions

In this case study that treats a National Road, restrictions are virtually nonexistent. This means that there is no real (measurable) restriction, either geographical, physical or legal that will hinder development in any significant way.

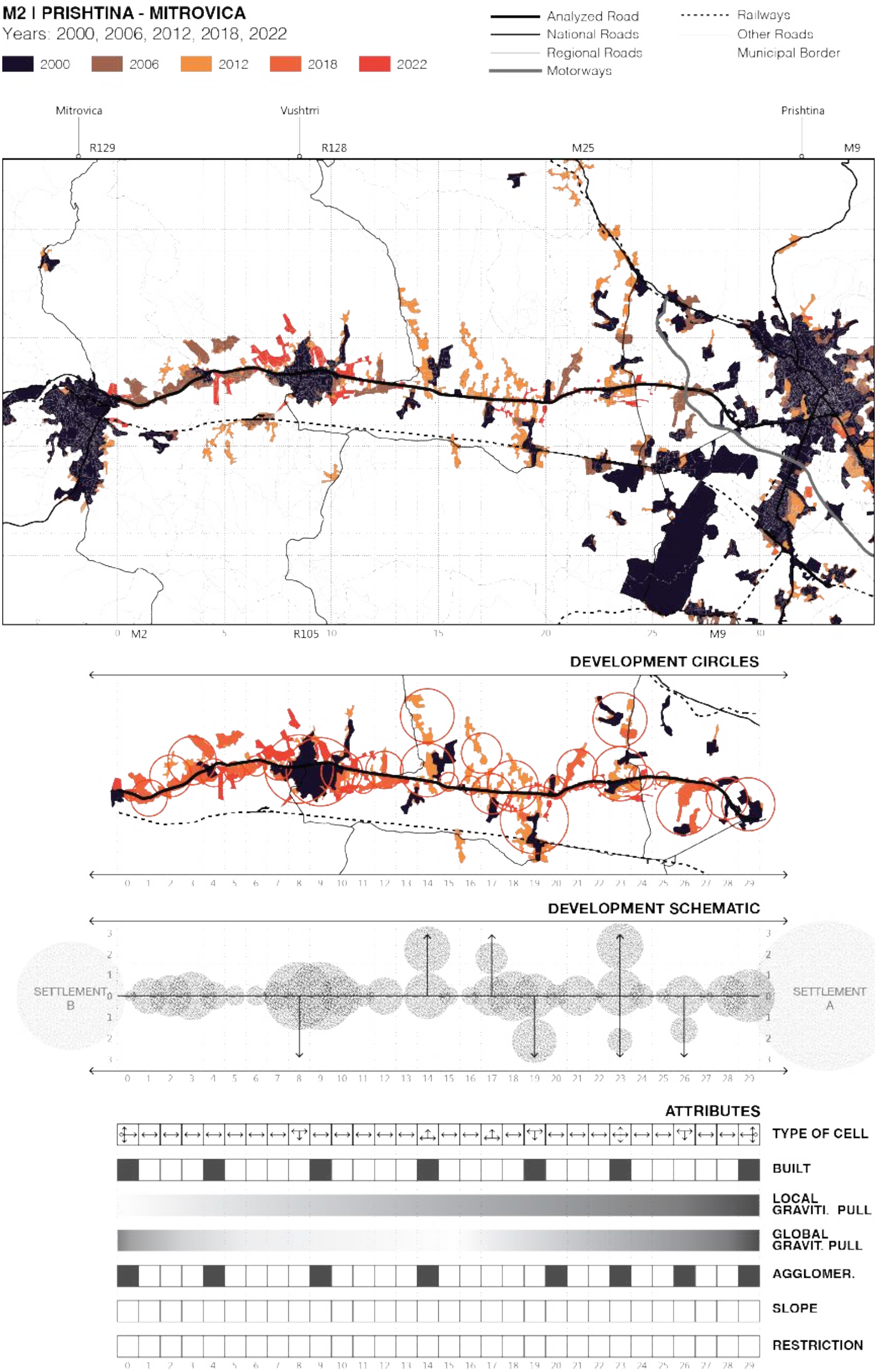


Figure 45 Study Case 1 – National Road: Prishtina - Mitrovica

Type of Road

This particular case study of a National Road that connects the settlements of Prishtina and Ferizaj, has a development that is more sporadic and more widely spread than with the previous case. The type of road here also has a significant effect on development, as it is accessible at any point along the road infrastructure. This means that besides chasing proximity to either settlement, new development also has incentive to chase the proximity to the road infrastructure.

Gravitational Pulls

Both the capital of Prishtina and the other significantly large settlement Ferizaj, have great gravitational pulls in their directions. Additionally, the settlement of Lipjan is mid-way from each of them, however it is not directly connected to the analyzed road in this case study. This means that besides the gravitational pulls towards Prishtina and Ferizaj (with the one towards Prishtina being significantly more powerful), there is a secondary gravitational pull in the middle of the road infrastructure. This is caused indirectly by Lipjan, as much of the region around it is developed.

Accessibility

This particular case study has a number of secondary road connections and is quite accessible. Furthermore, parallel to it, there is the railway as well as the newer motorway, both of which contribute in improving development. As with the previous case, in junctions and other connections, the chance for new development raises by quite a bit.

Agglomerations

The existing settlement of Lipjan that is positioned halfway between both larger settlements, acts as a large agglomeration of development that further attracts new development near it, especially along connecting road infrastructure. Additionally, the linear growth of both Prishtina and Ferizaj along the analyzed road infrastructure, serves as an agglomeration that is continuously growing.

Restrictions

In this case study that treats a National Road, restrictions are virtually nonexistent. This means that there is no real (measurable) restriction, either geographical, physical or legal that will hinder development in any significant way. There is however the motorway that passes near the analyzed road, which poses all these restrictions discussed. In the segments where the analyzed road passes near the motorway, there is hindering in terms of development and the opposite is true when distance is larger.

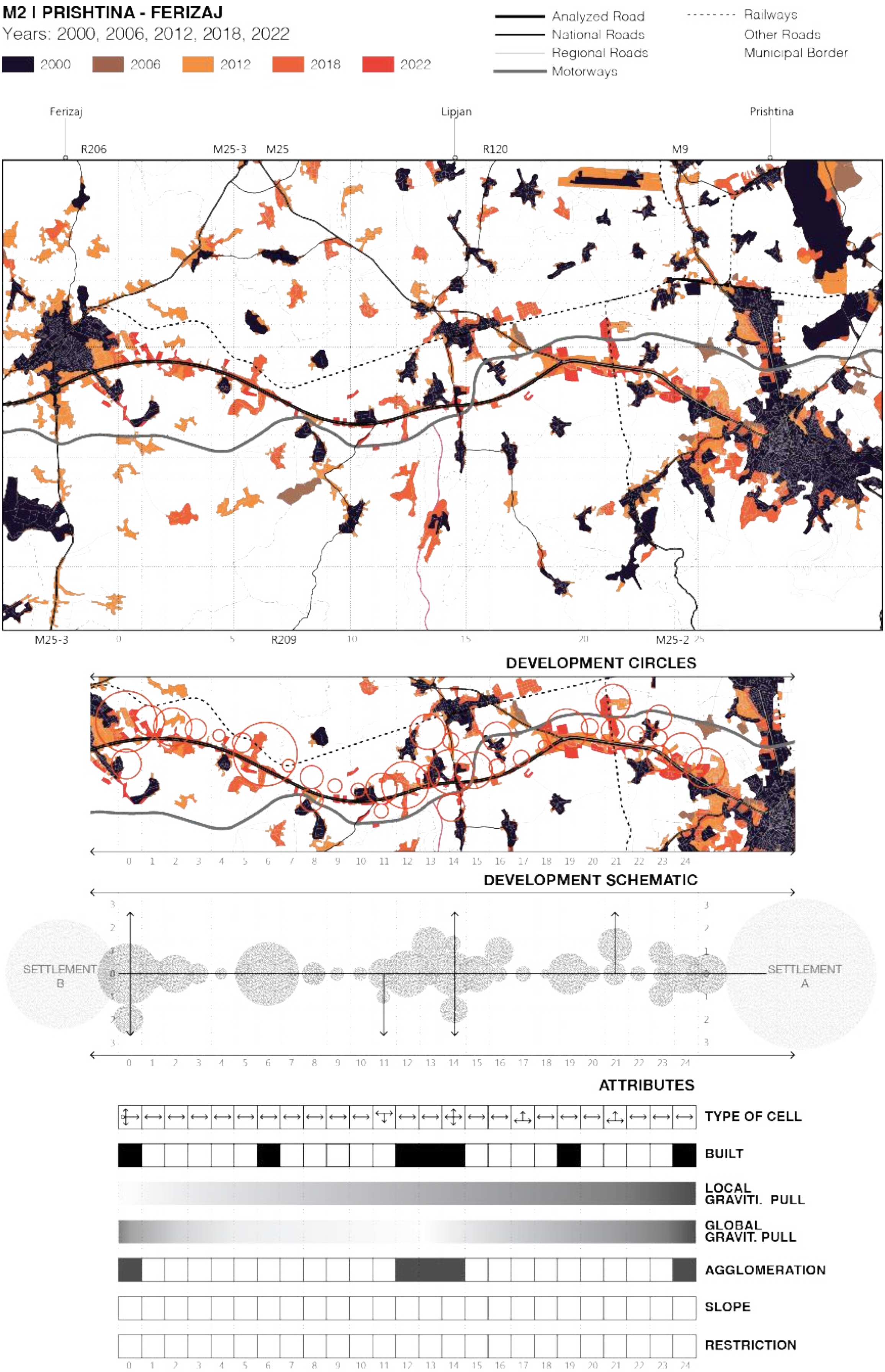


Figure 46 Study Case 2 - National Road: Prishtina - Ferizaj

Type of Road

The type of road of the next two case studies is regional road, which connects areas that are not covered either by motorways or national roads. This means that these roads are of a secondary importance, and not as attractive to new development. That being said, in this case study, as well as on the next one, linear growth along the road infrastructure can be witnessed. This again suggests that besides the proximity to settlements, new development also pursues proximity to road infrastructure. Additionally, as can be witnessed by both case studies, regional roads tend to have more connections and access to other roads, as conditions favor this kind of development.

Gravitational Pulls

There are two major gravitational pulls of the two settlements at both ends of the road segment, Peja and Gjakova. Peja is slightly larger in size and population than Gjakova, so for this reason it has a greater pulling force. Additionally, there is a secondary settlement almost midway, Decan, which also accounts for some pull of new development.

Accessibility

The settlement of Decan has developed in a junction with road R108 connecting to the road analyzed, which serves as a double reason for new development to cluster there. Additionally, as the number of connections to other road is much higher for this type of road, there have been clusters developing along these junctions.

Agglomerations

Although they have evolved at varying rates and intensities, these clusters of development at junctions have taken advantage of every opportunity to do so. The trends indicate that certain intersections will continue to receive preference from new developments.

Restrictions

Regarding the Regional Road that is the subject of this case study, there are hardly any regulations at all. This indicates that there are no genuine (measurable) restrictions, either geographical, physical, or legal, that will limit development in any meaningful way. These restrictions might be any of the following: geographical, physical, or legal.

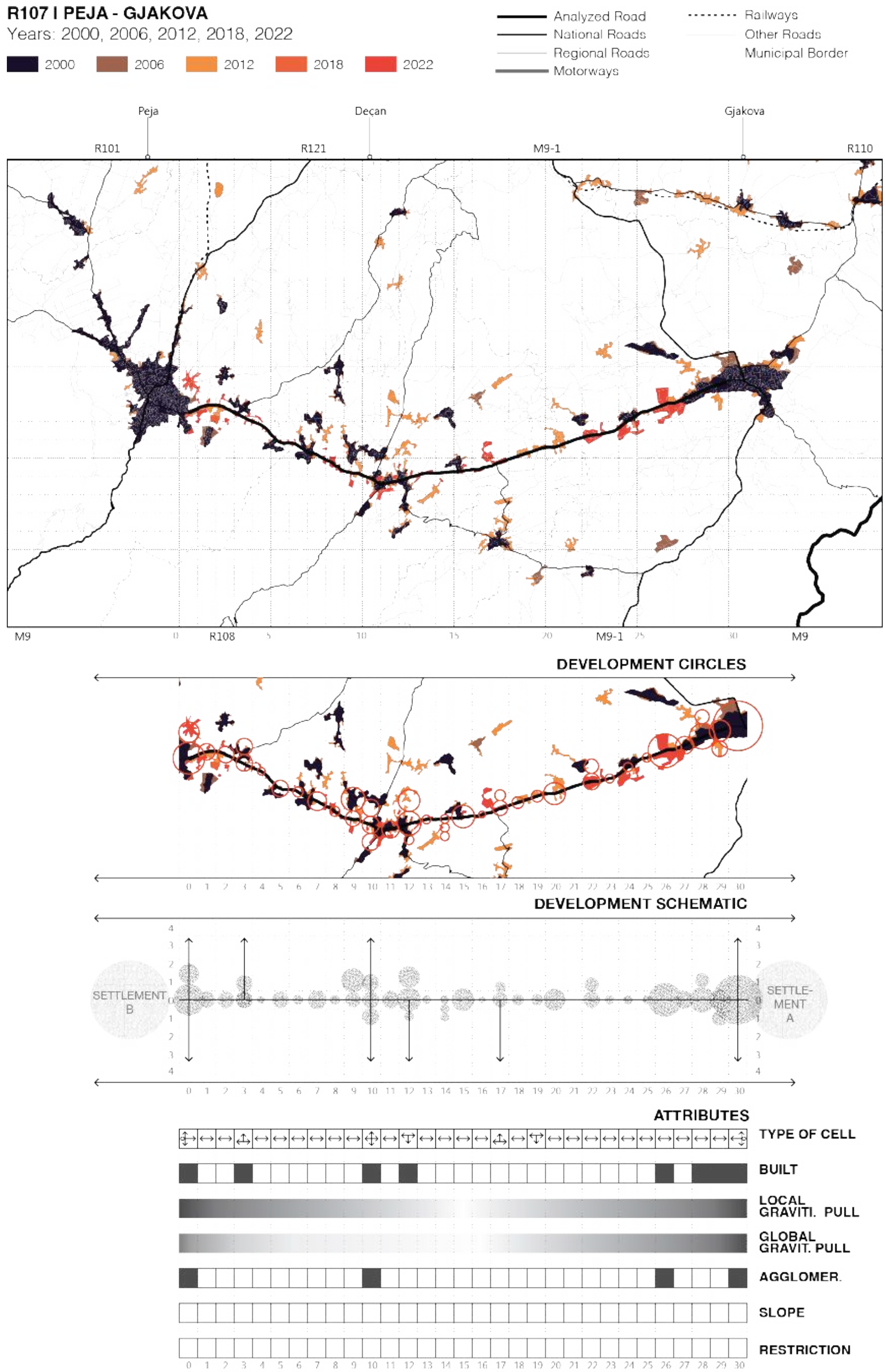


Figure 47 Case Study 5 - Regional Road: Peja - Gjakova

Type of Road

The case study examined here also belongs to the type of regional roads. These roads are of a slightly lower importance and are therefore less desirable for new development compared to those of the type of national road and motorways. In this case study too it is possible to observe linear expansion along the road infrastructure. This again implies that new construction seeks access to road infrastructure in addition to proximity to populated areas.

Gravitational Pulls

Gjakova and Prizren, the two settlements at each end of the road segment, exert two significant gravity forces. Prizren is slightly larger and has a higher population than Gjakova, hence it exerts a stronger attraction.

Accessibility

The settlement of Prizren is also close to one of the two major motorways of the region. This motorway, even though is prohibited to have development parallel to it, has been used to amplify development close to the analyzed road segment close to Prizren. Additionally, this case study has the largest number of connections compared to its length, resulting in clusters of development especially close to junctions.

Agglomerations

Due to the shorter length of the road infrastructure, clusters of development are much more compact compared to the previous case study. These are usually developed nearby existing junctions, but not exclusively.

Restrictions

Regarding the Regional Road that is the subject of this case study, there are hardly any regulations at all. This indicates that there are no genuine (measurable) restrictions, either geographical, physical, or legal, that will limit development in any meaningful way. These restrictions might be any of the following: geographical, physical, or legal.

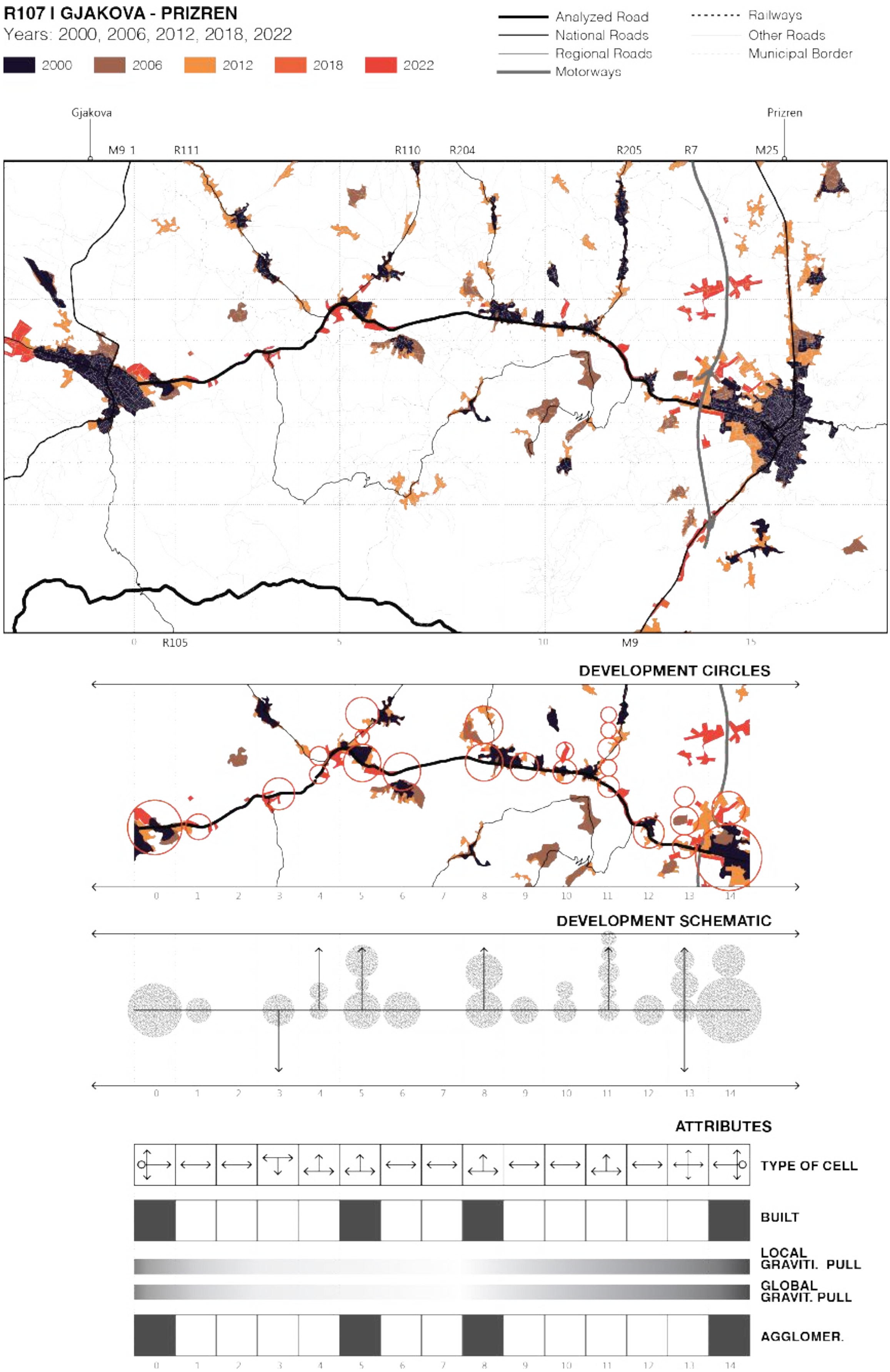


Figure 48 Case Study 6 - Regional Road: Gjakova - Prizren

4.6. Summary

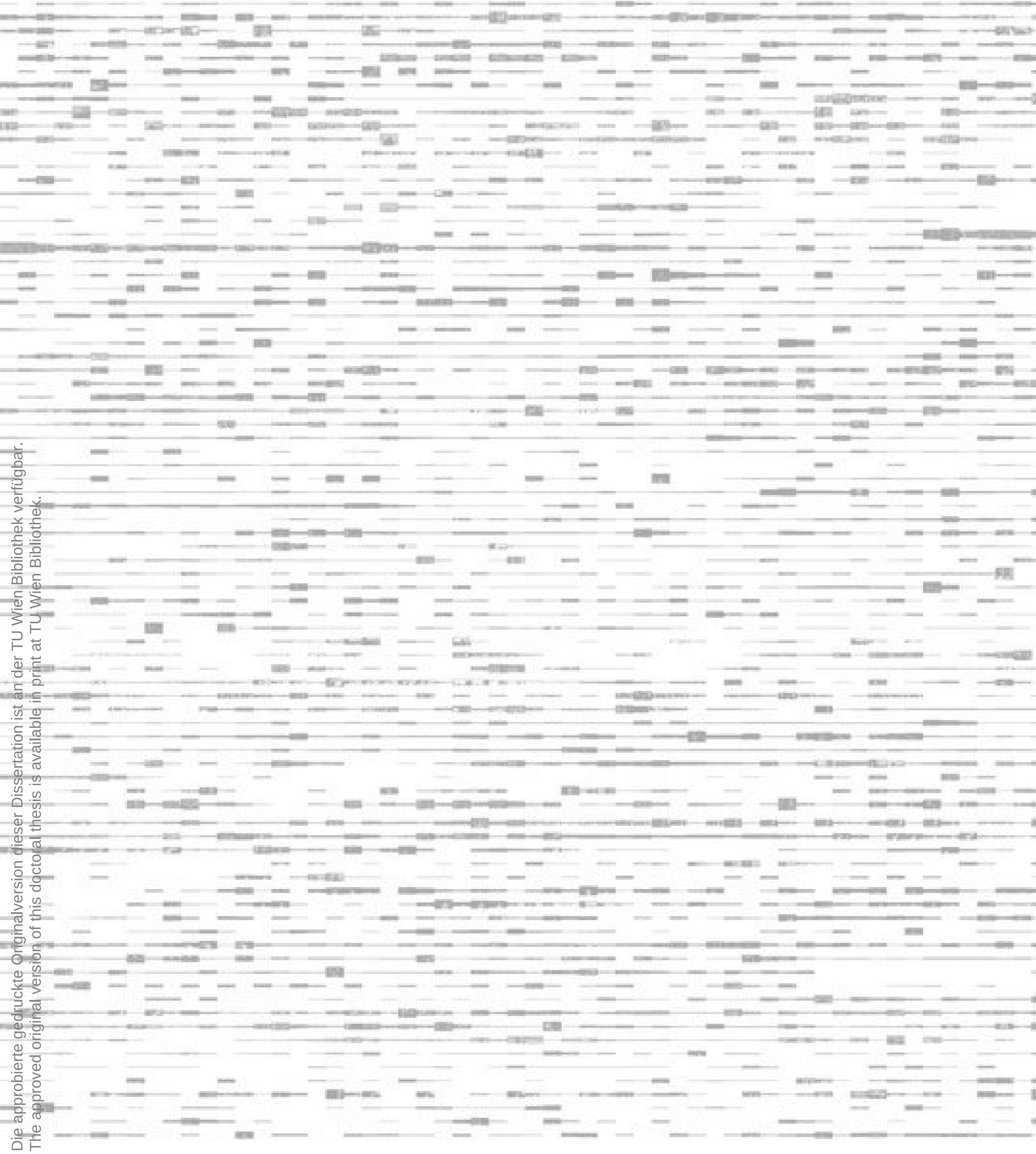
Following Kosovo's independence, the state of the country's road infrastructure has greatly improved. As recognized by the legal framework of Kosovo, there are four different levels or types of road infrastructure: Motorway, National Roads, Regional Roads and Local Roads. The government of Kosovo has concentrated the majority of its investments on the development of motorways.

The first step in the analysis of changes in Land-Use throughout time is by visualizing data gathered from Corine Land Cover. CORINE's Land Cover inventory began in 1985, and in 2000, 2006, 2012, and 2018, updates were published. For the purposes of this study, all classes of land cover have been simplified and divided into only built and not built, as the aim is to measure new development.

Road Infrastructure is a complex network with many nodes, paths and directions. In order to achieve a more effective and comprehensive analysis of roads, it is preferable to partition it into smaller segments. Each road is separated into segments, with the settlements serving as separators and the road segment being the section of road that connects them both.

The CORINE project aims to provide a map of land development over time, in order to give an accurate depiction of changes in land development. As most of the data is in a map form, and qualitative research also needs to be presented in a measurable form, diagrammatic maps will be developed. The maps of these different time periods will be stacked, so as to better observe the changes from one period to the next.

One is able to derive some inferences regarding what types of new developments are preferred based on the case studies. At first examination, it is clear that new developments favor locations that are close to existing settlements. Second, it is preferable to be in close proximity to existing road infrastructure. Third, it is preferable to be in close proximity to roads that approach the road infrastructure that is being analyzed.



CHAPTER 5

IN SEARCH OF SPATIAL PATTERNS: PROPOSING A NEW MODEL

This chapter elaborates on the reasoning for designing and using the model, as well as a detailed explanation of the structure, features and purpose of the model. Additionally, model attributes including their values and weight will be investigated in detail, including the methods of calculation.

5. IN SEARCH OF SPATIAL PATTERNS: PROPOSING A NEW MODEL

This chapter begins by giving a rationale for devising and using an 'urban model' for the purposes of better understanding the geographical and spatial phenomena we observe. We elaborate the benefits of using such models as tools to develop data-driven and better formulated arguments that are to be used in making decisions. We will also explore the drawbacks and disadvantages of using models for the purposes of predictions and simulations, and how these lessons can be added to the proposed model of this dissertation.

Next, this chapter shows the methods used to convert the observed empirical research of roads, into land-use maps, that are further developed into simplified diagrams, which in hand will be used to conceive and produce the data and values that are to be used as inputs for the model. As most of the research is empirical in nature, it is important to cover the explanation of the process of quantifying all of these observed phenomena, in the selected road case-studies.

Furthermore, a detailed examination of the 'anatomy' of the model is given, including the geometry, inputs and outputs, as well as the use-case for the model. This section elaborates and argues on the uses of cells as a method of devising what is considered a more bottom-up approach in prediction. Additionally, in this section the rules of the model are laid out, as well as the entire structure and architecture of the model. This information of this section is particularly important when covering more detailed discussions of attribute values and weights in Chapter 4 and 5.

The last part of this chapter elaborates on a number of carefully selected and observed phenomena and features of the research road case-studies, that will serve as model attributes. These attributes have been been designed in such a way that they possess a value that is different for each attribute, as well as a weight, as a form of measuring the impact it has in enforcing changes to the model. All model attributes will be examined individually, by explaining the theoretical approach, the mathematical reasoning and how they are to be calculated, as well as the presentation of specific cases as observed during the empirical research.

Lastly, other possible attributes that could potentially be included in the model, are discussed and elaborated upon. This chapter ends with a summarization for the entire model design and model attributes, to then continue on Chapter 5, which will deal with the calculation of the values and weights, as well as with the explanation of the predictions and the development of future generations. Ultimately, this chapter serves to present the entire design, architecture as well as data inputs and outputs of the model that will be used as a tool for making predictions in land-use development along roads.

5.1. Rationale for the Proposed Model

Urban models are remarkably useful tools for assessing the impact of changes in land-use patterns, spatially in relation to road infrastructure. The advent of digital computing, from which large-scale simulation sprang, as well as various governmental imperatives for studying the effects of large-scale public investments on cities, such as roads. This enabled, and to some degree enforced, the first appearance of urban models in North America in the 1950s. Urban models initially sprang from a general understanding of what the city was during the 19th century, the first emerging models in urban simulation and prediction used a more general approach of translating laws of mechanics into spatial behavior, like Newton's law on gravity to illustrate gravitational pulls of settlements/cities (Ball, 2004). But this does not mean that they were not correct, just that they lacked precision, for example, as proved by (Alex, 1983) the same logic behind the law on gravity, can be applied to demonstrate the gravitational pull of cities and settlements.

In the pursuit of identifying patterns in a geographical and spatial sense, models provide clear logical explanations for empirical phenomena. They have two characteristic features, in that firstly, they simplify reality by removing extraneous elements and details, making it more abstract, or constructing something entirely new from scratch. Second, they formalize by defining terms precisely. Models establish tractable spaces within which we may work through logic, generate hypotheses, build solutions, and fit facts by simplifying and making precise.

When building a model, the most crucial actors and entities, as well as relevant attributes are determined. Then it is easier to explain how these parts interact and aggregate, allowing to deduce the chronology of the phenomena that happens, thereby strengthening our reasoning and argument by doing so.

It is very clear that models are not always correct, especially when dealing with large-scale, top-down analyses and predictions. Noticing the effects of the individual or agent on the outcome of models (Batty, 2008) proposes a bottom-up approach for higher accuracy. Batty proposes using more dynamic and complex ways of creating models, which are based on agents, and the method that we will be using, cells. This approach enables to have a more specific and tiled view of the changes we are observing.

In order to ensure a more accurate outcome from the model, it is not enough to just design and run it, but rather a lot of calibration, testing and comparation with empirical data is needed to improve and enhance the preciseness of the model. Ultimately, the model proposed in this dissertation, will be used to make predictions of the likelihood of land-use development along road infrastructure. However, it is the purpose of this dissertation to explain and explore how to use these predictions in practice.

5.1.1. From Road Sample to Diagram to Model

Cartographic images are more prone to being noticed, which is something that is quite reasonable. Maps are good at sorting between different parts of reality, resulting in a representation of the observed. Most maps, including even the most extensively used ones, use similar methods to those that are usually used in modeling. For instance, eliminating or minimizing insignificant and trivial effects, in order to highlight important features that are needed for further analysis or interpretation.

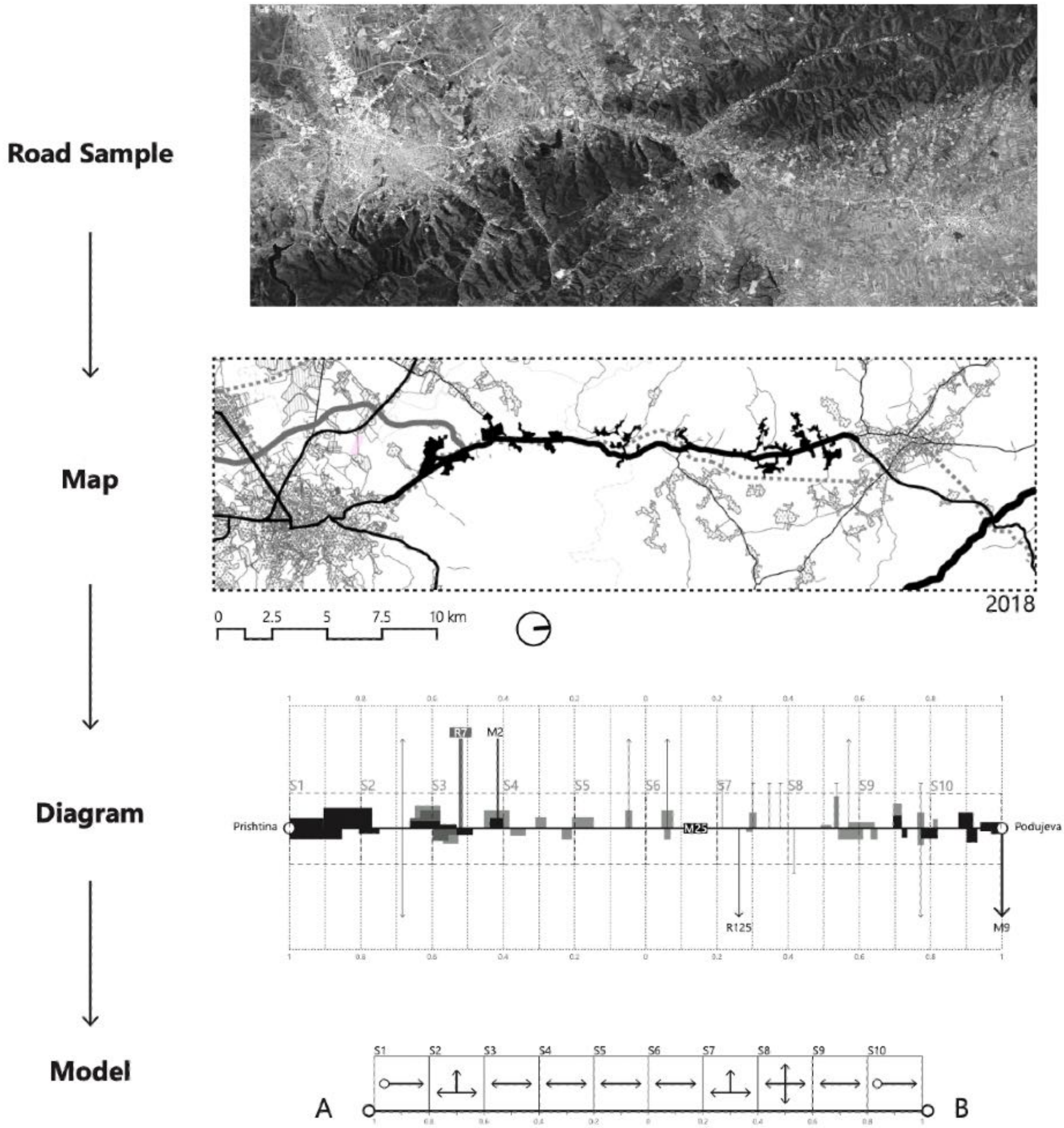


Figure 49 Process of developing the diagram from the road infrastructure map

In order to have the desired clean and informative presentation, the cartographic images need to be converted or transformed into simplified diagrams. The process thus begins with a complex "real-life" observation map (presented in a cartographic form), made up of complex and layered information on land-use, terrain, geography and road infrastructure. The building of a "schematic map" or diagram, comes as a result of a simplification (and thus an abstraction) of the facts and observations found on the cartographic image. If comparisons and generalizations, as well as synthetic summary formulations of a set of spatial processes, can be made, it can be therefore termed "a model".

To measure the impact that road infrastructure has on land-use, the gathered data are transposed into maps, further converted into diagrams that serve as a quantification tool, which provides the input values for the model. This process enables a structuring of the data and makes it more comprehensible, especially when setting up the 'rules' (protocol) of the model.

As previously noted, the purpose of this research is to develop a model that serves the function of predicting the likelihood of land development, in certain parts of an analyzed road. In exploring these questions through making use of the model, there will be a clearer understanding on how different types of road infrastructure shape the development. This process is repeated for all case studies, containing of roads of different hierarchical levels, regions and connections.

As previously discussed, the purpose of turning the map into a simple cells for the model, is to be able to turn complex phenomena that happen in real life, into values that can be entered as inputs. For example, measuring the accessibility of the road happens by slicing the diagram of the map, into corresponding cells, then each cell is analyzed to see how many connections with other roads it has, and thus turned into a value that can be put into the model. Similar actions are required for many of the attributes and features of all the cases analyzed.

In the process of converting the cartographic maps into useful material for the model, some simplification steps are necessary, such as, using straight lines instead of curves when visualizing roads. Additionally, complex forms that show land-use, will be turned into simple geometric forms for simplification reasons as well as for easier calculation.

The maps will again serve a purpose in comparing the output of the model to the current state of the case studies. In order to check if the model's output has been correct, we need to go backwards through the same process: from model to diagram to map. This process is to be repeated until we are happy with the calibration and the output of the model.

5.1.2. Anatomy of the Model - Designing the Model Matrix and Cells

The main design characteristic of the model is the two-dimensional mesh with coordinates for the X and Y axis. It functions much like a two-dimensional array, in that it contains values in each one of the coordinates. The X-axis goes horizontally, and represents the dimension going parallel to the road. The X-axis begins on the left side with the value 0, and continues to grow depending on the length of the road, which also present the number of cells. The Y-axis goes vertically, and represents the dimension going divergent to the cells representing the road. The Y-axis begins in the middle (center) with the lowest value (0), and continues to grow in value in both directions, as it moves away from the center.

Model Matrix - X and Y axis

As stated before, depending on the length of the road, the model can have different sizes on the X-axis (horizontally). The Y-axis however, can change depending on the type of road. Since this dimension represents the distance away from the road, it is higher for roads with a higher hierarchical level, and vice-versa. This is due to the fact that a higher-level road, can have an impact that can be felt further away from the center, whereas lower-level roads have a much narrower field that they can affect.

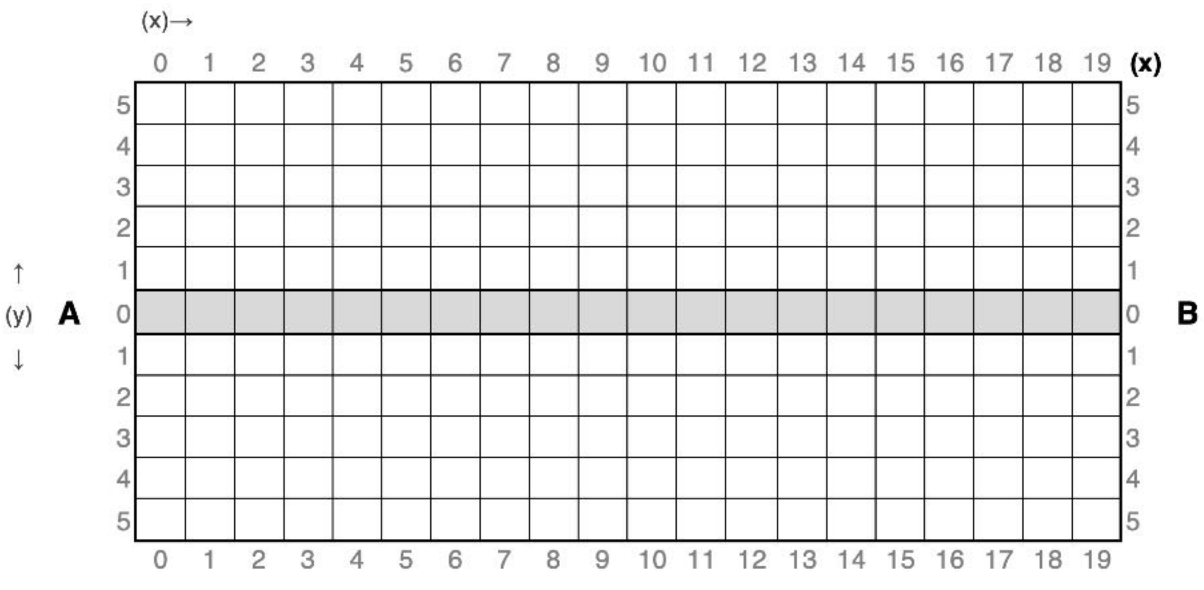


Figure 50 Model mesh with coordinates and positions of settlements

The middle array of cells (greyed out cells in Figure 10) represents the road that is being used as for the purposes of research. The road in itself is a row of cells that in fact will show values as they are processed by the model. The development showed at the cells at y(0) represent the very first 500 meters on either side of the road. The road in itself, is not actually visualized in the model, as we will only be measuring the impact it has, and not it's physical existence.

Both ends of the middle array, which in our case presents the road, represent the settlements which are each marked with the letter A and B respectively. The naming with the letters is of importance, since some inputs for some of the attributes, require the specification of the settlement by letter. In the coming sub-chapters, we will explore these inputs, and how they will need to be inserted for each of the settlements.

Model Cells

In order to better understand, and to have a higher accuracy of where land development is likely to happen, the road samples will be sub-divided into equal parts called Cells. The number of cells for each road sample will depend on the length of the road, i.e. the longer the road, the more cells it has. One cell by default will represent 1km of road length, as well as 1km of distance away from the road.

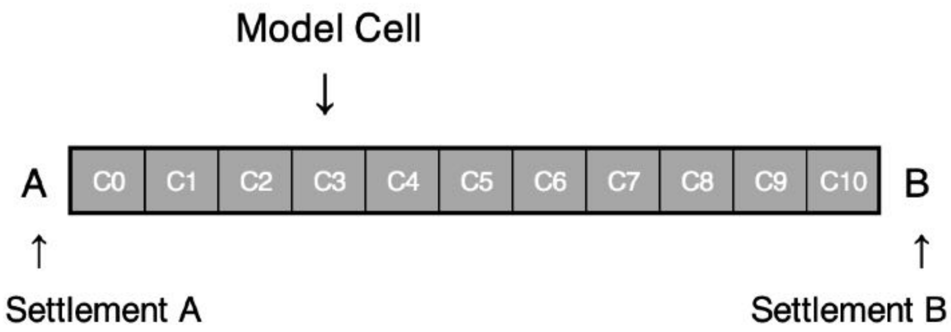


Figure 51 Model Cells and Cell naming

There are two main factors that dictate the final dimensions of the model, and those are the Type of Road and Road Length. The length of the road (attribute: Road Length) will affect the dimensions of the model in the x-axis, whereas the level of road (attribute: Type of Road) will affect the dimensions of the model in the y-axis. The naming scheme for the cells is also dependent on the length of the road, as it sets the number of cells in the array.

The first cell, as stated in the previous section, is named "0", whereas the last cell is named (n-1) where n is the road length (in kilometers with no decimals). For example, if the length of the road is 20km, the last cell's name will be "19" and the first cell's name will remain "0". These two factors or phenomena will also be explained and explored further down as model attributes.

Each of the cells will have a value and weight that derive from inputs, that will be calculated as outputs. The process explaining the calculating and mathematics behind the outputs, will be further explored in Chapter 5.

Model Attributes

Model attributes are the main source of inputs for the model, and are chosen to represent the similarly named phenomena as observed during the empirical research phase. Attributes differ in nature, and have different levels of impact, that will be calculated in the model as 'weight'. This means that each model attribute has a certain weight that is set as a rule in the model, but also a value that is put in by the user. The product of the value and weight, will give another value for each attribute, whereas the product of all attribute values will give the final value for the cell. Model attributes will be covered in detail in the following sub-chapter.

Inputs

The model begins functioning, only after wintering the inputs that are needed for each of the Model Attributes. As will be explained in the next sub-chapter, inputs are divided into local and global, depending on the number of model cells they affect (one, or many). All inputs are inserted by the user, except the Position of Cell, which is determined automatically beforehand. If no inputs for a particular Model Attribute are given by the user, the model will give default values and weights for each of the Model Attributes' inputs. If no inputs are given for all Model Attributes, the model will run a default calculation, based on default values and weights.

Output – Generation 0 (Current State) and Future Generations (predictions)

Besides having the Model Attributes as an input, the model cells will also have outputs, as a result of calculating the inputs values and weights. All measuring and quantification will be presented through these Model Cells. Each model cell will have a value that presents the product of all attributes for that cell. This value is shown in percentage, which represents the probability for development in that particular cell. Once a cell reaches a value, it cannot be demoted to a lower value, meaning it can either maintain the same percentage, or grow in value. This is due to the fact that we do not consider destruction as a possibility when running the model. Meaning that the model cannot predict whether a particular piece of land will be destroyed, but it can only predict whether it will stagnate in development.

The current state of development along the road infrastructure, will be shown in Generation 0. This is a direct result of the inputs from the model attributes. The model will show a heatmap, with the percentages of probability for development in those cells. Meanwhile, the second generation (Generation 1 - Prediction) as well as future generations will be produced as a derivate of Generation 0, and will occur as a second step in the process. All the predictions as well as Generation 0 can be viewed in real-time when changing the attribute values, which makes easy to observe all changes as a result of altering the inputs.

5.2. Identifying and Proposing Model Attributes

A model attribute is a property or characteristic of a phenomenon that is occurring and that can be observed during the phase of empirical research of the road study cases. As will all models, it is important to have features and attributes that try to best mimic that what is occurring in nature. When identifying these attributes, different phenomena and occurrences needed to be observed, so that a small number with higher impact could be filtered out. This means that there is a large variety of these phenomena that are not translated into attributes, since their impact for our research purposes is not high enough to be considered as such. Furthermore, some of these phenomena that become attributes are so impactful in shaping the outcome of the model, that it is not necessary to further expand on the gamut of used attributes.

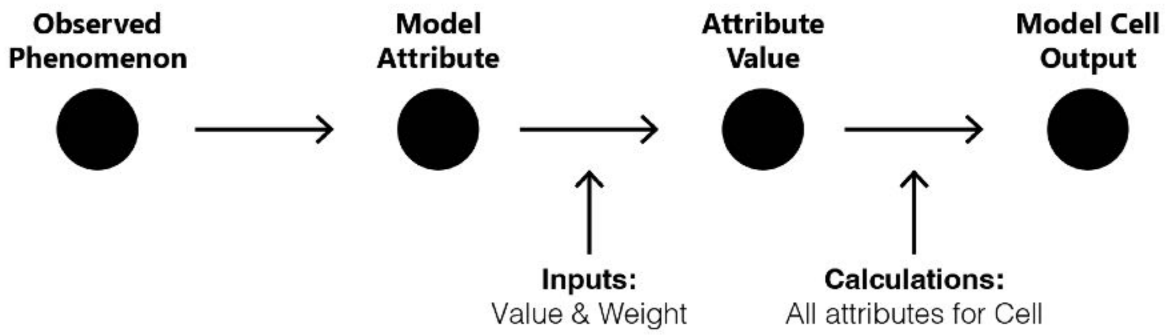


Figure 52 The process by which an observed phenomenon is turned into a model attribute

The purpose of model attributes is to quantify the qualities of these natural occurring phenomena, into something that can be considered as standard for all. This enables us to calculate all inputs simultaneously for all model cells. Some attributes, such as Road Length, are already quantified and much easier to incorporate in the calculation. However, other types of attribute are accounted for, that need further processing and calculating, in order to best represent those naturally occurring phenomena. Such are the Local Gravitational Pull, which calculates the direction of development, depending on the size of settlements on both ends of the road.

The Model is designed to function by requiring inputs that derive from Model Attributes, and producing outputs for each Model Cell. Model Attributes are identified and derive from observations in study cases. These Attributes are the main ‘input’ of the model which in term shape what the results will be for Model Cells, and so shape Generation 0 of the model. Some attributes have been identified and proposed, however there are many more that will be analyzed, added, and potentially even removed from the list. After all attribute values and weights have been inserted, then the model will proceed with the calculation for each of the road cells, consequently showing the outcome for each of the model cells in the road array, as well as the cells in the up and down direction of the road, as they are directly affected.

Global and Local Inputs

There are two levels of inputs that are required for the model. The first level of inputs affects only the cell they are destined for and are called Local inputs (see figure below). These inputs have to be put individually for each of the cells in the road array, however they all have a default value which is considered to be the most common one. This set of inputs includes: Type of Cell, Position of Cell, Cluster. Slope and Restricted. The idea with this level is that if a cell possesses a feature or attribute, it shows for that particular cell, and not for its neighbors. However, this outcome will affect the values of the neighboring cells in all future generations when running the predictions for the model.

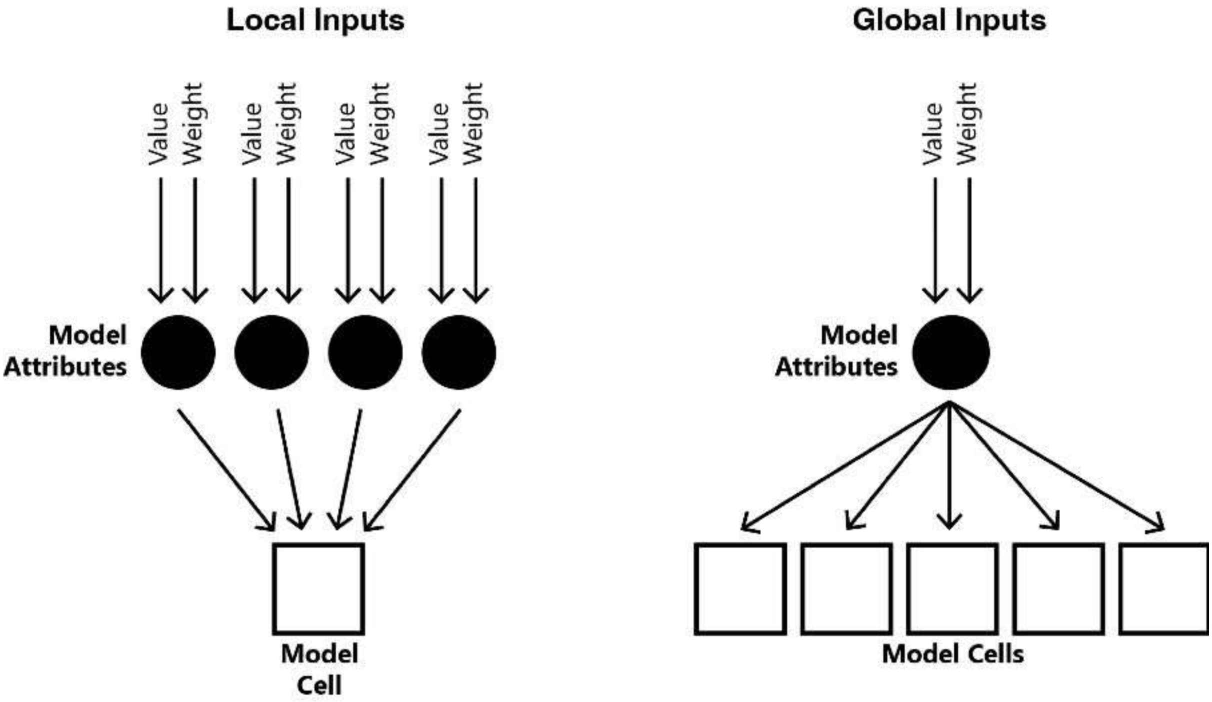


Figure 53 Process and Structure of Local (left) and Global (right) Inputs and their effect on Model cells

The second set of inputs however, affects the entirety of the model, including all the cells, are the Global Inputs. The values that serve as input for this level of inputs is entered at the beginning, when setting up the model values. All these inputs are singular, but have different outcomes for each of the cells of the model. This set of inputs includes:

- Road Length,
- Type of Road,
- Local Gravitational Pull,
- Global Gravitational Pull and
- Limits of Growth.

5.2.1. Type of Road

Type of Road refers to the different hierarchical levels of road infrastructure, as specified by the legal framework of Kosovo. Currently there are four types or levels of road infrastructure, and these are (in descending order):

- Motorway,
- National Road,
- Regional Road and
- Local Road.

The higher-level roads, are fewer in number, and vise-versa. This means that there are fewer case studies available for motorways and national roads, whereas for regional and local roads, the number case studies is much higher.

The road transport in Kosovo has significantly improved following the independence of Kosovo. The government of Kosovo in recent years has focused the majority of investments on the construction of numerous motorways specifically on constructing the R6, R7 and R7.1 which connect Kosovo with its neighboring countries.

There are three main sections of Motorways built in Kosovo as of now: the R7 connecting Kosovo with Albania, the R7.1 linking the capital Pristina with the Serbian border at Dheu i Bardhë and the R6 connecting Pristina with the Macedonian border at Elez Han.

The R7 Motorway (part of Albania-Kosovo Motorway) links Kosovo to Albania's Adriatic coast in Durrës. This motorway will eventually link Kosovo through the present European route (E80) motorway with the Pan-European corridor X (E75) near Niš in Serbia. The R6 Motorway, forming part of the E65, it is the second motorway constructed in the region and it links the capital Pristina with the border with North Macedonia at Elez Han, which is about 20km from Skopje. Lastly, the construction of the new R7.1 Motorway which began in 2017, will link the capital Pristina with the Serbian border at Dheu i Bardhë. The motorway is also known under the name Autostrada Prishtinë–Gjilan. Motorways are defined as roads with at least two lanes in each direction including an emergency lane and a speed limit of not less than 130 kilometers per hour.

As the second highest level road infrastructure, National Roads usually connect larger settlements, but have a much better accessibility, since they are more frequently connected with other road infrastructure. This makes National Roads the most suitable option for development. Furthermore, National Roads in the cases of nearby Motorways, go parallel to them, serving as a secondary artery that is often much more developed than the land closer to the motorways. For the purposes of this research, all National Roads have been used to analyze and test the model.

Regional Roads serve to cover the gaps that National Roads cannot cover. There are two kinds of Regional Roads, those which have a role in completing the road network map and constitute the connection between the main axes and regions, or connect important settlements on a regional basis, as well as Regional Roads which have only limited national and even regional importance and connect small settlements to the main network. The number of Regional Roads is much higher, and therefore only a selected number has been used for this research.

Lastly, Local Roads are the lowest-raking level of road, since they usually cover short distances but differ in nature. Many of them are not entirely paved, and only serve single households. For the purpose of this research, only a select few will be analyzed.

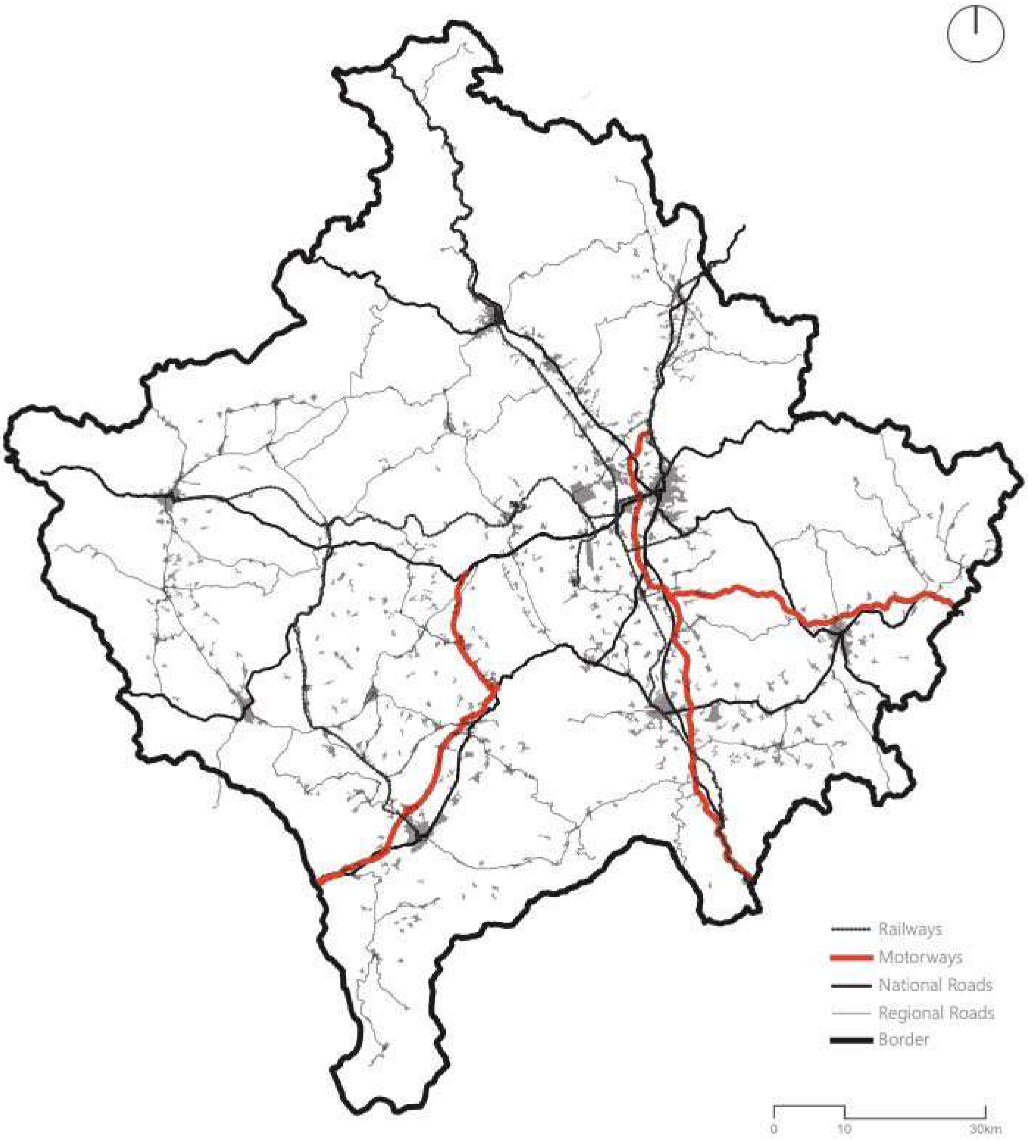


Figure 54 Road Infrastructure in Kosovo with build areas[115]

[115] Data from CORINE Land Cover and the Kosovo GeoPortal (Illustration by Author)

Effects of Model Attribute

Type of Road is one of the most important determinates of the of development it will influence. The pool of case studies in this research, features roads from all four levels, as defined by the legal framework of Kosovo. Since all four types attract such different levels of development, it is one of the most important features for the model. Another manner how the Type of Road attribute affects the output of the model in a more technical level, is by determining the dimensions of the model in the y-axis. As the impact of the road on the development parallel to it, rises together with the level of road. This means that Motorways affect development further away from the road array, whereas on the opposite end, local roads only affect close to the road array. In the model this is visualized with local roads affecting on the the next array of cells going parallel to the road array, Regional Roads affect the next two rows, National Roads affect the next four rows, and Motorways affect the next five rows. This is illustrative to the level of impact they each have in reality.

For example, National roads are the highest-level roads with the highest likelihood for impact on Land development. This means that development tends to favor roads of a higher hierarchy or importance.

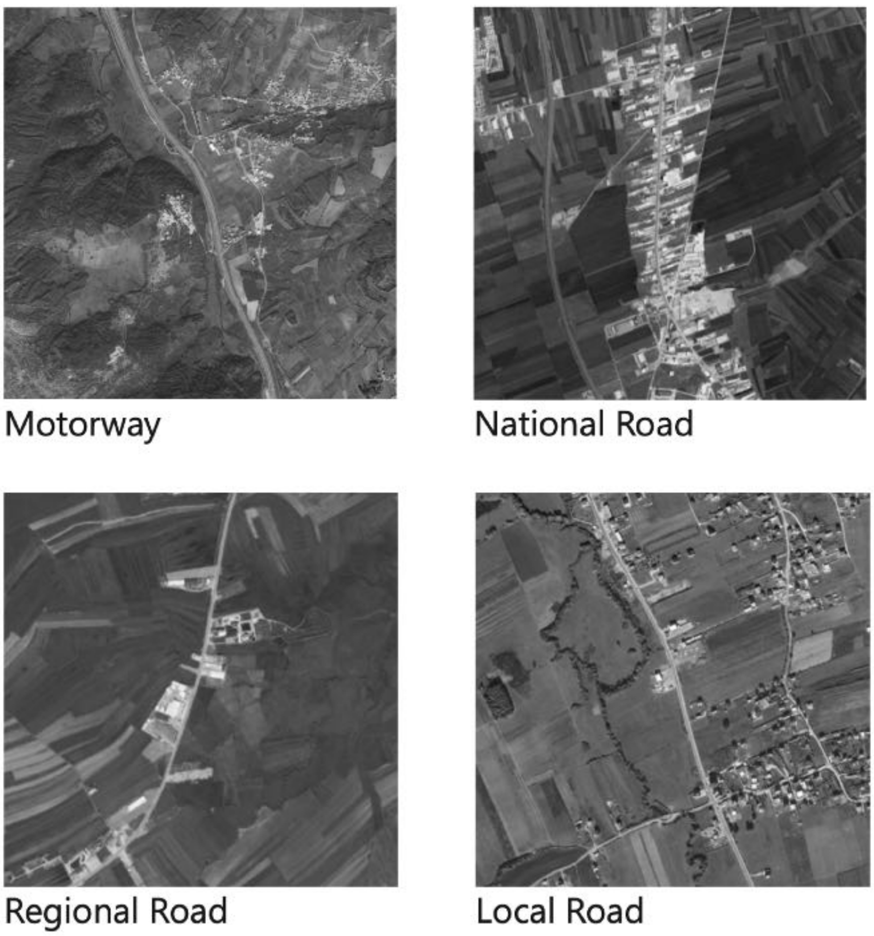


Figure 55 Different hierarchical levels of Road Infrastructure in Kosovo

As can be observed from the examples in the figure above, the motorway as expected works much like a corridor, meaning that due to the speed at which vehicles drive as well as other restrictions (such as buffer zones), development is rare but sometimes clustered around junctions, or if it was existing prior to the construction of the motorway. On the other hand, National and Regional Roads tend to collect more development around them, due to the accessibility as well as the speed at which vehicles travel. The figure above also shows that the National Road level is favored by development much more than all other levels of road infrastructure. This attribute however is only useful in measuring the current state of the road analyzed, since for predictions this attribute cannot be changed. This is due to the fact that this attribute has features that are more naturally occurring, such as distance, geography and terrain, and is not a matter of choice as it is with following attributes. The Type of Road is almost always predetermined by the existing conditions and state of that particular region.

Operation of Model Attribute

This particular model attribute functions by assigning it a value that is representative of the type of road, as well as a weight that this attribute has for the model. The production of these two values, will be the outcome for all the cells of this attribute. The Type of Road attribute is assigned the letter ‘A’ as a name, and each cell is named A(n), where n is the number of the cell.

Value

As will all other attributes to come, the model requires an input that signifies the Type of Road the user wants to select. Depending on the Type or Road, there are four possible input values for this attribute, that represent the levels of the road:

for Local Road – 1;
for Regional Road – 2;
for National Road – 3;
for Motorway – 4.

Different levels of road bear a different value which the model calculates. Since, as seen from the previous figure, Motorways have a lesser level of development, they are calculated as 0, and the opposite is true for National Roads, which are calculated as 3. For example:

Level 1 – Local Road will be calculated as ‘1’ by the model;
Level 2 – Regional Road will be calculated as ‘2’;
Level 3 – National Road will be calculated as ‘3’;
Level 4 – Motorway will be calculated as ‘0’ by the model.

Regardless of the Type of Road entered by the user, the calculation will be different, as assigned to the model. This calculated value is called *‘tor_value’*, and it is an integer.

Table 16 Type of Road and their corresponding values

Number	Type	Value
1	Local Road	1
2	Regional Road	2
3	National Road	3
4	Motorway	0

Weight

In order to calculate the impact of each attribute for the model, a certain ‘weight’ has to be set. This weight will make some attributes purposefully more impactful than others. The calculated weight is called ‘tor_weight’, and it is a number that represents the percentage of the overall calculation for the cell. In this case, the weight is 0.1 which means the *tor_value* will have an impact of 10% in the overall calculation of the cell. This number is a quantification of the observations made from the empirical research using the case studies.

Output

The output is organized in different levels. Each road contains a cell array, comprising of a number of cells. Each cell is the product of the attribute value and weight, in this case the output value for cell ‘A’ *‘tor_sum’* is the product of *tor_value* and *tor_weight*. As the position of the cell is of great importance, each cell has a corresponding number that shows it’s position: A(n) where (n) is the cell number in the array. For example, the first cell in in the array of the ‘A’ attribute, is A0, the second is A1, and so forth.

Table 17 Type of Road value, weight and cell sum calculation

A = tor	
tor_value	Type of Road / 3
tor_weight	0.1
tor_sum	0.1
A =	**0.1**

As this is an array for an attribute that falls under the group of Global Inputs, all cells of the output ‘A’ of the road array will be the same, regardless of the position of the cell.

A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Figure 56 The cell output for Attribute A (Type of Road)

5.2.2. Road Length

Along with Type of Road, the Road Length attribute is one of the most important and determinant elements of the model. As the name suggests, this attribute accounts for the length of the analyzed road, and the effect it will have in development, in terms of distance from the road. The length of the road in this case is measured between two settlements, meaning that if a settlement interrupts the road segment in the middle, that particular road needs to considered as two separate roads.

The Road Length attribute is important for determining the density of development, with the reasoning being that the longer the road is, the more dispersed the development along it is likely to be. Meaning that in short distances, there is a tendency for development to stack away from the road, as accessibility is a lesser issue. This attribute will also serve to adjust the values for each individual model Cell, enhancing the accuracy.

Effects of Model Attribute

Road Length is also an important attribute that determines whether development will be focused near settlements, or if it will be more spread out. The longer the distance is between the two settlements, the higher is the chance for development to be concentrated at both ends of the road away from road center, or to influence the creation of clusters of development.

When the distance between two settlements is short and Road Length is therefore short, there is not much incentive for developers to chase access near settlements, they will rather only seek access to the road infrastructure. This is because the time it takes to access the road to the settlements, is just as feasible, or similar to being near a settlement. In this case, development is likely to happen all along the road infrastructure, often with the middle of the road being the most developed, as it has the best balance of cost and travel time.

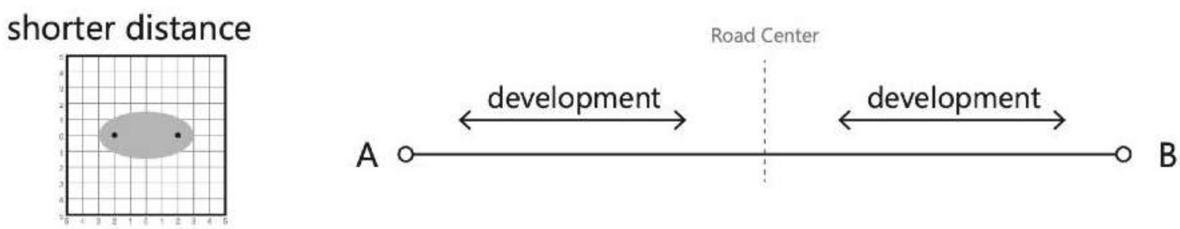


Figure 57 The shorter a road is, the more likely that the development is more evenly dispersed

This can be witnessed in the figure below, which shows the road connecting Fushë Kosova and the capital Prishtina. The two settlements are represented with dots, and the road is represented with the white line. The white opaque fill approximately shows the development affected by the road. As can be seen in the figure below, the development continues to stack away from the road, as soon as the slots closest to the road are filled.

Figure 58 Road from Fushë Kosova (left) to Prishtina (Right) - due to the short distance, the two settlements have started to merge

On the other hand, if two settlements are father apart, and Road Length is very high, then developers will simply try and invest as closely to the settlements as possible, or near already-existing clusters of development. This is due to the fact that there is no real benefit for developers to only access the road infrastructure, if they will then need to travel long (and costly) distances, in order to access the settlements.

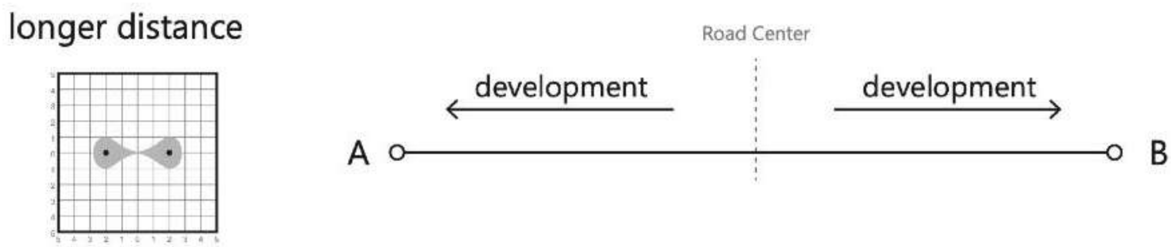


Figure 59 The longer a road is, the more likely that the development is concentrated close to the settlements

This can be witnessed in the figure below, which shows the road connecting Lipjan and the capital Prishtina. The two settlements are represented with dots, and the road is represented with the white line. The white opaque fill approximately shows the development affected by the road. As can be seen in the figure below, the development focuses around settlements as well as in shape of small clusters.

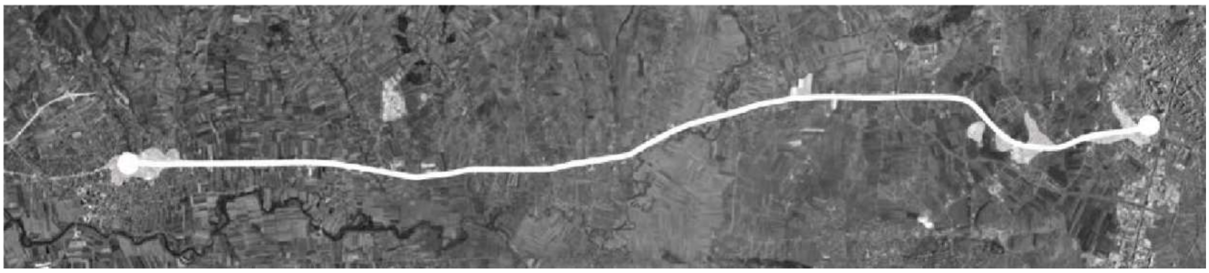


Figure 60 Road from Lipjan (left) to Prishtina (Right) - due to the long distance, development is scattered

Operation of Model Attribute

In the case of the model, this particular attribute affects the dimensions (length) of the model. As each cell is representative of 1 kilometer by 1 kilometer, the road length will determine the number of cells in the road array. This means that if a road is 10km long, the model will analyze 10 cells, whereas if the road is 50km long, the model instead will analyze 50 cells.

Value

The input value for the Road Length attribute is an integer, and varies from 5-60. This is due to the fact that there are no case studies of roads that are longer than 60 kilometers, nor shorter than 5 kilometers. The attribute values is called *'rl_value'*, and since this input is an integer, it means that the user will have to round the numbers to a value that more closely resembles the measured distance. For better calculation, the *rl_value* is calculated as in the equation below. This is to equalize the *rl_value*, as it can produce a very large compared to the other attributes.

$$rl\_value = \frac{(\max road\ length - road\ length)}{(\max road\ length - \min road\ length)}$$

Weight

In order to calculate the impact of this attribute for the model, the 'weight' has to be set. This weight is designed to set a level of impact for this particular attribute. The calculated weight is called *'rl_weight'*, and it is a number that represents the percentage of the overall calculation for the cell. In this case, the weight is 0.1 which means the *rl_value* will have an impact of 10% in the overall calculation of the cell.

Table 18 Road Length value, weight and cell sum calculation

B = rl	
rl_value	0.55
rl_weight	0.1
rl_sum	0.05
B =	**0.05**

Output

As this is an array for an attribute that falls under the group of Global Inputs, all cells of the output 'B' of the road array will be the same, regardless of the position of the cell. This means that *rl_weight*rl_value* will produce the number representing the percentage for each cell.

B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Figure 61 The cell output for Attribute B (Road Length)

5.2.3. Position of Cell

The position of each cell will affect the probability level for development, depending how near it is to the settlement in the x-axis, as well as to the road infrastructure in the y-axis. This attribute can be visualized as a mesh, with coordinates in both axes. Each cell of the mesh has a value that is representative of the gravitational pulls towards the settlements and the road. For example, the cell with the coordinates (0,0) will have the highest value, which is 1, and it decreases in both directions away from either the settlement or the road. The same goes for the proximity of the cell in regards to the road, meaning that the closer the cell is to the road, the higher the value it holds, and vice-versa.

This attribute is needed to better convey how development tends to occur in reality. Each cell's position is important in determining the likelihood for development, and the weight that position i.e. proximity, has on affecting these outputs. The combination (or production) of the proximity to either one of the settlements, together with proximity to the road infrastructure, will give the combined value for each cell of the model's mesh. If the position of the cell is disregarded, the model will fail to show an accurate depiction of these phenomena that occur in nature.

Effects of Model Attribute

Proximity to already developed or build land is one of the most significant and inciting causes of further development. It is always more economically feasible to build close to where's already built, since investing in infrastructure (both for the developer and the government) has a much lower cost compared to land developed far away from existing infrastructure.

In terms of how this is presented for the model, it is calculated in two directions, namely analyzing the distance (proximity) of the cells to the settlements, as well as the distance to the road infrastructure itself. For this purpose, two separate meshes are needed, the first representing proximity to settlements, and the second representing proximity to the road array (infrastructure).

In the direction of the x-axis, two of the cells closest to the settlements (first and last cells in the road array) will have the highest value possible, which in the case of this model is 1, representing 100% chance for development. This in order to illustrate that the cells i.e. land, that is closest to the settlements, inevitably will develop first, and in most cases is already developed.

Each of the following cells in the direction of the middle of the road array, will continue to drop to 75% of the value of the previous cell. This means that if the first cell has a value of 1, the next cell will have a value that is 75% of the previous cell, and so on.

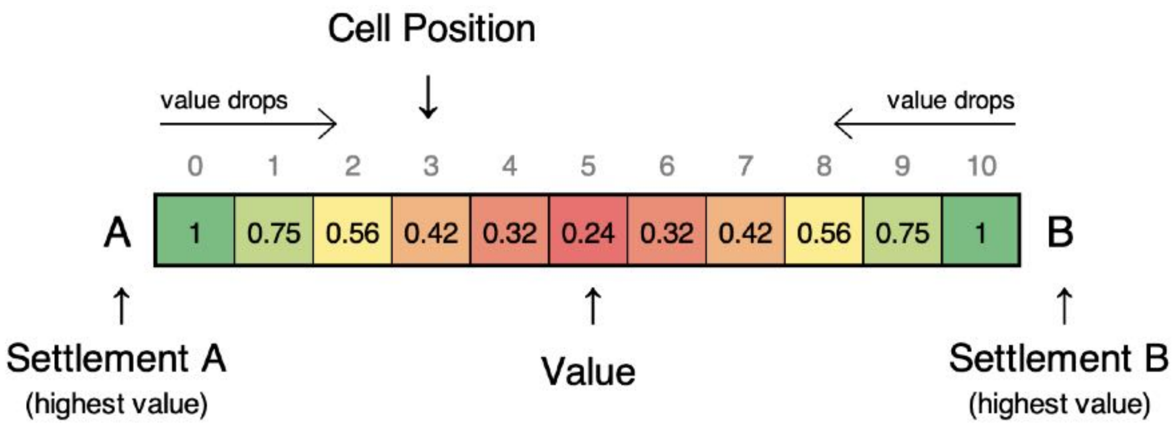


Figure 62 Changes in value, depending on the Proximity to both Settlements

This pattern continues with each following cell, and depending on the Road Length it can affect the model differently. Regardless of the Road Length, 0 is the asymptotic limit, meaning that theoretically there is always a chance for development in all cells, even for those that are furthest from the settlement. This attribute strengthens the idea that if two settlements are closer together, the development that occurs mid-way between the two, can benefit from both settlements, with the cost of not being near neither of them.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
5	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	5
4	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	4
3	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	3
2	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	2
1	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	1
0	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	0
1	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	1
2	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	2
3	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	3
4	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	4
5	1	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.1	0.08	0.08	0.1	0.13	0.18	0.24	0.32	0.42	0.56	0.75	1	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	

Figure 63 Proximity to Settlements (Mesh "A")

In the direction of the y-axis, the cells that represent the road array, have the highest value possible, which in the case of this model is 1, representing 100% chance for development. This in order to illustrate that the cells, i.e. land, that is closest (or in) the road array, has a much higher chance for development.

The following cells that progress away from the road array, will continue to drop to 50% of the value of the previous cell. This means that if the first cell on the road array has a value of 1, the next cell will have a value of 50%, and so on.

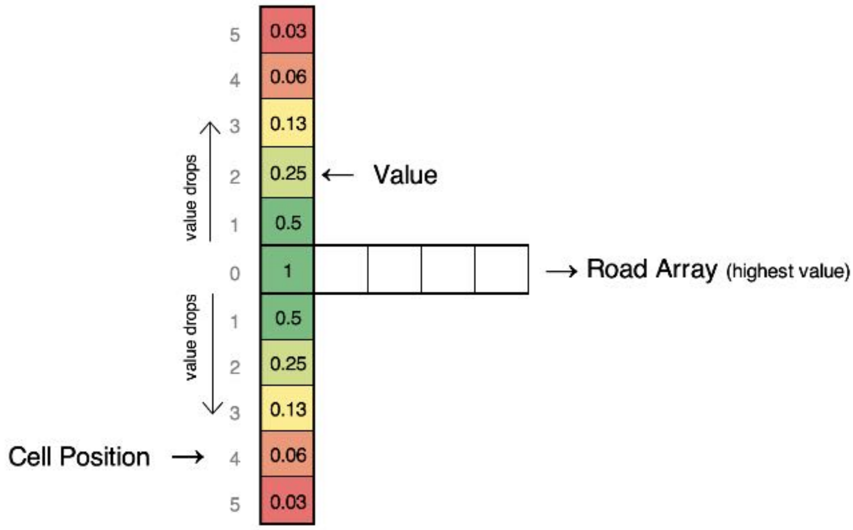


Figure 64 Changes in value, depending on Proximity to Road Array (Infrastructure)

This pattern continues with each following cell, and depending on the Type of Road it can affect the model differently. Regardless of the Type of Road, 0 is the asymptotic limit, meaning that theoretically there is always a chance for development in all cells, however small that might be.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
5	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	5
4	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	4
3	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	3
2	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	2
1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1
2	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	2
3	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	3
4	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	4
5	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	

Figure 65 Proximity to Road Infrastructure (Mesh "B")

Operation of Model Attribute

The overall purpose of this attribute is to serve as a calibrator in order to fine tune the outputs of all other attributes, as they have different impacting powers depending on various proximities.

Value

In terms of input values, the user does not have to input anything, rather the model generates the values automatically, depending on the Position of Cell, the Road Length as well as the Type of Road. Position of Cell *'poc_value'* determines the slope of values, the further away from the settlement the lower, and vice-versa. As the Road Length attribute determines the number of cells in the road array, it also affects the value of the cells, especially in the middle part. Finally, as the Type of Road attribute determines the number of cells rows in the y-axis, it also affects the values of the cells away from the road array.

Weight

In order to calculate the impact of this attribute for the model, the 'weight' has to be set. This weight is designed to set a level of impact for this particular attribute. The calculated weight is called *'poc_weight'*, and it is a number that represents the percentage of the overall calculation for the cell. In this case, the weight is 0.1 which means the *poc_value* will have an impact of 10% in the overall calculation of the cell.

Table 19 Position of Cell value, weight and cell sum calculation

C = poc	
poc_value	x
poc_weight	0.1
poc_sum	0.1*x
C =	**x**

Output

As this is an array for an attribute that falls under the group of Global Inputs, all cells of the output 'C' of the road array will not be the same, depending on the position of the cell. The final output of this attribute, is the average of the same cell from both meshes (proximity to settlements and proximity to road array). For example, if a cell with coordinates (2,2) in the proximity to settlements mesh has a value of 0.56, and the corresponding cell with the same coordinates (2,2) of the proximity to road array mesh has a value of 0.25, then the output of the attribute will be:

$$[A(i,j) + B(i,j)] / 2 = (0.56 + 0.25) / 2 = 0.14$$

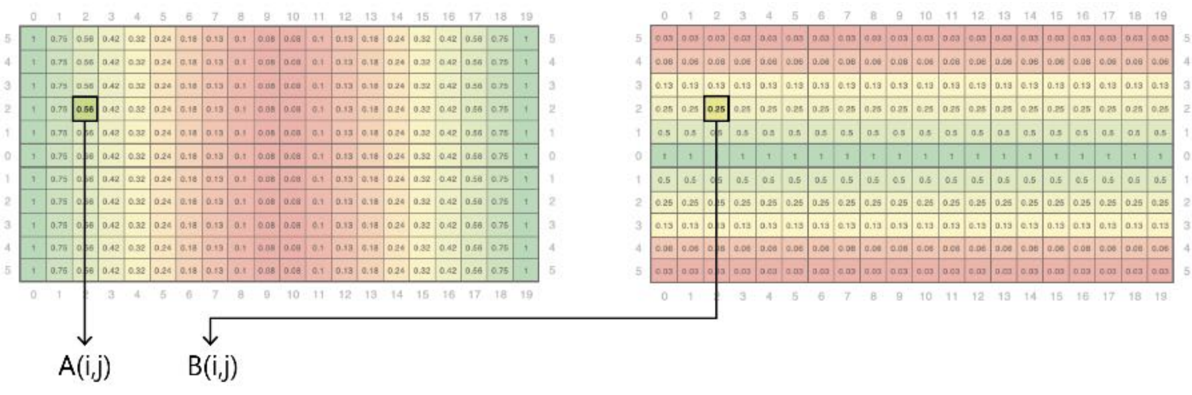


Figure 66 The cell with same coordinates from both meshes is calculated

The value of 0.14 translates into 14% of chance for development on that particular cell, however as we have already determined, this value is further processed by the weight of this particular attribute *poc_weight*, as well as with all other outputs of attributes of the model.

To sum up, the output mesh, depending on the Type of Road and Road Length attributes, will show greater values for the cells positioned closer to the settlements and the road array. The values of these cells will continue to drop for cells that are positioned further away either from the settlements, or the road array.

	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	
5	0.516	0.391	0.297	0.227	0.174	0.134	0.105	0.082	0.066	0.053	0.053	0.066	0.082	0.105	0.134	0.174	0.227	0.297	0.391	0.516	5
4	0.531	0.406	0.313	0.242	0.189	0.15	0.12	0.098	0.081	0.069	0.069	0.081	0.098	0.12	0.15	0.189	0.242	0.313	0.406	0.531	4
3	0.563	0.438	0.344	0.273	0.221	0.181	0.151	0.129	0.113	0.1	0.1	0.113	0.129	0.151	0.181	0.221	0.273	0.344	0.438	0.563	3
2	0.625	0.5	0.406	0.336	0.283	0.244	0.214	0.192	0.175	0.163	0.163	0.175	0.192	0.214	0.244	0.283	0.336	0.406	0.5	0.625	2
1	0.75	0.625	0.531	0.461	0.408	0.369	0.339	0.317	0.3	0.288	0.288	0.3	0.317	0.339	0.369	0.408	0.461	0.531	0.625	0.75	1
0	1	0.875	0.781	0.711	0.658	0.619	0.589	0.567	0.55	0.538	0.538	0.55	0.567	0.589	0.619	0.658	0.711	0.781	0.875	1	0
1	0.75	0.625	0.531	0.461	0.408	0.369	0.339	0.317	0.3	0.288	0.288	0.3	0.317	0.339	0.369	0.408	0.461	0.531	0.625	0.75	1
2	0.625	0.5	0.406	0.336	0.283	0.244	0.214	0.192	0.175	0.163	0.163	0.175	0.192	0.214	0.244	0.283	0.336	0.406	0.5	0.625	2
3	0.563	0.438	0.344	0.273	0.221	0.181	0.151	0.129	0.113	0.1	0.1	0.113	0.129	0.151	0.181	0.221	0.273	0.344	0.438	0.563	3
4	0.531	0.406	0.313	0.242	0.189	0.15	0.12	0.098	0.081	0.069	0.069	0.081	0.098	0.12	0.15	0.189	0.242	0.313	0.406	0.531	4
5	0.516	0.391	0.297	0.227	0.174	0.134	0.105	0.082	0.066	0.053	0.053	0.066	0.082	0.105	0.134	0.174	0.227	0.297	0.391	0.516	5
	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	

Figure 67 The cell (mesh) output for Attribute C (Position of Cell)

5.2.4. Local Gravitational Pull

The Local Gravitational Pull attribute accounts for the ‘gravitational pull’ that existing settlements have on attracting new development. Larger Settlements with higher population tend to have a higher chance for development, pulling away from smaller settlements. The main purpose of this attribute is to determine the direction in which development is likely to spread. This attribute is called the “Local Gravitational Pull” as it calculates the gravitational pulls between two settlements, along the analyzed road infrastructure. Whereas the following attribute called “Global Gravitational Pull” calculates the forces that pull development away from the settlements and the analyzed road infrastructure.

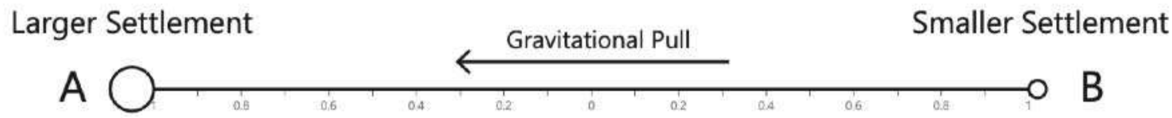


Figure 68 Local Gravitational Pull

This attribute will essentially serve to readjust the model so that development will gravitate towards the already larger settlement. This way, larger settlements will appear to outpace smaller settlements in development, in normal conditions and without input from the user.

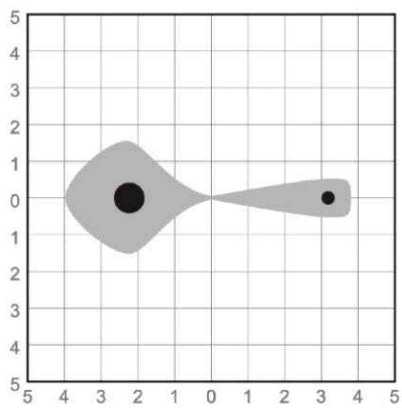


Figure 69 Local Gravitational Pull - Larger settlement (left) smaller settlement (right)

Effects of Model Attribute

If both settlements at the end of the road are of the same size, then the gravitational pull in a sense is neutralized, as both settlements have the same pull. On the other hand, if a settlement is larger than the other, then it will have a greater pull and will continue attracting new development. This is due to the fact that larger settlements tend to have more services available which new developers will try to access. Larger settlements sometimes even outweigh the distance aspect when it comes to new development, since the cost of travel distance are outweighed by the services and opportunities offered by the larger settlements.

In many cases, as one settlement is larger than its neighbor, it will continuously make it more difficult for the neighboring settlement to develop at the same rate. This is again due to the fact that new development will favor the existing services of the larger settlement, which in turn will provide even more services, and thus entering a loop.

In order for both settlements to have the same chance for similar developing levels, often times policies are needed to 'control' growth in the desired direction.

Operation of Model Attribute

The overall purpose of this attribute is to serve as a calibrator in order to fine tune the outputs of all other attributes, as they have different impacting powers depending on various proximities.

Value

There are two input values for this attribute, namely the number of population for both settlements (in thousands). For instance, if settlement A has a population of 100,000, then the user inputs the value 100, and settlement B has a population of 50,000, the user inputs the value 50.

All other calculations and values are done by the model in a few steps, as follows:

1. The first step is calculating the **Local Gravitational Pulls** for each of the settlements individually.
2. The second step is calculating the average for the **Local Gravitational Pulls Binary** for both settlements, depending on the size of each of them.
3. The third step is calculating **Local Gravitational Pull with Distance** – The values from the LGP-Binary, are multiplied by the position of cell value (as with the attribute Position of Cell, the cell closest to the settlements have a value of 1, and they descend to 75% of the value of the previous cell).
4. The fourth and final step is calculating **the Local Gravitational Pull Final** -

For illustration purposes, let us say that The Local Gravitational Pull, for settlement A (LGPA) is 100, and The Local Gravitational Pull for settlement B (LGPB) is 50.

In order to calculate the Local Gravitational Pull for settlement A, we calculate:

$$\frac{LGPA}{LGPB + LGPA}$$

And to calculate the Local Gravitational Pull for settlement B, we calculate:

$$\frac{LGPB}{LGPA + LGPB}$$

As the value for LBPA = 100 and LBPB = 50, we calculate that for settlement A, the Pull is *LBPA / (LGPB + LGPA) = 100 / (50 + 100) = 0.67* and for settlement B, the Pull is *LBPB / (LGPA + LGPB) = 50 / (100 + 50) = 0.33.* This means that settlement A has a local gravitational pull with the a capacity of 67%, whereas settlement B has a local gravitational pull with the a capacity of 33%.

Table 20 Local Gravitational Pull Value calculation

input	
LGPA	100
LGPB	50
Pull for A	0.67
Pull for B	0.33

The calculation for each individual settlement, in the model appears as the figure below. The top figure is that of settlement A, and the bottom figure is that of settlement B. The color of the heatmap is representative of value (green is higher, red is lower), and the values used are only for illustration purposes.

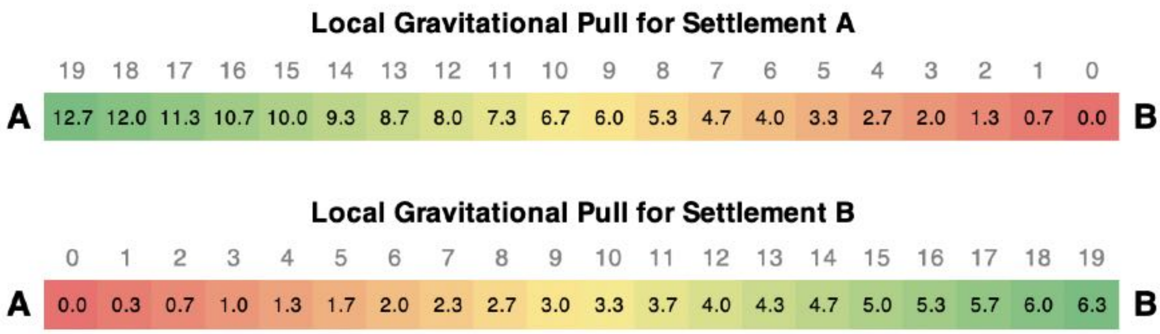


Figure 70 Local Gravitational Pull for each settlement, A (LGPA) and B (LGPB)

In order to calculate the direction of the development, the model calculates Local Gravitational Pull – Binary value, which is the average of LGPA and LGPB, or (LBPA + LGPB) / 2. The model uses this calculation to determine the general direction of growth between the two different-sized settlements. In this case, since settlement "A" is larger than "B", the model determines that the cells nearing settlement "A" will have a slightly better chance of turning developed in future generations of the simulation.

The way development is represented up to this point by the model, is a slope with consistent growth towards the larger settlement. This calculation disregards the proximity or distance aspect, and assumes that all development will tend to go towards the larger settlement, even that which is near a smaller settlement. However, since this is not a realistic representation of what actually happens in real-life, the model needs to do further calculations to come up with the exact curve of development (see next two figures). In reality, after a certain point, due to the proximity/distance aspect, it is much more beneficial for new development to be near settlements, even if they are smaller in size.

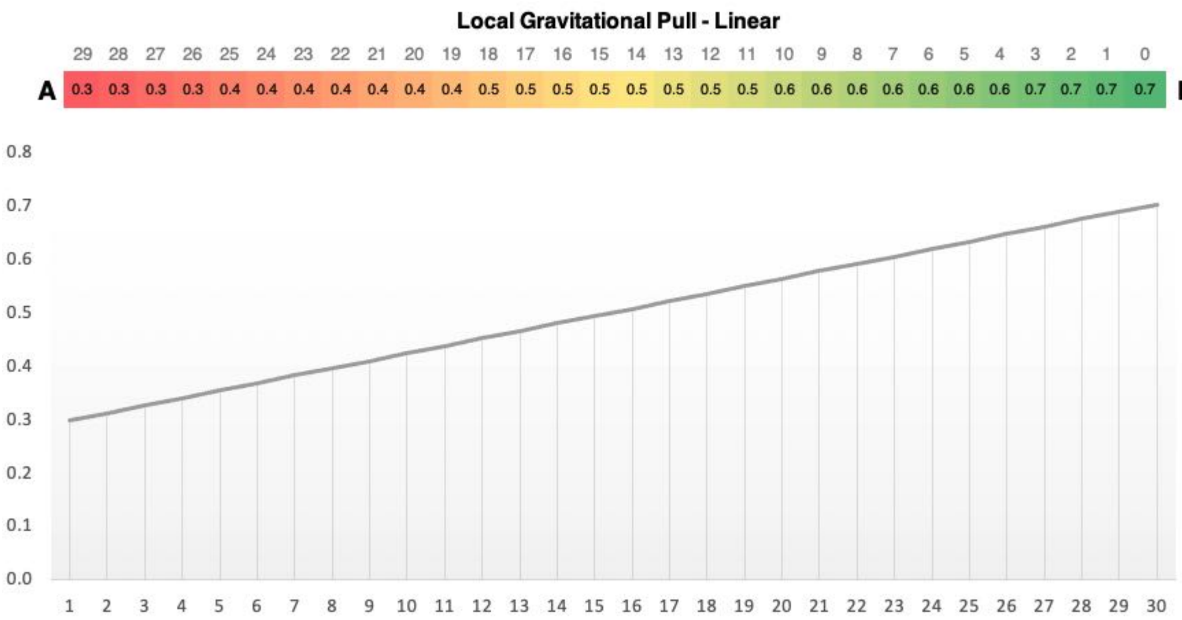


Figure 71 Local Gravitational Pull - Binary - The direction of development as average of LGPA and LGPB

From there on, Local Gravitational Pull – Binary is multiplied by the descending value it has away from the settlements (each settlement has a value of 1, descending towards the middle of the road to 75% of the value). This calculation presents the heatmap and diagram suggesting that the larger settlement A has a greater capacity for development compared to that of settlement B.

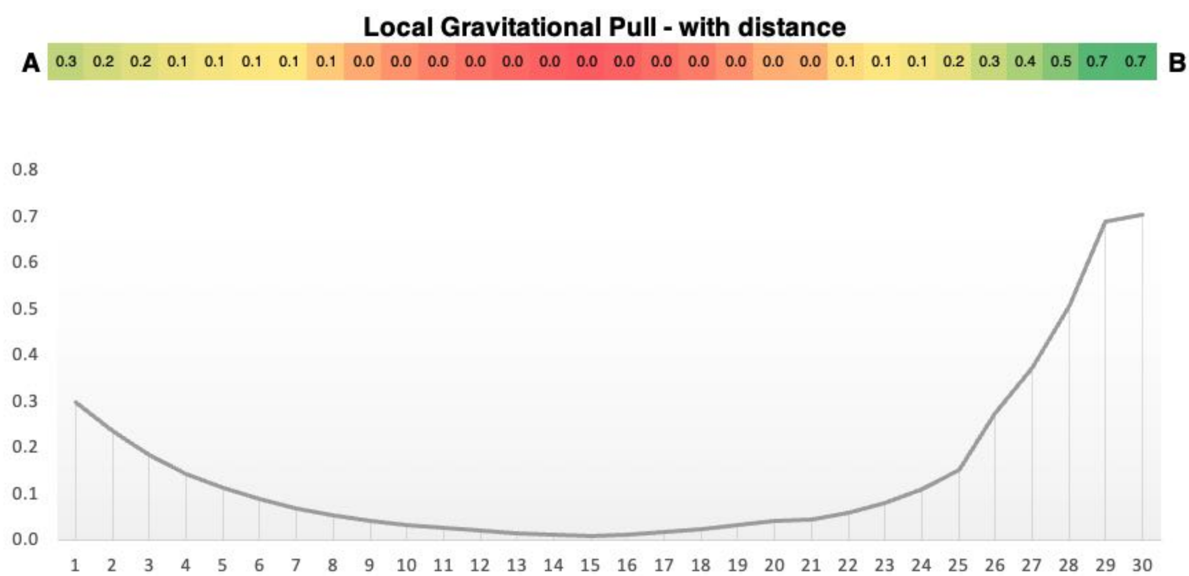


Figure 72 Local Gravitational Pull - with Distance - The direction and intensity of development compared to position of cell

The previous figure shows that regardless of the values and sizes of each settlement, the center of the road remains as the point with the lowest chance for development. As this is not the case as seen in real life, the model multiplies this array with the Local Gravitational Pull – Binary, in order to come up with an array and representation that is more accurate and more akin to that which happens in real life.

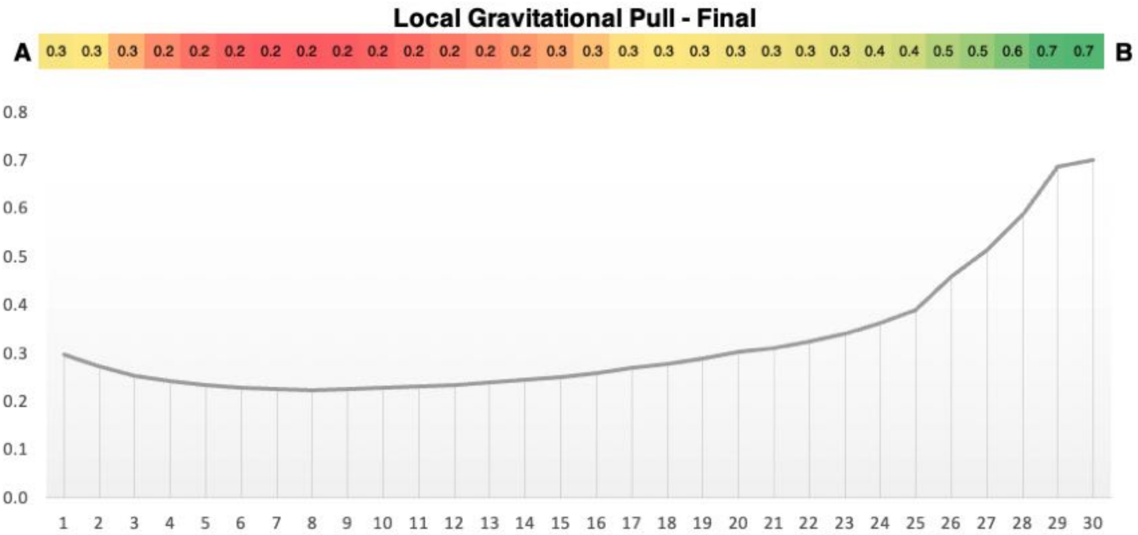


Figure 73 Local Gravitational Pull - Final

Weight

In order to calculate the impact of this attribute for the model, the 'weight' has to be set. This weight is designed to set a level of impact for this particular attribute. The calculated weight is called *'lgp_weight'*, and it is a number that represents the percentage of the overall calculation for the cell. In this case, the weight is 0.2 which means the *poc_value* will have an impact of 20% in the overall calculation of the cell.

Table 21 Local Gravitational Pull, weight and cell sum calculation

D = lgp	
lgp_value	x
lgp_weight	0.2
lgp_sum	0.2*x
D =	**0.2*x**

Output

As this is an array for an attribute that falls under the group of Global Inputs, all cells of the output 'D' of the road array will not be the same, depending of the position of the cell. This means that *lgp_weight * lgp_value* will produce the number representing the percentage for each cell.

D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29
0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Figure 74 The cell output for Attribute D (Local Gravitational Pull)

5.2.5. Global Gravitational Pull

Many roads stretch out through a number of settlements. All of these settlements serve as gravitational pulls for development. This attribute considers whether the settlements at both of the ends of the analyzed road, have other settlements that might be pulling the potential for development away. By the same logic, this attribute is experienced differently in the case where the settlement functions as a dead-end for the road.

The Global Gravitational Pull accounts for the 'gravitational pull' that existing settlements outside the road infrastructure have on new development. If a settlement "A" has another settlement on the other direction of the analyzed road infrastructure, than that outer settlement will have some effect on pulling development away from settlement "A". Same goes for the settlement "B" on the other side of the road infrastructure. This phenomenon is visualized in the figure below.

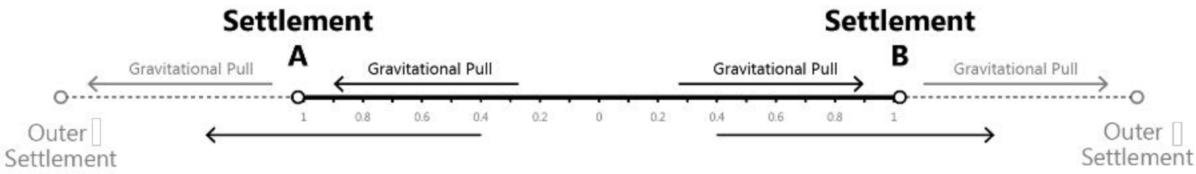


Figure 75 Visual representation of Global Gravitational Pull - Outer settlements pulling development away from road array

The main purpose of this attribute is to determine the force with which development is likely to be pulled away from the road center . This attribute is called the "Global Gravitational Pull" as it calculates the gravitational pulls away from the two settlements, and not along the analyzed road infrastructure. Whereas the previous attribute called "Local Gravitational Pull" calculates the forces that pull development between the settlements of the analyzed road infrastructure. However, the output of this attribute is for the cells of the road array, as the model will calculate the impact of the analyzed road only.

Effects of Model Attribute

The effect of this attribute is to flatten the peaks near the settlements, thus creating a more accurate portrayal of what actually happens in real-life. If the road is analyzed with both settlements as end-points, then the output of the model will favor the closest points towards the settlements, whereas if there are outer settlements (as is often the case in our case-studies), then these peaks are much flatter. This is because new development also has the equal opportunity of reaching the same proximity to the same settlements on either side of it. This model does not however account for the sizes of the outer settlements, as it is considered that due to the distance to the analyzed road, the effects are negligible.

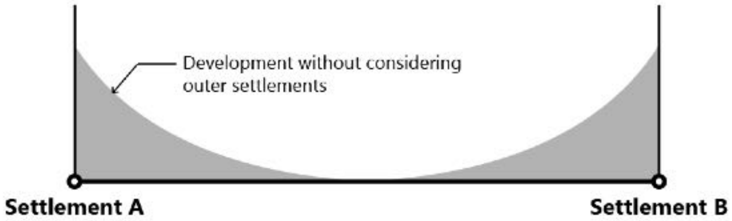


Figure 76 Development when outer settlements are not taken into consideration

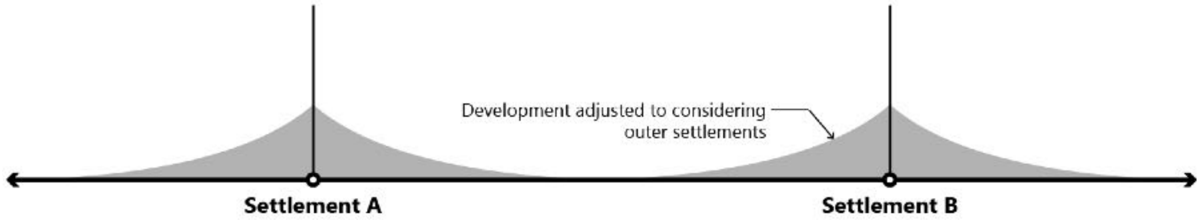


Figure 77 Development when outer settlements are taken into consideration

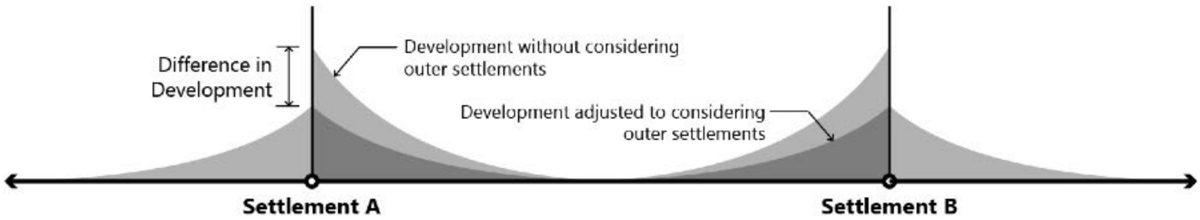


Figure 78 The difference in development outer settlements impact

Operation of Model Attribute

The overall purpose of this attribute is to serve as a calibrator in order to fine tune the outputs of all other attributes, as they have different impacting powers depending on various proximities.

Value

The manner in which this attribute functions, is by first seeing whether either of the two settlements of our analyzed road have other settlements on their outer sides. For the purpose of illustrations, let us say that Settlement "A" has another settlement on the outer side, whereas Settlement "B" does not. In terms of value input, the user needs to put in **TRUE** for Settlement "A" (as it is true that it has an outer settlement), and **FALSE** for Settlement "B" (as it is not true that it has an outer settlement).

Table 22 Global Gravitational Pull Value calculation

input	
GGPA	**TRUE**
GGPB	**FALSE**
Pull for A	1.0
Pull for B	0.0

The TRUE and FALSE statements translate into the value 1 and 0, so when multiplied, if a settlement does not have an outer settlement, it results as 0. In the figure below, the model is calculating the Global Gravitational Pull (GGP) for Settlement A (GGPA) and Settlement B (GGPB). As it has been previously determined for the sake of illustration that Settlement “A” has an outer settlement (GGPA = TRUE) and Settlement “B” does not (GGPB = FALSE), the model produces the two scenarios, which will then be combined to calculate the average.

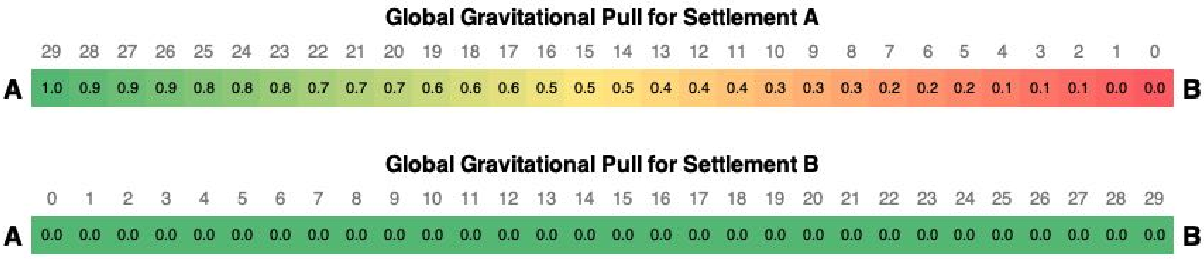


Figure 79 Global Gravitational Pull for each settlement, A (GGPA) and B (GGPB)

The Global Gravitational Pull – Average is calculated as (GGPA + GGPB) / 2. Through this calculation, the model produces an output and array that is a gradual and consistent raise in value towards the settlement that possesses an outer settlement. Had the value of both GGPA and GGPB been the same, this output would be the same for all cells of the array.

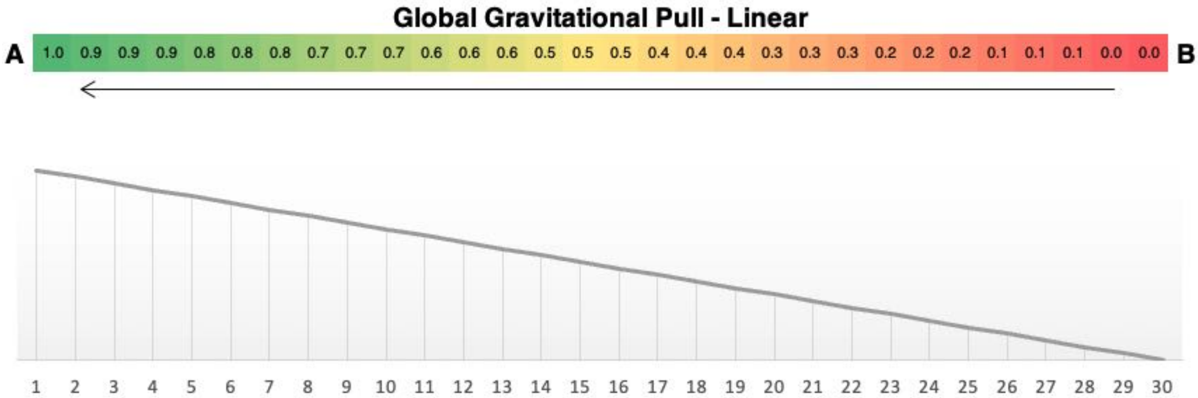


Figure 80 Global Gravitational Pull - Binary - The direction of development as average of GGPA and GGPB

As this is not the case as seen in real life, the model multiplies this array with the Global Gravitational Pull – Final, in order to come up with an array and representation that is more accurate and more akin to that which happens in real life. The idea here is that an outer settlement on the same side as the larger settlement of the analyzed road, will have a larger amount of force pulling new development in that direction.

Through this calculation, the model outputs an array and diagram that resembles that which happens in the observed case studies. This effect can be seen in the following figure.

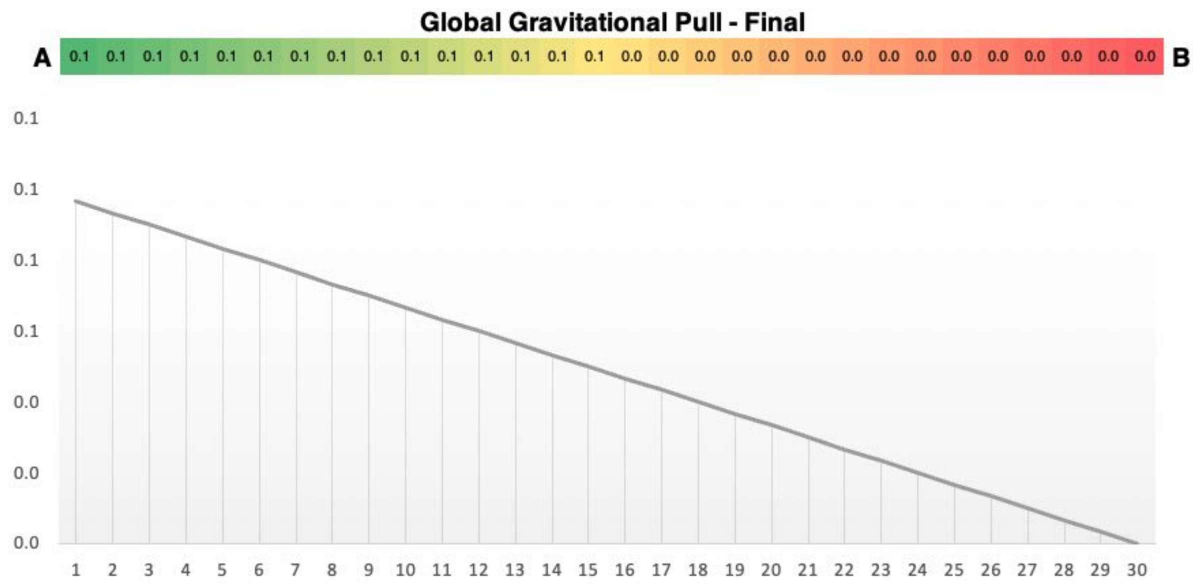


Figure 81 Global Gravitational Pull - Final

Weight

In order to calculate the impact of this attribute for the model, the 'weight' has to be set. This weight is designed to set a level of impact for this particular attribute. The calculated weight is called *'ggp_weight'*, and it is a number that represents the percentage of the overall calculation for the cell. In this case, the weight is 0.2 which means the *ggp_value* will have an impact of 20% in the overall calculation of the cell.

Table 23 Global Gravitational Pull, weight and cell sum calculation

E = ggp	
ggp_value	0 or 1
ggp_weight	0.2
ggp_sum	0 or 1 * 0.2
E =	**0 or 1 * 0.2**

Output

As this is an array for an attribute that falls under the group of Global Inputs, all cells of the output 'E' of the road array will not be the same, depending of the position of the cell. This means that *ggp_weight * ggp_value* will produce the number representing the percentage for each cell.

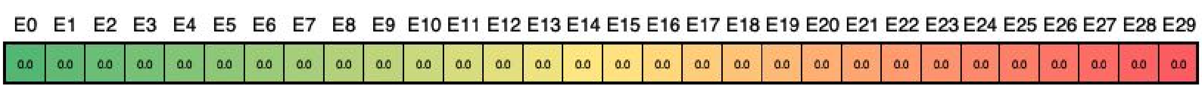


Figure 82 The cell output for Attribute E (Global Gravitational Pull)

5.2.6. Type of Cell

Type of Cell essentially is an attribute that shows the level of connectivity that particular cell has, and therefore the likelihood for development. As each cell is representative of 1km of the analyzed road, it is possible to determine the level and type of accessibility each cell has. In this manner, the better connected a cell is, the higher the chance for development is for that particular cell. Depending on the connectivity/accessibility of each cell, there are a number of types that can be chosen by by the user.

Effects of Model Attribute

Roads that are better connected with a more sophisticated network of different levels of roads, have a higher chance of influencing development. Accessibility is important since it has been proven that foreign investors evaluate potential sites based on hard factors (e.g. transport connection, space availability, employment market, energy supply, local and national taxes).

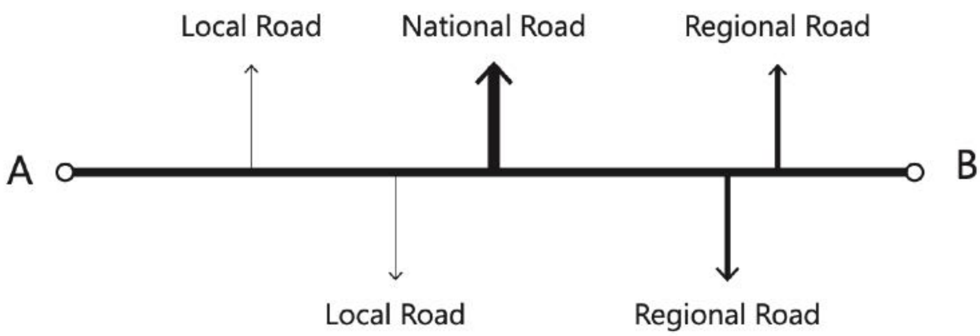


Figure 83 Illustration of the variety of connections an analyzed road can have

This offers new development perspectives, in particular for regions which are well-connected within the country itself but also cross-nationally as investors often decide against capital city locations. This means that the better connected a country is, the bigger the chance for finding investors that can contribute to development.

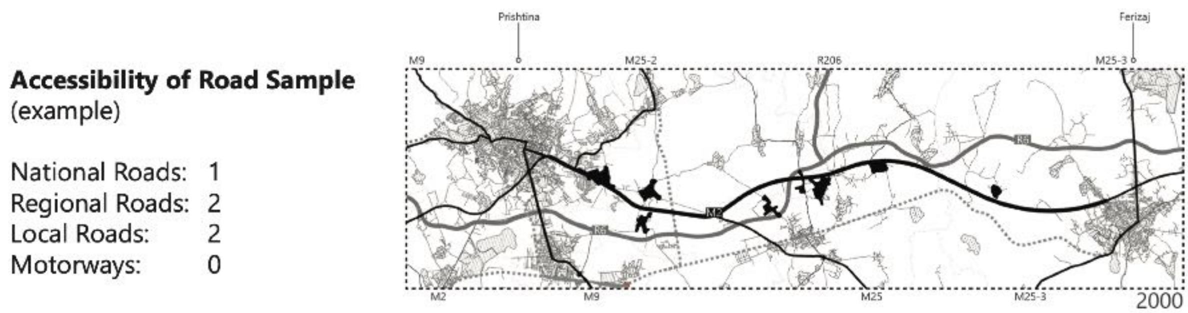


Figure 84 Calculation of Accessibility and types of connections for a Sample Road

Operation of Model Attribute

The purpose of this attribute is to fine tune each individual cell, and account for the effect connectivity and accessibility have on each cell for the first generation, and all future generations of the simulation.

In order to better visualize and for the model to be able to calculate the level of accessibility and the type of connections each of the cell might have, eight types of cells are proposed. Four are destined for the cells at both ends of the road array, whereas the other four are meant for the cells in between, that do not include endpoints.

The first level of the attribute "Type of Cell" is cells that are positioned in-between the road array, and not the endpoints.

- **Type 1** – is a default setting in the model, unless otherwise specified by the user. This type indicates a road open at both and, and presents a low chance for development
- **Type 2a** – is "T" junction, with a connection to the northern side of the model, which will continue to affect the cells on the northern side of the model. This type can be position anywhere within the road array and presents a medium chance for development.
- **Type 2b** – is "T" junction, with a connection to the southern side of the model, which will continue to affect the cells on the southern side of the model. This type can be position anywhere within the road array and presents a medium chance for development.
- **Type 2c** – is a Cross junction, with a connection on both sides of the model, which will continue to affect the cells in both sides of the model. This type can be positioned anywhere within the road array. The cross junction has a higher chance of development than the "T" junction.

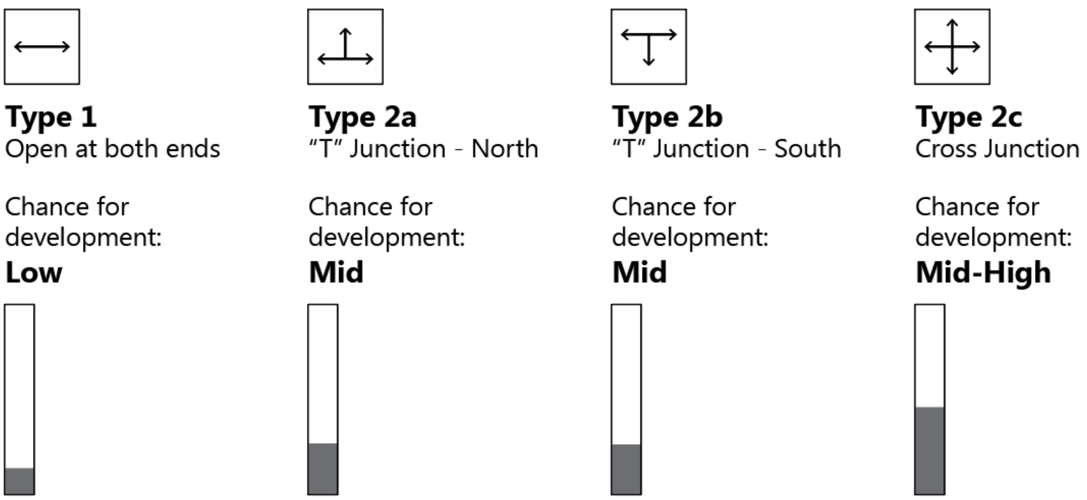


Figure 85 Type of Cell - All cells in-between the road array, and that are not endpoints

The second level of the attribute “Type of Cell” is cells that are position at the end of the road array, and not in the cells positioned in-between (but excluding) the endpoints (settlements). There four types present a much higher chance for development, since they are already close to existing development. In many cases, these cells will already be developed.

- **Type 3a** – is a default setting in the model for endpoints, unless otherwise specified by the user. This type is always positioned at the end of the road, next to the settlements. This type presents a high chance for development.
- **Type 3b** – is an end-point type that also contains the qualities of the “T” junction, with a connection to the northern side of the model, which will continue to affect the cells on the northern side of the model. This type can be position at the end of the road array and presents a high chance for development.
- **Type 3c** – is an end-point type that also contains the qualities of the “T” junction, with a connection to the northern side of the model, which will continue to affect the cells on the southern side of the model. This type can be position at the end of the road array and presents a high chance for development.
- **Type 3d** – is an end-point type that also contains the qualities of the Cross junction, with a connection on both sides of the model which will continue to affect the cells in both sides of the model. This is representative of a settlement that has access to road infrastructure that spat different directions. This type can be positioned anywhere within the road array. The cross junction has the highest chance of development out of all the other types.

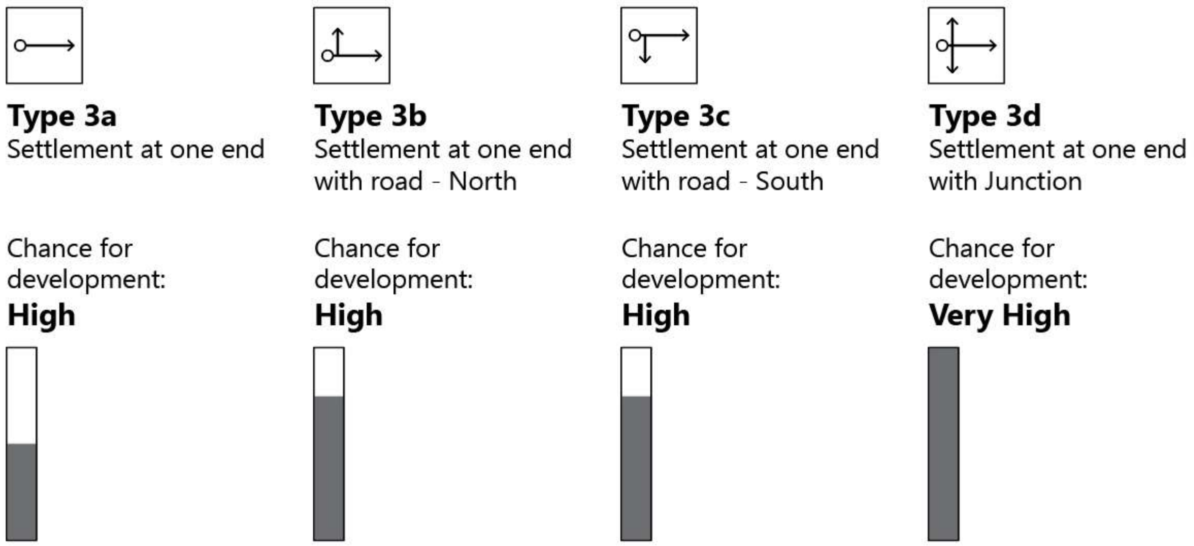


Figure 86 Type of Cell - All cells at the end of the road array - endpoints

Value

The Type of Cell attribute requires the user to input the type of cell for each of the individual cells. There are two default types of cell: **Type 1** is the default for all cells that are not end-points, whereas **Type 3a** is the default for both cells at the end of the road segment. This enables the user to skip most of the cells when inputting the values (types), and overalls speeds up the process of inputting values.

In order for the model to convert the types of cells into a quantified value, each type will have an assigned value depending on the chance for development they present (as seen in the two previous figures). Namely, Type 1 has a value of 1, Type 2a and Type 2b a value of 2, Type 2c a value of 3, Type 3a a value of 4, Type 3b and Type 3c a value of 5 and Type 3d a value of 6.

Table 24 Type of Cell Value calculation

Type	Nr	Value	Symbol
<>	1	1	⇔
<^>	2a	2	⇐⇑⇒
<v>	2b	2	⇐⇓⇒
<^v>	2c	3	⇐⇕⇒
endpoint	3a	4	◎⤇
<^|	3b	5	◎⇑⤇
<v|	3c	5	◎⇕⤇
<^v|	3d	6	◎⇕⤇

Example

For illustration purposes, the example below will show how a sample road can be used as a study case for determining the Types of Cell for the model. In this case, the road infrastructure connecting the two settlements, Prishtina and Podujeva has been selected. As can be seen by the following figure (a), the road has a few connections that need to be represented by types of cells in the model. As the distance between the two settlements is approximately 20 kilometers, the model will show 20 cells, each representing a length of 1 kilometer of the road infrastructure.

The figure below (b) shows the visual representation of the Type of Cells for each of the cells, that best resemble the real-life situation in the existing road infrastructure. For example, as can be seen in the figure (a), the road leading to both connections, also has additional road connecting close to the endpoints. This is represented in the model by the Type of Cells that have endpoints as a feature, as well as connections to either north or south, in this case Type 3b for both sides of the road (both settlements). The cells in-between have also been selected in that manner that they best represent the existing state in the road infrastructure in real-life. As previously stated, each selected Type of Cell has a particular value, that will then be multiplied by the weight of the attribute, to produce the final output for this particular attribute.

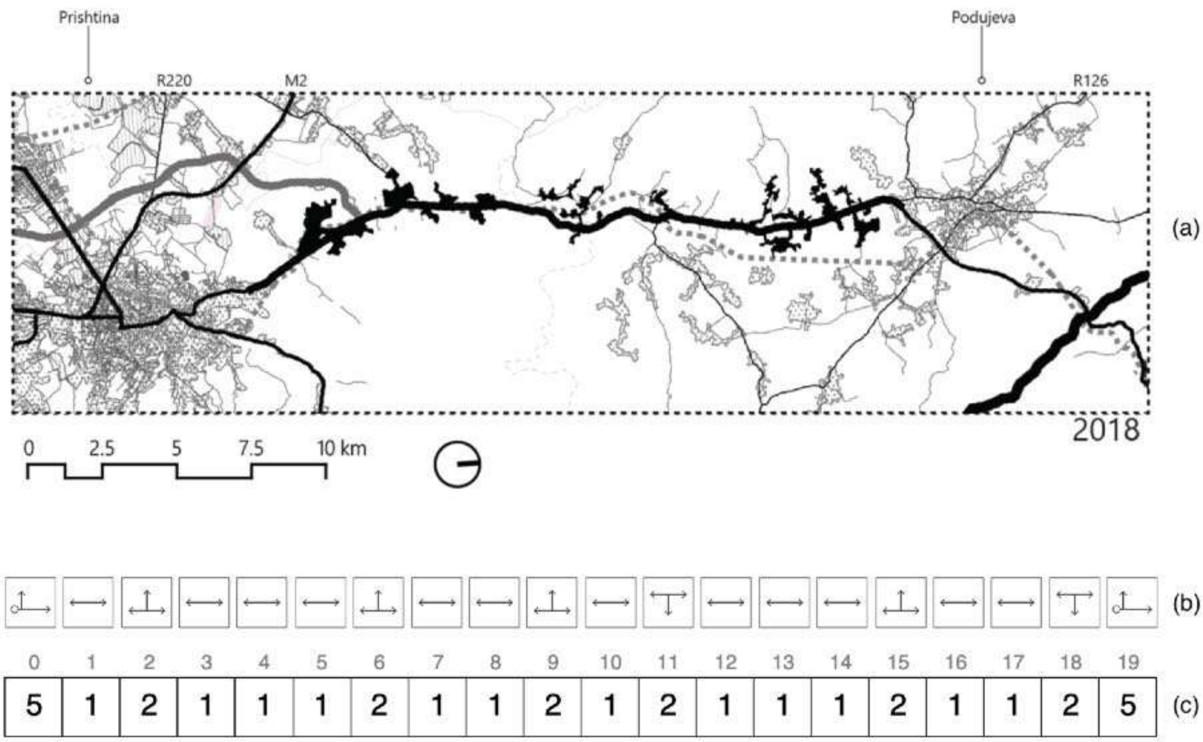


Figure 87 Assigning the Type of Cell value - (a) Sample Road, (b) Type of Cell, (c) Type of Cell Values

Weight

In order to calculate the impact of this attribute for the model, the ‘weight’ has to be set. This weight is designed to set a level of impact for this particular attribute. The calculated weight is called *‘toc_weight’*, and it is a number that represents the percentage of the overall calculation for the cell. In this case, the weight is 0.2 which means the toc_value will have an impact of 30% in the overall calculation of the cell.

Table 25 Type of Cell, weight and cell sum calculation

F = toc	
toc_value	x
toc_weight	0.2
toc_sum	x * 0.2
F =	**x * 0.2**

Output

As this is an array for an attribute that falls under the group of Local Inputs, all cells of the output ‘F’ of the road array will not be the same, depending of the position of the cell. This means that *toc_weight * toc_value* will produce the number representing the percentage for each cell.

F0	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19
0.2	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.2

Figure 88 The cell output for Attribute F (Type of Cell)

5.2.7. Agglomeration

The Agglomeration attribute accounts for existing development, and the force it has in pulling further new development near it. Some existing clusters of developed land will influence further development nearby, and this phenomena can be observed in the empirical study just as well.

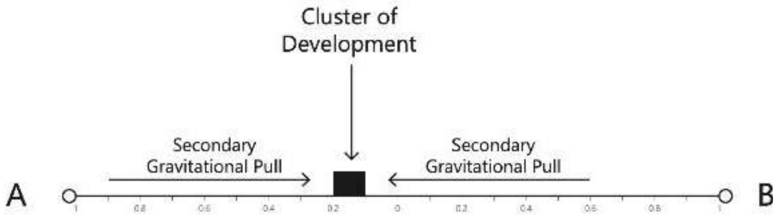


Figure 89 Development pull by the Cluster of existing development (Agglomeration)

The idea behind this theory is that, once a particular piece of land is developed, it will in all likelihood bring with it all the necessary infrastructure, covering the large majority of the cost for building it. On the other hand, once new development comes, they will only need to invest in expanding the existing infrastructure from the existing development.

Furthermore, the existing development will bring the initial business as well as people and foot traffic. New developments can benefit from this existing presence of people and business, and can further enhance it by bringing their own skate to it. Thus it becomes a sort of urban symbiosis, where the existing and new development continuously benefit from each other. This can be expanded with further new developments, and has great capacity for growth.

Effects of Model Attribute

For simplification, and for it to have applicability with the model, each cell that has existing development, will be valued as such, and in simulations for future predictions, the neighboring cells will have a higher chance of development depending on the values of other attributes as well.

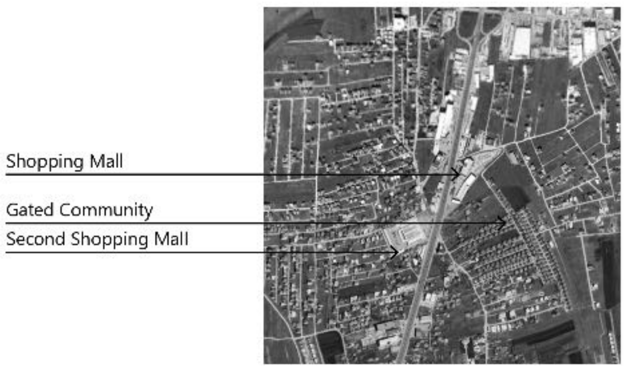


Figure 90 New development attracted by existing (old) development

For example, a shopping mall that is a lone structure, will in all likelihood pull and impact further development of that area. If a Cell has this attribute it is very likely there will be further development in that Cell. Additionally, the very next Cells will have a raised chance for development as the cluster will behave as a secondary gravitational pull.

Operation of Model Attribute

The purpose of this attribute is to fine tune each individual cell, and account for the effect existing development has on each cell for the first generation, and all future generations of the simulation.

Value

The manner in which this attribute functions is by determining whether a selected cell has already (existing) development. If so, than the statement for that cell is **TRUE,** if else, it is **FALSE.** If True, the cell has a value of 1, whereas if False, the cell has a value of 0.

Table 26 Agglomeration, weight and cell sum calculation

G = agg	
agg_value	1 or 0
agg_weight	0.2
agg_sum	1 or 0 * 0.2
G =	**1 or 0 * 0.2**

Weight

In order to calculate the impact of this attribute for the model, the ‘weight’ has to be set. This weight is designed to set a level of impact for this particular attribute. The calculated weight is called *‘agg_weight’*, and it is a number that represents the percentage of the overall calculation for the cell. In this case, the weight is 0.2 which means the *agg_value* will have an impact of 20% in the overall calculation of the cell.

Output

As this is an array for an attribute that falls under the group of Local Inputs, all cells of the output ‘G’ of the road array will not be the same, depending of the position of the cell. This means that *agg_weight * agg_value* will produce the number representing the percentage for each cell. The figure below is a representation of an array of cells, some of which have been selected at random and valued as TRUE for the attribute of Agglomeration.

G0	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19
0.2	0	0	0	0	0	0	0.2	0	0	0	0	0.2	0.2	0	0	0	0	0.2	0.2

Figure 91 The cell output for Attribute G (Agglomeration)

5.2.8. Terrain Slope

The Terrain Slope attribute accounts for slopes in terrain and other geographical formations that hinder the development in that particular area. The aim of this attribute is to enable the model to show undeveloped cells or areas of the land.

Effects of Model Attribute

As is often the case, some areas of land will remain undeveloped for a variety of reasons, the main being the unfavorable conditions of the terrain or geography. With the attribute Terrain Slope, the model will be able to identify these areas and will prevent other attributes from raising the chance for development for these particular cells or area.

When identified during the analysis of the sample roads or empirical study, and once the user can confirm that the terrain formation is hindering development, then the user can conclude that that particular model cell can be valued as having a development-hindering slope in terrain.

Operation of Model Attribute

The purpose of this attribute is to fine tune each individual cell in particular if terrain slopes do not allow for development for the first and all future generations of the model simulation.

Value

The manner in which this attribute functions is by determining whether a selected cell has a slope in the terrain. If so, than the statement for that cell is **TRUE,** if else, it is **FALSE.** If True, the cell has a value of 1, whereas if False, the cell has a value of 0. If the value for this attribute is TRUE, that particular cell will remain undeveloped in all future generations of the simulation, as the spatial hindering will continue to be true regardless of the temporal aspect,

Weight

This type of attribute has a 'weight' that cancels out all other attributes, if the value of Terrain Slope is **TRUE**. If the value is **FALSE**, then there is no weight to this attribute.

Output

As this is an array for an attribute that falls under the group of Local Inputs, all cells of the output 'H' of the road array will not be the same, depending of the position of the cell. This means that *ts_weight * ts_value* will produce either a value that cancels all other attribute outputs to 0, or a value that does not affect the outputs of other attributes.

5.2.9. Built

In many cases, some areas of land are already developed, removing the need for the model to predict development for those cells that cover that area. The Built attribute accounts for this already-existing developed land, bypassing all other attributes that calculate the chance for development.

Effects of Model Attribute

As the main purpose of the model is to try and predict chances of development for land affected by road infrastructure, with this attribute it can be determined where these areas of land are already developed, and will remain so for the foreseeable future.

When identified during the analysis of the sample roads or empirical study, and once the user can confirm that the area of land is developed, then the user can conclude that that particular model cell can be valued as having existing development.

Operation of Model Attribute

The purpose of this attribute is to fine tune each individual cell in particular depending whether those cells are already developed. This attribute will affect the first and all future generations of the model simulation.

Value

The manner in which this attribute functions is by determining whether a selected cell has an already-existing development. If so, than the statement for that cell is **TRUE,** if else, it is **FALSE.** If True, the cell has a value of 1, whereas if False, the cell has a value of 0. If the value for this attribute is TRUE, that particular cell will remain developed in all future generations of the simulation, as there is no need for the model to calculate chance of development.

Weight

This type of attribute has a ‘weight’ that cancels out all other attributes, if the value of Built is **TRUE**. If the value is **FALSE**, then there is no weight to this attribute.

Output

As this is an array for an attribute that falls under the group of Local Inputs, all cells of the output ‘I’ of the road array will not be the same, depending of the position of the cell. This means that *b_weight * b_value* will produce either a value that cancels all other attribute outputs to 1, or a value that does not affect the outputs of other attributes.

5.2.10. Restriction

The Restriction attribute accounts for a variety of reasons why this particular area or cell cannot be developed. The aim of this attribute is to enable the model to show undeveloped cells or areas of the land, that can come due to barriers that are physical in form or as a result of policies or measures.

Effects of Model Attribute

As is often the case, some areas of land will remain undeveloped for a variety of reasons, the main being the unfavorable conditions of the terrain or geography. However, there could be other reasons why development cannot occur in a particular area of land. These reasons can also be of the political nature, through the means of policies, measures and regulations. With the attribute Restriction, the model will be able to identify these areas and will prevent other attributes from raising the chance for development for these particular cells or area. When identified during the analysis of the sample roads or empirical study, and once the user can confirm that the development is not possible or should not be possible for a variety of reasons, then the user can conclude that that particular model cell can be valued as having a development-hindering or ‘restriction.

Operation of Model Attribute

The purpose of this attribute is to fine tune each individual cell in particular if restrictions do not allow for development for the first and all future generations of the model simulation.

Value

The manner in which this attribute functions is by determining whether a selected cell has a restriction. If so, than the statement for that cell is **TRUE,** if else, it is **FALSE.** If True, the cell has a value of 1, whereas if False, the cell has a value of 0. If the value for this attribute is TRUE, that particular cell will remain undeveloped in all future generations of the simulation.

Weight

This type of attribute has a ‘weight’ that cancels out all other attributes, if the value of Restriction is **TRUE**. If the value is **FALSE**, then there is no weight to this attribute.

Output

As this is an array for an attribute that falls under the group of Local Inputs, all cells of the output ‘H’ of the road array will not be the same, depending of the position of the cell. This means that *rest_weight * rest_value* will produce either a value that cancels all other attribute outputs to 0, or a value that does not affect the outputs of other attributes.

5.2.11. Limit of Growth

As with all growing things, development too has a limit of growth. This can come due for multiple reasons varying from financial, to population growth, to simply running out of land that can be developed.

The proposed model of this dissertation offers outputs and predictions that belong to the spatial dimension, rather than the temporal dimensions. This means that the predictions of the model will show how development will happen in terms of space, where time is not a factor. The idea is that the temporal aspect of the prediction can be influenced by factors such as this attribute, Limit of Growth. For example, if there is a growth in the GDP of the area, then it is more likely that development will be hastened, but will remain within the same spatial prediction of the model. On the other hand, if for example population growth stagnates, than the pace in which development continues will slow down before reaching the peak development as predicted by the model.

Research on limits of growth have been also done by Jay W. Forrester, where he has developed a diagram depicting development, maturity as well as growth stagnation. The figure below is a 250-year urban life cycle developed by the computer based on the model's urban theory. The graphic displays a 100-year development from nearly vacant terrain. By then, land is filled, new development declines, and the urban system stagnates with underemployed dwellings and diminishing industry. Too much underemployed workers hurts the economy. Too much underemployed housing and dwindling industry exist.

As the area transitions from expansion to stagnation, aging structures and changing activities cause these changes. In the growth phase, industrial land area and employment are both high. At the same time as housing is built for the expanding industry, the residential population is economically successful and the population density per residential land area is low. The type of building determines the industrial-to-residential ratio. As structures age, industrial vitality fades, new industries start elsewhere, and industrial land employment falls. Population declines when housing ages. Rental costs fall and population density per unit of residential land moves to those whose economic circumstances require it. [116]

Starting from a balance between industry and people at the conclusion of the expansion phase, employment diminishes while population rises until an equilibrium is reached in which the area's economic state falls enough to limit population growth.

[116] Forrester, J. W. (1970). Urban dynamics. IMR; Industrial Management Review (pre-1986), 11(3), 67.

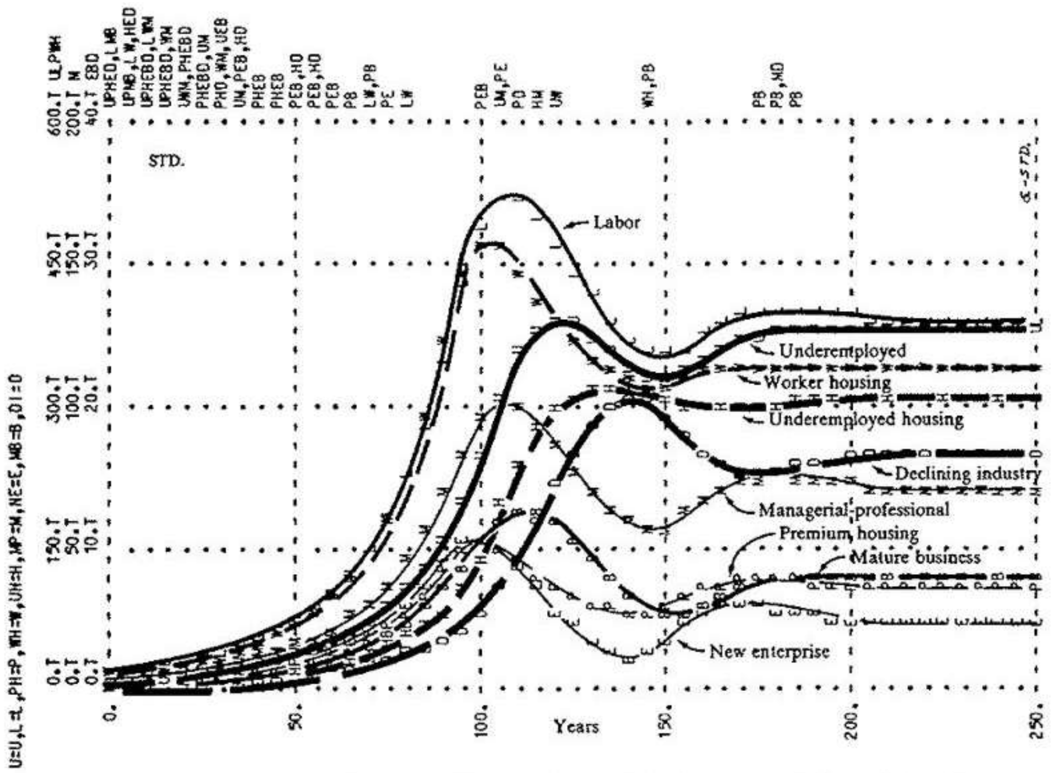


Figure 92 Life cycle of an urban area - 250 years internal development, maturity, and stagnation (Forrester, J.W. 1969)

Economic Growth

There is a number of ways how economic development can be traced, such as manufacturing output, production, energy demands, etc. However the indicator that is the most widely used with all the weaknesses that it has, is that of the Gross Domestic Product. In this sense, growth in GDP can be correlated with growth in population as well as with growth in the sense of new developments (land-use development). With a stagnating GDP, development tends to also stagnate, which is not necessarily a negative thing.

Population Growth

With a growing population, the demands for settlement and services grow too. This growth can often lead to demand for new development which translates in land-use development. This pattern can also be observed from the empirical studies, which with economic growth, so came population growth which resulted in new land-use development.

Operation of Model Attribute

The purpose of this attribute is to break the cycle of the model so it does not continue simulation growth in the future. The idea is that after a certain amount of time, development matures and stagnates, meaning it cannot continue to grow at a linear rate.

5.2.12. Other Attributes

The attributes presented until now are the ones considered with a level of impact that is worth surveying, and that can have a noticeable effect on the outcomes of the model. There are a number of other attributes that have been analyzed. A few examples include Local GDP, Population, Daily Commuting, Existing Social Infrastructure, etc. However all these attributes can either be considered as sub-components of the other attributes, or have such small impact in the overall outcomes of the model, that are not worth calculating.

5.3. Summary

This chapter has covered the reasoning for proposing the model, the way it is structured, the composing elements and features as well as the way the user can interact with the model. As mention in the chapter, urban models are astoundingly helpful instruments for surveying the effect of changes in land-use patterns, spatially in relation to road infrastructure. The features they have are helpful in the sense that they simplify reality by removing unnecessary elements and details, making it more abstract, or constructing something entirely new from scratch. In this sense, complicated phenomena can be translate into more simplified versions of themselves, that can more easily be measured. Additionally, models establish tractable spaces within which we may work through logic, generate hypotheses, build solutions, and fit facts by simplifying and making precise. In order to quantify the effect that road infrastructure has on land-use empirical studies are translated into maps, further developed into diagrams that fill in as a measurement device, which gives the input values to the model. This cycle enables a structuring of the data and makes it more comprehensible, especially when setting up the ‘rules’ (protocol) of the model.

The main design characteristic of the model is the two-dimensional mesh with coordinates for the X and Y axis. It functions much like a two-dimensional array, in that it contains values in each one of the coordinates. The models main components are the cells, attributes (that include inputs and weight) as well as the output.

In order to dissect and simplify the empirical study into calculable and quantifiable sections, attributes are proposed as the main tool to achieve this. A model attribute is a property or characteristic of a phenomenon that is occurring and that can be observed during the phase of empirical research of the road study cases. In total there are 10 attributes that operate in a Global sense (all cells of model) and a Local sense (individual cells). All attributes have values and weights that are calculated in order to produce the final output of the model for the first generation (t_0). Throughout this chapter, a basis has been set that explains how the model works and how it can be utilized through the next chapters.

CHAPTER 6

QUANTIFICATION OF ATTRIBUTE VALUES FOR THE MODEL CELLS

In this chapter, the outputs from the model are calculated and attributes are quantified into exact results. This chapter presents the development of the first generation of the model prediction, as well as future generations, which entail predictions for future development.

6. QUANTIFICATION OF ATTRIBUTE VALUES FOR THE MODEL CELLS

The model attributes introduced in the last chapter are measurements of the real-life phenomena that occur during the empirical study of the case studies. As established, all of these attributes have a certain value and weight that serve as a quantification tool of these phenomena that result from observations that can fall under qualitative research. In order for the model to make these calculations, all attributes have been quantified into calculable values. The duty of the model now is to structure all these values and weights into calculations that in the end output values that show the likelihood for development in particular cells that represent land areas.

Calculation

This chapter will explain the calculation matrix and formulas that are used in order to come up with the model output. As the initial phase of the calculation process, is for the model to structure and calculate all the quantified values and weights of the attributes. In this phase the model output is a mesh of values that represent Generation 0 (t_0) of the model, which serves as a baseline and that in hand is a representation of the actual state of the analyzed road sample (study case).

Generation 0

As the Generation 0 output shows the current state, it can be used as a starting point for doing initial analysis by planners, as the values can be adjusted to try out different outcomes. This generation can also serve as the first step in calibration, as the user (planner) can adjust the values and weights of the attribute so that the output of the model best resembles the state in real-life observations.

Future Generations

The next phase of the model calculations is prediction future outcomes in a few step. The initial step in predictions is output of Generation 1 (t_1), which the first look into the future. This is a direct derivative from Generation 0 and it shows the next possible step in land development. As the model shows a timeline that is spatial rather than temporal, Generation 1 will show land development in the future, without a specific timeframe, as this is subject to the attribute Limit of Growth.

The phase including the future generations will be calculated by analyzing neighborhoods of cells in a cluster-like fashion, the sum of which will be the value of a particular cell. As the model operates in cell, the method in calculating future values of the cells will be done with modalities of Cellular Automata, which is a science of analyzing and exploring the impact of neighbor cells in the cell that the model is calculating. This methodology along with all the explored modalities will be further explained in this chapter.

6.1. Calculation Matrix and Formulas

As it has been established in the previous chapter, the model consists of cells which have a value that indicates the likelihood for land development in that area. The array of cells that represent the road is called the road array, and is the initial calculation made by the model. Each of the cells in the road array, has a particular value that needs to be calculated by the model, and that is the sum of all attribute values for that cell. The other arrays of cells are a derivative of the initial road array, and will vary depending on the values as calculated by the model. This is particularly important in coming up with Generation 1 and future Generations.

There will be three main steps that the model processes before coming out with the final outcome of values.

- The first step is **Cell Calculation**, where attribute values and weights are calculated to come up with a cell value.
- The second step is **Cell Array Calculation**, where all cells of the road array are calculated
- The third and final step is **Model Mesh Calculation**, where all the other cells that are dependent and derive from the initial Road Array are calculated

As a starting point, the model already needs to have all Attribute Values and Weights set by the user. If no values or weights have been entered, then the model will use default values. Below is a table consisting of the Attribute names, values and weights that are used as values for the Cell outcomes. The Values and Weights are for illustration purposes only, and are not final. These numbers are subject to change by the user.

Table 27 Table of Calculations for Values and Weights for all Attributes - Cell Outcome

Letter	Attribute	Value	Weight (%)
A	Type of Road	3	10
B	Road Length	20	10
C	Position of Cell	array	10
D	Local Gravitational Pull	Two inputs	20
E	Global Gravitational Pull	True/False	10
F	Type of Cell	nine options	20
G	Agglomeration	True/False	20
H	Slope	True/False	n/a
I	Built	True/False	n/a
J	Restriction	True/False	n/a
K	Limit of Growth	n/a	n/a
			100

Cell Calculation

After inserting all attribute values and weights by the user, the first step in the process is the calculation of the cell outcome values, which is the sum of all attribute outcome values. The overall outcome of the model for each cell is:

$$y=f(x)$$

where x is $(A + B + C + D + E + F + G + H + I + J + K)$.

For example, if the Cell n (Cn) is calculated, it's unique outcome Yn is only applicable to that particular Cell. This means that the model takes the values and weights from the Global Inputs as a general input, and uses Local Inputs for tighter calibration for that particular cell.

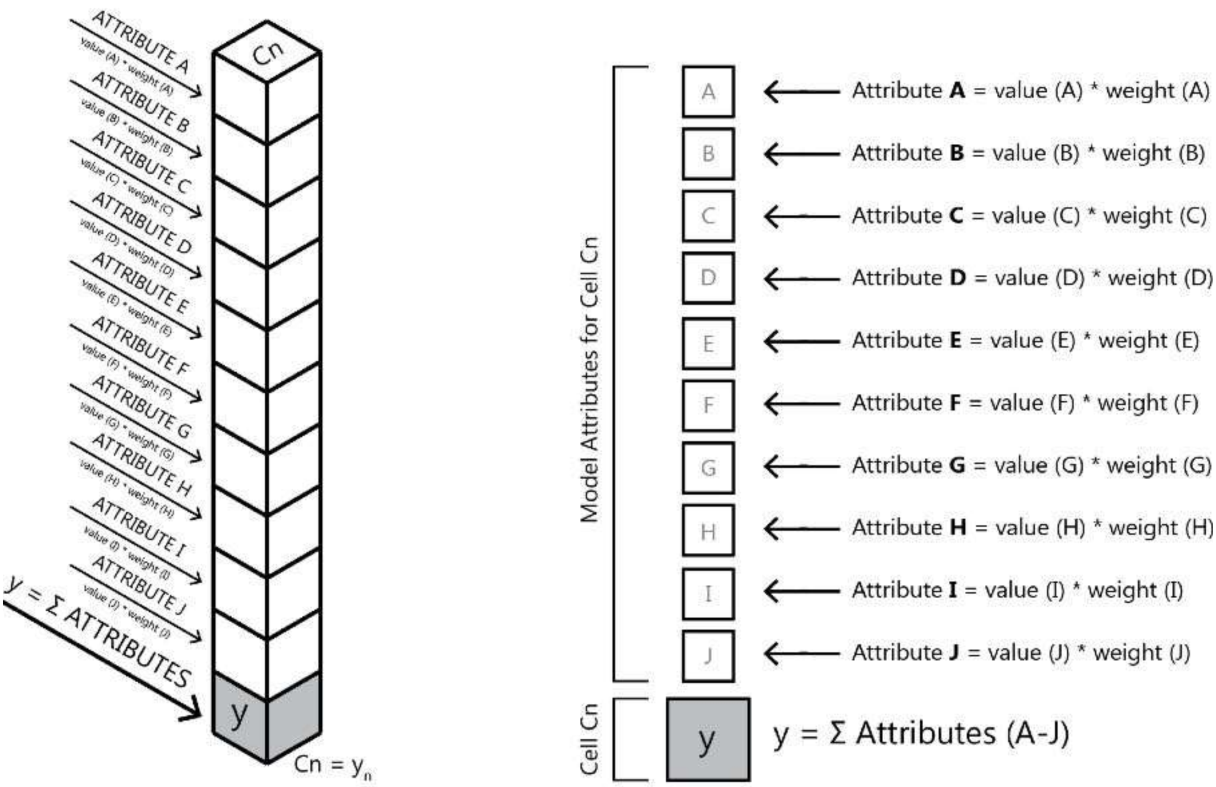


Figure 93 Cell Calculation - Bottom square represent the final outcome of the cell, stacked squares represent attributes

The sum of all products from two columns of the previous table (attribute values and weights), gives a value 'y' for each of the model Cells. The output value of the 'y' will show the level or chances for land development for each model Cell.

The total of the weights for Cell Calculation cannot exceed 100%, in order for all cells to be in sync and levelled with each other.

Cell Array Calculation

After the individual cells have all been calculated by the model, the next step is calculation the Road Cell Array. This array is the line of cells in the center of the model, that represent the road infrastructure and land that is closest to it. This can be visualized as a brick wall, with attributes stacked on top of each other for all individual cells, and the road array outcome is the bottom row.

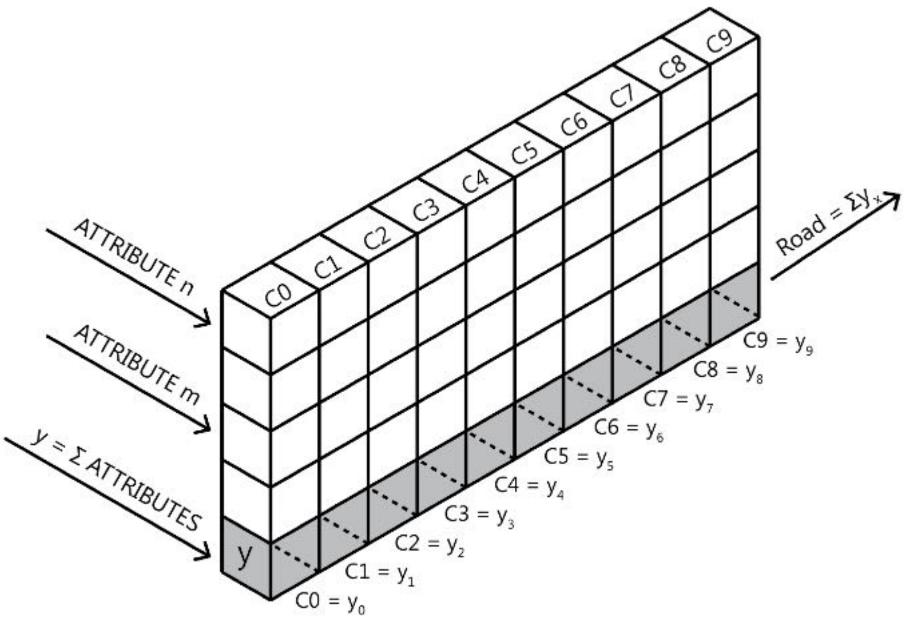


Figure 94 Cell Array Calculation - Bottom row is the final outcome, stacked rows represent the attributes

The outcome of this step is a row (array) of cells with various values that represent the chance or likelihood for land development in those cells which represent land areas. This means that the road array is a collection of y's which are dependent on all attributes.

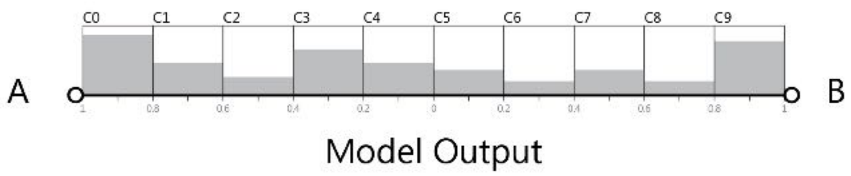


Figure 95 Cell Array Calculation Output

As a process, the model will begin with these calculations as soon as the user has entered all the values, and initiates the model calculation. The process is not visible to the user, however the outcome is immediate, which allows for user interference through changing the values and weights of the model attributes.

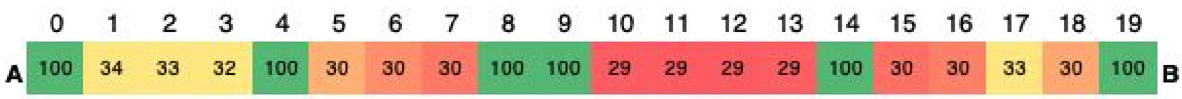


Figure 96 Cell Array Calculation Output in the model application

Cell Mesh Calculation

The third and final step of this set of calculations by the model is Cell Mesh Calculation, which is the calculation of the cell arrays that are parallel to the Road Array. Most of the rules for these calculations have been set in by a number of Attributes that affect Cell Mesh Calculation, such as :

- Position of Cell – is the main determinant of the values of the Cell Mesh Calculation, as all cell have a set value depending on their position, in the form of a coordinates table. As it has been established in this Attributes sub-chapter, the further away from the road the cell is, the lower the likelihood for development. The same rule applies to the distance (proximity) to the settlements.
- Type of Road – is an important determinant as the number of rows depends directly from this attribute. Depending on the Type of Road, the model can produce entirely different meshes.
- Type of Cell – is an attributes that is set for the Road Array, however all other cells check to see whether the cell that is their closest neighbor in the direction of the Road Array, possesses this attribute. These cells also check to determine the exact type of cell, since depending on the Type of Cell, they can be more likely to develop.

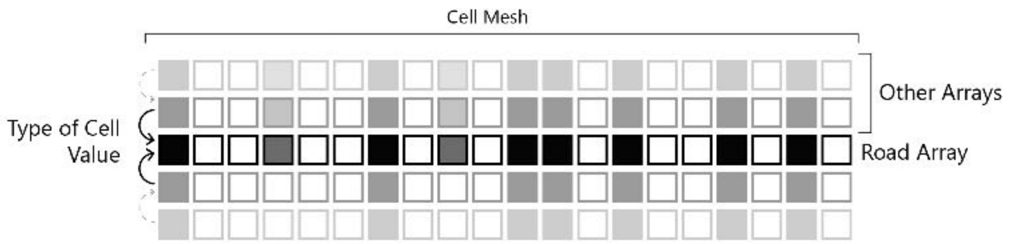


Figure 97 Impact of Type of Cell on Other Cell Arrays - Each cell asks neighboring cell about Type of Cell Value

All the other Local Attributes that affect only the individual cell for which the user inputs the values, and that are Agglomeration, Terrain Slope, Built and Restriction, will affect the Cell Mesh Calculation. This is due to the fact that if for example some restrictions are in the neighboring cells in the direction of the road, these cells then will have a harder time to develop, and therefore will show a lower likelihood for development.

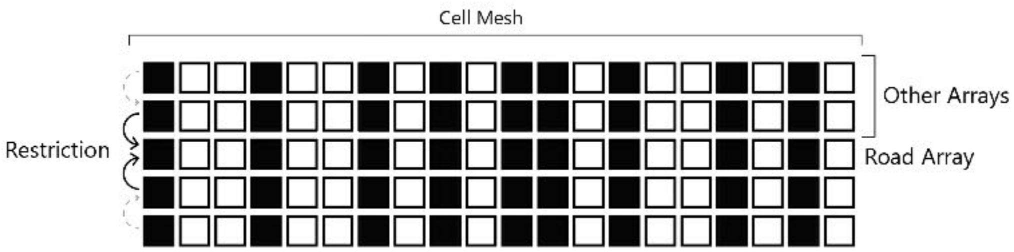


Figure 98 Impact of other attributes (Restriction on this case) on blocking development in cells of Other Arrays Each cell asks neighboring cell about Type of Cell Value

6.2. Model Production – Generation 0 (t_0)

Up to this point, the user has entered all the Attribute Values and Weights, and the Model has processed all three steps of calculation, namely, Cell, Array and Mesh Calculation. The Model product of this phase is a mesh with values for each individual cell, which are a direct derivative of the values entered by the user (planner).

Following and by completing all the previous three steps, the model will produce Generation 0 (t_0), which is named so as it represents the current state of development that the model has visualized. The purpose of this Generation is to show as closely as possible, the actual state of land development in for the areas that are covered by the model cells.

GENERATION 0 - t0 - Current State

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
5	5	4	3	2	2	1	1	1	1	1	0	0	0	0	2	0	0	2	0	1	1	1	1	4	2	2	3	4	5	10	5
4	5	4	3	2	2	1	1	1	1	1	1	1	0	0	3	0	0	3	1	1	1	1	1	5	2	2	3	4	5	12	4
3	6	4	3	3	2	2	2	1	1	1	1	1	1	1	4	1	1	4	1	1	1	1	2	6	2	3	3	4	6	14	3
2	6	5	4	3	3	2	2	2	2	2	2	1	1	1	5	1	1	5	2	2	2	2	2	8	3	3	4	5	6	18	2
1	8	6	5	5	4	4	3	3	3	3	3	3	3	3	8	3	3	8	3	3	3	3	3	11	4	5	5	6	8	23	1
0	100	34	33	32	100	30	30	30	100	100	29	29	29	29	100	30	30	33	30	100	15	16	16	100	18	20	25	24	27	100	0
1	8	6	5	5	4	4	3	3	8	3	3	3	3	3	3	3	3	3	3	8	3	3	3	11	4	5	10	6	8	23	1
2	6	5	4	3	3	2	2	2	6	2	2	1	1	1	1	1	1	1	2	5	2	2	2	8	3	3	8	5	6	18	2
3	6	4	3	3	2	2	2	1	4	1	1	1	1	1	1	1	1	1	1	4	1	1	2	6	2	3	6	4	6	14	3
4	5	4	3	2	2	1	1	1	3	1	1	1	0	0	0	0	0	1	1	3	1	1	1	5	2	2	5	4	5	12	4
5	5	4	3	2	2	1	1	1	2	1	0	0	0	0	0	0	0	0	0	2	1	1	1	4	2	2	5	4	5	10	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	

Figure 99 Generation 0 (t_0) - First outcome of the model - Values are hyperbolic for the purposes of illustration

The product of the model will be a heatmap, with Green representing higher chance of development, Yellow/Orange represents a medium chance for development, whereas Red colored cells represent little to no chance for development. The heatmap coloring is a product of the output values for each of the cells of the model.

Generation 0 (t_0) can also be thought of ˙as a baseline for future predictions and simulations. This product serves as the first step in calibration by the user, as the outcome of the Generation 0 can show if values and weights entered by the user have been accurate enough for a correct model outcome. This means that the user can evaluate whether the outcome of the model is in anyway accurate to the observations from the empirical studies. If not, then by adjusting the values a better and more accurate outcome from the model can be produced. The accuracy of the model at this stage is important, since it will be able to produce better and more accurate results in simulating future Generations.

6.3. Simulation – Generation 1 (t_1)

The second product of the model is Generation 1 (t_1), which is the first look into a possible future by the model. Generation 1 will be a derivative product of Generation 0, namely each cell of Generation 1 is a by-product of the cell with the same coordinates of Generation 0.

GENERATION 0 - t0 - Current State

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
5	5	4	3	2	2	1	1	1	1	1	0	0	0	0	2	0	0	2	0	1	1	1	1	4	2	2	3	4	5	10	5
4	5	4	3	2	2	1	1	1	1	1	1	1	0	0	3	0	0	3	1	1	1	1	1	5	2	2	3	4	5	12	4
3	6	4	3	3	2	2	2	1	1	1	1	1	1	1	4	1	1	4	1	1	1	1	2	6	2	3	3	4	6	14	3
2	6	5	4	3	3	2	2	2	2	2	2	1	1	1	5	1	1	5	2	2	2	2	2	8	3	3	4	5	6	18	2
1	8	6	5	5	4	4	3	3	3	3	3	3	3	3	8	3	3	8	3	3	3	3	3	11	4	5	5	6	8	23	1
0	100	34	33	32	100	30	30	30	100	100	29	29	29	29	100	30	30	33	30	100	15	16	16	100	18	20	25	24	27	100	0
1	8	6	5	5	4	4	3	3	8	3	3	3	3	3	3	3	3	3	3	8	3	3	3	11	4	5	10	6	8	23	1
2	6	5	4	3	3	2	2	2	6	2	2	1	1	1	1	1	1	1	2	5	2	2	2	8	3	3	8	5	6	18	2
3	6	4	3	3	2	2	2	1	4	1	1	1	1	1	1	1	1	1	1	4	1	1	2	6	2	3	6	4	6	14	3
4	5	4	3	2	2	1	1	1	3	1	1	1	0	0	0	0	0	1	1	3	1	1	1	5	2	2	5	4	5	12	4
5	5	4	3	2	2	1	1	1	2	1	0	0	0	0	0	0	0	0	0	2	1	1	1	4	2	2	5	4	5	10	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	

GENERATION 1 - t1

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
5	8	6	5	4	3	2	2	1	1	1	1	1	1	1	2	1	1	3	1	1	1	1	2	5	4	4	5	6	10	14	5
4	10	8	6	5	4	3	2	2	2	1	1	1	1	2	4	2	2	4	2	1	2	2	4	7	5	5	6	8	13	20	4
3	11	9	7	6	5	4	3	3	2	2	2	2	2	3	5	3	3	5	3	2	2	3	5	9	6	6	7	9	14	23	3
2	12	10	8	7	6	5	5	4	4	3	3	3	3	4	8	4	5	8	5	3	4	4	7	12	8	7	8	10	17	29	2
1	38	31	20	28	26	26	16	25	33	33	24	15	15	25	29	25	17	21	26	22	21	11	23	31	25	15	17	19	34	54	1
0	100	55	45	52	100	49	40	49	100	100	48	39	39	48	100	48	40	43	50	100	33	22	35	100	38	29	35	36	52	100	0
1	38	31	20	28	26	26	16	26	39	34	24	15	15	24	24	24	15	16	26	28	22	11	23	31	25	16	22	20	34	54	1
2	12	10	8	7	6	5	5	6	8	5	3	3	3	3	3	3	3	3	5	8	5	4	7	12	8	8	13	12	17	29	2
3	11	9	7	6	5	4	3	4	6	3	2	2	2	2	2	2	2	2	3	6	3	3	5	9	6	7	11	10	14	23	3
4	10	8	6	5	4	3	2	3	4	2	1	1	1	1	1	1	1	1	2	4	3	2	4	7	5	6	9	9	13	20	4
5	8	6	5	4	3	2	2	2	3	1	1	1	1	1	0	1	1	1	1	3	2	1	2	5	4	4	7	7	10	14	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	

Figure 100 Generation 1 (t_1) - Second outcome of the model - Values are only for the purposes of illustration

In order to achieve this, a few methodologies have been explored. However, since the model operates in cells, using Cellular Automata is the most appropriate method to model the phenomena and all the complexities observed. The next section of the chapter will explore Cellular Automata and specifics of its application.

Cellular Automata

Cellular Automata is a model simulation method that serves to analyze, use and interpret specific data that provides a certain state being growth, development, stagnation or regression. Cellular Automata, as a model, relies on data collection that are used to provide a basic state that is needed to run further simulation in order to identify changes that can occur within a certain period of time.

The main actors that have contributed to the development of Cellular Automata, are John Von Neumann and Stanislaw Ulam during the 1940s, a few researchers like Michael Batty, 2004, 2011; Batty and Longley, 1994; White, 1997; Torrens, 2000, 2012; Clark and Gaydos, 1998, etc. These researcher have explored and examined the ability of Cellular Automata to display different peculiarities and phenomena, for instance urban development and growth as well as other complexities.[117]

Moreover, according to Torrens, Cellular Automata are comprised of an element known as an Automaton, which is a parallel process capable of performing more than one process at the same time. The machine is fed with data, from which it extracts the information it needs to function.

Cellular Automata is considered as a collection of cells where each cell has a particular state at a certain moment. The state of the cell will be prone to changes depending on the changes that neighboring cells will undergo as a result of some predefined rules. The state of the cells will constantly change as a result of the continuous application of these rules.

Therefore, a simplified Cellular Automata model shall consist of the following:

- A cell,
- Neighboring cells,
- A certain state of being and
- Predefined rules

This version and mode of application on CA is considered too simplified to provide information and prediction on urban/spatial planning. Therefore, additional and more advanced components are needed in order to ensure better functionality and broader applicability of the CA framework. When using cellular automata, empirical data are necessary to run accurate predictions of essential evolutions occurring in urban/spatial planning. Through the use of the model, spatial planning dynamics happening in a city

[117] Torrens, P. M., Nara, A., Li, X., Zhu, H., Griffin, W. A., & Brown, S. B. (2012). An extensible simulation environment and movement metrics for testing walking behavior in agent-based models. *Computers, Environment and Urban Systems*, *36*(1), 1-17.

can be simulated offering significant information about the city's growth and development.

Neighborhoods

In terms of how the value of cells is determined, the model needs to define cell neighborhoods. Cell Neighborhoods consist of a pattern of cells that surround the cell which will be given the value. All cells of the simulation need to take their value from the cell of the same coordinates, but from the previous generation. This means that the Cell Cn in Generation 1, will depend in the neighboring cells of Cn in Generation 0. In this sense, if the cell of Generation 0 has had a very developed neighborhood, the same cell will take those values into account when producing Generation 1. Among many versions of neighborhoods, there are two more commonly applied neighborhood versions of Cellular Automata:

- Neumann Neighborhood – by Von Neumann, is a two-dimensional square lattice which comprise of four cells enclosing a cell in a square.[118]
- Moore Neighborhood – by Edward F. Moore, two-dimensional square lattice which comprise of eight cells outwardly of a square grid of a central cell, along these lines.[119]

Depending on the needs of the calculations that need to be made, both versions of neighborhoods can be expanded as seen fit. Both of these two types of Cellular Automata Neighborhoods have been presented in the image below.

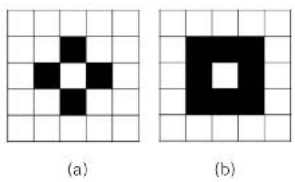


Figure 101 Structure of neighborhood in Cellular Automata (Left: von Neumann neighborhood, Right: 3x3 Moore neighborhood).

In addition to the two versions of Cellular Automat neighborhoods, there is a variety of CA neighborhoods that can be used. A few of them are presented in the figure below.

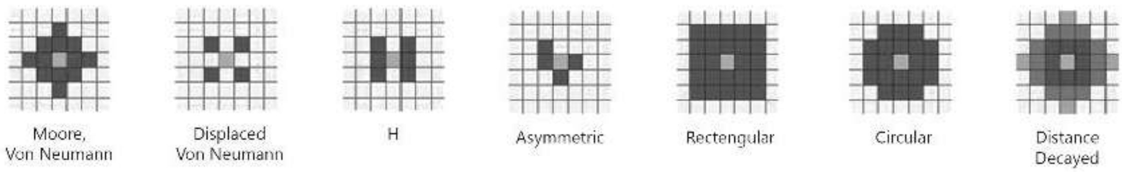


Figure 102 A variety of Cellular Automata Neighborhoods

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[118] Toffoli, Tommaso; Margolus, Norman (1987), Cellular Automata Machines: A New Environment for Modeling, MIT Press, p. 60.
[119] ibid

Markov Chains

Another methodology that is often used in calculating cell values according to the state of their neighbors are Markov Chains. A Markov chain or Markov process is a stochastic model describing a sequence of possible events in which the probability of each event depends only on the state attained in the previous event.[120] Among the distinguishing characteristics of a Markov chain is that, no matter how the process got at its current state, the probable future states are always known in advance. In other words, the chance of transitioning to any certain condition is purely reliant on the current state and the amount of time that has passed. The state space, which is the collection of all potential states, can contain anything: letters, numbers, weather conditions, baseball scores, or stock performance results, to name a few possibilities.

Many real-world processes may be studied using Markov chains as statistical models, including cruise control systems in automobiles, lineups or lines of consumers arriving at an airport, currency exchange rates, and animal population dynamics, to name a few examples.

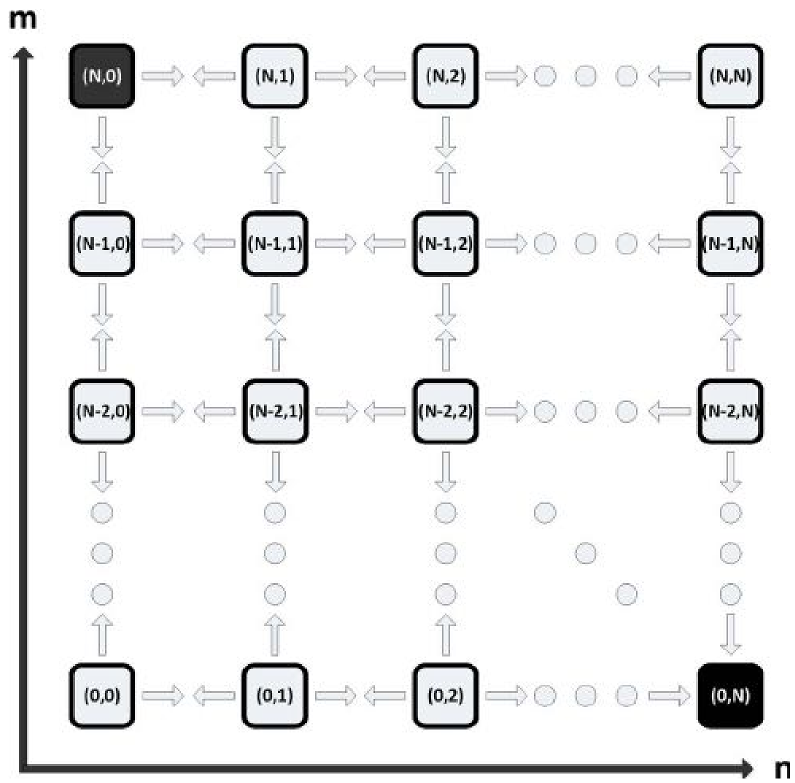

Figure 103 Markov Chains – cell value dependency from other neighboring cells

In other words, knowing the probability distribution of the prior state is all that is required to determine the probability distribution of the present state. Because it allows for non-stationary transition probabilities and, as a result, time-inhomogeneous

[120] Gagniuc, P. A. (2017). Markov chains: from theory to implementation and experimentation. John Wiley & Sons.

Markov chains, this definition is more expansive than the one discussed above. That is, as time progresses (steps increase), the probability of transitioning from one state to another may fluctuate.

6.4. Future Generations (t_n)

As with Generation t_1, all Future Generations t_n follow the same methodology, and continue to develop into the future. This means that Generation 2 (t_2) is a derivative of Generation 1 (t_1), the say way that each future generation is dependent on its immediate predecessor.

$$\{S_{t+1}\} = f(\{S_t\}, \{I^h{}_z\})$$

GENERATION 2 - t2

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
5	13	11	9	7	5	4	3	3	2	2	1	1	1	2	3	2	2	4	3	2	2	3	5	8	7	7	9	12	17	23	5
4	18	16	13	10	8	6	5	4	3	3	3	2	2	4	6	4	4	6	5	3	3	5	8	12	11	10	13	17	26	34	4
3	21	18	15	12	10	8	7	6	5	5	4	4	4	6	9	7	7	9	7	5	5	6	11	16	14	12	15	19	30	42	3
2	32	27	23	20	19	16	15	15	17	16	14	11	12	16	20	16	15	18	16	14	12	13	19	26	22	19	20	26	41	57	2
1	79	67	50	61	60	57	42	56	73	72	54	37	37	55	62	56	41	45	57	53	46	29	51	62	55	36	37	45	73	100	1
0	100	96	78	88	100	84	69	86	100	100	83	63	63	82	100	83	66	70	85	100	62	44	67	100	72	53	57	65	96	100	0
1	79	67	50	61	60	57	42	59	80	75	55	37	36	53	55	53	38	39	57	59	48	30	51	62	55	38	44	48	73	100	1
2	32	27	23	20	19	16	16	19	24	20	14	11	11	12	13	12	11	12	16	20	16	14	19	26	22	22	26	29	41	57	2
3	21	18	15	12	10	8	7	8	10	7	5	4	4	3	3	3	4	4	7	10	8	7	11	16	14	15	20	22	31	42	3
4	18	16	13	10	8	6	5	6	7	5	3	2	2	2	2	2	2	3	5	7	5	5	8	12	11	12	17	19	26	34	4
5	13	11	9	7	5	4	3	4	5	3	2	1	1	1	1	1	1	1	3	4	3	3	5	8	7	8	11	13	17	23	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	

Figure 104 Generation 2 (t_2) - Second outcome of the model - Values are only for the purposes of illustration

Continuing this method, the model will continue to generate future generations that show the advancement of development in each cell. As can be seen in the following figure, each new generation is produced depending on the changes from the previous generation. It means that if model inputs, values, and weights are changed, the model will produce a different output, but furthermore, future generations will be different as they have different values to process.

As will other growth models, future generations will show maturing growth as well as flattening and stagnation of growth.

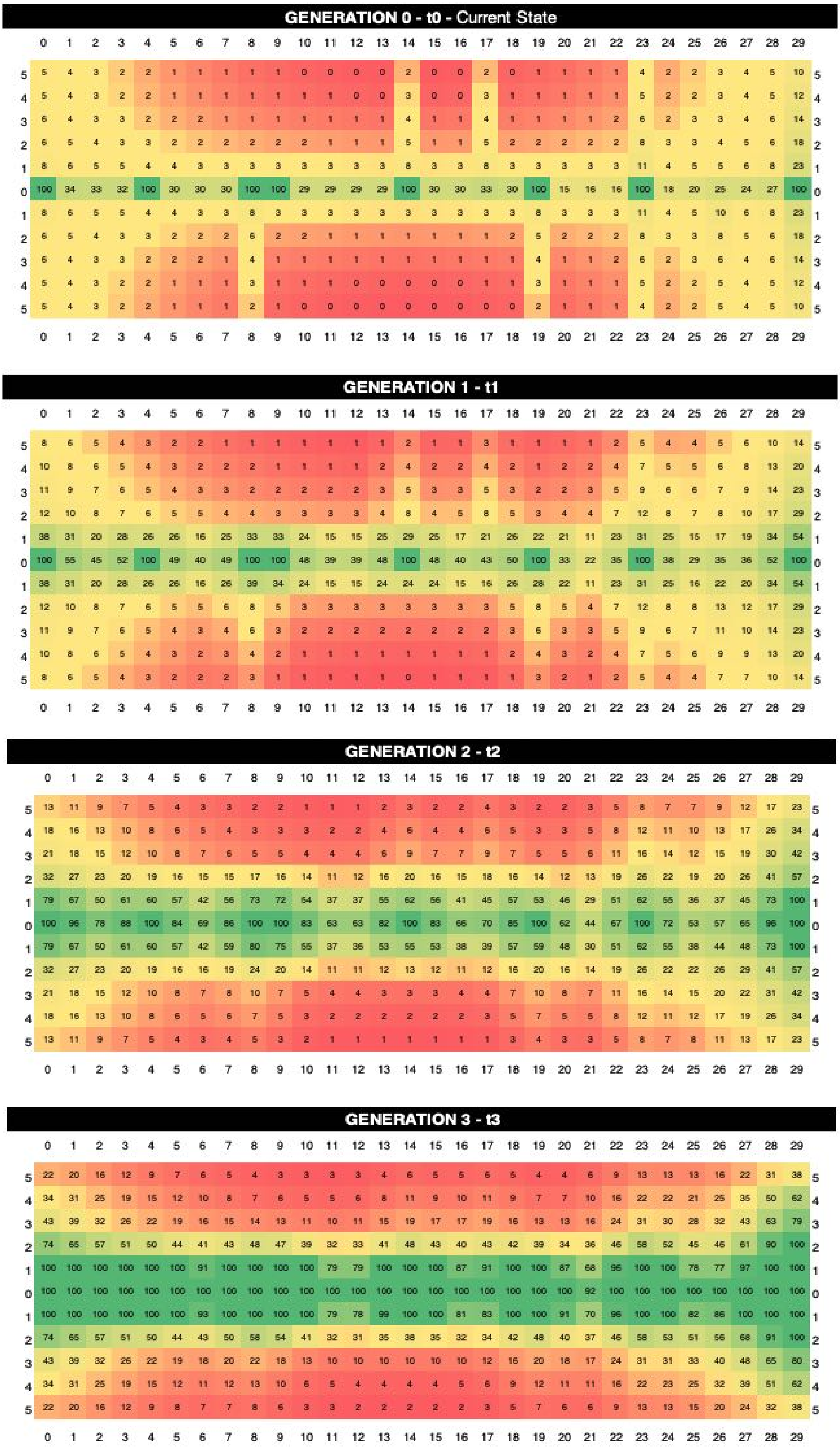

Figure 105 Future Generations (tn) - Second outcome of the model - Values are only for the purposes of illustration

The cells of future generations will continue to develop until they reach the value of 1, representing 100% development. This includes the cells that were developed to some degree for example in t_2, as they will continue to develop in t_3 too. Once cells reach the value of 1 they will stop developing, however they will continue to affect the values of neighboring cells, as the argument is that the more development there is in a particular cluster of cells, the more the likelihood for further development.

6.5. Summary

The quantification component of the model has been discussed in this chapter. The model is made up of individual cells, each of which is assigned a number that represents the probability of future land development in that particular location. After these values have been entered, the computer will perform the necessary calculations to determine the output of each cell.

The final result of the model for each individual cell is the total of the product of all of the cell's values as well as its weights. The level of land development potential, as shown by the value of the y output variable, will vary from model Cell to model Cell. The Road Cell Array is a row (or array) of cells that each have a different value that represents the possibility or likelihood of land development taking place in that particular cell. This can be pictured as a brick wall, with qualities piled atop one another for each individual cell, and the road array outcome being the row at the very bottom of the wall.

Following the completion of the initial calculation, the model will take its first glimpse into the potential future with the Generation 0 (t0) output. One way to think of it is as a starting point from which to make future predictions and run simulations. At this point in the process, it is essential that the model be as accurate as possible because this will allow for improved results when modeling subsequent generations.

Cellular Automata is a model simulation method that serves to analyze, use, and interpret specific data that provides a certain state, which may be growth, development, stagnation, or regression, and that is used for the purpose of generating these generations. These states may include growth, development, stagnation, or regression. Cellular Automata is used for the purpose of generating these generations.

The techniques used by Generation 1 (t1) will be utilized by subsequent Generations, which will then continue to develop. Generation 1 (t1) is the progenitor of One 2 (t2); hence, each succeeding generation is dependent on the generation that came before it. The model will generate subsequent generations via this technique, demonstrating cell development in the process. As can be seen in the figure, the success of each subsequent generation is contingent on the one that came before it. If the model's parameters, including its inputs, values, and weights, are changed, the resulting output of the model will be different, as will the output of any succeeding generations. The growth of subsequent generations will, like that of other models, gradually slow down, level out, and eventually stop.

CHAPTER 7

RESULTS AND CALIBRATION: FROM CURRENT, TO FUTURE, TO PLANNING

This chapter includes all the results that derive from chapter 5 and 6, and improves upon them by proposing a calibration loop. Furthermore, in this chapter future perspectives are analyzed in regards to thinking about how to use the model results as spatial planners, to improve the future outcomes. This includes changing policies, legal frameworks, or any other tool in the arsenal of a spatial planner.

7. RESULTS AND CALIBRATION: FROM CURRENT, TO FUTURE, TO PLANNING

The process of figuring out the calibration is one of the most significant elements in the process of working out and designing an urban model. The initial step in putting this model into operation is to calibrate it using the results of an up-to-date perspective analysis. The calibration process is an essential part of operating the model, despite the fact that it is frequently neglected. [121] It provides an understanding of the model's uncertainty, which can then be conveyed to end-users or utilized in the further processing of the model outputs. The theory and practice of calibrating a model are discussed in this section with the goal of extracting additional value from the predictions.

In order to calibrate a model using the traditional procedures, historical data sets for the important variables are needed (in the case of this dissertation, case the five different time periods of land-use change).

When determining which factors are dependent and which are independent, empirical analysis and experience are applied. For the purpose of regressing dependent variables upon independent variables, a method of subjectively selected equation fitting is chosen. In this setting, the emphasis is placed on conventional, data-based regression, which is referred to as "forward" regression. The theory can be summed up as follows: Given sufficient primary data, it is possible to find regression coefficients that construct the equation that provides the best fit to the data.[122]

Errors in regression equations can be calculated when primary data are available (which provides a standard). If primary data are available for all of the system's variables, then the equation used to determine the balance of the system should be more robust.

Even with the best calibration process, models will still not reach full precision, and there will always be a margin of error when it comes to predictions. The idea is to try and minimize this margin as much as possible, so that the outcome of the model is as precise as possible.

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[121] Crooks, A., Malleson, N., Manley, E., & Heppenstall, A. (2018). Agent-based modelling and geographical information systems: a practical primer. Sage.
[122] Akın, A., Clarke, K. C., & Berberoglu, S. (2014). The impact of historical exclusion on the calibration of the SLEUTH urban growth model. International Journal of Applied Earth Observation and Geoinformation, 27, 156-168.

7.1. Testing of the Model with Current Perspective Analysis Data

As with all models, the precision of the proposed model cannot be high in the first try, therefore testing, and comparing with existing data is needed. One of the most typical applications of calibration is to adjust the values of the model's parameters so that they correspond to the conditions that have been observed. This can be accomplished by running the model with a variety of various parameter values and comparing the results of the modeling to some actual data by making use of the observations presented in Chapter 4 of this dissertation.

After being adjusted to correspond with the goal data in the most accurate manner feasible, a model may then be in a position to provide some information regarding the actual system. To give just one illustration, the model's parameters that have the most influence are probably also the ones that carry the most weight in the actual world, such as junctions, gravitational pulls of settlements, etc.

In addition, calibration can be utilized to approximate the value of factors that either cannot be directly observed or cannot be directly known, for such attributes as 'position of cell'. Finding the value that is optimal for a parameter that, for example, governs some aspect of the behavior of a cell may give useful information about the theory that underpins the behavior of the cell. Therefore, calibration is a tool that may be utilized to improve one's comprehension of the dynamics of a model. Through this process, the determination can be achieved on which attributes and parameters are redundant (those that have a limited impact on the model results) and which attributes are highly sensitive to changes in their values by modifying the parameters' values and weights within a certain range.

As discussed before, there are five different periods that serve as data sets, meaning the model has five checkpoints in testing to see whether it is correct. The following figure provides an illustration of the fundamental steps involved in the calibration process.

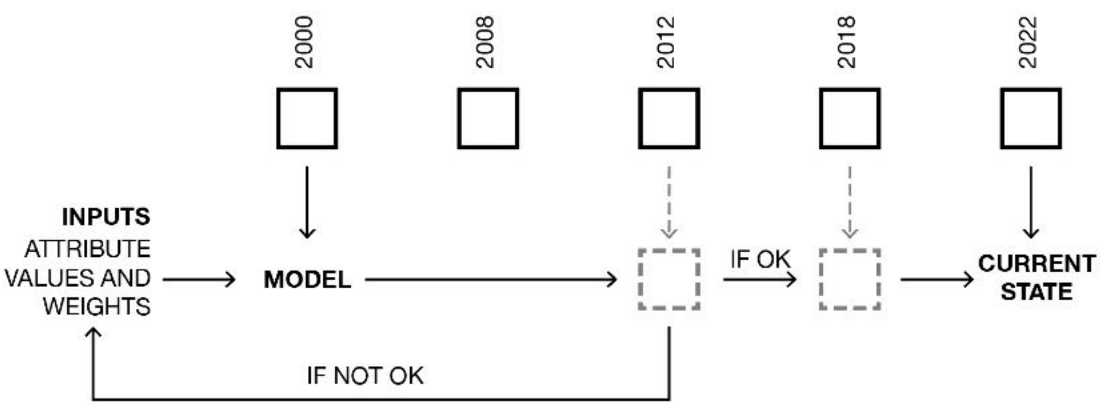

Figure 106 Process of checking the calibration of the model with current perspective analysis data

To get started, the model is put through its paces, and then synthetic data is compiled. This is then compared to observations made in the real world, and the disparity, or amount of error, that exists between the two different data sets is then determined.

The magnitude of the error is sometimes referred to as the fitness[123], and those model configurations that produce the least amount of error are considered to have the highest level of fitness. After that, the model's parameters are changed, and it is run again, in order to yield an output with a reduced error.

This means that, in order to test the model's accuracy, it is fed data from an older source, such as the year 2000, in order to construct what, from the model's perspective, is the future, such as the year 2012. As the data for 2012 is also accessible, it can be evaluated for suitability. If acceptable, it is presumed that the model forecast is accurate, no calibration is required, and subsequent predictions can proceed. If the examined data is not acceptable, however, calibration is required through the adjustment of attribute values and weights.

The procedure is carried out multiple times until the model generates an error that is low enough. The level of error that is deemed "acceptable" is a matter of opinion and is contingent not only on the system being investigated but also on the goals of the modeler.

However, there is some debate as to whether or not having zero errors is desirable. If a model mimics the observed patterns too closely, then it may explain the random noise in addition to the underlying 'real' system dynamics. This is because the observed data will most likely contain some element of random noise. This process is is called overfitting.[124]

7.2. Reviewing and Adjusting Attribute Values and Weights

Qualitative calibration adjusts a model without comprehensive examination. This approach can involve only the modeler's intuition and subject expertise, or external experts and stakeholders. Face validation is when a modeler calibrates through intuition. By keeping a basic understanding of how the simulated process should seem and evolve, a model may be changed until something 'looks right' to the modeler.

This decision can be made by model observations or statistics, charts, and maps. In examining a model's architecture, the modeler should consider both individual agent

[123] Crooks, A., Malleson, N., Manley, E., & Heppenstall, A. (2018). Agent-based modelling and geographical information systems: a practical primer. Sage.
[124] Crooks, A., Malleson, N., Manley, E., & Heppenstall, A. (2018). Agent-based modelling and geographical information systems: a practical primer. Sage.

behavior (micro-validity) and collective behavior patterns (macro-validity), as well as how these patterns arise over time.[125]

In many simulations of real-world phenomena, face validation is a first step towards a more in-depth empirical calibration and validation procedure. In others, where hypothetical behaviors and interactions are the major focus, intuition is a good approach to model building.

Due to limited contextual information or insufficient data, it may be difficult for a modeler to determine the validity of simulation output.[126] In certain cases, a modeler may consult spatial planning experts on the simulation's accuracy. This can happen in several ways, including 'companion modelling' technique, which needs deep interaction and strives to integrate stakeholders and decision-makers in the modelling process, in the construction and design of the model, as well as in the and medication of attribute values and weights.[127]

This technique focuses on model precision in aligning it with observed behavior, rather than accuracy in terms of what certain data sets show.[128] In the Werker–Brenner technique, expert evidence is merged after empirical validation to determine the most resilient model solution from valid alternatives.[129] Such too is the case of the model proposed in this dissertation.

7.3. From Current to Future: Using the Model for Predictions

Overfitting happens when a model is overtrained on observable data, as discussed in the previous portion of this chapter. The model, rather than reflecting system dynamics, reproduces observed data, including noise that might be particular to one case study. It would be futile to reconfigure the model for new case studies, as the results would not be correct. A solution to this challenge is to divide the available observed data into training and test sets, so that each set of data (or each attribute) is tested in an isolated manner, before being applied to the overall results of the model.

In validation, the model isn't modified like in calibration. If the model works well on test data, we can be confident it hasn't been overfitted and will perform well on fresh input data representing unanticipated circumstances. If the model performs badly during

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[125] Ibid.
[126] Bharathy, G. K., & Silverman, B. (2010, December). Validating agent based social systems models. In Proceedings of the 2010 Winter Simulation Conference (pp. 441-453). IEEE.
[127] Barreteau, O., Antona, M., D'Aquino, P., Aubert, S., Boissau, S., Bousquet, F., ... & Weber, J. (2003). Our companion modelling approach.
[128] Moss, S. (2008). Alternative approaches to the empirical validation of agent-based models. Journal of Artificial Societies and social simulation, 11(1), 5.
[129] Bharathy, G. K., & Silverman, B. (2010, December). Validating agent based social systems models. In Proceedings of the 2010 Winter Simulation Conference (pp. 441-453). IEEE.

validation, it may suggest that the design is faulty and the model, in its current form, is not a reliable conceptualization of the system it is trying to reflect.

Although validation is motivated differently than calibration, the techniques are comparable. Like calibration, the model generates synthetic data and compares it to observed data. The same methods used to quantify calibration error can be used to synthetic and observed validation data.

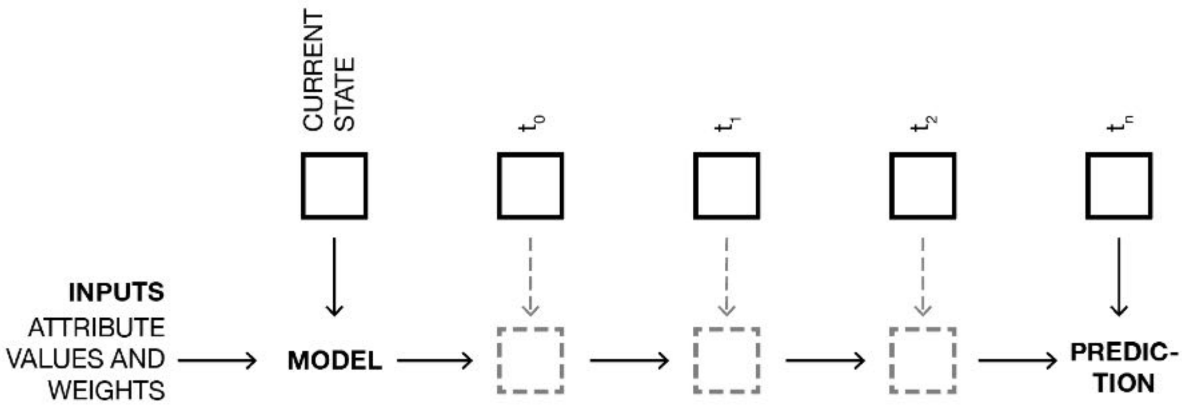


Figure 107 Process after calibration and validation of model attribute values and weights

In this case, if the calibration and validation process show that the model precision is satisfactory and up to the standards set by the modeler, the next phase can be using the model to make predictions on how development is likely to shape.

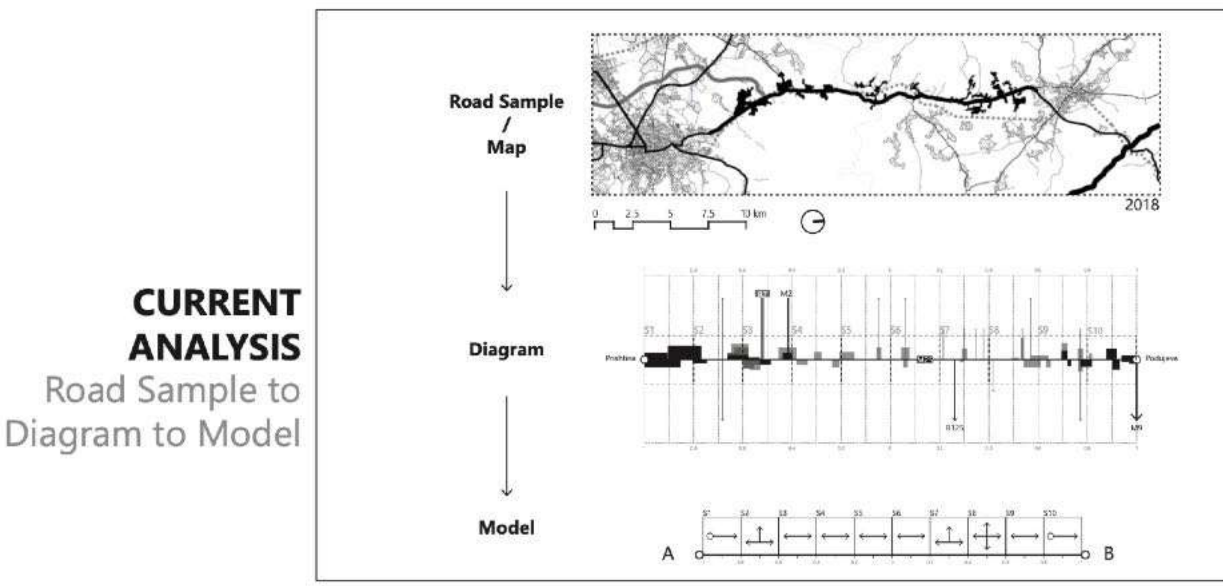


Figure 108 Model Process - Road Sample to Diagram to Model

7.4. In Terms of Spatial Planning

Data plays a crucial part in spatial planning by supplying the planners with information that is essential to carrying out additional study and guiding the research in the appropriate direction so that an informed decision can be made when it comes to drafting plans, rules, or laws.

In addition to this, it is strongly recommended that spatial planners conduct field research and data collection in addition to relying solely on desk research. Therefore, the option of utilizing a model that would allow opportunities of merging the data to conduct an actual calibration would provide a more accurate picture of the current situation as well as a more accurate prediction of what will happen in the future.

Model calibrations work as a valid tool for experiencing the observational aspect in combination with the data available. As a result, the availability, identification and use of appropriate attributes for calibration, is of utmost importance to have a more accurate understanding of the situation.

In addition to establishing the attributes necessary for the operation of the model, the weight and value that should be assigned to each attribute should also be determined. This will ensure that the results of the many calibrations will be consistent.

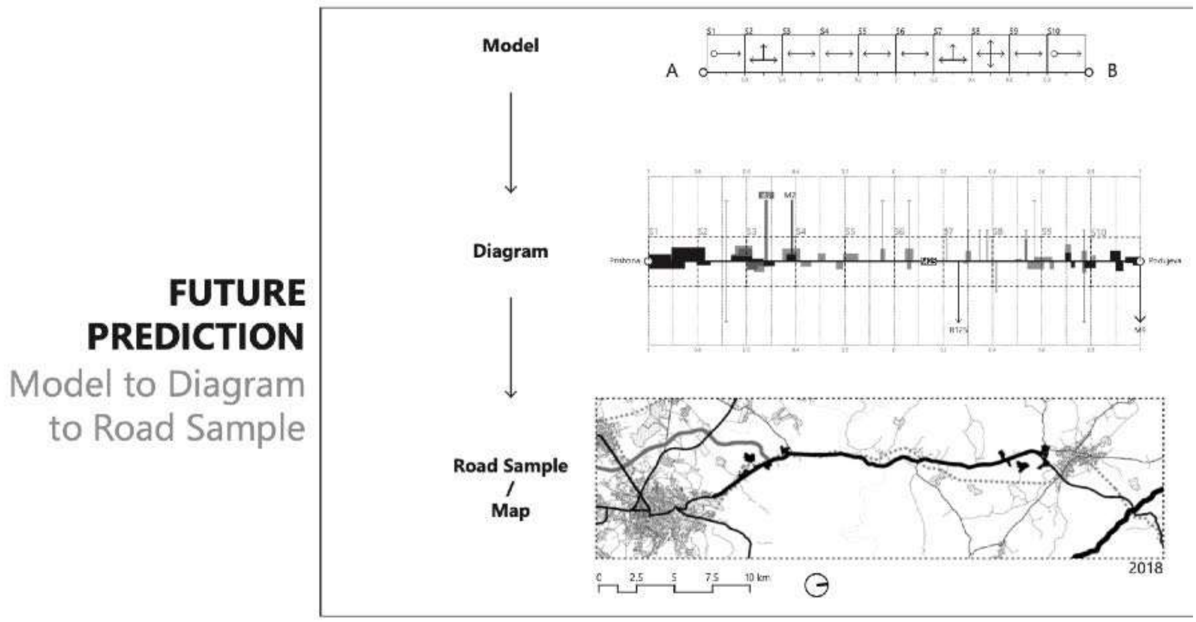


Figure 109 Model Process - Model to Diagram to Road Sample

The characteristics of attributes enable the model to be adapted to the circumstances that exist in the field as well as the data that has been gathered for actual examples that are currently being investigated and analyzed, thereby producing significant inputs. Due to the fact that this model gives a variety of inputs, planners are able to make use of those inputs in the future as a foundation and a viable opportunity for additional hypothetical instances. In this manner, a specific case study can have a variety of distinct situations developed for it.

7.5. Summary

The theory and practice of calibrating a model are discussed in this section with the goal of extracting additional value from the predictions. The theory can be summed up as follows:. Given sufficient primary data, it is possible to find regression coefficients that construct the equation that provides the best fit to the data. Calibration is the process of running a model and comparing its results to observations made in the real world. This allows one to approximate the value of factors that cannot be directly observed or known.

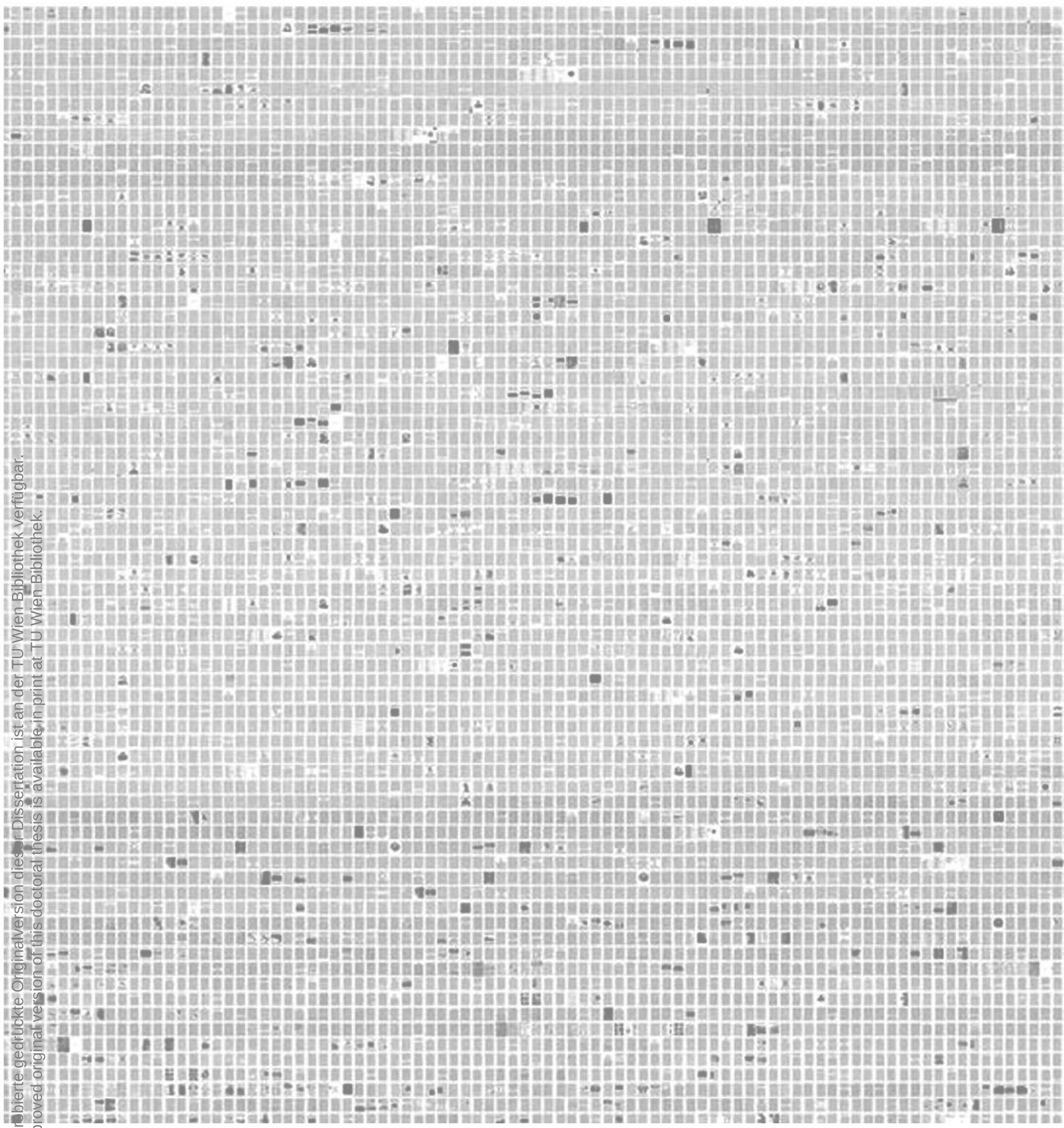
Finding the value that is optimal for a particular parameter may give useful information about the theory that underpins the behavior of a cell. When a model is used to predict the future, it must be able to make an error that is low enough to be considered 'acceptable'.

The level of error is contingent on the system being investigated and the goals of the modeler. If a model mimics the observed patterns too closely, then it may explain the random noise in addition to the underlying 'real' system dynamics. In many simulations of real-world phenomena, face validation is a first step towards a more in-depth empirical calibration and validation procedure. By keeping a basic understanding of how the simulated process should seem and evolve, a model may be changed until something 'looks right' to the modeler.

The results from the model will be compared and tested with the data from analysis of the case studies. If the results from the model do not match the case studies analysis, the input can be reviewed and calibrated to get a better matching result. On the other hand, if the results from the model match those from case study data, then we can proceed with applying the model to future analysis (predictions).

By having a model that can to some accuracy predict patterns of land-use, we will have a better understanding of how changes in land-use occur when there are no policies in place. Once there is a clearer understanding of this behavior, then it is much easier to control changes in land-use and development through policies as well as physical attributes of road infrastructure.

It is of the utmost necessity to have the availability, identification, and utilization of acceptable attributes for calibration in order to have a more accurate picture of the current circumstance. Planners have a tool at their disposal with which they can experiment with a variety of outcomes for their case studies.



CHAPTER 8

IN SEARCH OF FUTURE SPATIAL PATTERNS: PREDICTING SPATIAL DEVELOPMENT

In this chapter three selected case studies of different road levels, that of Motorway, National and Regional, are tested with the model in order to simulate potential futures of development, running parallel to the road infrastructure. Furthermore, potential measures that can be undertaken by spatial planner are briefly discussed as well.

8. IN SEARCH OF FUTURE SPATIAL PATTERNS: PREDICTING SPATIAL DEVELOPMENT

The part that follows will demonstrate the examination of three various types of road infrastructure. This means that the chapter will analyze three separate case studies, one from each of the case study pools described in Chapter 4 of the dissertation.

As examples from various road types exhibit unique characteristics, cases of the same road type demonstrate comparable behavior. Due of this, only one case study per road type was chosen for further research using the model. In addition, the findings of the cases will be assessed, and recommendations for necessary Intervention Actions will be presented in this section.

8.1. Testing Case Studies with the Model

The testing for the case study kicks off with an analysis of the map depicting the current state of the road that is being investigated. After this, both quantitative and qualitative data are introduced into the model in the form of inputs; thus, the values and weights of the attributes relevant to each case study are derived.

The following step is to execute the model in order to generate the output of the current state, also known as generation 0. The procedure of calibrating and validating the inputs, which is covered in Chapter 7, is started after this outcome has been observed.

The process of analyzing and producing new generations by the model is finished at the point in time when it is determined that the output of the model is compatible with that of the current state map to a level that is considered satisfactory. The pattern that the shaped development will take in the future can be seen in these future generations.

This output of the model corresponds to the spatial dimension rather than the temporal dimension, as was covered in Chapters 5 and 6, which indicates that development is not restricted to a particular time frame but rather depends on the availability of opportunities for development (e.g. better or improved economic conditions, enable the development and achievement of one of these outputs in a faster time).

Following is an analysis of the model outputs in order to better comprehend the development patterns in the model's horizontal dimension. This means that the diagram illustrates which critical sections of the assessed road are undergoing development and at what rate.

The three case studies will also be studied in terms of Intervention Actions and policies that can be implemented to alter or control the predicted future development.

8.1.1. Case Study 1 – Motorway

Explanation of the graphical analysis

The figure below shows four different diagrams that measure development in different ways. In a) the map shows development as it has occurred in five different time periods, additionally, red circles indicate the development clusters along the road infrastructure; in b) the development is shown in a schematic manner, this diagram is used to compare the outcome of the model which can be found in c) it can be concurred that the model's output matches the schematic to a great degree; Finally, d) shows the collective sum of all development that has occurred along the road infrastructure.

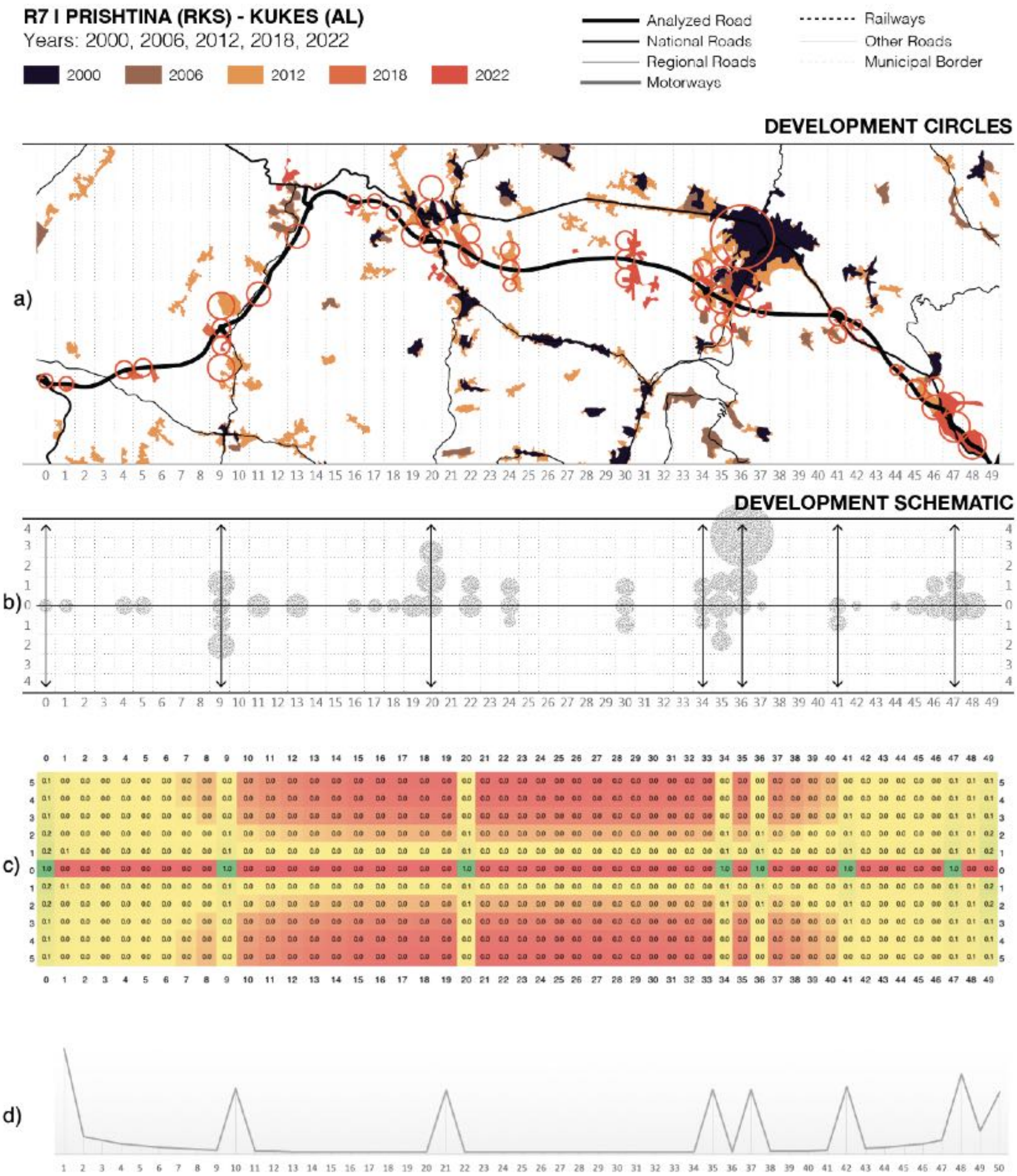


Figure 110 Case Study 1 - Graphic analysis of development along road infrastructure: a) map, b) diagram, c) model output, d) sum of development

Model Output

The figures below show the development of the case study, in this case the motorway, in four different generations (ticks). As stated in chapter 5 and 6, Generation 0 shows the current state of development, and as can be seen in the figure below, since there are restrictions all along the road infrastructure for the case of motorways, development has had chance to occur only near junctions. Since the restriction on development along the road remains, this pattern grows further and is observable in future generations too, with development expanding on the outer rims of the road infrastructure too. Furthermore, in Generation ‘n’, the clusters of development along junctions and close to settlements, begin to merge into one-another.

Generation 0 – t_0

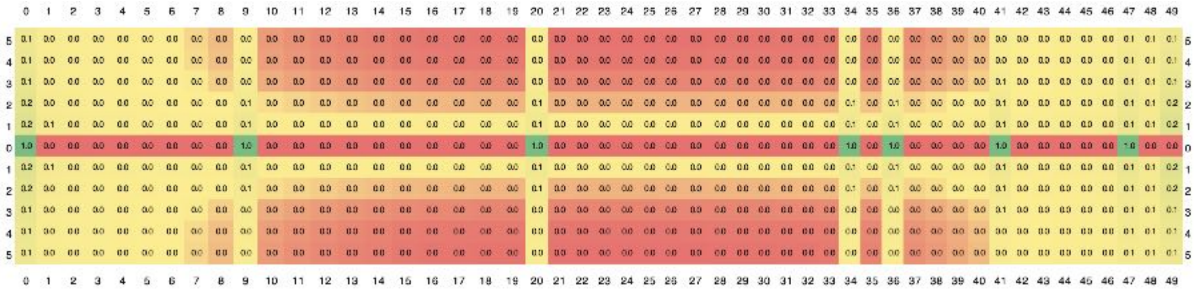


Figure 111 Case Study 1 - Output: Generation 0

Generation 1 – t_1

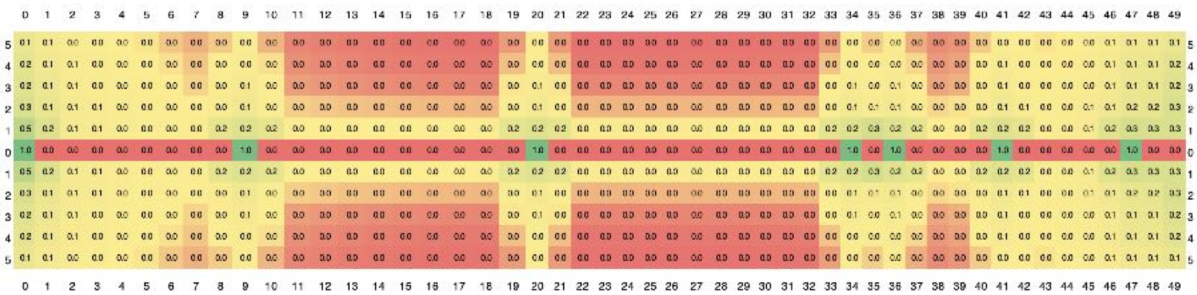


Figure 112 Case Study 1 - Output: Generation 1

Generation 2 – t_2

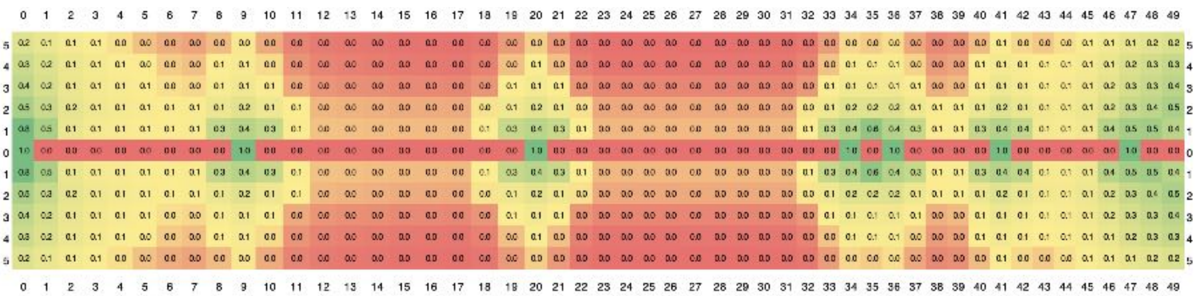


Figure 113 Case Study 1 - Output: Generation 2

Generation n – t_n

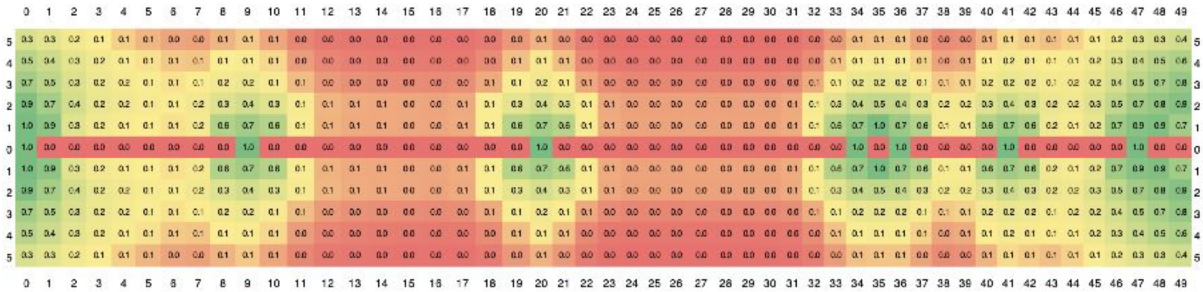


Figure 114 Case Study 1 - Output: Generation 'n'

Synthesis of Model Output

The figure below shows the differences in development for two generations, namely Generation 0 (the current state) depicted with the blue line, and Generation 'n' (a predicted state of the future) depicted with the orange line. The gap between the two lines shows the intensity of development for that particular cell or area.

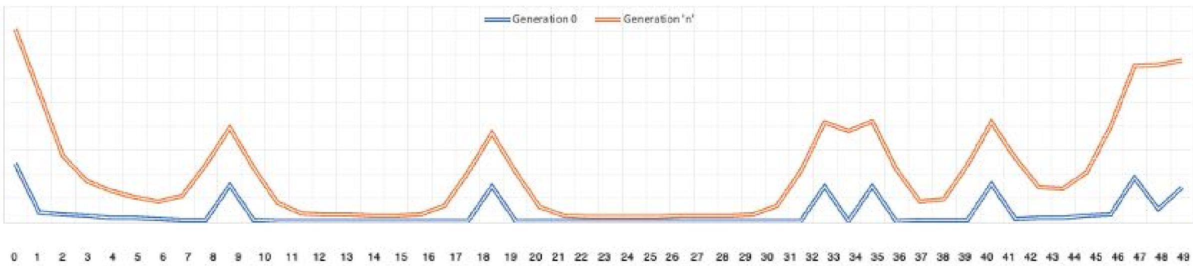


Figure 115 Case Study 1 - Changes in development in Generation 0 (blue) and Generation 'n' (orange)

Key Findings

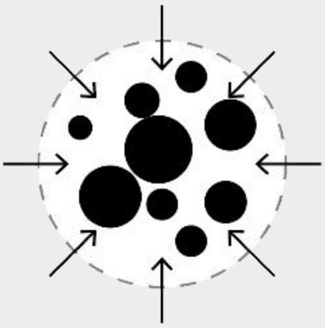
- The main findings arising from the model outputs are that the main source of development remains existing settlements, which tend to continue to grow further.
- IN the case of motorways, there is the likelihood for development to occur away from the road infrastructure, raising the chance for agglomeration development.
- In cases where there was no initial development in the current state (for example the segments of the road without any junctions or other connections), the likelihood for development to occur in that zone in the future remains low.
- The development in the case of motorways takes place mainly around junctions, as legal restrictions do not allow for parallel development with road infrastructure. When left to grow on its own, development around two junctions is likely to merge with one-another, especially when close to existing settlements.

Proposed Intervention Actions

In the example of this case study, and based on the results and findings after the model outputs, three Intervention Actions are proposed:

Table 28 Proposed Intervention Actions for Case Study 1

Intervention Action 1

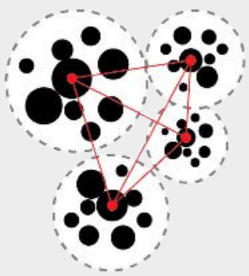


Compact Settlement

Where there is an existing settlement with a toponym - whether rural or suburban - it is redefined by urban plan as a town-city settlement. This way the existing settlements' growth is maintained within reasonable limits, and sporadic development together with the formation of new agglomerations are discouraged.

Proposed Action:
This can be achieved if settlements are identified and marked by Municipal Development Plans, whereby municipalities are charged with protecting and encouraging compact growth of these settlements. Borders and/or outer limits to these settlements can be proposed at this level of planning, and shall go into further details with Municipal Zoning Maps.

Intervention Action 2



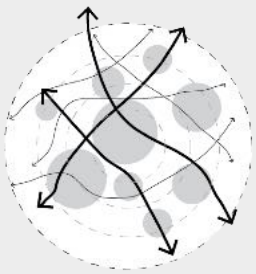
Polycentric and Balanced Spatial Development

Where there is the potential for agglomeration — that is, where there is no defined urban rural settlement but the development has occurred merely because of the condition of the junction — a regional plan is to be developed that encourages and treats polycentric development. This Intervention Action would need a cross-border (cross-municipality) cooperation and plan.

Proposed Action:
The central government shall devise incentives that encourage and favor the development of cross-municipality plans, including Municipal

Development Plans as well as Municipal Zoning Maps. Once cooperation is established in a planning level too, it is much easier for agglomerations of development to be planned and connected in a more compact way, ensuring a more sustainable development.

Intervention Action 3



An Integrated Approach for Improved Transportation Network

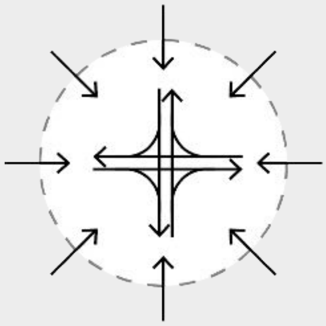
Towns and villages must be linked to one other, their hinterlands, and the regional economy. Efficient transportation and good access to telecommunications are essential for the social and economic cohesiveness of peripheral and less-favored regions. Transport and telecommunications promote polycentric development. Efficient transport and telecommunication networks and services boost the economic attractiveness of cities and regions.

This Intervention Action is in accordance with the policy options from the ESDP Policy Aims and Options for the Territory of the EU document, specifically Policy 107.[130]

Proposed Action:
To help with the transition of urbanization, rural zones shall get better connections, in terms of telecommunications as well as road infrastructure. In this regard, through the Spatial Plan of Kosovo, the municipality is obligated to analyze each settlement and make projections in terms of population and land-use growth. In this manner, networks are then to be planned in accordance with each settlement growth/shrinkage.

130 European Commission - ESDP - European Spatial Development Perspective. Towards Balanced and Sustainable Development of the Territory of the European Union. Luxembourg: Office for Official Publications of the European Communities

Intervention Action 4



Planned Junctions

Along motorways, most of the development occurs near junctions. This is due to the legal restrictions that hinder development along the road infrastructure. This is a necessary tool that helps control development, however a version of it is needed for junctions as well.

Proposed Action:

As junctions present a much improved opportunity for development along motorways, it is possible for the central level to propose special plans - for example Detailed Regulatory Plans (DRP) – for the junction zones. This process would encourage cooperation between municipalities in preparing cross-border and regional plans. Furthermore, this tool would help in containing development and stop any uncontrolled growth, such as those predicted by the model.

Translating Intervention Actions Spatially

The Intervention Actions that were suggested in the previous part are shown in a spatial dimension, along the road infrastructure that was assessed. In light of the fact that each of the four recommended Intervention Actions or interventions addresses a distinct problem in a distinctive way, it is essential to include the spatial context as well.

Figure 116 Proposed Intervention Actions for Case Study 1

8.1.2. Case Study 2 – National Road

Explanation of the graphical analysis

The figure below shows four different diagrams that Intervention Action development in different ways. In a) the map shows development as it has occurred in five different time periods, additionally, red circles indicate the development clusters along the road infrastructure; in b) the development is shown in a schematic manner, this diagram is used to compare the outcome of the model which can be found in c) it can be concurred that the model's output matches the schematic to a great degree; Finally, d) shows the collective sum of all development that has occurred along the road infrastructure.

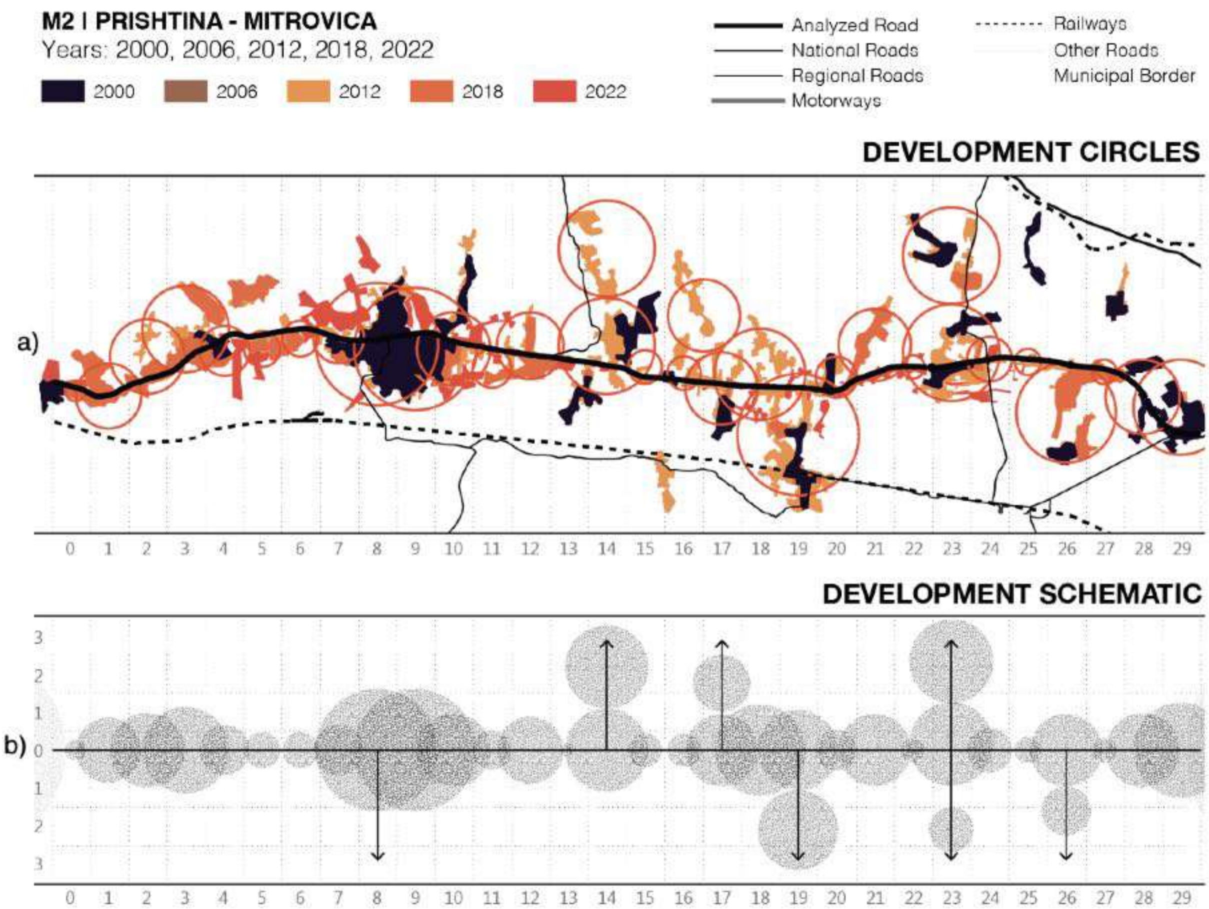


Figure 117   Case Study 2 - Graphic analysis of development along road infrastructure: a) map, b) diagram

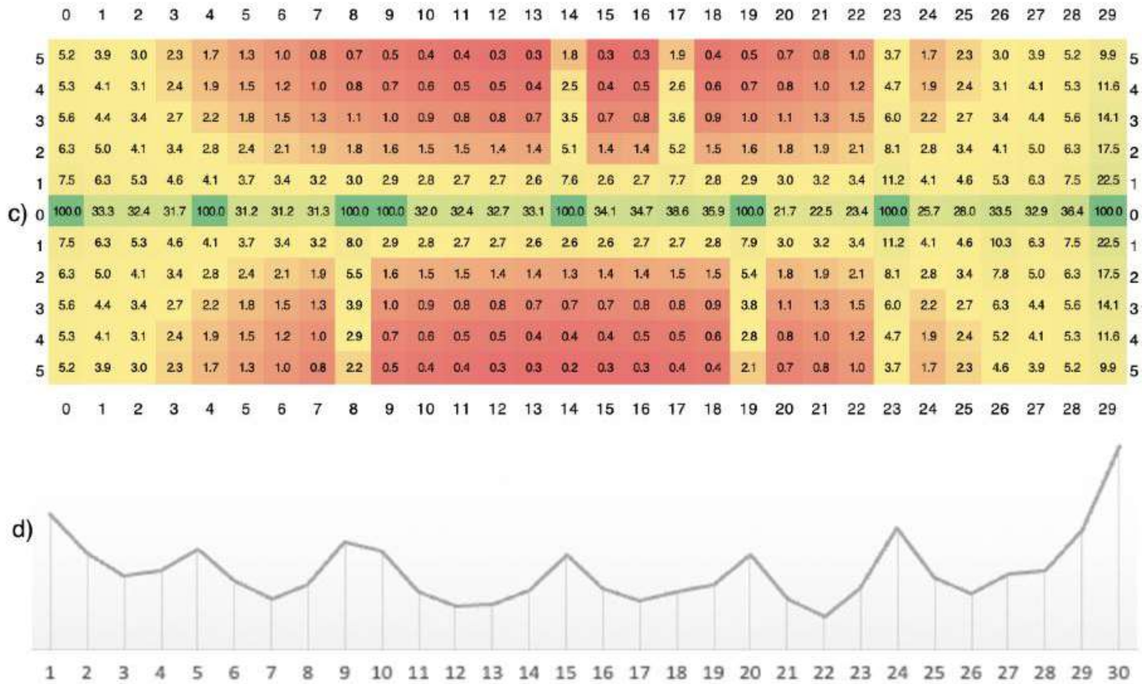


Figure 118 Case Study 2 - Graphic analysis of development along road infrastructure: c) model output, d) sum of development

Model Output

The figures below show the development of the case study, in this case the national road, in four different generations (ticks). As can be seen in the figure below, in Generation 0 (current state), development is heaviest near the settlements at both ends of the road infrastructure, as well as near connections to secondary road infrastructure. In future generations these agglomerations of development near secondary infrastructure influence further growth on the cells nearest to them. Eventually, when left to develop on its own, these agglomerations begin to merge, with them being heaviest near original clusters (which usually indicate existing smaller settlements) as well as near the settlements at both ends.

Generation 0 – t_0

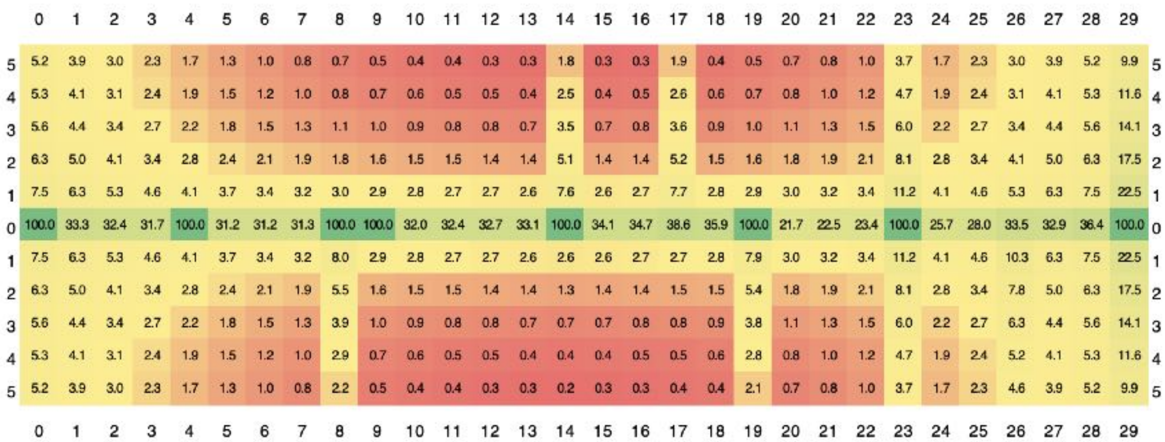


Figure 119 Case Study 2 - Output: Generation 0

Generation 1 – t_1

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
5	7.8	6.5	4.9	3.8	2.9	2.3	1.8	1.4	1.1	0.9	0.8	0.7	0.6	1.0	2.3	1.0	1.0	2.5	1.2	0.9	1.1	1.4	2.5	5.0	3.6	3.8	4.9	6.5	9.5	14.3	5
4	9.9	8.3	6.4	5.0	3.9	3.1	2.5	2.0	1.7	1.4	1.3	1.1	1.0	1.7	3.5	1.7	1.8	3.8	2.1	1.4	1.7	2.0	3.7	7.1	5.1	5.0	6.4	8.3	12.7	19.7	4
3	10.6	9.0	7.1	5.7	4.6	3.8	3.2	2.7	2.4	2.1	1.9	1.8	1.7	2.7	5.1	2.7	2.8	5.3	3.0	2.1	2.4	2.7	4.8	9.1	6.2	5.7	7.1	9.0	14.2	23.3	3
2	12.0	10.4	8.4	7.0	5.9	5.1	4.5	4.1	3.8	3.5	3.3	3.2	3.1	4.4	7.7	4.4	4.5	7.9	4.8	3.5	3.8	4.1	6.7	12.2	8.1	7.0	8.4	10.4	16.6	28.7	2
1	37.7	30.5	20.4	27.6	26.6	25.8	16.8	25.0	33.3	33.2	24.6	16.1	16.1	25.6	30.1	26.0	18.4	23.0	27.0	23.9	22.4	13.1	24.9	32.4	27.1	18.0	20.0	22.6	35.9	56.0	1
0	100.0	54.6	44.5	51.8	100.0	50.4	41.5	50.7	100.0	100.0	50.7	42.5	42.9	52.3	100.0	53.5	46.4	50.1	56.5	100.0	39.9	30.5	43.2	100.0	46.7	39.5	45.7	47.0	62.1	100.0	0
1	37.7	30.5	20.4	27.6	26.6	25.8	16.8	26.1	38.8	34.3	24.6	16.1	16.1	24.5	24.7	24.9	17.3	17.6	27.0	29.4	23.5	13.1	24.9	32.4	27.1	19.1	25.5	23.7	35.9	56.0	1
2	12.0	10.4	8.4	7.0	5.9	5.1	4.5	5.5	8.5	4.9	3.3	3.2	3.1	3.0	2.9	3.0	3.1	3.2	4.8	8.2	5.2	4.1	6.7	12.2	8.1	8.5	13.2	11.8	16.6	28.7	2
3	10.6	9.0	7.1	5.7	4.6	3.8	3.2	3.8	5.9	3.2	1.9	1.8	1.7	1.6	1.6	1.6	1.7	1.8	3.0	5.7	3.5	2.7	4.8	9.1	6.2	6.7	10.6	10.1	14.2	23.3	3
4	9.9	8.3	6.4	5.0	3.9	3.1	2.5	2.9	4.4	2.3	1.3	1.1	1.0	0.9	0.9	0.9	1.0	1.1	2.1	4.1	2.5	2.0	3.7	7.1	5.1	5.8	9.1	9.1	12.7	19.7	4
5	7.8	6.5	4.9	3.8	2.9	2.3	1.8	1.9	3.0	1.4	0.8	0.7	0.6	0.5	0.5	0.5	0.6	0.7	1.2	2.8	1.6	1.4	2.5	5.0	3.6	4.2	6.8	6.9	9.5	14.3	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	

Figure 120 Case Study 2 - Output: Generation 1

Generation 2 – t_2

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
5	12.8	11.2	8.7	6.7	5.2	4.0	3.2	2.6	2.1	1.7	1.5	1.3	1.3	2.1	3.4	2.3	2.4	3.7	2.6	1.9	2.1	2.8	4.9	7.8	6.9	6.9	8.7	11.7	17.2	22.7	5
4	18.4	16.1	12.7	9.9	7.8	6.2	5.0	4.1	3.5	3.0	2.6	2.3	2.4	4.0	5.8	4.3	4.4	6.2	4.6	3.3	3.5	4.6	8.0	12.1	10.8	10.3	12.7	17.1	25.7	34.4	4
3	20.5	18.1	14.6	11.7	9.5	7.9	6.7	5.7	5.1	4.5	4.2	3.9	4.1	6.2	8.7	6.6	6.8	9.2	6.9	5.0	5.1	6.4	10.8	15.8	13.6	12.3	14.6	19.5	30.2	41.7	3
2	31.6	27.3	23.1	20.3	19.2	16.5	15.4	15.5	17.0	16.6	14.1	11.7	12.0	15.9	20.3	16.6	15.8	19.0	16.7	14.7	13.0	14.2	19.6	27.1	22.8	19.6	20.9	27.1	41.6	57.9	2
1	79.2	66.5	49.8	60.7	60.8	57.2	42.7	56.8	73.4	73.1	56.2	39.4	39.9	57.7	64.4	59.1	45.3	50.0	60.7	56.1	49.8	35.1	55.2	66.0	60.0	43.3	44.8	53.4	78.8	100.0	1
0	100.0	94.8	77.4	88.5	100.0	85.4	71.2	88.0	100.0	100.0	87.1	68.4	69.1	87.3	100.0	89.5	75.2	79.2	93.8	100.0	71.9	56.2	77.1	100.0	83.6	68.1	72.7	80.9	100.0	100.0	0
1	79.2	66.5	49.8	60.7	60.8	57.2	43.0	59.4	80.0	75.7	56.5	39.4	39.6	55.2	57.7	56.2	42.5	43.6	60.7	62.5	52.3	35.4	55.2	66.0	60.4	45.8	51.5	55.9	79.1	100.0	1
2	31.6	27.3	23.1	20.3	19.2	16.5	15.8	19.0	23.8	20.0	14.6	11.7	11.6	12.5	13.5	12.7	11.9	12.7	16.7	21.0	16.5	14.7	19.6	27.1	23.3	23.0	27.7	30.5	42.1	57.9	2
3	20.5	18.1	14.6	11.7	9.5	7.9	7.1	8.5	10.4	7.3	4.6	3.9	3.6	3.5	3.4	3.5	3.6	4.3	6.9	9.8	7.8	6.8	10.8	15.8	14.0	15.1	19.9	22.2	30.6	41.7	3
4	18.4	16.1	12.7	9.9	7.8	6.2	5.3	6.2	7.4	5.0	2.9	2.3	2.1	2.0	1.9	2.0	2.1	2.6	4.6	6.9	5.5	4.9	8.0	12.1	11.1	12.3	16.6	19.1	26.0	34.4	4
5	12.8	11.2	8.7	6.7	5.2	4.0	3.3	3.7	4.6	2.8	1.6	1.3	1.1	1.0	0.9	1.0	1.1	1.4	2.6	4.2	3.2	3.0	4.9	7.8	7.0	8.0	11.2	12.8	17.3	22.7	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	

Figure 121 Case Study 2 - Output: Generation 2

Generation n – t_n

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
5	21.9	19.7	15.7	12.2	9.5	7.5	5.9	4.8	3.9	3.3	2.8	2.5	2.8	4.2	5.7	4.8	5.0	6.3	5.0	3.9	4.1	5.7	9.3	13.1	12.8	13.1	16.0	21.9	31.1	38.2	5
4	34.1	30.7	24.8	19.5	15.4	12.4	10.1	8.4	7.1	6.1	5.4	5.0	5.5	8.2	10.5	9.3	9.6	11.3	9.5	7.2	7.3	10.0	16.2	21.9	21.5	21.1	25.3	34.6	50.1	61.9	4
3	42.8	38.7	32.0	26.3	22.0	18.7	16.2	14.8	13.8	12.8	11.5	10.5	11.4	15.4	18.7	17.0	17.1	19.2	16.7	13.4	13.1	16.2	24.2	31.5	30.0	28.0	32.0	43.2	63.3	79.7	3
2	73.9	65.2	56.8	51.5	49.8	44.0	41.5	43.4	48.4	47.5	40.3	33.4	34.4	42.6	49.7	45.0	42.4	45.4	44.4	41.3	36.3	38.6	48.5	60.1	55.0	48.6	50.2	65.0	92.7	100.0	2
1	100.0	100.0	100.0	100.0	100.0	100.0	93.4	100.0	100.0	100.0	100.0	84.2	85.1	100.0	100.0	100.0	95.9	100.0	100.0	100.0	94.9	79.7	100.0	100.0	100.0	92.4	93.1	100.0	100.0	100.0	1
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0
1	100.0	100.0	100.0	100.0	100.0	100.0	94.5	100.0	100.0	100.0	100.0	84.2	84.0	100.0	100.0	100.0	90.1	92.7	100.0	100.0	99.6	80.8	100.0	100.0	100.0	97.1	100.0	100.0	100.0	100.0	1
2	73.9	65.2	56.8	51.5	49.8	44.1	43.1	50.0	58.8	54.1	41.9	33.4	32.7	36.0	39.1	36.7	34.3	36.5	44.4	50.1	42.8	40.2	48.6	60.3	56.7	55.2	60.7	71.6	94.3	100.0	2
3	42.8	38.7	32.0	26.3	22.0	18.8	17.8	20.3	22.5	18.3	13.0	10.5	9.8	9.8	9.9	9.9	10.1	11.9	16.7	20.6	18.5	17.8	24.4	31.6	31.5	33.5	40.7	48.8	64.9	79.9	3
4	34.1	30.7	24.8	19.5	15.4	12.5	11.2	12.4	13.4	10.2	6.5	5.0	4.4	4.2	4.1	4.2	4.6	5.9	9.5	12.5	11.3	11.1	16.3	22.0	22.6	25.2	31.7	38.7	51.2	62.1	4
5	21.9	19.7	15.7	12.2	9.5	7.5	6.5	7.0	7.7	5.5	3.4	2.5	2.2	2.0	1.9	2.0	2.2	3.0	5.0	7.1	6.3	6.3	9.3	13.2	13.4	15.3	19.8	24.1	31.7	38.3	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	

Figure 122 Case Study 2 - Output: Generation 'n'

Synthesis of Model Output

The figure below shows the differences in development for two generations, namely Generation 0 (the current state) depicted with the blue line, and Generation 'n' (a predicted state of the future) depicted with the orange line. The gap between the two lines shows the intensity of development for that particular cell or area.

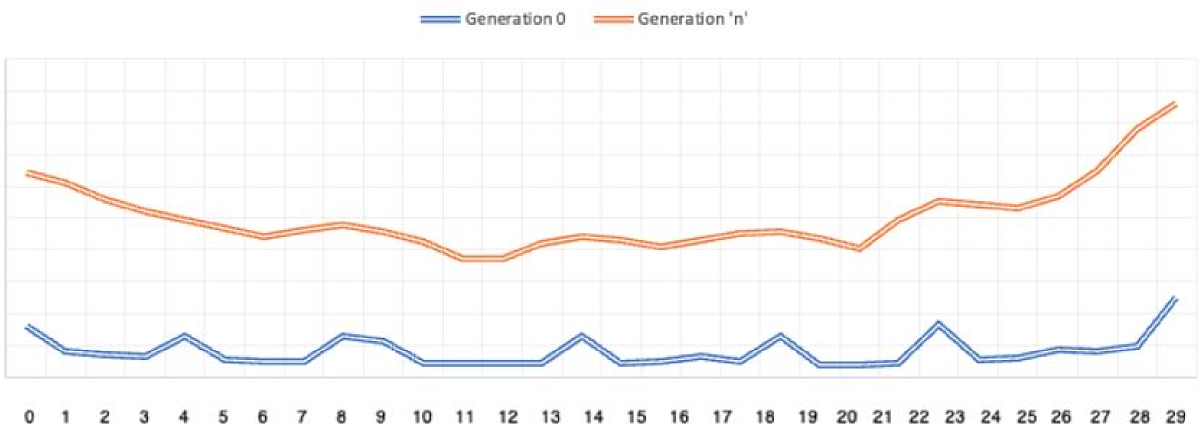


Figure 123 Case Study 2 - Changes in development in Generation 0 (blue) and Generation 'n' (orange)

Key Findings

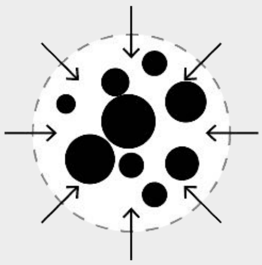
- The main findings arising from the model outputs are that the development in the case of national roads takes place mainly around the existing settlements, as well as near connections to secondary road infrastructure.
- When left to grow on its own, development around existing agglomerations or clusters that usually indicate the presence of a smaller settlement, is likely to merge with one-another.
- Since there are no restrictions on development around road infrastructure, national roads continue to develop along both dimensions. This means that development will likely spread vertically (away from the road infrastructure) as well as horizontally (away from settlements at road ends).
- Even though development along secondary road infrastructure is initially present (Generation 0), it tends to merge with the surrounding area in future generations, as those areas (or cells) begin to develop to a similar degree.

Proposed Intervention Actions

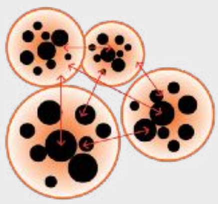
In the example of this case study, and based on the results and findings after the model outputs, four Intervention Actions are proposed:

Table 29 Proposed Intervention Actions for Case Study 2

Intervention Action 1

	**Compact Settlement** Where there is an existing settlement with a toponym - whether rural or suburban - it is redefined by urban plan as a town-city settlement. This way the existing settlements' growth is maintained within reasonable limits, and sporadic development together with the formation of new agglomerations are discouraged. **Proposed Action:** This can be achieved if settlements are identified and marked by Municipal Development Plans, whereby municipalities are charged with protecting and encouraging compact growth of these settlements. Borders and/or outer limits to these settlements can be proposed at this level of planning, and shall go into further details with Municipal Zoning Maps.

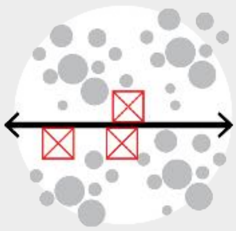
Intervention Action 2

	**Dynamic, Attractive and Competitive Settlements** Many of the region's less dynamic settlements have a narrow economic base dominated by a single sector, whose decline hurts the regional economy. Diversifying these settlements' economic basis increases their competitiveness, which then help boost the neighboring rural communities. Material and social welfare in settlements is crucial for social, environmental, and economic growth. Local factors affect the development policies to reach these goals.

This Intervention Action is in accordance with the policy options from the ESDP Policy Aims and Options for the Territory of the EU document, specifically Policy 81.[131]

Proposed Action:
The creation of a service and business network map/platform (as part of the Spatial Plan of Kosovo) that identifies and matches settlement's unique and competitive economic potentials. Through this device the central level will be able to understand the economic growth potential and competitive advantages in a spatial manner. Using this platform, networks for each service/product will be established, which then will be used by municipalities to facilitate trade, and remove barriers. This encourages cross-municipal cooperation for enhancing the economic growth potential for each settlement, relative to the services and products they have a competitive advantage for.

Intervention Action 3



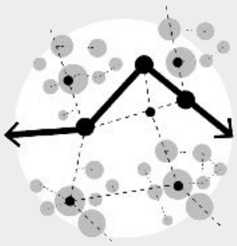
Partial Restrictions

For a number of reasons, road infrastructure development in certain areas should be restricted. By implementing these restrictions, undesirable forms of future development may be prevented. These restrictions can take the form of a legal document, plans, or a detailed regulatory plan for a section of road infrastructure.

Proposed Action:
The first and fastest form of introducing these measures, would be to have them on the Municipal Zoning Map. However, as this type of road infrastructure usually stretches across multiple municipalities, it requires the cooperation of them. For this purpose, a map of road development and restrictions is to be developed between all affected municipalities. This requires amendments to the Law on Spatial Planning, to make it as a necessary and obligatory tool for municipalities.

[131] European Commission - ESDP - European Spatial Development Perspective. Towards Balanced and Sustainable Development of the Territory of the European Union. Luxembourg: Office for Official Publications of the European Communities

Intervention Action 4



Efficient and Sustainable Use of the Infrastructure

A coordinated and integrated infrastructure planning and management is necessary, in order to avoid unnecessary investments (such as superfluous parallel transport infrastructure development) and make the most of existing infrastructure. This requires better coordination of spatial development policy, land use planning, transportation, and telecommunications.

This Intervention Action is in accordance with the policy options from the ESDP Policy Aims and Options for the Territory of the EU document, specifically Policy Option 124.[132]

Proposed Action:

This can be achieved through the improvement of public transportation in small and medium-sized settlements. It also requires reducing negative consequences in high-traffic areas through increasing environmentally-friendly mobility, charging road tolls, and internalizing external costs. For this purpose, a regional plan of rail network is necessary, in order to cover the major settlements as well as their hinterlands through regional rail network. Additionally, a plan expanding and planning the rail network to neighboring countries is needed, especially with Albania with whom Kosovo has yet to establish rail connections. Lastly, promoting intermodal connections for freight movement is required, especially on European routes.

[132] Ibid

Translating Intervention Actions Spatially

The Intervention Actions that were suggested in the previous part are shown in a spatial dimension, along the road infrastructure that was assessed.

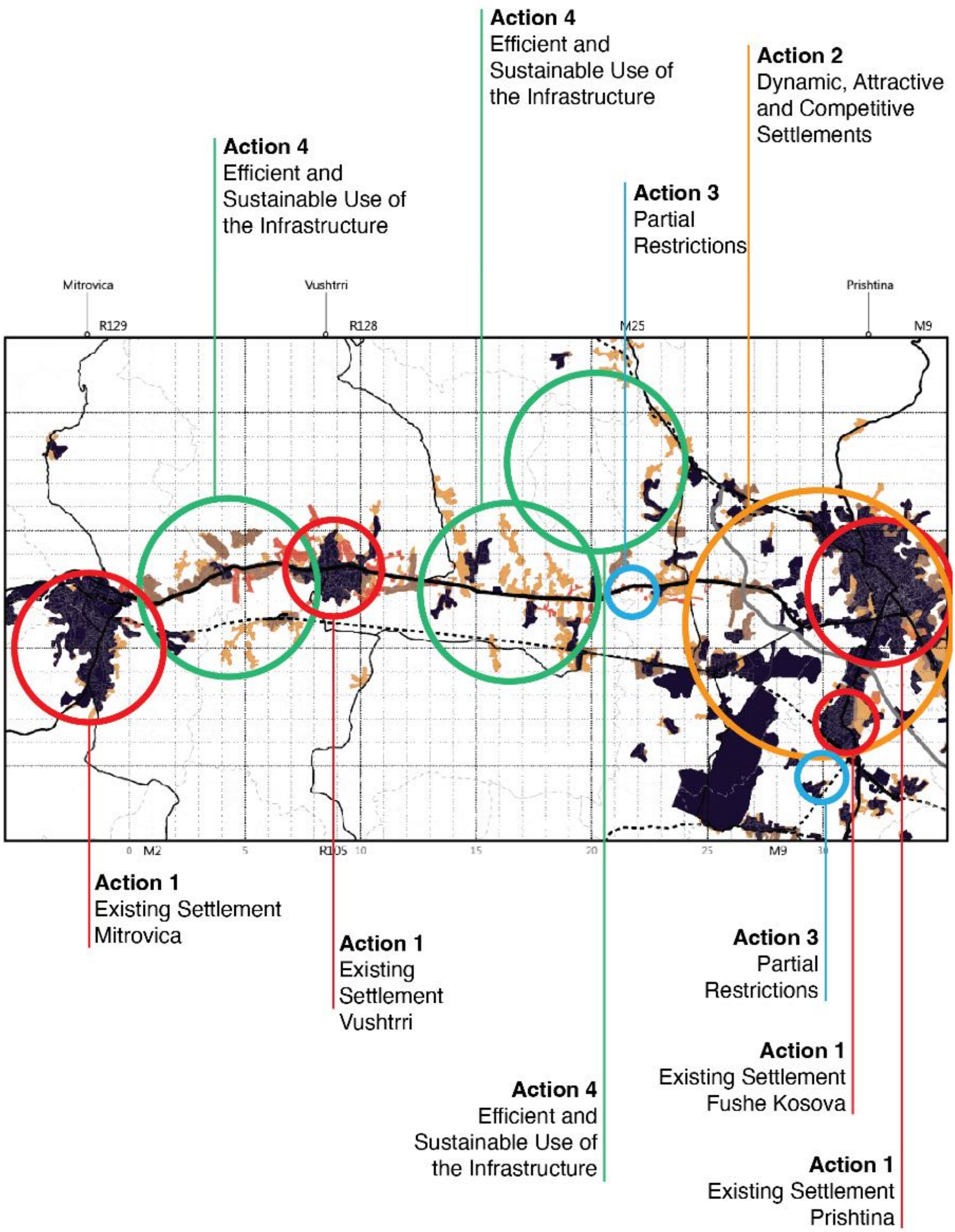


Figure 124 Proposed Intervention Actions for Case Study 2

8.1.3. Case Study 3 – Regional Road

Explanation of the graphical analysis

The figure below shows four different diagrams that Intervention Action development in different ways. In a) the map shows development as it has occurred in five different time periods, additionally, red circles indicate the development clusters along the road infrastructure; in b) the development is shown in a schematic manner, this diagram is used to compare the outcome of the model which can be found in c) it can be concurred that the model's output matches the schematic to a great degree; Finally, d) shows the collective sum of all development that has occurred along the road infrastructure.

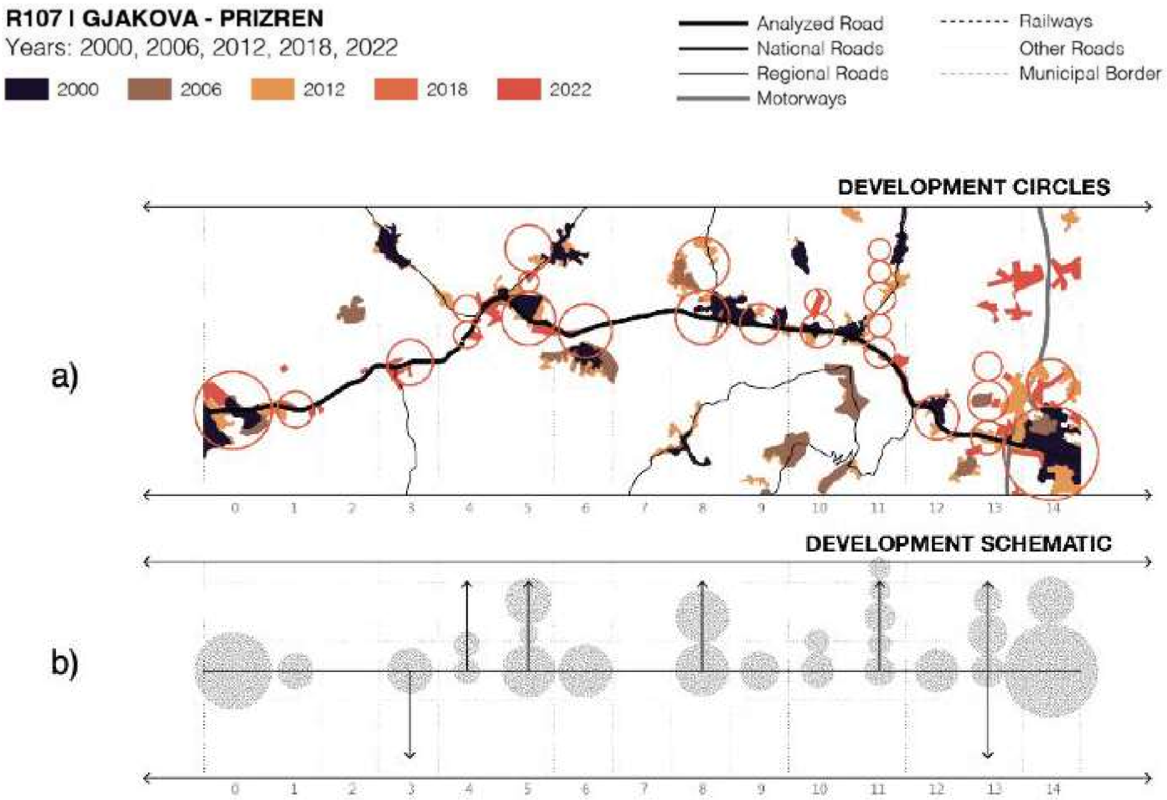


Figure 125 Case Study 3 - Graphic analysis of development along road infrastructure: a) map, b) diagram

c)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
5	5.2	3.9	3.0	2.3	3.3	2.9	1.0	0.8	2.6	1.3	1.7	2.3	3.0	6.3	9.9	5
4	5.3	4.1	3.1	2.4	4.0	3.6	1.2	1.0	3.3	1.5	1.9	2.4	3.1	7.2	11.6	4
3	5.6	4.4	3.4	2.7	5.0	4.6	1.5	1.3	4.3	1.8	2.2	2.7	3.4	8.6	14.1	3
2	6.3	5.0	4.1	3.4	6.6	6.2	2.1	1.9	5.9	2.4	2.8	3.4	4.1	10.6	17.5	2
1	7.5	6.3	5.3	4.6	9.1	8.7	3.4	3.2	8.4	3.7	4.1	4.6	5.3	13.8	22.5	1
0	100.0	46.7	45.4	47.8	47.2	100.0	43.0	42.8	100.0	44.4	45.5	47.0	48.8	58.0	100.0	0
1	7.5	6.3	5.3	9.6	4.1	3.7	3.4	3.2	3.4	3.7	4.1	4.6	5.3	13.8	22.5	1
2	6.3	5.0	4.1	7.1	2.8	2.4	2.1	1.9	2.1	2.4	2.8	3.4	4.1	10.6	17.5	2
3	5.6	4.4	3.4	5.5	2.2	1.8	1.5	1.3	1.5	1.8	2.2	2.7	3.4	8.6	14.1	3
4	5.3	4.1	3.1	4.5	1.9	1.5	1.2	1.0	1.2	1.5	1.9	2.4	3.1	7.2	11.6	4
5	5.2	3.9	3.0	3.8	1.7	1.3	1.0	0.8	1.0	1.3	1.7	2.3	3.0	6.3	9.9	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	

d)

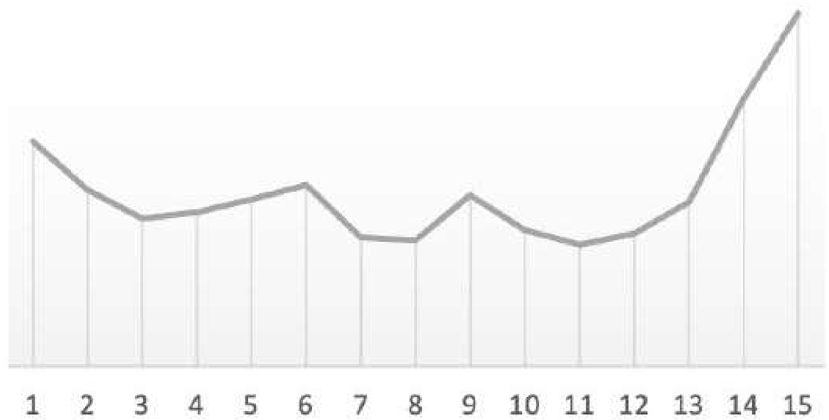


Figure 126 Case Study 3 - Graphic analysis of development along road infrastructure: c) model output, d) sum of development

Model Output

The figures below show the development of the case study, in this case the regional road, in four different generations (ticks). As can be seen in the figure below, same with the case of the national road, in Generation 0 (current state), development is heaviest near the settlements at both ends of the road infrastructure, as well as near connections to secondary road infrastructure. However, as this type of road infrastructure is usually shorter in length, the development is more evenly dispersed between the cells. In future generations these agglomerations of development near secondary infrastructure influence further growth on the cells nearest to them. Eventually, when left to develop on its own, these agglomerations begin to merge, with them being heaviest near original clusters (which usually indicate existing smaller settlements) as well as near the settlements at both ends. With the case of regional roads, the emphasis on the larger settlement is more visible, as in Generation ‘n’, the greater gravitational pull of the larger settlement can be clearly seen.

Generation 0 – t_0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
5	5.2	3.9	3.0	2.3	3.3	2.9	1.0	0.8	2.6	1.3	1.7	2.3	3.0	6.3	9.9	5
4	5.3	4.1	3.1	2.4	4.0	3.6	1.2	1.0	3.3	1.5	1.9	2.4	3.1	7.2	11.6	4
3	5.6	4.4	3.4	2.7	5.0	4.6	1.5	1.3	4.3	1.8	2.2	2.7	3.4	8.6	14.1	3
2	6.3	5.0	4.1	3.4	6.6	6.2	2.1	1.9	5.9	2.4	2.8	3.4	4.1	10.6	17.5	2
1	7.5	6.3	5.3	4.6	9.1	8.7	3.4	3.2	8.4	3.7	4.1	4.6	5.3	13.8	22.5	1
0	100.0	46.7	45.4	47.8	47.2	100.0	43.0	42.8	100.0	44.4	45.5	47.0	48.8	58.0	100.0	0
1	7.5	6.3	5.3	9.6	4.1	3.7	3.4	3.2	3.4	3.7	4.1	4.6	5.3	13.8	22.5	1
2	6.3	5.0	4.1	7.1	2.8	2.4	2.1	1.9	2.1	2.4	2.8	3.4	4.1	10.6	17.5	2
3	5.6	4.4	3.4	5.5	2.2	1.8	1.5	1.3	1.5	1.8	2.2	2.7	3.4	8.6	14.1	3
4	5.3	4.1	3.1	4.5	1.9	1.5	1.2	1.0	1.2	1.5	1.9	2.4	3.1	7.2	11.6	4
5	5.2	3.9	3.0	3.8	1.7	1.3	1.0	0.8	1.0	1.3	1.7	2.3	3.0	6.3	9.9	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	

Figure 127 Case Study 3 - Output: Generation 0

Generation 1 – t_1

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
5	7.8	6.5	4.9	4.2	5.2	4.6	2.2	2.0	3.6	2.7	2.9	3.8	5.6	10.6	14.9	5
4	9.9	8.3	6.4	5.8	7.4	6.6	3.3	3.0	5.1	3.9	3.9	5.0	7.6	14.7	20.9	4
3	10.6	9.0	7.1	6.7	9.2	8.4	4.3	4.0	6.7	4.9	4.6	5.7	8.7	17.6	25.2	3
2	12.0	10.4	8.4	8.5	12.1	11.3	6.0	5.7	9.3	6.6	5.9	7.0	10.6	21.8	31.4	2
1	40.3	33.8	25.7	25.7	37.1	35.9	29.4	29.1	33.9	30.4	23.3	24.7	29.1	47.1	62.5	1
0	100.0	69.7	61.9	64.1	70.6	100.0	64.1	63.8	100.0	66.0	60.1	62.3	67.9	87.0	100.0	0
1	40.3	33.8	26.8	30.1	31.7	29.3	28.3	28.0	28.5	29.3	23.3	24.7	29.1	47.1	62.5	1
2	12.0	10.4	9.9	11.7	7.4	5.1	4.5	4.2	4.5	5.1	5.9	7.0	10.6	21.8	31.4	2
3	10.6	9.0	8.2	9.2	5.7	3.8	3.2	2.9	3.2	3.8	4.6	5.7	8.7	17.6	25.2	3
4	9.9	8.3	7.2	7.6	4.7	3.1	2.5	2.2	2.5	3.1	3.9	5.0	7.6	14.7	20.9	4
5	7.8	6.5	5.4	5.6	3.4	2.3	1.8	1.5	1.8	2.3	2.9	3.8	5.6	10.6	14.9	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	

Figure 128 Case Study 3 - Output: Generation 1

Generation 2 – t_2

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
5	12.8	11.2	8.8	8.0	8.8	7.7	4.7	4.1	5.7	5.2	5.3	6.9	10.9	18.6	24.2	5
4	18.4	16.1	13.0	12.2	13.7	12.1	7.7	6.9	9.0	8.2	8.1	10.3	16.6	28.6	37.5	4
3	20.5	18.1	15.0	14.8	17.6	15.9	10.3	9.4	12.0	10.6	9.9	12.3	19.9	35.2	46.4	3
2	32.8	28.7	24.3	25.0	30.0	29.1	22.0	21.0	24.4	21.5	19.3	21.1	30.8	50.8	66.2	2
1	85.5	74.8	61.0	61.8	78.2	77.2	68.9	68.1	72.8	68.5	56.2	58.0	70.1	98.4	100.0	1
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	95.6	97.6	100.0	100.0	100.0	0
1	85.5	75.2	63.3	65.6	71.5	68.3	65.7	65.3	66.1	66.0	55.9	58.0	70.1	98.4	100.0	1
2	32.8	29.2	27.3	27.9	23.2	19.4	17.6	17.1	17.7	18.0	18.9	21.1	30.8	50.8	66.2	2
3	20.5	18.5	17.3	17.0	12.3	8.3	6.7	6.2	6.7	7.9	9.5	12.3	19.9	35.2	46.4	3
4	18.4	16.4	14.7	13.8	9.8	6.5	5.1	4.6	5.1	6.2	7.8	10.3	16.6	28.6	37.5	4
5	12.8	11.3	9.8	9.2	6.3	4.2	3.2	2.8	3.2	4.0	5.2	6.9	10.9	18.6	24.2	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	

Figure 129 Case Study 3 - Output: Generation 2

Generation n – t_n

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
5	21.9	19.8	16.4	15.0	15.5	13.5	9.5	8.4	9.9	9.7	10.2	13.3	21.0	33.3	41.1	5
4	34.1	30.8	26.0	24.6	25.8	22.9	16.6	14.8	16.8	16.4	16.7	21.6	34.4	54.8	68.1	4
3	43.4	39.2	34.0	33.7	36.7	33.7	25.8	23.5	25.9	24.7	23.9	29.3	45.7	72.3	90.1	3
2	78.4	70.2	61.7	62.8	69.9	69.1	59.5	57.0	59.9	55.7	51.6	55.7	76.6	100.0	100.0	2
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	1
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	1
2	78.6	71.7	66.5	65.0	59.5	53.6	49.8	48.6	49.3	49.1	50.0	55.5	76.6	100.0	100.0	2
3	43.6	40.6	37.9	35.3	28.0	20.9	17.3	16.3	17.1	19.1	22.3	29.2	45.7	72.3	90.1	3
4	34.3	31.8	28.9	25.8	19.5	13.5	10.4	9.5	10.3	12.4	15.6	21.4	34.4	54.8	68.1	4
5	22.0	20.3	18.0	16.0	11.7	8.1	6.1	5.5	6.1	7.5	9.6	13.2	21.0	33.3	41.1	5
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	

Figure 130 Case Study 3 - Output: Generation 'n'

Synthesis of Model Output

The figure below shows the differences in development for two generations, namely Generation 0 (the current state) depicted with the blue line, and Generation ‘n’ (a predicted state of the future) depicted with the orange line. The gap between the two lines shows the intensity of development for that particular cell or area.

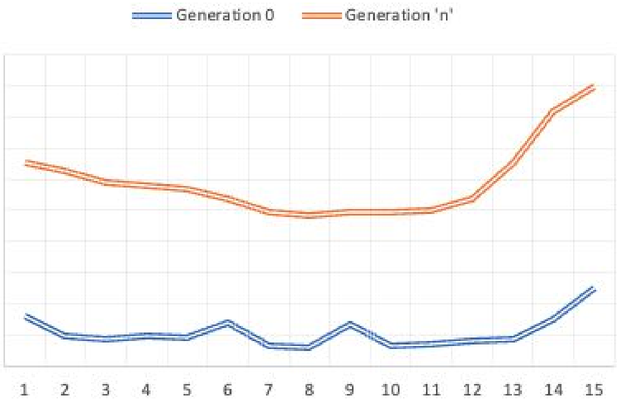


Figure 131 Case Study 3 - Changes in development in Generation 0 (blue) and Generation 'n' (orange)

Key Findings

- The main findings arising from the model outputs are that the development in the case of regional roads takes place mainly around the existing settlements, as well as near connections to secondary road infrastructure.

- When left to grow on its own, development around existing agglomerations or clusters that usually indicate the presence of a smaller settlement, is likely to merge with one-another.

- Since there are no restrictions on development around road infrastructure, national roads continue to develop along both dimensions. This means that development will likely spread vertically (away from the road infrastructure) as well as horizontally (away from settlements at road ends).

- Eventually, when left to develop on its own, agglomerations begin to merge, with them being heaviest near original clusters (which usually indicate existing smaller settlements) as well as near the settlements at both ends. With the case of regional roads, the emphasis on the larger settlement is more visible, as in Generation ‘n’, the greater gravitational pull of the larger settlement can be clearly seen.

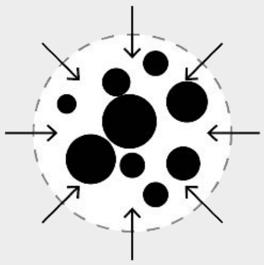
- Even though development along secondary road infrastructure is initially present (Generation 0), it tends to merge with the surrounding area in future generations, as those areas (or cells) begin to develop to a similar degree.

Proposed Intervention Actions

In the example of this case study, and based on the results and findings after the model outputs, five Intervention Actions are proposed:

Table 30 Proposed Intervention Actions for Case Study 3

Intervention Action 1

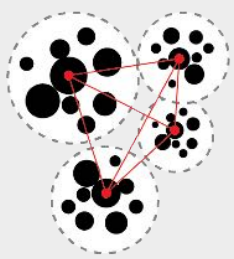


Compact Settlement

Where there is an existing settlement with a toponym - whether rural or suburban - it is redefined by urban plan as a town-city settlement. This way the existing settlements' growth is maintained within reasonable limits, and sporadic development together with the formation of new agglomerations are discouraged.

Proposed Action:
This can be achieved if settlements are identified and marked by Municipal Development Plans, whereby municipalities are charged with protecting and encouraging compact growth of these settlements. Borders and/or outer limits to these settlements can be proposed at this level of planning, and shall go into further details with Municipal Zoning Maps.

Intervention Action 2



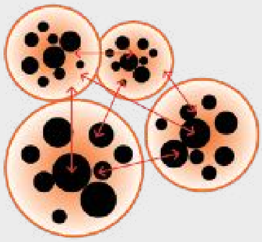
Polycentric and Balanced Spatial Development

Where there is the potential for agglomeration — that is, where there is no defined urban rural settlement but the development has occurred merely because of the condition of the junction — a regional plan is to be developed that encourages and treats polycentric development. This Intervention Action would need a cross-border (cross-municipality) cooperation and plan.

Proposed Action:
The central government shall devise incentives that encourage and favor the development of cross-municipality plans, including Municipal Development Plans as well as Municipal Zoning Maps. Once cooperation is established in a planning level too, it is

much easier for agglomerations of development to be planned and connected in a more compact way, ensuring a more sustainable development.

Intervention Action 3



Dynamic, Attractive and Competitive Settlements

Many of the region's less dynamic settlements have a narrow economic base dominated by a single sector, whose decline hurts the regional economy. Diversifying these settlements' economic basis increases their competitiveness, which then help boost the neighboring rural communities. Material and social welfare in settlements is crucial for social, environmental, and economic growth. Local factors affect the development policies to reach these goals.

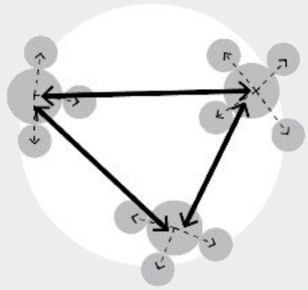
This Intervention Action is in accordance with the policy options from the ESDP Policy Aims and Options for the Territory of the EU document, specifically Policy 81.[133]

Proposed Action:

The creation of a service and business network map/platform (as part of the Spatial Plan of Kosovo) that identifies and matches settlement's unique and competitive economic potentials. Through this device the central level will be able to understand the economic growth potential and competitive advantages in a spatial manner. Using this platform, networks for each service/product will be established, which then will be used by municipalities to facilitate trade, and remove barriers. This encourages cross-municipal cooperation for enhancing the economic growth potential for each settlement, relative to the services and products they have a competitive advantage for.

[133] European Commission - ESDP - European Spatial Development Perspective. Towards Balanced and Sustainable Development of the Territory of the European Union. Luxembourg: Office for Official Publications of the European Communities

Intervention Action 4



Urban-Rural Partnership

Numerous local issues cannot be resolved without an integrated view of settlements and rural areas, as they tend to be regional in nature. Practical partnership is characterized by cooperation and coordination. However, in order for cooperation to develop into a successful long-term partnership, cross-border (cross-municipality) plans should be applied. Some of the main policies to be followed are:

- Maintain basic services and public transport in small and medium-sized settlements, especially those in decline.
- Promoting settlement-region cooperation to strengthen functional regions.
- Integrating the countryside around large settlements into urban development strategies to improve land use planning and quality of life.
- Promote and support partnership-based co-operation between small and medium-sized settlements through joint projects (such as joint plans) and experience exchange.
- Promote business and knowledge networks in settlements and rural areas.

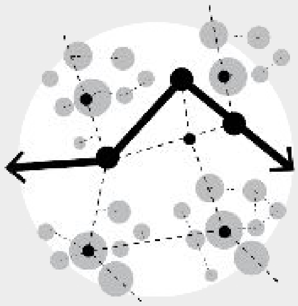
This Intervention Action is in accordance with the policy options from the ESDP Policy Aims and Options for the Territory of the EU document, specifically Policy Option 117.[134]

Proposed Action:
Cross-Municipal plans (Municipal Development Plans and Municipal Zoning Maps), that are developed between two or more municipalities are recognized and recommended by the existing legal framework. This however should be encouraged and incentivized in

[134] European Commission - ESDP - European Spatial Development Perspective. Towards Balanced and Sustainable Development of the Territory of the European Union. Luxembourg: Office for Official Publications of the European Communities

different manners. For example, the central government (through the Ministry of Finance), can fund these plans, taking the financial burden away from municipal budgets. Another inventive by the central government can be the prioritizing of capital investment projects, that are planned and span across two or more municipalities. Furthermore, the central government can raise the municipal budget, if those municipalities engage in a cross-municipal plan.

Intervention Action 5



Efficient and Sustainable Use of the Infrastructure

A coordinated and integrated infrastructure planning and management is necessary, in order to avoid unnecessary investments (such as superfluous parallel transport infrastructure development) and make the most of existing infrastructure. This requires better coordination of spatial development policy, land use planning, transportation, and telecommunications.

Proposed Action:
This can be achieved through the improvement of public transportation in small and medium-sized settlements. It also requires reducing negative consequences in high-traffic areas through increasing environmentally-friendly mobility, charging road tolls, and internalizing external costs. For this purpose, a regional plan of rail network is necessary, in order to cover the major settlements as well as their hinterlands through regional rail network. Additionally, a plan expanding and planning the rail network to neighboring countries is needed, especially with Albania with whom Kosovo has yet to establish rail connections. Lastly, promoting intermodal connections for freight movement is required, especially on European routes.

Translating Intervention Action Spatially

The Intervention Actions that were suggested in the previous part are shown in a spatial dimension, along the road infrastructure that was assessed.

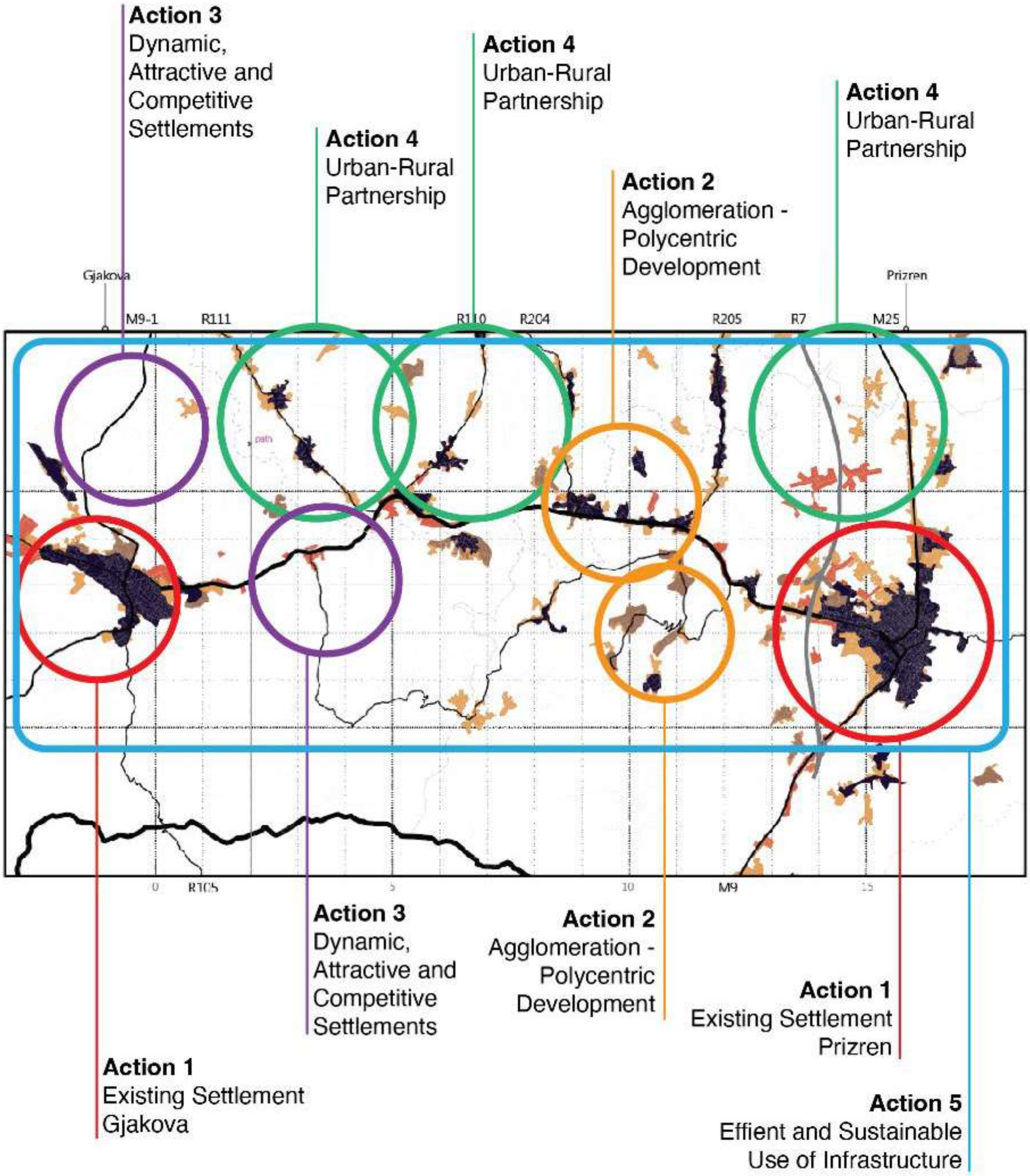


Figure 132 Proposed Intervention Actions for Case Study 3

8.2. Summary

Chapter 4 analyzed three types of road infrastructure, and it examined how the model generates future predictions of development. From the analysis of the model outputs and from further analysis of the maps, an assumption can be made that existing settlements are the main source of growth in terms of development. In the case of motorways, agglomeration development and other forms of development may occur away from the road infrastructure whereas development along national road focuses on existing settlements and secondary road connections.

From these findings, each of the case studies have been provided with Intervention Actions on how to address issues identified. The goal is to create a better link of rural and urban settlements and the overall region.

As discussed in Chapter 1, development in Kosovo has happened initially as an undriven process, then as a politically driven process. The aim of this dissertation is to introduce a third step, that of data-driven development, but taking that a step further, it introduces Intervention Actions that are in line with the ESDP.

ESDP promotes cross-border, inter-municipality cooperation to improve the quality of life in small and medium-sized urban settlements and rural areas. Most Intervention Actions introduced in this chapter try to follow the ESDP Policy Aims and Options for the EU Territories.

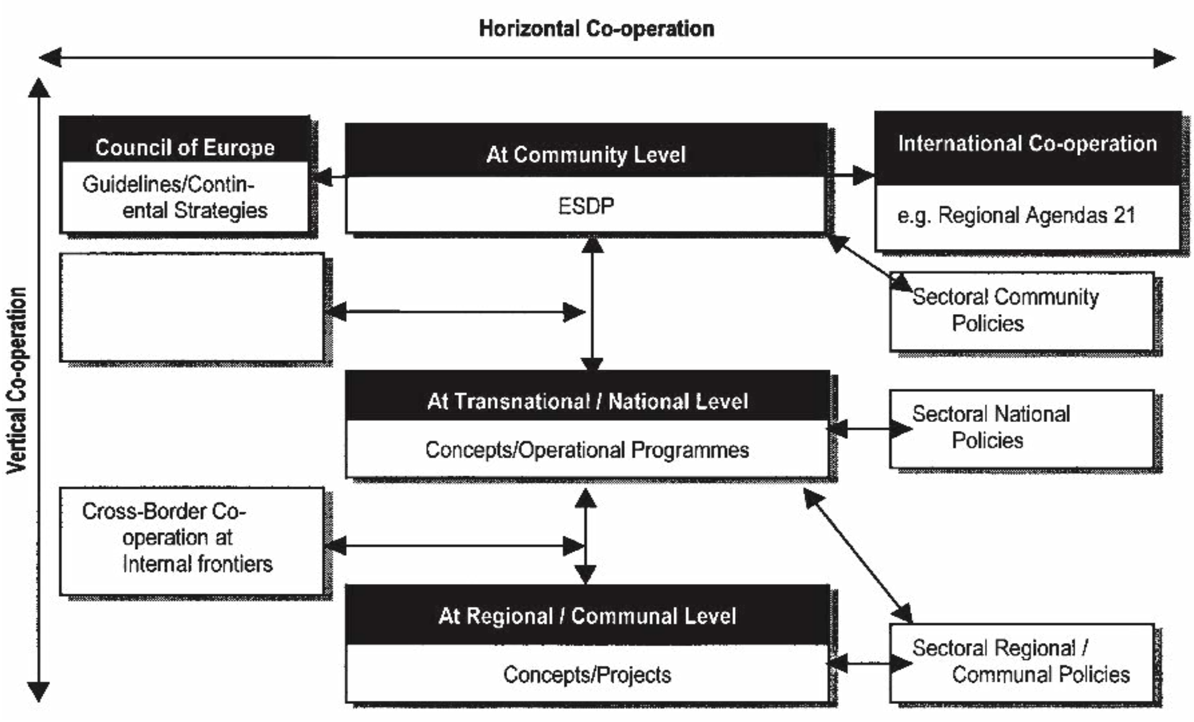


Figure 133 ESDP Ways of Cooperation for spatial development

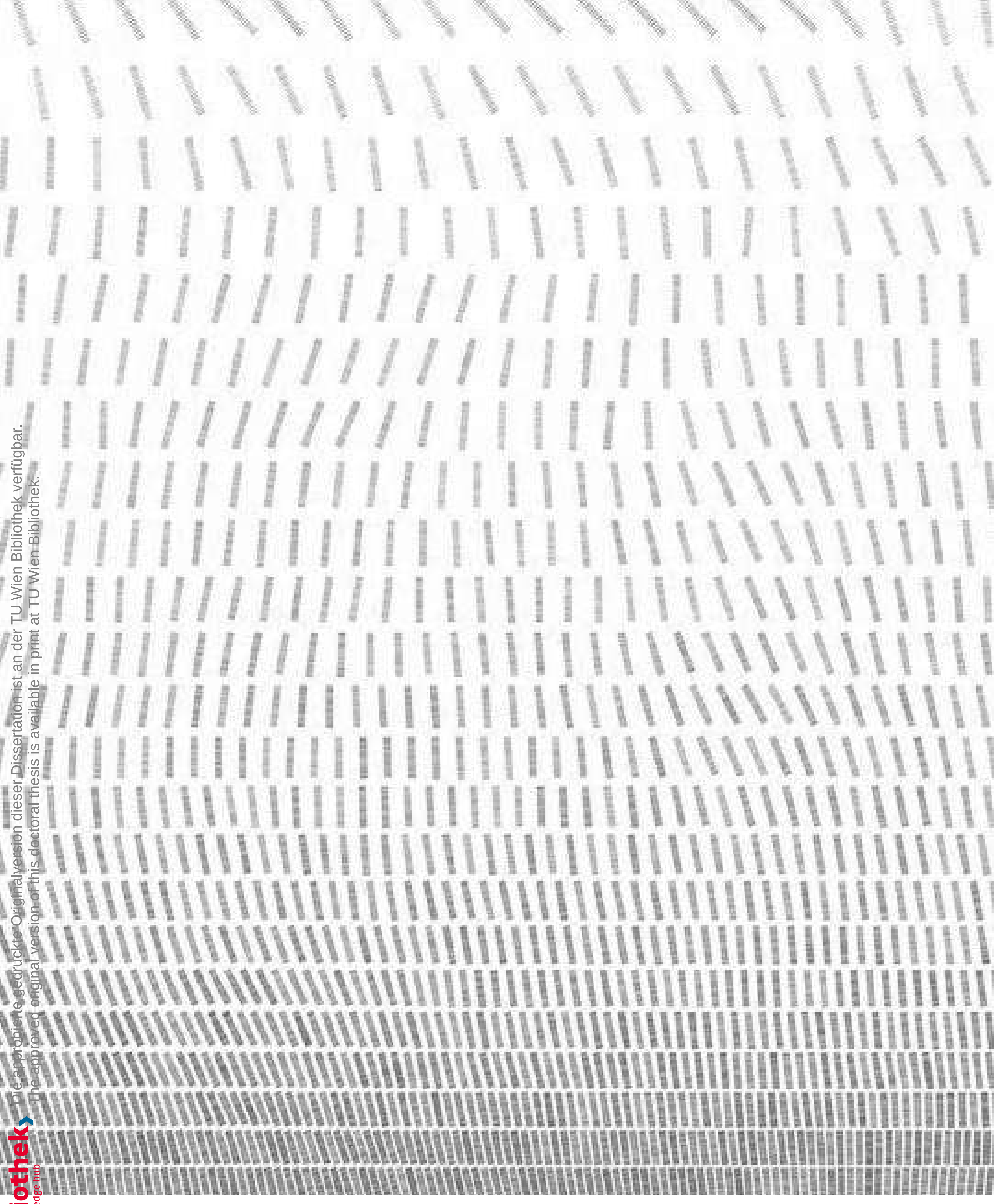
Further Recommendations

- Kosovo's development has happened in two major ways, first in the form of an undriven development (post 1999), secondly in the form of politically driven development (post 2008). The aim of the country should now be to have a data-driven form of development.

- The transitional period from one system to the other, to the other again has cost Kosovo in a legal and planning frameworks that is not in sync and coordination with itself. These frameworks need to be further adjusted to better fit with one another - for example, one legal document should not interfere or cancel another one. Additionally, there is no clear incentive in drafting cross-municipality plans, even though they are recommended and allowed by the legal and planning framework. This needs to be fixed either by an amendment of the law, or by a new regulatory document, making these type of plans more attractive for municipalities.

- As witnessed throughout the presented case studies in chapter 3 and 4 of this dissertation, the development of settlements has happened in a concentrated time period and is constantly being impacted by external factors. A close consideration of these factors in combination with continuous observation should be followed and applied by planners from all relevant institutions in order to influence the development in the right directions as well as take appropriate Intervention Actions that are in line with the legal and planning framework.

- For the purpose of analyzing and forecasting urban growth and development, the use of tools such as urban models is highly recommended. This dissertation provides an example of one such tool, in order to get an idea of what the process would look like.



CHAPTER 9

CONCLUSIONS

This chapters includes conclusions and recommendations on the measures and actions to be taken.

9. CONCLUSIONS

This chapter intends to summarize findings and conclusions from all chapters of the dissertation.

- Road infrastructure planning can boost regional growth. It can be used to redirect growth to alleviate regional land disparity. This research aims to analyze road infrastructure's role and influence on spatial development. This dissertation studies road infrastructure's impact on Kosovo's land use. It attempts to provide a scientific, data-driven basis for planning and investing in road infrastructure. The research will produce a tool to simulate infrastructure's effects on landscape change. Kosovo's roads were built without government involvement in 2000. Kosovo intends to join a regional road network, which would improve economic trade opportunities. Kosovo is often shown as a blank island on regional and international maps due to limited or no data. This dissertation's methodology aims to address this gap by providing quantitative results for future decision-making. This dissertation intends to improve the use of data and scientific outcomes in Kosovo's spatial planning decision-making. This dissertation aims to help enhance spatial and urban analytics in Kosovo.

- Kosovo's legal structures, ambitions, and institutions have shaped the country in many ways. Chapter 2 describes Kosovo's spatial planning laws, plans, institutions, and practices, as well as their history. This helps understand how each framework affects road infrastructure and the development that occurs as a result of it.

- Urban growth is a process that has been studied for a long time, however studying it through urban models gives the researcher a possibility to look into the future of development. Urban growth in simplified models tends to follow Euclidian mathematics, and rules can be designed to predict this kind of behavior. Therefore urban modelling tools present a great opportunity for spatial planners to have a look into the future of what a particular urb-element will grow.

- Six case studies from different road types are picked in order to analyze development and other phenomena. Based on the case studies, one can draw some conclusions about what types of new developments are preferred. On first glance, it is clear that new developments prefer locations close to existing settlements. Second, being close to existing road infrastructure is preferable. Third, it is preferable to be close to roads that approach the road infrastructure being studied.

- Urban models are helpful for assessing the spatial impact of land-use changes on road infrastructure. Their features simplify reality by removing unnecessary elements and details, making it more abstract, or creating something new. Complex phenomena can be simplified and measured in this way. Models help to work through logic, generate hypotheses, build solutions, and fit facts by simplifying and being precise. To quantify the impact of road infrastructure on land use, empirical studies are translated into maps and diagrams that serve as inputs to a model. This cycle structures data and makes it more comprehensible, especially when setting up the model's 'rules' (protocol).

- Each cell in the model is assigned a number representing the likelihood of future land development there. After entering these values, the computer calculates each cell's output. Each cell's final model result is the product of its values and weights. The y output variable shows land development potential in each model Cell. The Road Cell Array is a row (or array) of cells with different values that represent land development likelihood. This can be pictured as a brick wall, with qualities stacked for each cell and the road array result at the bottom.

- Calibration compares model results to real-world observations. Given enough primary data, regression coefficients can be used to construct the best-fitting equation. This allows one to estimate unknown factors. Finding the optimal value for a parameter can inform cell behavior theory. When predicting the future, a model's error must be 'acceptable' Case study data is compared to model results, whereupon, in the case that model results don't match case study analysis, input can be reviewed and calibrated. However, if the model matches case study data, it can be applied into future analysis (predictions).

- Based on model outputs and map analysis, it appears that existing settlements are the main source of development growth. Motorway agglomeration and other forms of development may occur away from the road infrastructure, while national road development focuses on existing settlements and secondary road connections. Each case study has Intervention Actions to address issues based on these findings with the goal being the improvement of rural-urban and regional connections. According to Chapter 1, Kosovo's development was initially undriven and then politically driven. This dissertation introduces a third step, data-driven development, and ESDP-aligned Intervention Actions.

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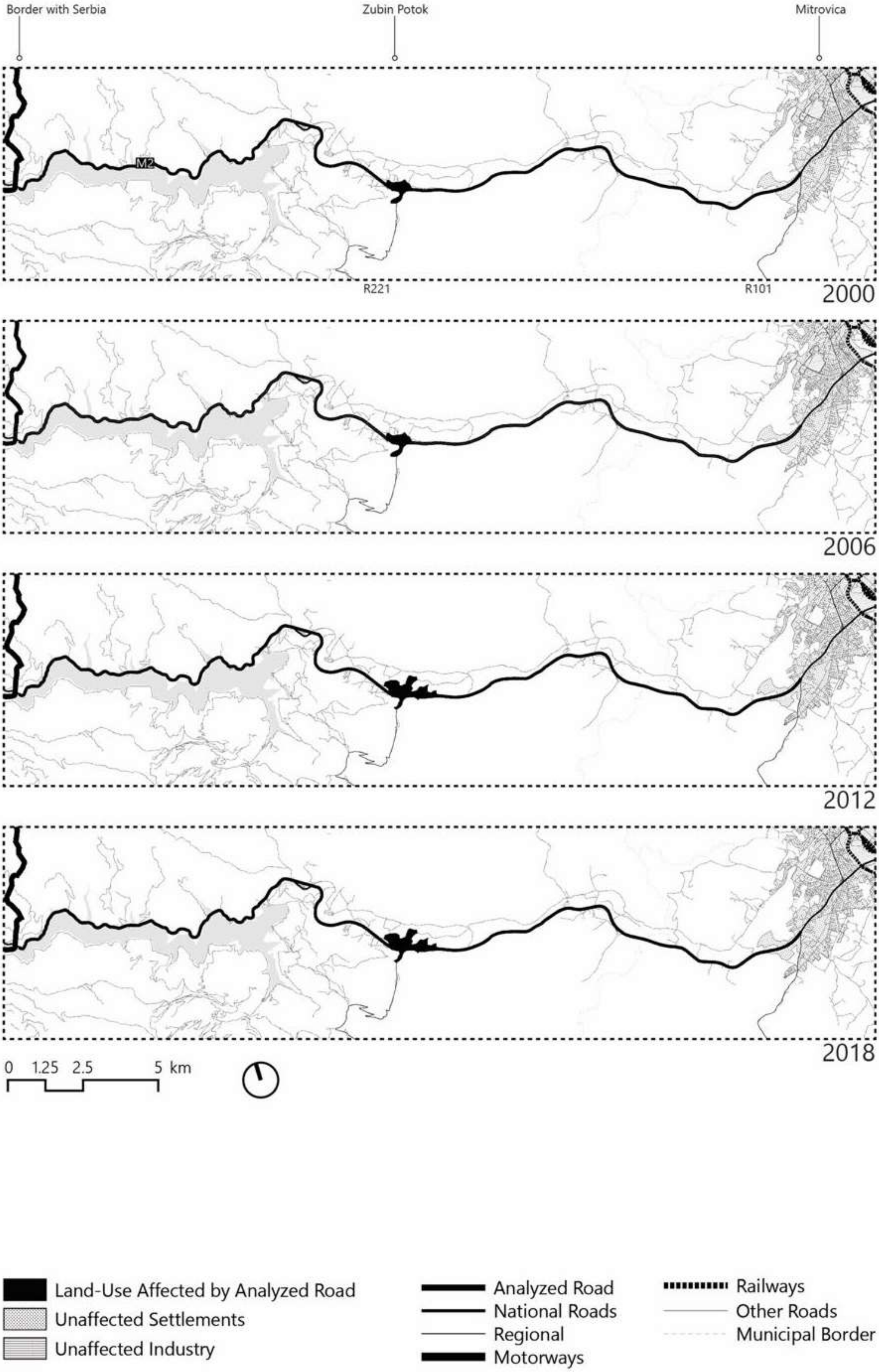
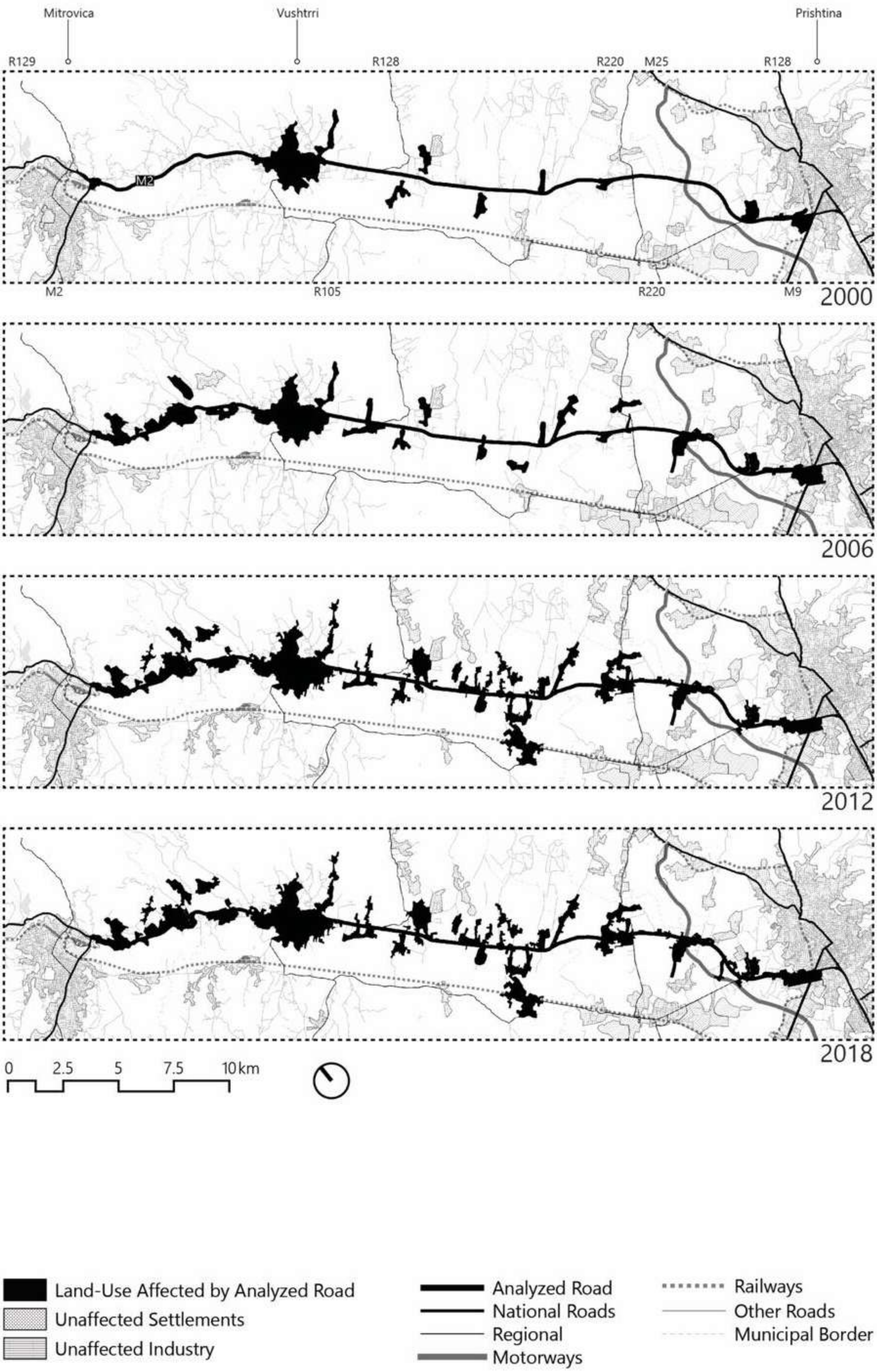
APPENDIX

No.	Type of Road	Settlement A	Settlement B	Population A	Population B
1	National Road	Mitrovica	Fushë Banjë	84,235	n/a
2	National Road	Prishtina	Mitrovica	198,897	84,235
3	National Road	Prishtina	Ferizaj	198,897	108,610
4	National Road	Ferizaj	Hani i Elezit	108,610	9,403
5	National Road	Prishtina	Komoran	198,897	4,393
6	National Road	Komoran	Zajm	4,393	1,267
7	National Road	Peja	Zajm	96,450	1,267
8	National Road	Gjakova	Dollc	94,556	300
9	National Road	Ferizaj	Gjilan	108,610	90,178
10	National Road	Prishtina	Podujeva	198,897	88,499
11	National Road	Prishtina	Shtime	198,897	27,324

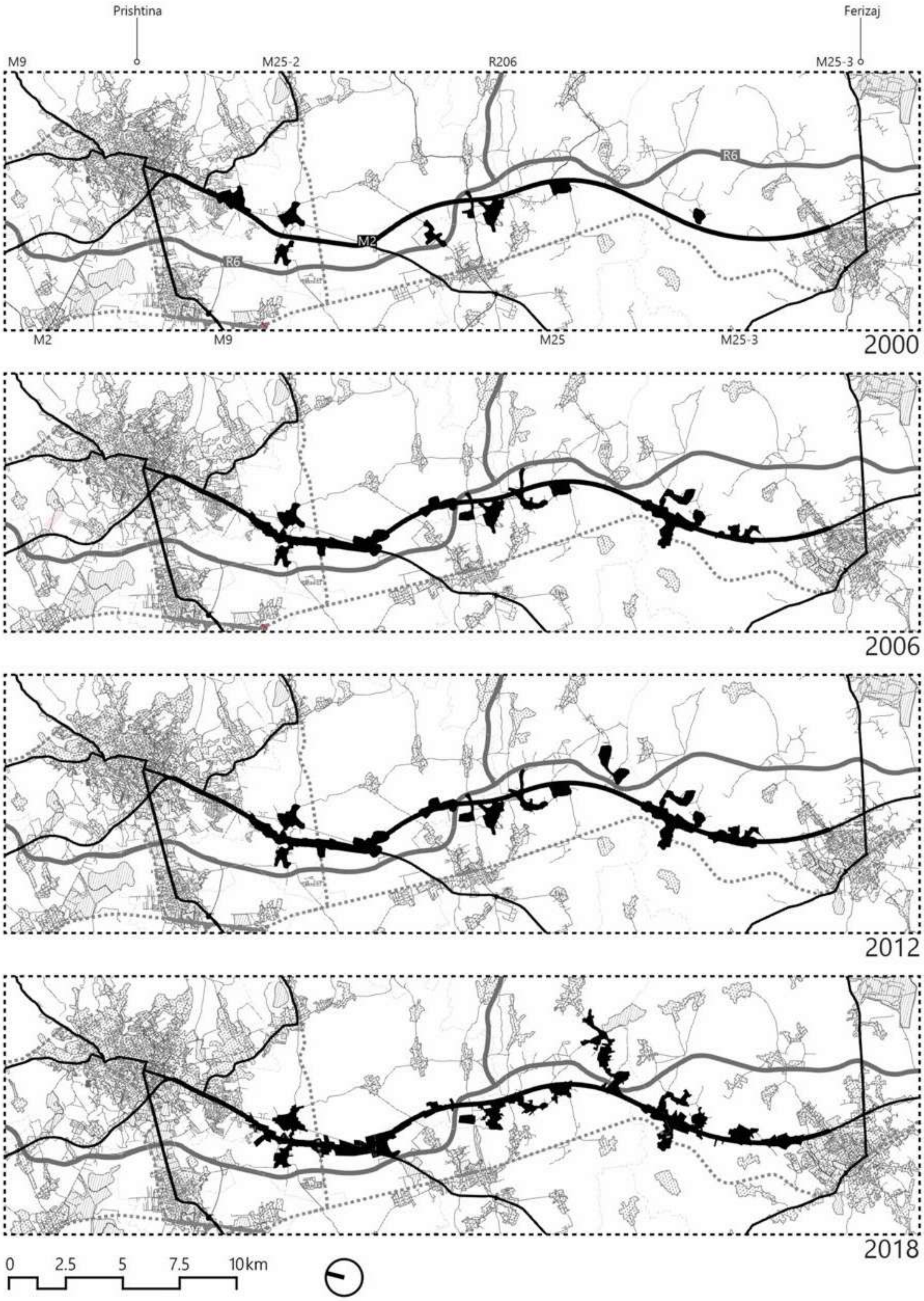
M2 | Fushë Banjë - Mitrovica



M2 | Mitrovica - Prishtina

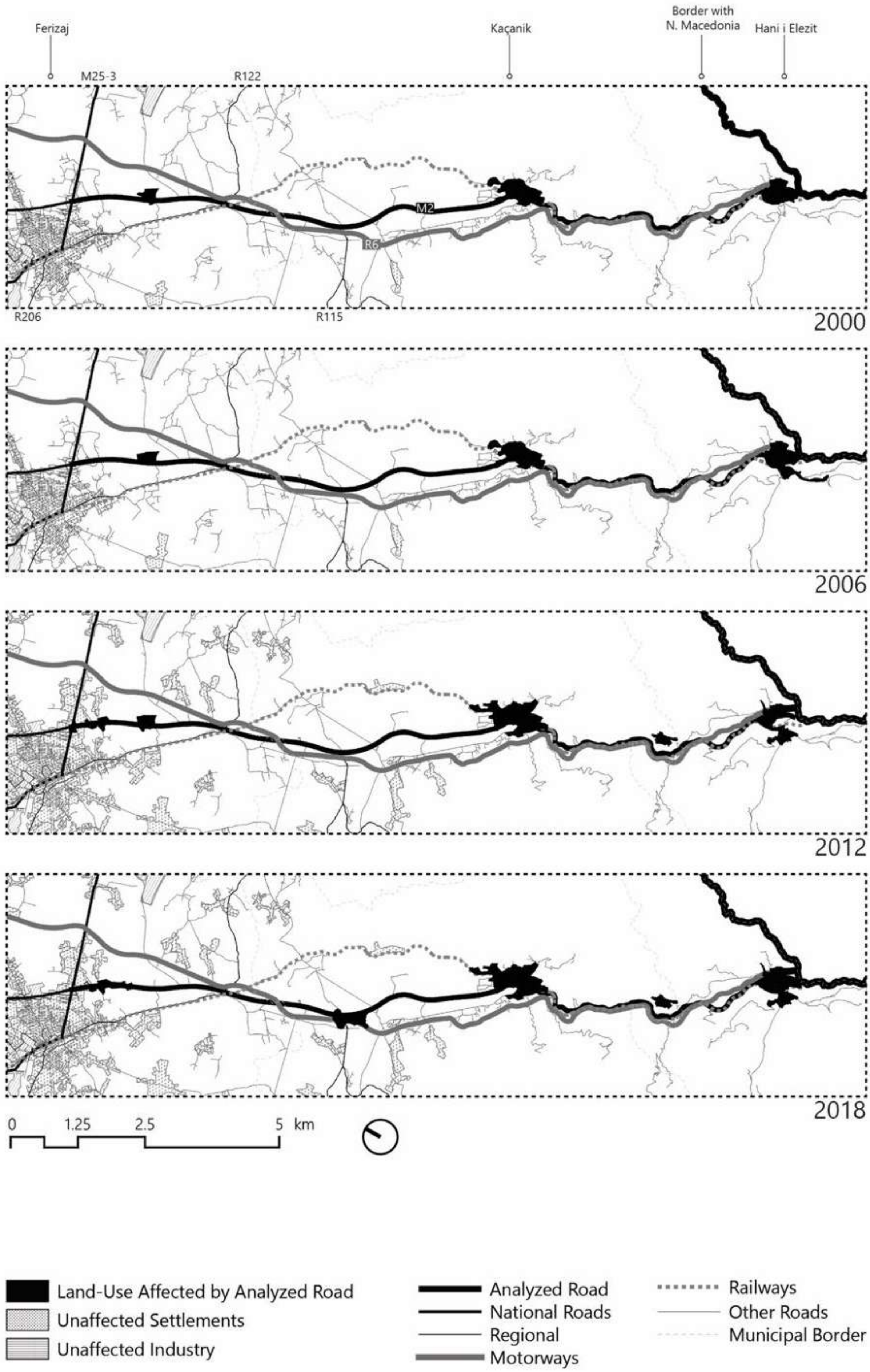


M2 | Prishtina - Ferizaj

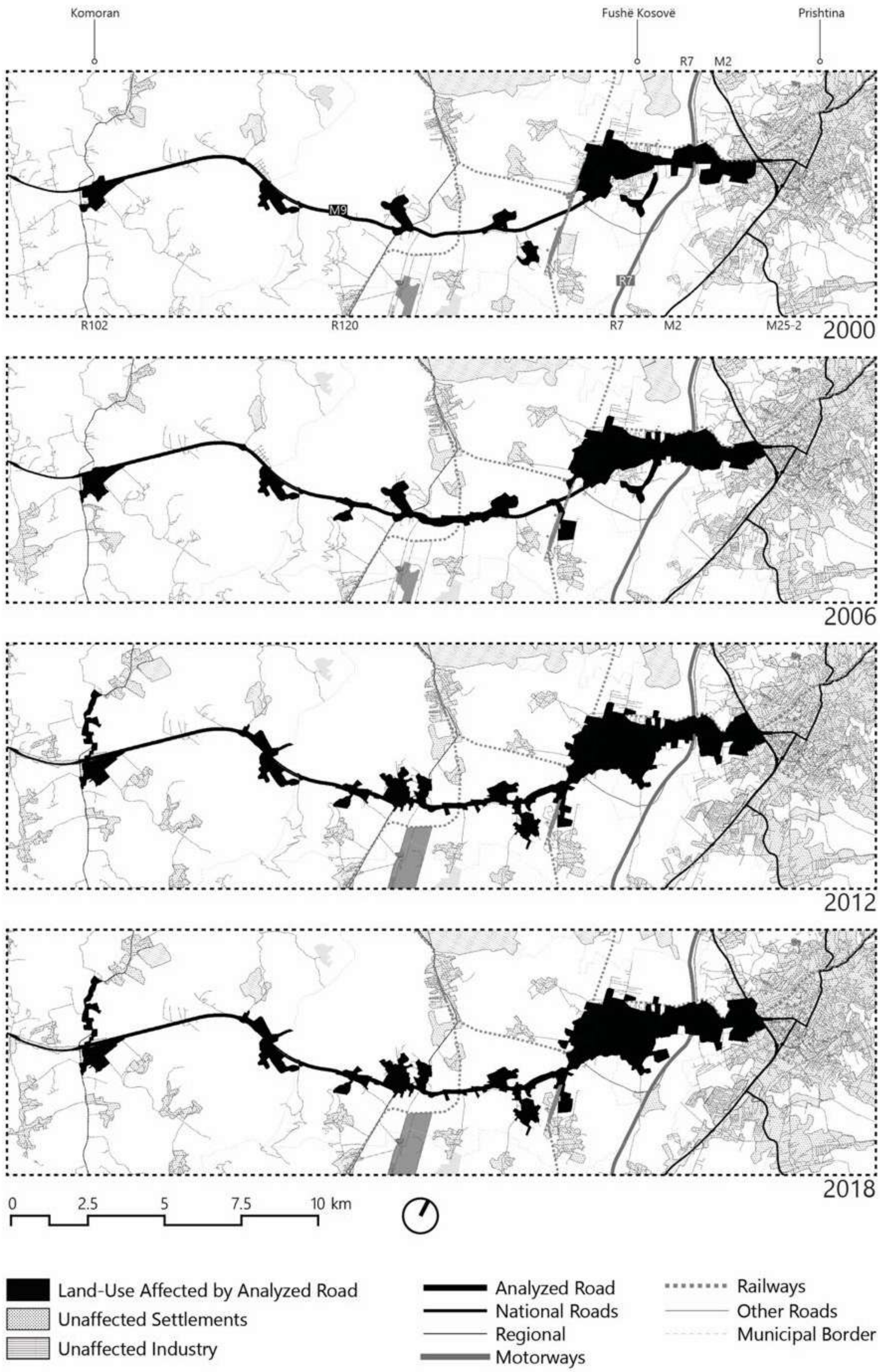


Land-Use Affected by Analyzed Road
Unaffected Settlements
Unaffected Industry
Analyzed Road
National Roads
Regional
Motorways
Railways
Other Roads
Municipal Border

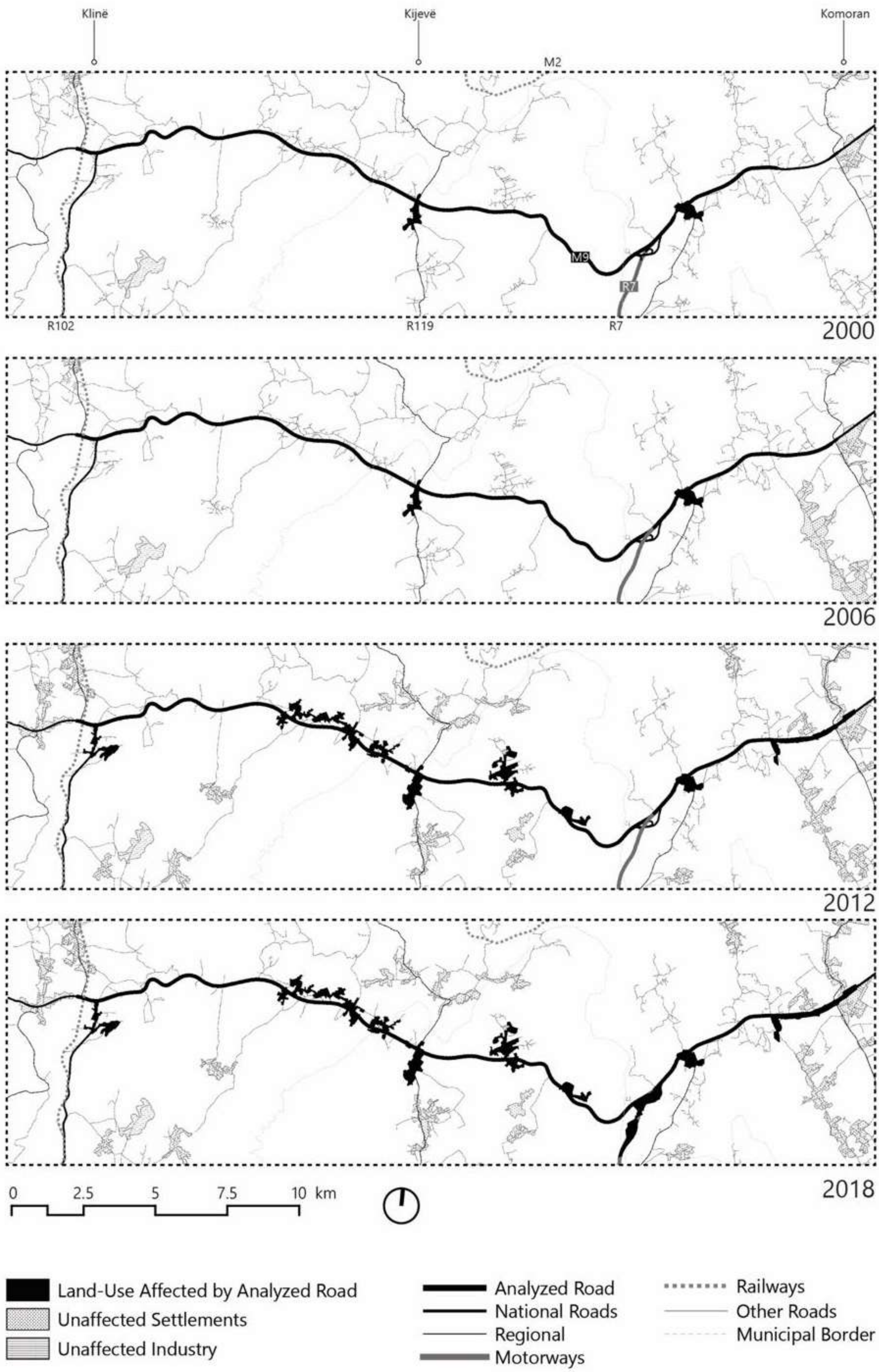
M2 | Ferizaj - Hani i Elezit



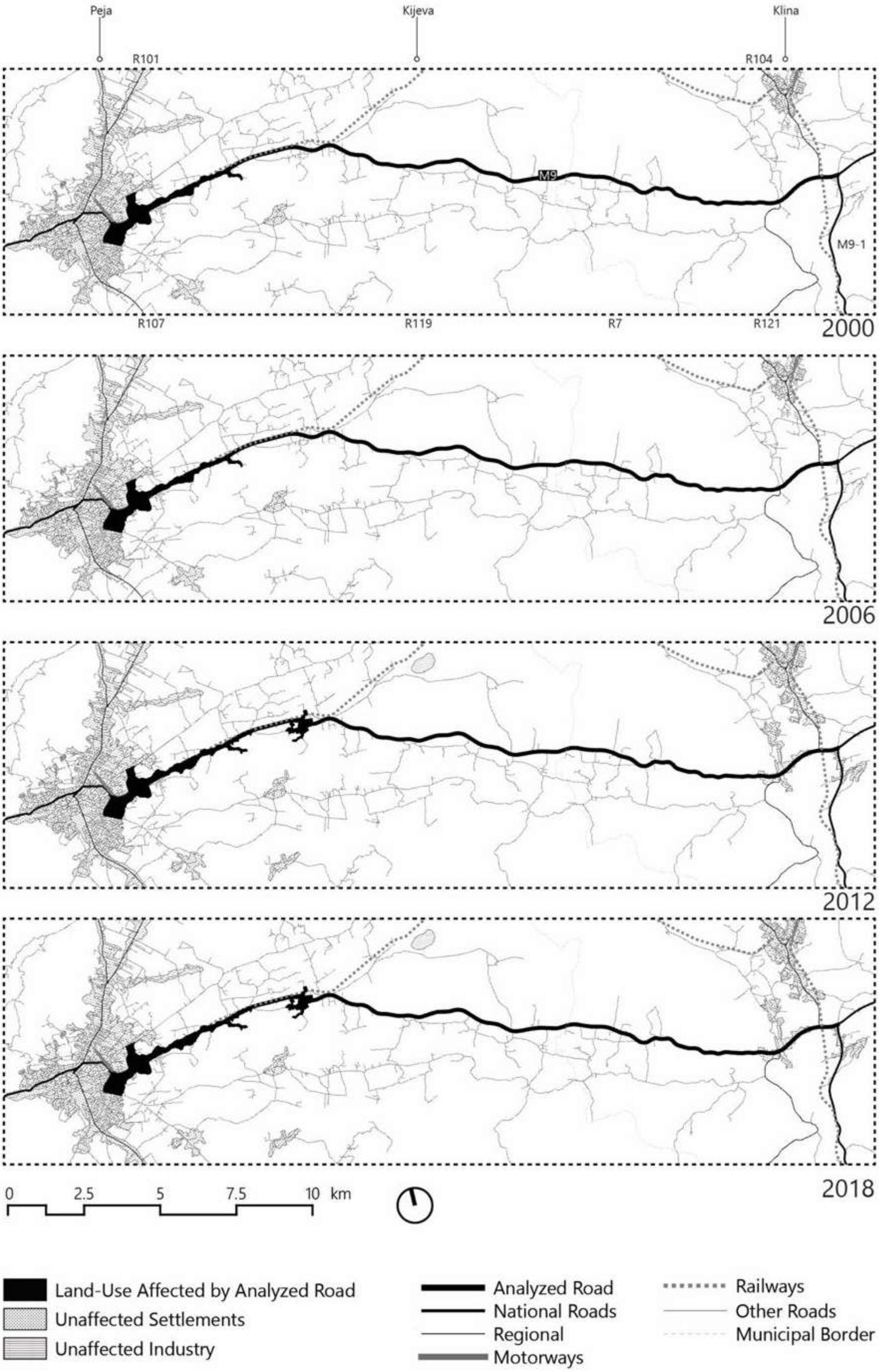
M9 | Prishtina - Komoran



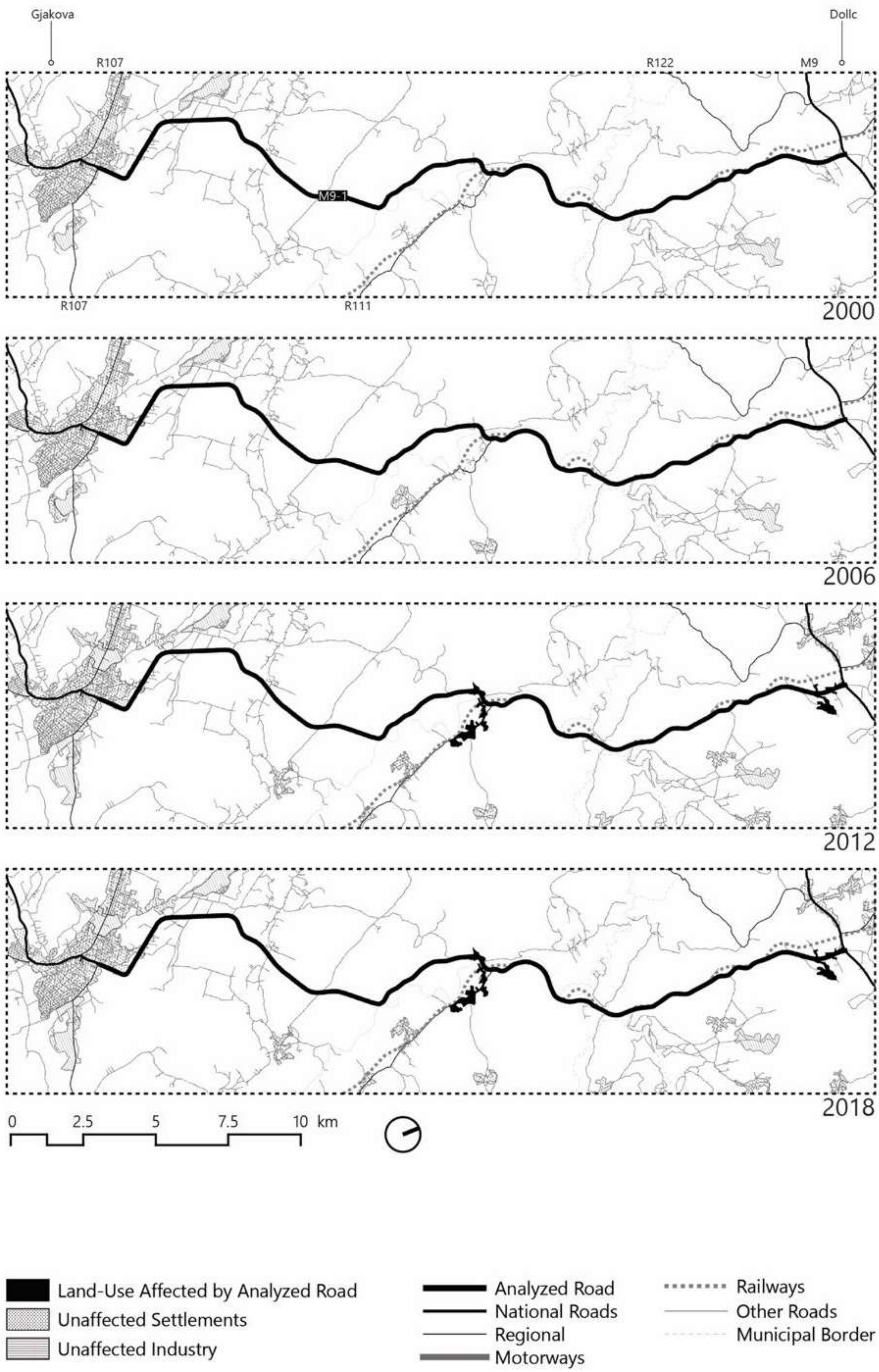
M9 | Komoran - Zajm



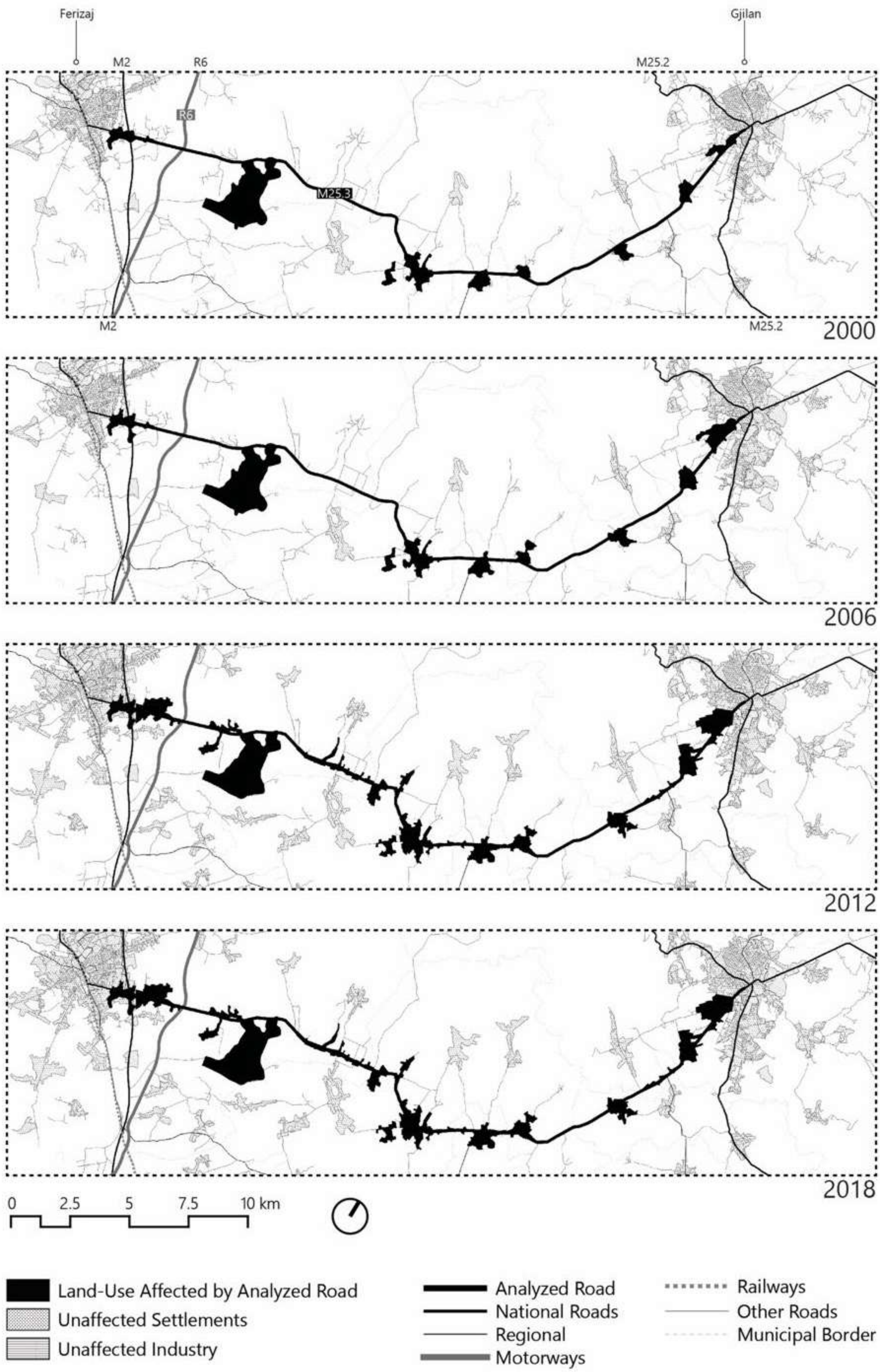
M9 | Zajm - Peja


Peja
Kijeva
Klina
R101
R104
M9
M9-1
R107
R119
R7
R121
2000
2006
2012
2018
0
2.5
5
7.5
10 km
Land-Use Affected by Analyzed Road
Unaffected Settlements
Unaffected Industry
Analyzed Road
National Roads
Regional
Motorways
Railways
Other Roads
Municipal Border

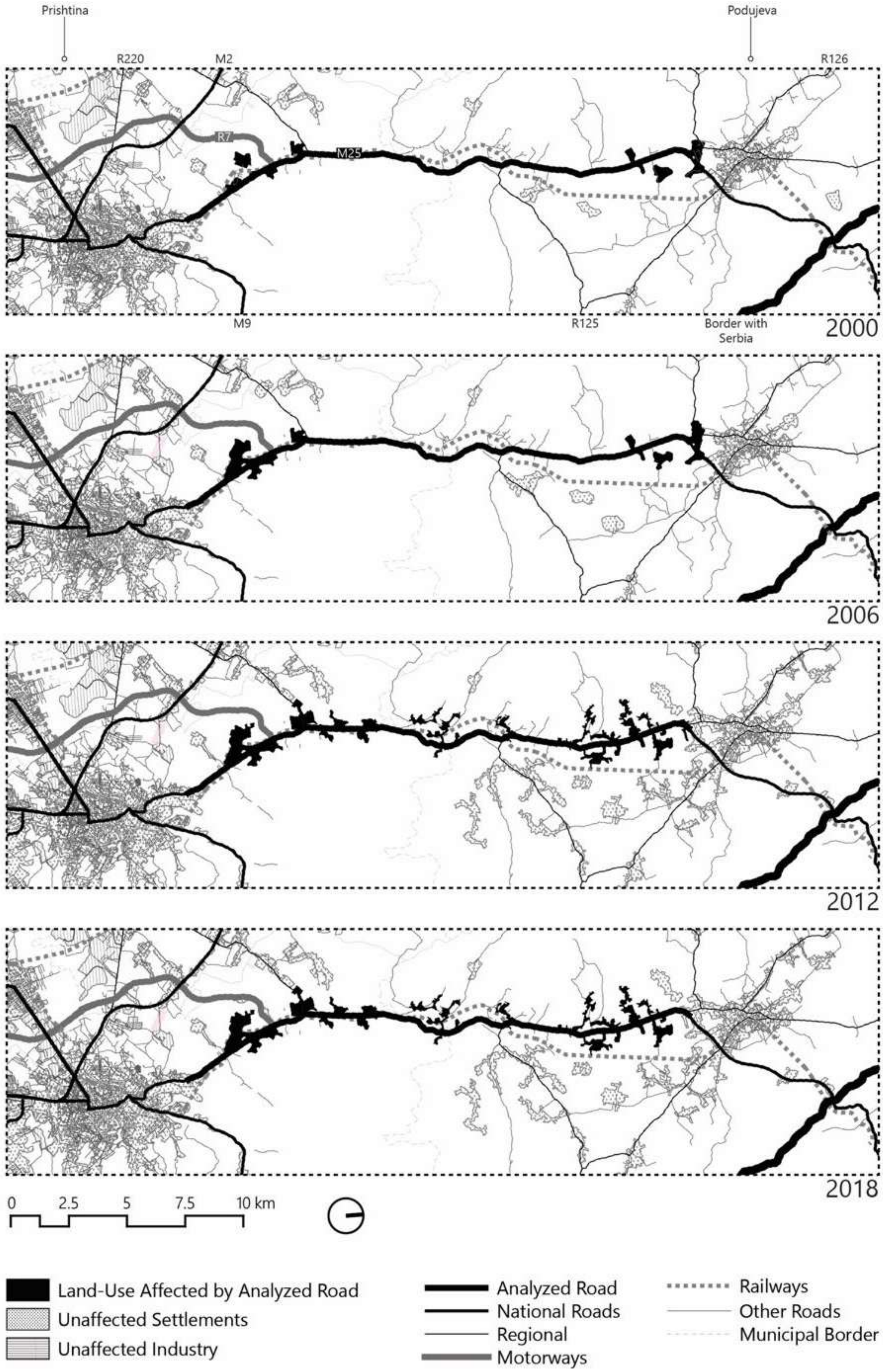
M9-1 | Dollc - Gjakova



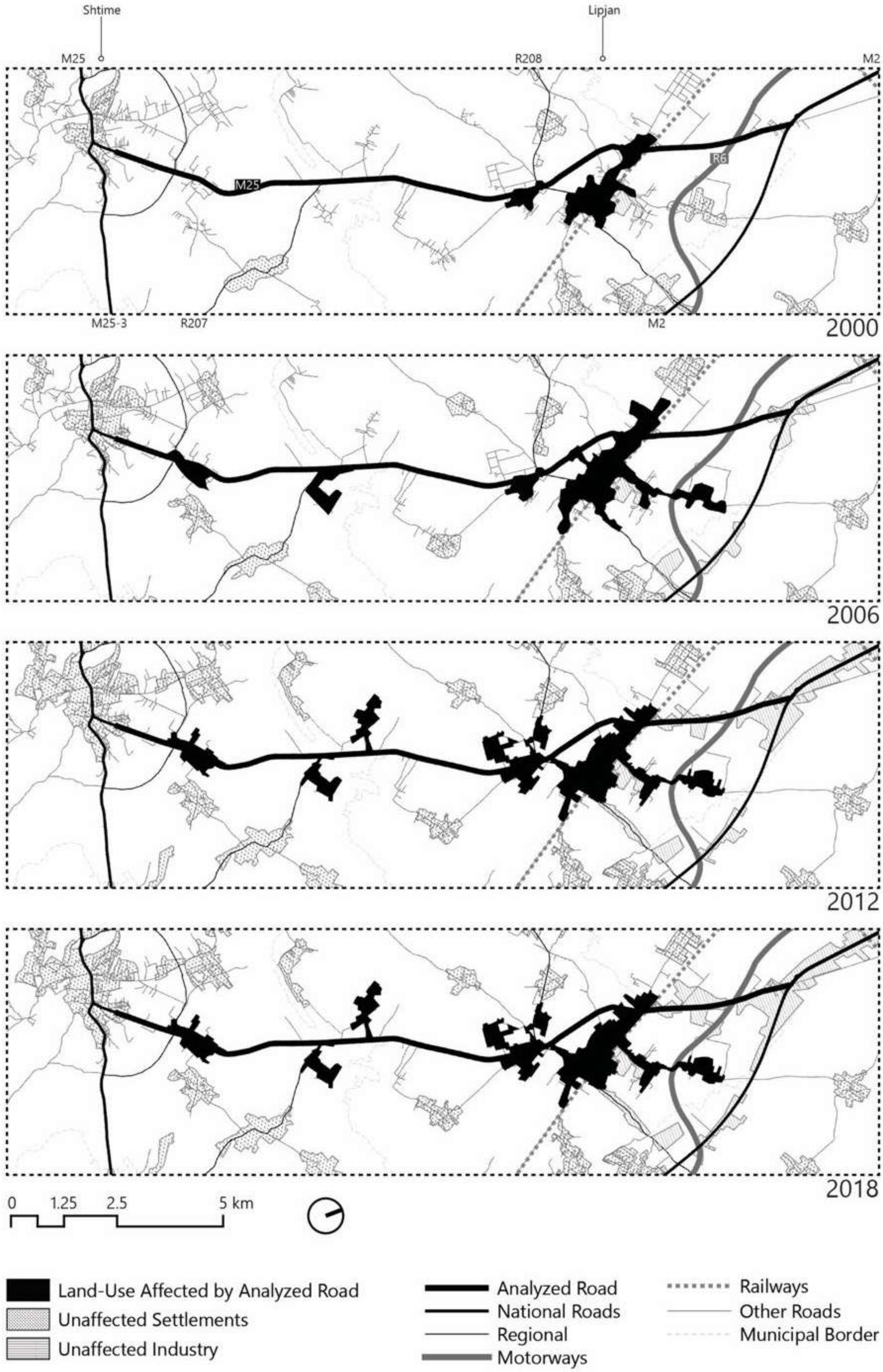
M25.3 | Ferizaj - Gjilan



M25 | Prishtina - Podujeva



M25 | Prishtinë - Shtime



RRON BEQIRI curriculum vitae

[redacted]

EDUCATION

Technical University of Vienna
Doctoral Candidate in Spatial Planning and Development
Scholarship by OeAD, Austria

October 2018 – Ongoing
Vienna, Austria

Dissertation Title: “In search of spatial patterns: how road infrastructure impacts land development”

- Sustainable Spatial Planning and Development
- European Spatial Planning
- Spatial Analysis
- Spatial Statistics
- Network Analysis

University of Prishtina, Prishtina, Kosovo
Master of Technical Science, Architecture

2014 – 2016
Prishtina, Kosovo

- Spatial Planning and Development
- Heritage Planning and Management
- Architectural Design
- Policy Design and Implementation

Technical University of Vienna
Research Semester

2015
Vienna, Austria

- Spatial Planning and Development
- Digital Architecture
- Open-Source Architecture
- Information Architecture

University of Prishtina, Prishtina, Kosovo
Bachelor of Architecture

2009 - 2014
Prishtina, Kosovo

- Architectural Design
- Urban Design
- Spatial Planning
- Theory and History of Architecture

WORK EXPERIENCE

University of Prishtina, Faculty of Architecture

October 2016 – Ongoing

Prishtina, Kosovo

Teaching Assistant

- Taught courses of Spatial Planning, Regional Planning and Urban Design
- Preparation of course syllabus through updated literature and theories.
- Support the Faculty of Architecture in preparation of required documents for yearly valuation and accreditation.
- Establishing and maintaining partnerships with institutions, including civil society organizations, youth platforms, public institutions (municipalities and central government) and other faculties within University of Prishtina.
- Participation in Conferences and Symposiums related to Architecture and Spatial Planning,
- Liaise with respective institutions for reviewing and implementation of student projects.
- Participating in conferences and roundtable discussions for policies in social housing and other subjects.
- Designed and Reviewed Student Assignments.

Ministry of Culture, Youth and Sports

June 2022 – Ongoing

Prishtina, Kosovo

Consultant: Coordinator for the Process of Information system for the management of cultural heritage inventory (SIMIT)

- Determines the work methodology for the sectoral and thematic groups in cooperation with the sectoral coordinators;
- Draws up the action plan, including activities, responsibilities, deadlines;
- Develops the list of necessary data for the drafting of the concept document and other subsequent documents;
- Develops the summary of the material provided by the sectoral coordinators;
- Develops the final draft, in cooperation with the sectoral coordinators, of the content part of the concept document for culture;
- Organizes meetings and consultations with sectoral coordinators, and meetings with the coordinating group;
- Provides professional support to sector coordinators in the design of work tools, process management and other activities as needed;
- Supervises, monitors and evaluates the progress of the drafting process of the concept document and the work of the sectoral and thematic coordinators;
- Systematically reports (according to the Action Plan) to the Coordination Group through written and verbal reports in coordination meetings about the implementation of the Action Plan and the main findings from the process;

Kosovo Affordable Housing Market Assessment | The World Bank/IFC, The Institute for Housing and Urban Development Studies (IHS), Urban Plus

Local Expert / Researcher

May 2022 – Ongoing

Prishtina, Kosovo

- Scanning and assembly of literature, documentation, information, project dashboards, reports
- Review, analyzing and reporting on the findings about Kosovo's housing sector
- Identifying knowledge and information Gaps
- Site visits, inspections of the project site(s) in the city/cities
- Key metrics, indicators and key information about Kosovo's housing sector: construction cost, average income, housing prices, finance, laws, etc.
- Preparing draft papers to feed the housing market study report.
- Assess potentials, strength and weakness of the sites vis-a-vis costs and benefits for the city as well as for the target beneficiaries and the financing agency.
- Analysis of environmental impacts, the land use and norms subject to enforcement, site inspection for possible contamination and existence of explosives originated from the conflict, the carbon footprint.
- The technical and financial viability of the site development.

Architecture for Humans

Architect | Director, Founder

www.architectureforhumans.com | info@architectureforhumans.com

April 2016 – Ongoing

Prishtina, Kosovo

- Team leader of architectural and research projects, designed and implemented by Architecture for Humans.
- Conduct research and analytical examinations during design process.
- Manage and supervise the development and implementation of all projects and activities.
- Ensure implementation and follow-up of all projects and activities carried out by the enterprise.
- Identification and mapping of potential project partners and stakeholders.
- Regular communication and coordination with partners and clients, for projects and processes.
- Develop workplans and project proposals and monitor and evaluate work-progress.
- Establish partnerships with different institutions, including civil society organizations, local governments, municipalities, universities, private businesses, youth platforms, etc.
- Ensure effective realization of an inclusive and participatory process before project implementation.
- Conduct market screening research, analyze cost and benefits of projects.
- Organize corporate-social-responsibility (CSR) activities.
- Organized, conducted, and designed research projects.

Architecture for Humans Portfolio includes, but is not limited to:

- PrishtinaTrees.org
- The Yellow Pavilion
- Zero Emission Neighborhood
- Drive-in Cinema in Prishtina
- Affordable Housing for Kosovo, etc.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
Expertise for the detailed design of container locations in the municipalities of North Mitrovica, Zvecan, Leposavic and Zubin Potok

January – March 2021

North Kosovo, Kosovo

- Analysis of the existing container's sites in close cooperation with the municipal working group.
- Develop a proposal for the technical design and produce technical drawings for multiple waste collection points which need to be technically adjusted.
- Provide bill of quantities BoQ and technical specifications of the project design based on the revised project design and work description.
- Close cooperation with GIZ team throughout the entire project duration.
- Meetings and coordination sessions with representatives from municipalities of North Mitrovica, Zvecan, Leposavic and Zubin Potok
- Regular site visits to North Mitrovica, Zvecan, Leposavic and Zubin Potok

Prishtina Institute for Political Studies, PIPS
Professional Consultant

June – December 2019

Prishtina, Kosovo

- Provide paper on the benefits and difficulties of drafting and implementing a Sustainable Urban Mobility Plan.
- Research case studies with similar size, demographics, and development for comparison.
- Thorough research of legal framework both at local and central level, affecting the potential implementation of SUMPs.
- Publish paper on SUMP for PIPS.
- Conduct a round table with stakeholders, members of the parliament and other experts on the topic of mobility and SUMP implementation.
- Present the outcomes of the paper

USAID Partnerships for Development
Technical Spatial Planning Drafting Expert

June – November 2016

Prishtina, Kosovo

- Provided technical drawings and language on the Guidelines for the Municipal Zoning Maps document.
- Provided technical drawings and reviews for the Technical Norms Administrative Instructions Document.
- Developed visual cues and graphics to illustrate complex legal implications regarding planning and building.
- Regular meetings with relevant Ministry representatives, for the development of Guidelines for the Municipal Zoning Maps.
- Working groups with different stakeholders.
- Continuous cooperation with Ministry of Environment and Spatial Planning working group.
- Cross reference and checking of legal documents to ensure no interference is present.
- Work closely with program manager and international experts in the field of spatial planning.
- Regular reporting to USAID and Chemonics.

Municipality of Prishtina
Professional Consultant – Architect, Planner

March – June 2019

Prishtina, Kosovo

- Research, analysis, and design of the master plan for the Road B Park.
- Site research, measurements, and interviews with citizens.
- Provision of design solutions for the park, to the Municipality of Prishtina.
- Compilation of the document for the 'Audit of Green Spaces' in the city of Prishtina
- Site analysis and research for the city of Prishtina,
- Geographical Mapping and tracking of elements identified for the audit.

Kosovo Archeological Institute
Architect
Supervisor: Elvis Shala, elvis.shala@gmail.com

June – September 2016

Kline / Prishtina, Kosovo

- In-situ survey of the archaeological remains of the Dresnik site.
- Detailed measuring and drafting of the remains and architectural elements of the site.
- Digitalization of existing and new drawings of the site.
- 3D modelling and reconstruction of the site. This requires deep understanding of architectural history and techniques that are typical to the context.
- Preparation of technical drawings and documents for the site.
- Photogrammetric capturing of remains.

Urban Plus
Architect

July 2015 – July 2016

Prishtina, Kosovo

- Aided in design buildings taking into account local and state environmental and safety regulations
- Prepared scale drawings of planned developments using computer-aided design software
- Drafted detailed information on design, structural specifications, materials, and costs of new buildings
- Site Analysis and research for plans and maps being drafted

Urban Plus
Intern

October – January 2013

Prishtina, Kosovo

- Prepared scale drawings of planned developments using computer-aided design software
- Drafted detailed information on design, structural specifications, materials, and costs of new buildings

HONORS AND AWARDS

OeAD - HERAS Scholarship for Doctoral Studies 2018 - 2022

Winner of First Prize 2016
Young Professional Category, Frozen Music Kosovo

CEEPUS Scholarship for Academic Research, TU Wien 2015

Winner of Second Prize, 2014
With Urban Plus, in the competition: Prishtina's Kurrizi Competition

Winner of Second Prize, 2013
with Urban Plus, in the competition: Peja's City Center

RESEARCH AND PUBLICATIONS

PrishtinaTrees.org 2020 Prishtina
Open platform that maps trees, green spaces and public spaces in Prishtina.

The Yellow Pavilion / Architecture for Humans, ArchDaily 2020 Santiago
www.archdaily.com/933108/the-yellow-pavilion-architecture-for-humans

SUMP – A Joint Commitment! - Towards an overarching institutional coordination and policy development in drafting and implementing SUMPs, Prishtina Institute for Political Studies 2019 Prishtina
https://pips-ks.org/DesktopModules/EasyDNNNews/DocumentDownload.ashx?portalid=0&moduleid=1446&articleid=21&documentid=4071&localeCode=en-GB%20|%202019/

Architecture for Humans Proposes Zero Emission Neighborhood to Address Climate Change, ArchDaily 2019 Santiago
www.archdaily.com/900643/architecture-for-humans-proposes-zero-emission-neighborhood-to-address-climate-change

One Region / One Vision 2050 – A Vision for the Danube Macro Region, Faculty of Planning and Architecture - Urban and Regional Planning, TU Wien 2019 Vienna

Measuring Vitality of the Ottoman Public Space in Kosovo Cities, JOSHA Journal of Science, Humanities and Arts – Ilir Gjinolli, Rron Beqiri 2018 Prishtina

University of Prishtina Campus, Safe and Suitable Public Spaces for Everyone, EC ma Ndryshe 2018 Prishtina
https://ecmandryshe.org/repository/docs/180712113334_Kampusi_i_Universitetit_te_Prishtines_reduced.pdf

Gjakova: Cycling, Public, Youth, EC Ma Ndryshe https://ecmandryshe.org/repository/docs/180924115548_Gjakova___Shtegu_i_ciklizmit.pdf — 2018 Prishtina

AI: Architecture Intelligence - Future Architecture Platform https://futurearchitectureplatform.org/projects/94a6ee8f-247f-4e63-aaae-b4007d063eef/ — 2016 Prishtina

"Prishtina - or how I learned not to worry about plans and love chaos" - Technical University in Vienna — 2015 Vienna

"Healthy living through ZERO Emission Building", Thesis, University of Prishtina — 2016 Prishtina

"Sustainable Social Housing", Thesis, University of Prishtina — 2014 Prishtina

PROJECTS, ACTIVITIES AND WORKSHOPS

Autostrada Biennale – Tutor of metal and wood workshop – Design of urban intervention for the 2021 Biennale — May – July 2021 Prizren, Kosovo

Council of Europe Schools of Politics and Prishtina Institute for Political Studies - Certificate for completion of course — 2017 - 2018 Various locations

Co-Founder of "Përtej Pragut" (Beyond the Threshold), an organization that encourages "Place Making" strategies. — 2014 - 2016 Prishtina, Kosovo

Editor and Designer of the faculty magazine "Arkitektura". — 2013 - Ongoing, Prishtina, Kosovo

Creator and Editor of the Department's Website www.katedra.tk — 2012 - Ongoing, Prishtina, Kosovo

Tutor of the "Cre8.bit" Workshop, European Architecture Student Assembly — 2014, Veliko Tarnovo, Bulgaria

Tutor of the "Përtej Pragut" (Beyond the Threshold) Workshop in cooperation with the University of Prishtina — 2014, Prishtina, Kosovo

Participant on the "Public Spaces" Workshop, European Architecture Student Assembly — 2013, Zuzemberg, Slovenia

Participant on the "Sustainability" Workshop, in Cadiz, Spain, 2011 — 2011, Cadiz, Spain

Volunteer at "Hope and Aid Direct" which is a British humanitarian organization that provides charity for countries in need. — 2005 - 2012, Prishtina, Kosovo

PROFESSIONAL SKILLS

- Analytical Abilities and Project Management
- Great Interpersonal Skills and Excellent Communication
- Strategic Planning and Fundraising Skills
- Understanding of the social and environmental impact of planning decisions on communities
- Ability to work with the public and articulate planning issues to a wide variety of audiences
- Problem Solving Skills through innovative and critical thinking
- Knowledge of plan-making and project evaluation
- Ability to analyze demographic information to discern trends in population, employment, health, etc.
- Demonstrated Research Abilities
- Cooperative and well-organized
- Ability to work individually or in groups.

LANGUAGES

Albanian - Native
English - Fluent
German - Very Good

COMPUTER SKILLS

- Graphisoft Archicad
- QGIS
- Trimble Sketchup
- V-Ray
- Kerkythea
- Adobe Indesign
- Adobe Photoshop
- Adobe Illustrator
- Adobe Premiere Pro
- Adobe After Effects
- Affinity Photo
- Affinity Design
- Affinity Publisher
- Depth Map X
- Lumion 3D
- Blender
- Autodesk AutoCAD
- Microsoft Office
- Wordpress
- Rhino
- Input app
- Python (basic)
- Java (basic)