Tradable Development Certificates in Germany

A Theoretical and Empirical Analysis

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1 Introduction

In Germany, there is an ongoing conversion of agricultural land into residential and commercial areas. Negative ecological and economic consequences related to this trend compromise the ecological function of space as a resource for humans, animals, and plants.

One of the reasons for the ongoing consumption of land is the tight financial situation of many municipalities (Jörissen and Coenen, 2007). At a first glance, the development of new areas in the outer zones of municipalities appears to be attractive because, often, it is cost neutral or even linked to proceeds from selling land. Moreover, a larger estate per capita ratio is expected by the settlement of young families which will have a positive impact on the redistribution of income taxes. However, recent studies have shown that urban sprawl can also increase the long term costs of the public infrastructure and, thus, amplify the financial burden in the long run (e.g. Gutsche, 2006; Preuß and Floating, 2009; Siedentop, 2007).

A further challenge for the federal government within this context is the large number of protagonists, who are involved in the process of land utilization, and the reconciliation of their interests, which may counteract with a sustainable land usage. The federal government and the federal states provide the legal framework but cannot directly control the land consumption caused by these actors. The municipalities are responsible for spatial planning and are empowered to draw up the relevant local development plans. Thereby, the municipalities have practically full planning sovereignty within their territory. Still, their decisions result from a complex interaction between planning and political bodies within the municipal administration as well as investors and conservationists.

1.1 Background

In this context, the Strategy for Sustainability of the federal government expresses the intention to develop a practical program for housing and transport-related land utilization while considering ecological, social, and economic objectives (Bundesregierung, 2002, 2004). Furthermore, the federal government has set the ambitious goal in its 2002 Strategy for Sustainability to reduce the new land development to 30 ha per day by 2020. In this program, land-related financial, fiscal and development policy instruments will be examined to minimize the urban sprawl, the fragmentation of the countryside and the loss of natural habitat.

Since the passage of the Strategy for Sustainability, the development of new areas has only slightly declined. Today, there is still a huge gap between the current development of 95 ha per day and the national target of 30 ha per day in 2020 (Figure 1.1).[1] Von Haaren and Michaelis (2005), therefore, argue that the actual German planning policies are not sufficient to assure a sustainable development. The government's own assessment of its above mentioned Sustainability Strategy identifies a particular challenge in addressing the consumption of land in the large number of protagonists and the reconciliation of their interests (Bundesregierung, 2004, p. 193f). To overcome these issues, the 2004 assessment discusses several financial instruments and highlights the importance of economic incentives.

The situation in Germany has given rise to a discussion about innovative planning approaches and new policy instruments. The present land use planning policy has only been partially successful in limiting land consumption and urban sprawl. It seems to be necessary that the federal government implements an effective medium- and long-term policy for a sustainable development on the basis of new economic instruments, as legal instruments alone are apparently not sufficient to reduce land consumption (Bundesregierung, 2004, p. 19):

> *"Subsidies, taxes, duties and development programs need to be examined with respect to their potential contribution to land consumption reduction. To that end, social, economic and financial effects must also be considered."*

[1] Source: http://www.umweltbundesamt-daten-zur-umwelt.de/umweltdaten/public/theme.do?node Ident=2898 (27.11.2010).

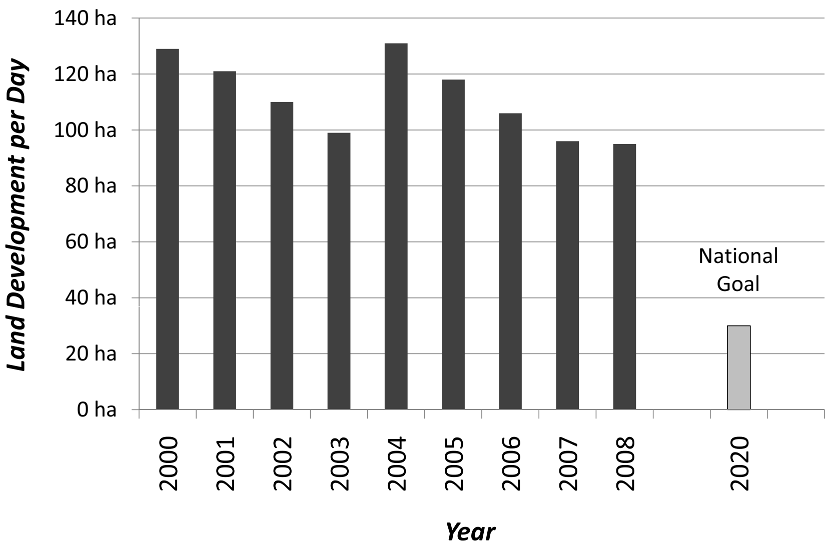

Figure 1.1: New Land Development in Germany

A promising economic instrument to cope with the 30 ha/d target would be a system with tradable development certificates (TDCs).[2] Such a system has been suggested by the parliament's expert advisory board with the constraint that several design questions must be solved prior to an actual implementation (Sachverständigenrat für Umweltfragen, 2002, 2004). The government, however, has several legal concerns regarding a TDC system. Moreover, a TDCs system is a merely quantitative instrument and does not differentiate qualitative aspects. Therefore, the Government envisions a system of TDCs in combination with other planning guidelines and concludes: "Before any fundamental decision is taken on the continued pursuance of such approaches, the results of pilot projects [...] must be ascertained, carefully evaluated and discussed with the participants, particularly those in the municipalities" (Bundesregierung, 2004, p. 208).

In addition to the examination of new land-related financial, fiscal and development policy instruments, the Strategy for Sustainability of the federal government focuses on inter-disciplinary methods to achieve a stronger link between the existing ecological and planning approaches. To achieve these more ambitious targets, the coalition agreement of the recently elected federal government also foresees trade systems in pilot studies:[3]

[2]Synonyms for the term *development certificate* are the terms *development allowance*, *development right*, or *development permit*. The term development certificate is used to differentiate the new instrument from development rights which have been used in the US for many years.

[3]The coalition agreement between the CDU, CSU and FDP for the 17th legislative period 2008-2013. GROWTH.EDUCATION.UNITY. Page 41.

> *"We intent to initiate a voluntary pilot project that would allow municipalities to test a supraregional trade system for land use."*

Such a pilot project can provide real life experience for municipalities and city planners with new policy instruments and can serve as a basis to analyze the strategic behavior and the decision processes of actual decision makers in local authorities. Furthermore, the usage of the experimental methodology allows the comparison of actual efficiency gains of the trading scheme with those postulated by theory and the evaluation of different scheme designs with respect to the behavior of the participants and the market outcome.

1.2 Experimental Methodology

Experience with cap-and-trade systems has led to a rich empirical and experimental academic literature. *Theoretical studies* focusing on the market design allow to make predictions about the market outcomes of different designs in particular situations on the basis of stylized data. Empirical experience with environmental markets gained in *field studies* gives evidence of how well the theory is in accord with actual results. In comparison to the results from theoretical studies, field studies have a higher external validity as actual data is being used.

Another way to analyze new cap-and-trade systems is to test and refine environmental markets in the laboratory—the so-called test bedding method (see Plott and Porter, 1996; Plott and Cook, 2005). For the evaluation of environmental policy instruments, different experimental methods have recently been used. In the classical *controlled laboratory experiment*, a group of human participants is sitting in front of a set of computers and is linked with each other by specialized software (Roth, 1988; Smith, 1994). Experiments have less external validity than field studies, but provide a specific level of internal validity. The participants have to cope with decision tasks, which include carefully controlled incentives, choices, information, and other characteristics. By varying one design parameter between different experimental sessions, while holding all other factors constant, the experimentalists can test how the respective treatment variable affects the market outcome. Typically, students are recruited for the experiments. They receive a payment based on their performance in the experiment. These economic experiments are increasingly used to investigate public policy, economic theories, and institutions (Figure 1.2).[4]

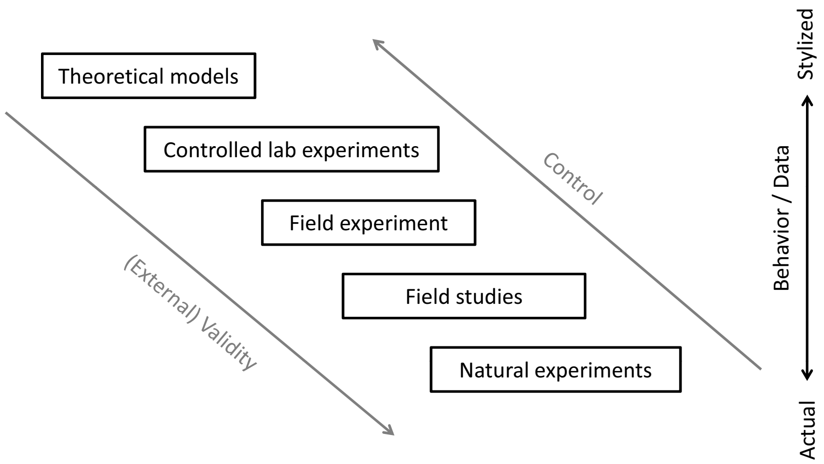

Figure 1.2: Comparison of Different Methodologies

In addition to the classical laboratory experiments, more realistic *field experiments* with a specific contribution to economic policy making have been carried out in the last years (see Cardenas and Carpenter, 2005; Carpenter et al., 2005; Harrison and List, 2004; Shogren, 2005; Sturm and Weimann, 2006). In particular prior to the actual implementation, some of the national and regional emissions trading systems in the US were simulated in field experiments to test selected properties (e.g. Holt et al., 2007). The explorative approach can also lead to new findings which, because of the complexity of the environment, could not have been derived from theory. The simulation game SET UP on emissions trading (Ehrhart et al., 2003) combined the advantages of a field experiment and a controlled lab experiment. Companies that participated in the ex-ante simulation took also part in such a system in reality afterwards. The artificial testing environment developed for SET UP allowed the controlled analysis of the participants' actual decision processes and strategies.

[4]Source: Presentation 'Controlled field experiments' by Stefan Seifert at the annual conference of the *Gesellschaft für experimentelle Wirtschaftsforschung, 2008.*

1.3 The Project Spiel.Raum

Against this background, a cap-and-trade scheme in Germany for land development was investigated with local authorities within the field experiment *Spiel.Raum* which represents the basis for the analyses in this book. The Spiel.Raum study was funded by the Federal Ministry of Education and Research program *Research for Sustainability* within the initiative *Economics for Sustainability* and was conducted by the Fraunhofer Institut für System- und Innovationsforschung in cooperation with the Karlsruhe Institute of Technology (KIT), the Büro Stadt-Land-Fluss (Prof. Dr. Küpfer), the Takon GmbH and the author of this book as a member of the Graduate School Information Management and Market Engineering of the KIT. The purpose of this project was to gain insights into how to design such a system in the real world and how real world actors might behave in such a system. In addition to a decentralized simulation over the internet, the design of the new instrument in general was discussed with the participating municipalities and communal interest groups on several workshops.

The data basis of the field study has been used for additional analyses in this book and will be presented in some sections. The role of the author of this book in the Spiel.Raum project was to design and implement the software platform, to conduct the simulation runs of the field experiment and to support the data analysis of the experimental results. Furthermore, the author conducted additional lab experiments with different student groups and also analyzed interdisciplinary aspects of a cap-and-trade scheme for land development as a member of the Graduate School. Hence, the contents of this book are interdisciplinary aspects of a cap-and-trade scheme for land development, the design of the software platform as a decision support tool, as well as additional analyses of the simulation and survey results that have been not subject of investigation within the scope of the project. Nevertheless, also the results of the field study will be addressed and presented within this book.

The main results of the field study are published in Ehrhart et al. (2008), Ostertag et al. (2009), Ostertag et al. (2010), and Müller et al. (2010). Further papers are currently in preparation. The results of the project will be summarized and presented in Section 2.2.2 (Design Primary Allocation), in Section 4.5 (Design Decision Support

Tool), as well as in the Sections 5.1 and 5.3 (Results of the Field Experiment).[5] While this book presents results of the project in more detail, it contains – to some extend – also material which is included in the mentioned publications and working papers. Within the scope of the field study, also laboratory experiments had been conducted to analyze the decision making within such a system in more detail. Hence, the results of the lab experiments will be referenced in this book (published by Müller et al., 2010a,b).

1.4 Research Questions

Complementary to the field study Spiel.Raum, this book reports in more detail on the behavior of the real world actors by regarding the actual design of a cap-and-trade scheme for land use from different disciplines. In addition to economic aspects (e.g. allocation rules) also the legal and institutional framework will be analyzed for an interdisciplinary view on the topic. In order to model and support the decision making processes of the participants in the field experiment, also the analysis of the structure of the municipal decision processes is particularly important in this book. Based on the analysis of the municipal decision processes, different designs of decision support tools will be proposed. A decision support tool prototype has also been implemented within the field experiment. The design of the decision support tool that will be presented is this book, has been the main task of the author of this book within the above mentioned project. Furthermore, the book analyzes to what extent the efficiency gains of the new instrument, which are postulated by theory, are realized under close-to-real conditions by combining the results of the field experiment with survey data. The surveys are conducted to analyze and evaluate the strategic behavior of actual decision makers of local authorities and the impact of non-economic criteria during the decision making. Hence, the following four research questions outline the main subjects of the investigation within the scope of this book:

- What are the important aspects when **designing a cap-and-trade scheme for land development** in Germany while considering market mechanisms, legal framework, and allocation rules simultaneously?

[5] Furthermore the contents of Table 2.2, Figure 5.4, Figure 5.5, Figure 5.6 have been adapted from previous publications and working papers.

- Which are the main characteristics of **municipal decision processes** in local land development and how could they influence the market design for a cap-and-trade scheme in Germany?
- How can a **decision support tool** be modeled in order to reflect a municipal decision situation and to support the municipal decision making in a cap-and-trade scheme for land use in Germany?
- What are the characteristics of the **strategic behavior of actual decision makers** in the field experiment and which **efficiency gains of the trading scheme** can be observed in the experiment compared to those postulated by theory?

To answer these research questions, concepts and methods from economics are borrowed, particularly from game theory and experimental economics, and combined with institutional aspects. In the next section, an overview of the chapters will be given.

1.5 Structure of the Book

In line with the research questions, the book is divided into six chapters: An introductory chapter, four main parts following the research questions and a final chapter (Figure 1.3). After a short introduction, each chapter emphasizes the research focus and the applied methodology. In each chapter, the results from the theoretical or empirical analyses are presented in the main part, before being reflected in a short summary. The final chapter sums up all results and gives an outlook for future work on the research topic.

After the introductory chapter, Chapter 2 presents the design of a cap-and-trade scheme in Germany. The chapter starts with the comparison of economic instruments and regulatory approaches, and summarizes the main characteristics of the instruments. Afterwards, the design of a cap-and-trade scheme for land usage in Germany will be introduced, including the market differentiation and the design of the new environmental good. Furthermore, the chapter discusses legal aspects and the regulatory choice problem, which have to be considered when designing an appropriate cap-and-trade scheme. In this context, the design of the primary allocation and the suitability of different allocation criteria will also be presented. The chapter concludes with a discussion wherein an allocation process for the new certificates is presented that emphasizes the need to

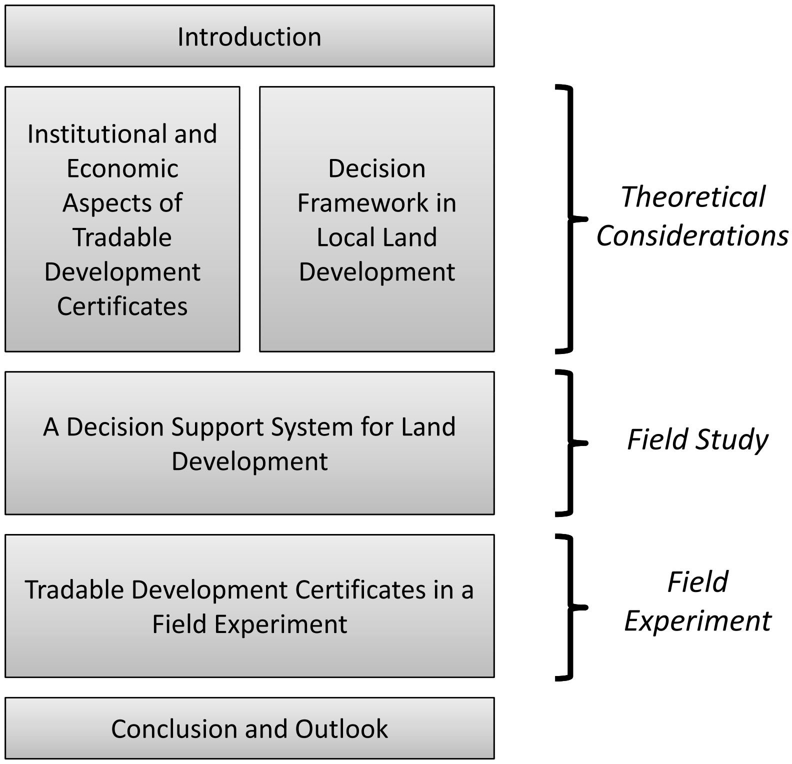

Figure 1.3: Structure of the Book and Applied Methods

analyze the decision making of the involved actors, e.g. land development decisions of local representatives, in more detail.

For the further analysis of different aspects of land development decisions, an enhanced view on the complex decision making is necessary. In Chapter 3, a comprehensive framework is elaborated, which closes the gap between the interdisciplinary studies and the experimental analysis for a transdisciplinary view on decision processes in land development. The framework describes different dimensions that can influence local land development decisions based on recent insights from literature. The chapter presents a comprehensive analysis of the decision making processes by introducing a framework for the description of the land development context, and for the description of the decision making chain within this framework. By means of the framework, the potentially arising cost paradox and the development dilemma, caused by a collective action of decision makers, is discussed. The results give an insight into how the behavior of local decision makers in particular decision situations leads to inefficient regional structures regarding the infrastructure costs. Based on the framework, the chapter motivates further transdisciplinary research areas in this domain and highlights the need to structure the municipal decision making in order to implement decision support tools.

Chapter 4 starts with a short overview of recent decision support tools in land usage. Afterwards, the modeling of the own decision support tool implemented within the Spiel.Raum field study is introduced. This tool supports the strategic planning within the context of policy making and spatial planning. In order to implement a cap-and-trade system for land usage, the tool can be extended and adjusted by modular components. Furthermore, the implementation of the decision support tool into a realistic use case is presented. During the practical implementation, further requirements to design new, more appropriate tools or to redesign existing systems for land use can be identified. The chapter concludes with a distinction between the new decision support tool and other decision support tools and stresses the importance of the tool for the field experiment.

In Chapter 5, the design and the results of the Spiel.Raum field experiment, which was conducted to test a trading scheme in Germany, are presented. The simulation has been conducted with spatial planners of 14 German cities and municipal syndicates, and used the actual data of the participating municipalities. Based on their current data, the participating municipalities simulated the period from 2008 to 2022 under the rules of a cap-and-trade system. In order to have an empirical benchmark for the results, the simulation game was repeated in the lab with a student control group using the same municipal data. To analyze the efficiency gains of the trading scheme, the observed outcomes in the field experiment will be compared to those postulated by theory. In order to get deeper insights into the decision making processes of the local representatives and to analyze the strategic behavior of actual decision makers, the results of the field experiment will be combined with the results of surveys. Finally, Chapter 6 summarizes the results from the main parts and gives an outlook for future research.

2 Institutional and Economic Aspects of Tradable Development Certificates

In the recent years, there have been many discussions regarding adaptations of the current planning law and whether this adaptations would be sufficient to reduce the high new land development in Germany. It is questionable if strict regulations, e.g. by adaptations of the planning law for municipalities (see Köck et al., 2007), are appropriate instruments to reduce the land development in Germany. Other instruments that could be implemented to reduce the land usage are economic instruments such as taxes, levies, and cap-and-trade systems. Especially, cap-and-trade systems have gained more and more attention and have been implemented with respect to different environmental issues (e.g. EU ETS), and are also promising instruments to reduce the land development in Germany.

The success of new policy instruments, such as cap-and-trade schemes for land development, depends on its specific design, e.g. the design of the market. Various factors have to be considered in theoretical analyses, results from laboratory or field experiments, or experiences from real world markets, to be able to choose a proper market design (see Stavins, 2003; Weinhardt et al., 2003). In this chapter, different policy instruments will be compared, the main design aspects of a cap-and-trade scheme for land development in Germany will be discussed and similarities and differences of the design to an emission trading scheme will be shown. The chapter focuses on the research of the last years from the institutional and economic perspective and concludes with a recommendation of a specific market design in Germany.

2.1 Market-based Instruments

Market-based Instruments (MBIs) are economic instruments that intend to tackle external effects on the environment by introducing a price for the use of natural resources (Stavins, 2003; Whitten et al., 2004). As mentioned above, examples are taxes, levies, or cap-and-trade systems. Especially, cap-and-trade systems such as environmental certificate systems have been used in many applications to manage the usage of environmental resources (for an overview see Tietenberg, 2003). An environmental certificate represents the right of his owner to use a specific environmental resource within a certain period of time. By providing only a limited amount of certificates, the usage of the natural resource can be regulated by a supervisory authority. The owner of a certificate is allowed to use or sell it to other actors; therefore these rights are called tradable. To facilitate trading, environmental markets have been established. Participants can offer certificates on the market for sale, or they can ask for certificates to purchase. The actors decide whether to buy or sell certificates by comparing the costs caused by avoiding the use of the resource, with the price of the certificates at the market. In theory, market participants with high marginal abatement costs will not reduce the usage of the environmental resource and buy certificates, while market participants with low abatement costs will sell certificates. Furthermore, if the market works the usage of the resource can be reduced at low overall costs. Further administration activities of the government or the supervisory authority related with the instruments comprise the setting of an appropriate global cap, the monitoring of the market, and the sanctioning of not legalized resource usages (see Section 2.2).

2.1.1 Cap-and-trade Schemes for Environmental Resource Protection

The idea of using certificate systems to protect environmental resources emerged in the 1960s. Dales (1968) developed the idea of tradable allowances based on the classical approaches of Coase (1960) and Crocker (1966). However, in the 1960s and 1970s, most economists were critical toward these new instruments, which hindered the application of certificate systems for environmental protection. It lasted quite long until the idea of market-based approaches and tradable allowances had been accepted in environmental policy, which long had preferred regulatory approaches (a comprehensive review is given by Stavins, 2003).

Generally, two fundamental types of certificate systems exist: Credit-based systems and cap-and-trade systems (Ellerman, 2003; Tietenberg, 2003). In credit-based systems, the certificates can only be traded when they exceed a specific standard. Thereby, each transfer of a certificate has to be granted by a regulatory authority, whereas in a cap-and-trade system, the certificates can be traded without a grant. Due to the limited transferability, credit-based systems still count as a regulatory system even though they are a more flexible approach than classical regulatory approaches.

The introduction of certificate systems has taken place step by step. Initially, credit-based regulatory approaches for emissions regulation started in the United States in the 1970s (US Emissions Trading Program) followed by an adoption of the approach to other applications (for an overview see Ellerman, 2003). The turning point, and thereby the origin of modern cap-and-trade systems, was the introduction of a certificate system in the US Clean Air Act in 1990. By introducing the allowance market in 1995, the United States Environmental Protection Agency limited the overall atmospheric levels of sulfur dioxide and nitrogen oxides, which cause acid rain (Tietenberg, 1995; Ellerman et al., 2005; Tietenberg, 2006). Based on this trading system, other emission schemes, such as the Regional Clean Air Incentive Market (RECLAIM) for SO_X and NO_X reductions or the NO_X Budget Trading Program, were implemented in the following years.

While certificate systems became more and more important in the US, Europe still preferred the usage of price based instruments, for example taxes or levies. Finally, the Kyoto Protocol initiated many programs and pilot projects that analyzed the usage of certificate systems in Europe. After the proposal of the European Commission in 2003 (European Union, 2003), the new emissions trading scheme (EU-ETS) with more than 10,000 technical installations started in 2005. Today, the program is the most important trading scheme next to the Acid Rain Program in the United States. In the 1980s, first analyses have shown that the savings from using economic instruments instead of regulatory instruments can amount to up to 90% (Tietenberg, 1985). In the Acid Rain Program, one of the most important allowance markets, the savings estimates are about 50% (Ellerman et al., 1999). In the EU-ETS, the cost savings add up to 30% compared to a common regulatory system (Ellerman et al., 2005).

Certificate systems have been used for the management of different kinds of environmental resources, e.g. water resources (Kraemer et al., 2003). The tradable permit systems regulate the pollution of water, the usage of the water itself, or the usage of associated resources such as fishing grounds. The first programs that limited the pollution of water started in the 1980s (e.g. David et al., 1980). Despite the fact that most water markets are quite illiquid, even few transactions of the permits can enable an efficient reduction of water pollution (Woodward, 2003). Moreover, the application of certificate-based systems to manage the settlement development or the urban planning of municipalities by introducing the so called tradable development rights also started in the 1980s. In addition to the numerous programs introduced in the United States, few tradable development rights systems have been realized in Italy and France (Renard, 2000; Micelli, 2002). The next section discusses the main characteristics of certificate systems and compares the market-based systems with regulatory approaches.

2.1.2 Comparison of Policy Instruments

An alternative approach to the described market-based systems is the adaptation of the legal and regulatory framework to reduce the usage of environmental resources.[1] In order to achieve a reduction of the resource usage in a command-and-control system with equivalent abatement costs, it is necessary to set performance-based standards (uniform control targets or reduction goals) for each actor depending on his individual abatement costs. However, the unequal treatment of the actors entails political debates especially if actors compete directly for these resources and have different yields. The setting of appropriate individual standards by the regulatory authority requires precise information about the abatement costs of the actors, and high transaction costs are possible. Thus, only if the regulatory authority or a responsible local supervisory authority has all individual information and all associated costs and yields at its disposal, an accurate setting of the standard is possible, which guarantees a cost efficient reduction of the resource usage in a specific time horizon.

Due to the flexibility of the trading mechanism, a cap-and-trade system can reduce the usage of the resource with lower abatement costs. The transaction costs in a cap-and-trade scheme (e.g. search and information costs, bargaining and decision costs, costs for

[1] Regulatory approaches are also called *command-and-control systems*.

monitoring and enforcement) are normally supposed to be lower than in a command-and-control scheme (Stavins, 1995). However, Stavins emphasizes that systems of pollution taxes or cap-and-trade schemes can also involve high administration costs in some individual cases. Hence, for a more detailed comparison of the instruments, especially regarding the transaction costs, a case-by-case analysis is necessary and the transaction costs can be different.

In contrast to command-and-control approaches, MBIs can internalize the external effect efficiently by making the use of natural resource costly while giving a maximum of flexibility to the economic agents. Only the market price of the certificates is variable. Within the scope of the cap-and-trade approach, the regulatory or supervisory authority has no need to gather all individual information. If the market works, it gathers individual information, distributes the information by giving price signals, and enables cost optimal decisions regarding the reduction of the overall resource usage. Given any reduction of the pollutant caused by the instrument, this reduction is reached at the lowest overall costs. Similarly, given any environment-related financial burden taken on by the society, the pollution reduction achieved by a MBI is the maximum improvement that is possible within the limits of this budget.

From a theoretical perspective, a cap-and-trade system is also effective with respect to the protection of the environment. Effectiveness means that the environmental improvement (or the maximum damage to the environment) can be precisely specified in advance by limiting the total amount of available certificates. The quantity control of the resource usage is realized by issuing a limited amount of certificates. Hence, similar to command-and-control systems the achievement of the reduction goal is guaranteed in cap-and-trade schemes.

Other economic instruments, such as environmental taxes, manage the usage of the resource by setting a fixed price for the usage. The taxation of a pollutant will induce agents to pollute as long as the economic benefit is higher than costs caused by the tax, but avoid pollution when it is lower than the tax. Nevertheless, taxes and cap-and-trade schemes work quite similar. When developing new areas, municipalities or the private developers have to pay taxes to the federal states. In case of a cap-and-trade system, the municipalities have to buy certificates. For both, taxes and cap-and-trade schemes, the municipalities can calculate whether it is more profitable to pay taxes or to buy a certificate to develop new areas. Those municipalities that plan to develop new areas have to pay a price and the other municipalities or institutions receive this payment. In contrast to cap-and-trade schemes, price based instruments such as taxes, do not guarantee the attainment of the environmental goal and municipalities can develop an almost unlimited amount of new land.

Compared to the other instruments, a cap-and-trade scheme has a variable price signal that reflects the scarcity of the resource by regarding demand and supply. However, due to the uncertainty of the price, a lower planning certainty, at least in the short run, can be expected compared to a fix tax or a command-and-control system that sets specific standards. Table 2.1 summarizes the main characteristics of the discussed three policy instruments and emphasizes the differences.[2]

Characteristics	**Command-and-control**	**Taxes / Subsidies**	**Cap-and-trade**
Reduction Goal	guaranteed	not guaranteed	guaranteed
Price Signal	none	fix	variable (signals the scarcity of the certificates)
Planning Certainty	high	high	low
Transaction Costs	high	low	low

Table 2.1: Main Characteristics of the Discussed Policy Instruments

Due to the given national target of 30 ha/d, a cap-and-trade scheme seems to be a promising policy instrument for reducing the development of new settlement and commercial areas in Germany. The next section introduces the main design issues for such a new cap-and-trade scheme by comparing it with similar systems.

2.1.3 A Cap-and-trade Scheme for Land Usage

The idea of introducing a cap-and-trade scheme to reduce the land development in Germany was born in the 1990s (Maier-Rigaud, 1994; Bizer, 1996; Bizer et al., 1998; Weise, 1999). The total amount of new settlement and traffic areas could be reduced accurately

[2]The table gives only a rough, general overview of the instruments and the valuation can certainly vary case-by-case.

and efficiently by introducing certificates for land development. New settlement developments would be only permitted if municipalities are able to hand in the corresponding certificates. The cap-and-trade scheme would be utilized for the municipal land use planning and, particularly, the development plans of the municipalities.

In such a system, the right of local planning authorities to re-declare the type of use of land, determined in the land development plan, is linked to the obligation to submit the respective amount of development certificates for cancellation. Municipalities act as the authoritative decision makers in land development and have planning sovereignty in their territory. The development of the new local land will be reduced by emitting a limited total amount of certificates to municipalities in a specific region. By restricting the total number of certificates, the German government can limit the total new land development. Instead, municipalities might be forced to restructure inner areas (e.g. closing gaps and brownfields). Since certificates can be freely traded between municipalities, areas are developed in those places where they are most valuable or least costly.

> *Example: Instead of developing a new area with 5 ha associated floor space, a city could develop an appropriate area in the inner zone by converting a brownfield. In the former case, the proceeds of selling the real estate might cover all costs of the development, but the city would have to submit corresponding development certificates for cancellation. In the latter case, the city might face higher costs for the infill development but could sell (or would not have to buy) development certificates on the market.*

A system with *Tradable Development Certificates* (TDCs)[3] is quite similar to an ETS (cf. Table 2.2). Under an ETS, the total amount of emissions is limited and respective permits can be traded among emitting companies (and possibly intermediaries). The price of the permits constitutes a benchmark for the costs of emissions reduction measures, such as fuel switches or efficiency improvements. In contrast, under a system with TDCs, municipalities, as the sovereigns over the land development plans, are limited in how much land they can convert from open space to settlement and traffic areas.

[3] Synonyms for the term *development certificates* are the terms *development allowances*, *development rights*, or *development permits*. The term development certificates is used to underpin the different mechanism of the new instrument in comparison to development rights, which have been used in the US for many years.

Characteristics	**Emission Rights Trading**	**Development Certificates Trading**
Obliged Actors	CO_2-emitting companies	Municipalities / Local authorities
Goal	Reduction of total greenhouse gas emissions	Reduction of total additional land use
Certificates	Emission permit (1 ton CO_2)	TDC (development of 1 hectare settlement area)
Objective	Realizing total cap (CO_2 emissions) at minimal cost	Realizing total cap (development of new land) while providing maximum value of settlement area
Reduction Potential	Fuel switches, efficiency improvements of installations	Closing gaps, conversion of brownfields, smaller/denser development areas

Table 2.2: Emissions Trading vs. Trading Development Certificates

The development certificates are necessary for the planning act of re-declaring the type of land use independent of who owns this land or invests in the development. Thus, TDCs are traded among municipalities and not among land owners or investors.[4] The municipalities' mitigation measures consist in the restructuring of inner areas (e.g. closing gaps).

A similar basic approach has been investigated in Switzerland (Zollinger, 2005). However, the main goal of this approach is to ensure a constant settlement area per capita. Depending on the owner of the certificate and the subject of matter, four different types of policy instruments are defined within this book (Table 2.3). In contrast to a TDC system, a system with *Land Usage Certificates* (LUC) comprises quota limitations for the usage of total settlement areas in a region. When the land usage reaches the upper limit, the development of new land is only allowed under the condition that a municipality renaturates existing settlement areas. The mechanism is quite similar to a system of TDCs in which the renaturation of areas can create additional certificates. Whereas the addressees in a TDC system are only the municipal planning authority, the property owners are the suppliers and customers in a system with LUCs.

[4] Similarly, under an ETS, it is the emitter and not the consumer of electricity who is required to provide sufficient emission permits.

Instrument	Actors addressed by the regulations	Subject matter
Tradable Development Certificate (TDC)	Municipalities	Reduction of the new settlements
Tradable Land Usage Certificates (LUC)	Federation / Federation States / Municipalities	Limit the total amount of usage settlement areas
Tradable Development Rights, Compensation Certificates (TDR)	Builder / Property owner	Restrictions of specific land-use types of properties
Tradable Land Usage Rights, Sealing Rights (LUR)	Builder / Property owner	Restrictions of specific land-uses of properties

Table 2.3: Delimitation of Certificate Types

The design of a policy instrument, the specialties of the policy area, the resource and the institutional framework, affect the success of the instrument in practical applications. Regardless of whether the states or the federal government set the objectives in land use, an analysis of the economic and institutional requirements is necessary. Although a system with tradable development certificates is a typical cap-and-trade scheme in which transactions can be carried out with low regulatory restrictions, the system can only be a supplement to existing regulatory restrictions, which must be still considered when using the certificates. The main challenge is to design an appropriate certificate system as a policy mix that fits into the regulatory framework in Germany (see Section 2.3). Due to the interdependencies between the institutional aspects and the design of an appropriate market, such an analysis is not trivial. In the following sections, further institutional and economic requirements of the new policy instrument in Germany are discussed.

2.2 Economic Aspects of a Cap-and-trade Scheme

The design of the initial allocation and the secondary market is a determining factor for the functionality of the trading system and the resulting market outcome. When designing a market system, it is important to choose an appropriate market mechanism that allows an efficient price discovery process. It is necessary to consider these factors along with the institutional and legal requirements (Section 2.3) when choosing a market design for tradable development certificates. In this section, the specification of the environmental certificate, the design of the trading mechanisms and the allocation rules for a practical implementation of the cap-and-trade scheme are presented. Furthermore, design issues arising from the requirements of the market participants are discussed.

2.2.1 Tradable Development Certificates

Land consumption is typically measured by the growth of settlement and traffic area (for a more detailed description see Chapter 4). This area includes all areas that can be used for living or traffic and serves as a central indicator for the new land development in Germany. About 50% of the settlement and traffic area consists of already sealed surfaces (Deggau, 2006).[5] The usage of settlement and traffic areas is legally permissible by a passed land development plan (§§34, 35 BauGB) that is based on a preparatory land use plan (§1 Abs. 2 BauGB). Köck and Bovet (2008a, p. 97) argue that the indicator 'settlement and traffic area' is more appropriate than the sealed surfaces as reference value for TDCs because it reflects the difference between natural spaces and used areas. Furthermore, the Federal Statistical Office provides a comprehensive data basis, collects data and compiles statistics of the settlement and traffic areas. The office publishes the actual settlement and traffic areas (§4 Abs. 1 und 2 AgrStatG) each year, and a more detailed statistics on the usage of areas every four years. The data collection allows the observation of the land development in Germany, which is another benefit of settlement and traffic areas as a central indicator for measuring land consumption and as a reference value for TDCs.

The basis for all cap-and-trade systems is the definition of the tradable certificates and of the reference value. Within the scope of this book, the term tradable development certificate is defined as a good that legitimates a municipality to develop new residential and traffic areas in the outer area of a city. The period of validity of the certificates depends on the duration of a land utilization plan. Furthermore, an area is measured in hectares or 10,000 square meters. A cap-and-trade system, as described in Section 2.1.3, assumes that the areas are perfect substitutes in all municipalities with regard to the

[5] Green spaces and parks belong to recreation areas and are defined as sealed surfaces (see Statistisches Bundesamt, 2008).

national reduction goal. Due to the fact, that in practice, all areas differ strongly from each other, quality aspects of an area and the legal framework will be important. Only if all restrictions of the planning law are considered, the sufficient conditions of trading a homogeneous good will be fulfilled. Hence, having enough certificates is only a necessary condition when planning to develop new areas in a municipality.

The introduction of a TDC system makes further additions to §1 Abs. 3 BauGB of the German urban land-use planning law necessary (Köck and Bovet, 2008a, p. 108). Municipalities have to submit certificates for a local land development plan to become effective. Furthermore, the availability of certificates has to be ensured during the design of land utilization plans (§33 BauGB). For the development of new recreation areas, development certificates are necessary, whereas no certificates are necessary for the transformation of recreation areas into areas for settlement or commercial purposes. Therefore, Böhm et al. (2002) suggest to exclude these areas from the obligation to submit certificates.

For the development of inner areas, no certificates are necessary. A building plan already exists or a new development plan is not necessary according to §34 BauGB. Furthermore, Köck (2005) argues that with the cancellation of a development plan, additional certificates can be credited to the municipalities. Shrinking municipalities, which had offered too many new areas in the past that have remained unused, could cancel their development plans and sell the certificates at the market. The main prerequisite in the course of this process is that the respective settlement and development areas are unsealed or become unsealed again. Further exceptions could be made for regional facilities (e.g. universities, hospitals) that have to be developed by local authorities for subordinate purposes. Either would municipalities get additional certificates, or no certificates were required for the development of those facilities. Because these areas are only a very small proportion of the total development, Böhm et al. (2002) also suggest to exempt these areas from the obligation to submit certificates.

Tietenberg (2003) emphasizes that a certificate system works more efficiently when the environmental resource and the linked certificate are homogeneous. In the case of heterogeneous goods and regional differences among the market participants, regional specifics have to be taken into account when designing the new environmental market (e.g. Harrison and List, 2004; Wossink, 2004). Concerning the land usage, a differentiation of the market and different types of certificates could be useful if the utilization of different areas, respectively the environmental resource, is heterogeneous. In contrast, universal certificates legitimate the development of all area types or specific areas (e.g. residential, commercial or traffic areas). Furthermore, the design scheme can be adapted to the specific area type in separated markets. The major drawbacks of these submarkets, especially small regional submarkets, are efficiency losses with regard to the overall reduction goal in comparison to larger markets. For a well functioning market, an appropriate number of market participants is necessary. For example, the abuse of market power can lead to market failure in an illiquid market. Additionally, the more actors are participating in the market, the more cost savings are possible.

2.2.2 Allocation Rules for the Primary Allocation of TDCs

For the allocation of the certificates to the market participants different types of auctions, free allocation or hybrid approaches (so called semi-auctions) can be applied regarding regional characteristics. A free initial allocation of certificates is more suitable to reduce the political resistance and to avoid additional costs for the market participants, and is being preferred in theory and practice (Tietenberg, 2003). Due to the constitutionality of the German law, most studies propose a free allocation of the certificates (Schmalholz, 2002; Brandt and Sanden, 2003). Other studies argue from a political point of view, but also recommend the free allocation of the certificates (Nachhaltigkeitsbeirat der Landesregierung Baden-Württemberg, 2004; Walz et al., 2006, 2009). These results make the analysis of a suitable allotment formula necessary.

The distribution of the certificates is based on certain reference values that might change over time. An allotment formula is used for the initial allocation of the certificates and determines the potential winners and losers in a market for tradable development certificates. It is essential for the acceptance of the new policy instrument that the involved parties perceive the primary allocation as well as the trading rules as fair.

Many studies deal with questions of how to design an appropriate and fair primary allocation and how to allocate the certificate between the federal and federal states levels (Henger and Schröter-Schlaack, 2008; Henger et al., 2010; Walz et al., 2009; Ostertag et al., 2009). Bizer et al. (2008) emphasize that the allotment formula of the primary allocation should be easy to determine and monitor in order to support a practical application by the administration. Additionally, it should comprise the main factors that reflect the prospective floor space of the municipalities. However, the unanimous opinion amongst all studies is that the actual or predicted demand for floor space should not be included in the formula in order to bypass the recompense of a profuse land usage and to avoid counterproductive incentives. Köck et al. (2008) emphasize that the criteria should reflect the demand for new areas to be in conformity with the legal framework of the urban land-use planning (for the municipal process of land-use planning see BVerwGE 64, 33, 35).

Furthermore, a combination of different criteria for the primary allocation is possible (see Krumm, 2001 and Michaelis, 2002). The allotment formula should be easy to calculate and the collection of data must be feasible for practical usage. For the allotment formula, different indicators have been discussed in the literature. Jakubowski and Zarth (2003) propose the combination of the two criteria *local subdistrict area* for the determination of a basic endowment and *population* as a criterion for the demand. Municipalities with an increasing population should receive more certificates in order to cover the demand. Due to the fact that the proportion of settlement and traffic areas on the subdistrict area is lower in urban regions, the criterion local subdistrict area can be seen as a more ecological criterion. A problem of this approach is that the prognosticated population growth is difficult to verify and could be easily overestimated by the municipal representatives in order to benefit during the allocation process.

Henger et al. (2010) consider *population* and *district area* of a municipality as suitable criteria for the allocation of certificates. The higher the population and the district area of a municipality are, the more certificates it would receive. In contrast, surveys with field experts have shown that the district area is not perceived as a fair criterion for the primary allocation (Ostertag et al., 2009). Rather, the authors suggest to include the criterion *guidelines and targets of the regional planning* instead of *district area* into the allotment formula because it was considered as being more important by the field experts.

One problem connected with the distribution criteria can be the existence of *early actions* that describe initiatives of states or local authorities, which have already reduced the development of new settlement and traffic areas. In the emission trading scheme, an additional number of certificates is allocated to compensate actors in such situations

(National Allocation Plan, p. 43). Based on the equal treatment principle postulated by Art. 3 GG, a similar procedure in a system with TDCs is conceivable. Municipalities that initiated the recycling of inner areas, the implementation of systems for land use management (e.g. fallow land register) or participated in environmental programs would get additional certificates. However, the evaluation of early actions is complex in the context of land development and difficult to realize (Köck et al., 2008, p. 10).

The discussion emphasizes that the allocation rule should combine economical, ecological and social aspects. A measure that addresses economic aspects could also be the fraction of *population* over *settlement and traffic areas* as this measure gives an incentive to build denser areas. In addition, a positive effect on the infrastructure costs is likely when improving the floor space per capita (see Section 3.1). The proportion *nature protection area* of the open space provides an ecological measure that gives incentives to protect open space. By means of this proportion, the ecological sustainability of a municipality is evaluated. In the extreme case, the total open space consists of nature protection areas and no further development of new settlement and traffic areas is possible. In order to measure population dynamics, *historical population growth* could be used. By considering this social measure, the allocation of additional certificates to hotspots, in which the population has increased in the recent years, can be realized. A combination of these three criteria can address economical, ecological and social aspects when allocating certificates.

2.2.3 Secondary Market

The trading rules also define the secondary market. In a secondary market, the market participants can trade certificates on an exchange during a specific time period. In environmental markets, the double auction is used as an auction procedure (e.g. EPA's emission trading auction; Stavins, 2003). Usually, the pricing in this secondary market takes place continuously, which can induce price fluctuations. According to economic theory, the design of the primary market should not affect the efficiency of the trading system in the secondary market. If the initial allocation results in a misallocation, the secondary market should correct this situation and reallocate the certificates to the 'right' municipalities. The design and the trading rules of the secondary market can influence how fast the market can achieve a market equilibrium, in which no additional transactions can enhance the efficiency. To facilitate trading of development certificates, the federal states or the federation could implement such a secondary market in form of a stock exchange for the new certificates. The municipalities could receive information about the current certificate price and could enter buy and sell orders on this central market place.

It is likely that few submarkets with many participants are more liquid than few submarkets with only few participants (Section 2.3.1). The liquidity of this market is also influenced by the number of the participants trading on the market and the validity of the certificates (Bizer et al., 2008): For instance in a five year time period, if the validity of certificates is only one year, the municipalities will tend to trade in five years more often than in a scenario in which the certificates' validity is five years and wherein the available certificates can be used to legitimate the land development in the total time horizon. However, this fact implies that saving certificates for later use (Banking) or the usage beforehand (Borrowing) should be not allowed. Banking and borrowing of certificates enhances the flexibility of the trading schemes and can have a significant influence on the liquidity. In order to achieve the environmental targets at minimal costs, the market participants could use the flexibility of banking or borrowing to realize their abatement options in the appropriate planning periods. Furthermore, allowing the banking of certificates can reduce price fluctuations and can lead to earlier reductions of the resource usage (Ellerman, 2005).

As an additional mechanism to the continuous double auction, Bizer et al. (2008) discuss a bilateral exchange of certificates. In this model, municipalities have the possibility to choose how to transfer the certificates among each other. If the transactions costs of the bilateral exchange are higher, the market participants will prefer to transfer the certificates on the exchange instead of conducting bilateral trades.

The drawback of a free certificate allocation is the subsequent lack of price information in the secondary market. When the municipalities trade few certificates in that secondary spot market, the price is susceptible for any kind of external effect. Therefore, Bizer et al. (2008) propose a hybrid model in which only a limited proportion of the certificates is allocated for free (Figure 2.1). The remaining certificates are auctioned which generates price signals for the secondary market. In an auction the government would offer an amount of certificates in a region and the local municipalities would be able to

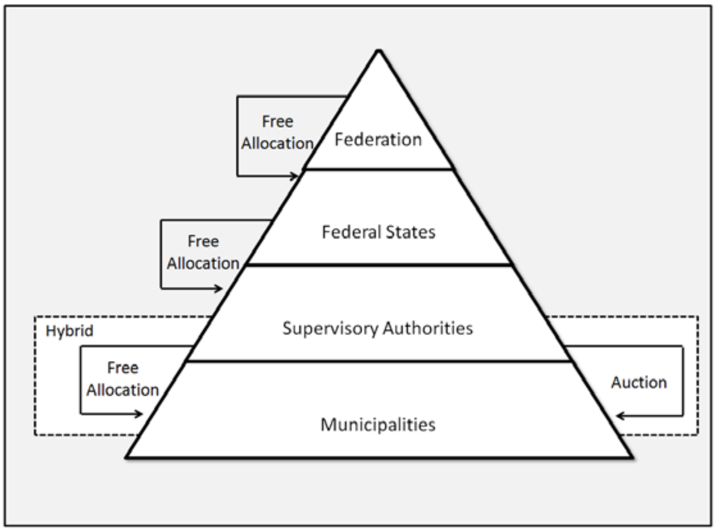

Figure 2.1: Hybrid Allocation Model (Bizer et al., 2008)

purchase the certificates. An advantage of this hybrid auction system is that municipalities which suffer from specific allocation rules still have the possibility to purchase certificates through the auction. Therefore, the hybrid model could cushion the distribution effects caused by a specific allotment formula of the free allocation. However, the auctioning requires additional financial resources from the municipalities.

2.2.4 Market Participants

From an economic perspective, it is desirable to establish a liquid market with many participants. Independent of the type of market differentiation, it is important to ensure a minimum number of market participants in order to achieve a cost-efficient solution of the overall reduction goal. In a market with many participants, market power and inefficient market prices arising out of monopoly situations are less likely. Therefore, the size of the market is an important aspect of the design. The smallest entities, which can decide to develop new areas, are the local municipalities. They are entitled to use new areas by realizing building plans. If the abatement costs differ between the market participants, efficiency gains by introducing a market-based system are possible. Furthermore, wrong price signals might cause some municipalities to sell certificates, even though the usage of the certificates for new areas would be more beneficial from the overall perspective. In a market wherein the market price reflects the marginal abatement costs, these negative effects will be excluded or at least reduced.

In addition to the municipalities, other actors or persons (e.g. broker or investors) could be given access to the market in order to increase the market liquidity. However, opening the market to other interest groups will bear the risk of the emergence of market participants who are guided by other goals (e.g. speculative trading that cause fluctuating market prices) than initially intended. Discussions at the Spiel.Raum workshops (see Chapter 5) strenghten the concerns of local representatives about a fluctuating certificate price that may influence their certainty for planning. To provide access to more market participants, a so-called opt-in regulation could also be applied. Thereby, possible influences of private investors that could enter such a system in the course of time have to be considered. The expectation of rising certificate prices, fostered by the shortage of certificates, can lead to speculative trade by private investors on the market.

Individual decisions at the market place need to be weighted by the market participants depending on the actual market situation. In order to make appropriate decisions, for example to buy or sell certificates at the right time, it is necessary to observe the market over a long time period. Even without the existence of a market for land usage, municipalities face many decision problems, for instance choosing a proper development plan. However, the number of tools to support development decisions and data management of municipalities in Germany is limited. Moreover, in most municipalities the personnel has no economic background to be able to deal with planning tools or extensive economic decision support systems (see Chapter 4). Therefore, it needs to be analyzed whether private brokers can assist municipalities when a market for development certificates exists. Nevertheless, both, assisted and unassisted municipalities, have to integrate the new instrument into their decision processes and the regional land usage plans (see Chapter 3).

2.3 Institutional Aspects of a Cap-and-trade Scheme

In this section, the main institutional requirements for a system of tradable development certificates in Germany and the consequences for the market design are presented. In the last years, several studies have analyzed different design aspects of a cap-and-trade program for land-use control in Germany (Hansjürgens and Schröter, 2004; Walz et al., 2006; Köck et al., 2008; Walz et al., 2009; Henger et al., 2010). Some of the basic design questions that arise during the implementation of such a system from different perspectives are discussed. This includes a possible differentiation of the market, defining the reduction goal and other aspects of the constitutional framework, which arise when introducing such a scheme in Germany. The constitutional framework requires the scrutinizing of legislative competences, the municipal right of self-administration and the constitutional property guarantee of property owners.

2.3.1 Market Differentiation

The most widely debated issue in the discussion of the new instrument is the definition of the market and on which institutional level a cap-and-trade system should be implemented (see Walz et al., 2006; Henger and Bizer, 2008; Walz et al., 2009). In a nation wide system, the market in Germany would include all 11,448 municipalities, which seems to be a sufficient number of participants. The design of tailor-made submarkets with municipalities and their region-specific characteristics, for instance a different geographic situation or population growth, is possible. In a nation wide system these possibilities for differentiation are missing. However, the more submarkets there are, the fewer participants will trade in the single submarkets. Within each market, the goods are homogeneous, so that the municipalities can trade any desired certificate between each other within a submarket.

Bizer (1996) proposes a differentiation of the TDC market by federal, spatial or land-use criteria. A market differentiation that is based on the federal structure would refer to the political structure in Germany and establish separate markets for the individual states or administrative districts. Henger and Bizer (2008) argue that such a model is only appropriate when a low liquidity within the market is expected, and propose a zonal permit system with different markets depending on spatial or land-use criteria.

Splitting the market based on spatial planning aspects (spatial differentiation) is another possibility for a differentiation of the market. Based on spatial criteria (e.g. population density, size of the municipality or soil parameters), separate markets can be implemented for different geographic areas. By a TDC system, individual qualitative land use targets can be specified for different regions, so that a land development in environmental hot spots and specific regions can be addressed. Similar to the municipal financial compensation system already implemented in Germany, a cap-and-trade system differentiated by spatial criteria could balance the land use of growing and shrinking regions. Shrinking municipalities could profit from the system by selling their surplus certificates on the market. It is conceivable that more certificates will be emitted in congested urban areas with a high land growth because a higher land development in the future can be expected.

A differentiation of the market by land-use criteria distinguishes between the different area types. An example is the differentiation between certificates for commercial and residential purposes, or a differentiation of the certificates related to the development of settlement and traffic areas. However, the difficulties with such a zonal differentiation are high transaction costs for the regulator and the definition of appropriate individual reduction goals (Henger and Bizer, 2008).

Another division of the market can be achieved by time differentiation. On the one hand, the time horizon of a planning period should be long enough to cover the spatial planning processes, which normally last about five years. On the other hand, the time horizon should not be too long (max. 15 years) to signal a shortage of certificates. Further critical design parameters within this context are the durability of the certificates and the transferability into other planning periods, which have been discussed in Section 2.2.3.

2.3.2 Legal Aspects

A cap-and-trade system includes the setting of a reduction goal and the implementation of a trading system. An analysis how such a system might fit into the legal framework and federal structure in Germany has been done in many studies over the last years (see Bovet, 2006; Senftleben, 2008; Köck and Bovet, 2008a). Figure 2.2 shows the administrative structure in Germany that consists of 16 federal states. The 11,448 municipalities are assigned to 413 administrative districts. The implementation of the new cap-and-trade system requires the breakdown of the national reduction goal to regional levels and the integration of the trading scheme into regional planning laws. For each component, a competence in the constitutional law has to be identified. Moreover, the regional planning is coordinated by regional associations that are organized very differently in the federal states.

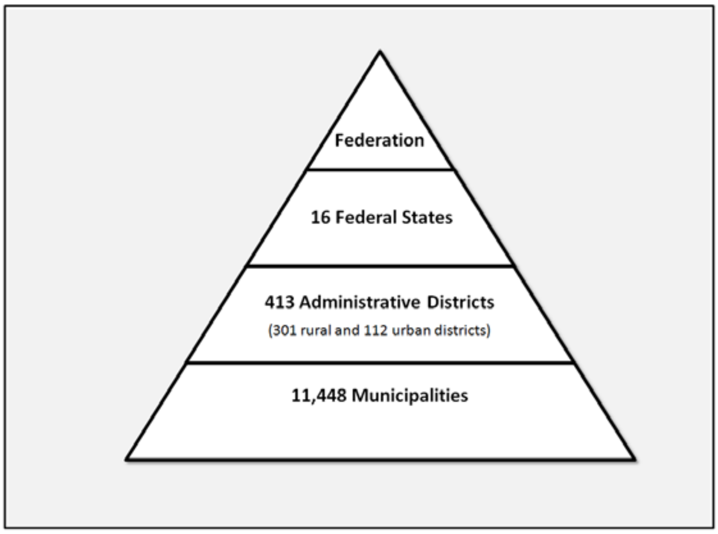

Figure 2.2: Administrative Structure

The German constitution confers legislative powers on the federal states (Art. 70 Abs. 1 GG). Furthermore, the constitutional rights of the federal states were amended through the federalism reform of the German Basic Law in 2006. As a result, the legislative power of the federation is further limited and divided into exclusive competence and concurrent competence (Art. 71 and 72 GG). The scopes of exclusive competence and concurrent competence are listed in Art. 73 and 74 GG. The federation would need exclusive competence to introduce the new instrument. However, in the legislative program of the exclusive competence, there is no statue for the implementation of a national cap-and-trade system for land development.

The jurisdiction *land use planning* could be used to legitimize the implementation of the cap-and-trade system and refers to the "aggregated superior planning and organization of space" (BVerfGE 3, pp. 407, 425; see Bovet, 2006, p. 477). However, jurisdiction was amended through the federalism reform and belongs to the concurrent competences of the federal states (Art. 74 Abs. 1 Nr. 31 GG). Whether or not other extraordinary legislative programs can be used is discussed very controversially (Ritter, 2006; Kment, 2006; Schmitz and Müller, 2007; Durner, 2009). Due to the fact that a national cap-and-trade system sets superior binding reduction goals to guarantee a sustainable land development, the jurisdiction land use planning can be used to legitimize the new policy instrument (Brandt and Sanden, 2003; Bovet, 2006, p. 477; Senftleben, 2008, p. 66). In the interest of a sustainable federal land development and planning, the federation can set binding reduction goals as a guiding principle for the planning in subordinated local authorities. A cap-and-trade system limits the development of new settlement and traffic areas initiated by local authorities and the municipal planning competence, but would not further restrict the building law §34 and §35 BauGB.

If the federation bases the system on this jurisdiction, the federal states are authorized by concurrent competences to implement deviating regulations (Art. 72 Abs. 3 Nr. 4 GG). The federal states can differ in their constitutional law for nature protection and spatial planning based on concurrent competences (Art. 72 Abs. 3 GG). Thus, the federation has to negotiate the guiding principle with the federal states to prevent deviations. Due to the fact that the negotiation process with all federal states for a Federal Law seems rather difficult, Köck and Bovet (2008a) consider the implementation of a *Federal States Model*, wherein the federal states set individual reduction goals, compared to a *Federal Model* as more likely. Therefore, the definition of national or regional reduction goals for land consumption and the implementation of a trading system will only be feasible if the federal states facilitate the introduction of the certificate system. An exclusive competence for the federation does not exist and the legal certainty of the trading system can only be guaranteed by a constitutional court decision (Köck and Bovet, 2008b).

The German constitution assures municipalities the own administration and regulation of local concerns (Art. 28 Abs. 2 Satz 1 GG). According to the constitution, municipalities have the planning competence for their area and can manage the municipal development as well as the intensity of the land usage in the long run. For this purpose, municipalities are authorized to specify the procedures and details of planning new buildings, as well as to set standards for the development of new areas (BVerfGE 56, 298 (310)). However, the planning competence is not unlimited and can be restricted by federal or state laws (BVerfGE 79, 127 (146)). For instance, the urban land-use planning has to correspond to the regional and land use planning (§1 Abs. 4 BauGB). By allocating an amount of certificates, the development of new settlement and traffic areas would be limited. Thus, a cap-and-trade scheme for land usage defines a cap for new land development and trenches on the planning competence of the municipalities.

Nevertheless, many studies argue that the TDC system is compatible with the basic planning competence of local authorities (Brandt and Sanden, 2003, p. 95; Unnerstall, 2004, p. 256). A cap-and-trade scheme for land usage only limits the total amount of new settlement and traffic areas and not the design of land development areas or the main scope of local land-use decisions (the scope of land-use decisions will be described in Chapter 3). Although the trading system increases the price of new land development, it ensures the planning flexibility of local authorities and does not directly intervene in the planning competence. The individual endowment is not a fixed cap for the individual development of new settlement and traffic areas. Rather, municipalities can use the flexibility of the trading system and buy additional certificates or sell surplus certificates on the market. Furthermore, based on public interest orientation, the need to protect the natural resource soil, or open space, justifies the restriction of the communal planning scope and activities in the interest of future generations (Unnerstall, 2004, p. 257). An implementation of the cap-and-trade system is also justified on the basis of the proportionality principle, due to the fact that more moderate instruments, for example the protective clause for open space (§1a Abs. 2 BauGB), are less appropriate for the achievement of objectives and have proven to be ineffective in practical use.

The German constitution includes a constitutional property guarantee to protect property owners and the possibilities of their property use (Art. 14 Abs. 1 Nr. 1 GG). In a TDC system, the provision of new building land is connected with the availability of certificates and also influences the rights of the property owner (Senftleben, 2008, pp. 69–70). In order to protect the natural resource basis (Art. 20a GG) and to support a sustainable land usage, Senftleben considers the quantitative restrictions on land development as proportionate.

When the certificates are allocated freely, a high financial burden for the municipalities can be avoided, and each municipality is able to realize a basic development without additional costs (Sachverständigenrat für Umweltfragen, 2002; Unnerstall, 2004). In this respect, a cap-and-trade solution is more favorable for local authorities than a solution with duties, levies or taxes wherein the local municipalities have to make additional payments. Köck and Bovet (2008a) emphasize that the allocation must take into account the additional demand of some municipalities. In this context, the identification of appropriate distribution criteria and the implementation of exemptions are necessary (see Section 2.2.2).

2.3.3 Regulatory Choice Problem

Bizer et al. (2008) discuss the regulatory choice problem, which consists in determining regional objectives according to the national objective. The main challenges are the decomposition of the national objective in land use and the analysis of regional differences and congruencies on the basis of the regional policy network. The realization of the targets set by the federation and the federal states is the subject of investigation in many studies (Hansjürgens and Schröter, 2004; Walz and Küpfer, 2005; Henger and Schröter-Schlaack, 2008). Due to regional differences, certain implementation problems arise when choosing the institutional arrangement. It is important to determine which political subdivision (federation, federal states, regions/administrative districts, municipalities) determines a specific land use restriction. Although the federal republic sets a national objective, the actual implementation of such a system would be the task of the states and the municipalities. A supervisory authority is responsible for setting the targets to limit the land use, but the municipalities are responsible to translate this into action. According to the principle of local self-government in the German constitution, municipalities have the planning competence for their area (Section 2.3.2).

Therefore, the decomposition of the national objective and the allocation of the TDCs to the federal states and regions is another challenge. Table 2.4 depicts some models for the institutional design of the cap-and-trade scheme. The table shows on which level of the federal structure a specific target will be set, who the market participants are and if the trading system is implemented on the national or federal states level. The models are named after the institution which sets the final environmental goal for the local authorities (e.g. in the States Models the federal states set the binding reduction goal for municipalities and not the federation).

Walz and Küpfer (2005) discuss the installation of some of these national, federal states and regional models for TDCs. The Federal Model is a top-down approach, in which the federation sets a national reduction goal and breaks down the goal to the

Model	Federation	Federal States	Administrative Districts / Regions (301)	Municipalities (1148)	Trading System
Federal Model I	**National Target**			**Market Participants**	National Level
States Model I	**National Target**	**Federal Target**		**Market Participants**	National Level
States Model II	**National Target**	**Federal Target**		**Market Participants**	Federal States Level
States Model III	**National Target**	**Federal Target**	**Market Participants**		National Level
States Model IV	**National Target**	**Federal Target**	**Market Participants**		Federal States Level
Regional Model I	**National Target**	**Federal Target**	**Federal Target**	**Market Participants**	National Level
Regional Model II	**National Target**	**Federal Target**	**Federal Target**	**Market Participants**	Federal States Level

Table 2.4: Allocation Models

underlying institutions. Certificate trading takes place within a national trading system that comprises all local authorities in Germany. The federation sets local reduction goals and allocates the certificates directly to the local authorities or municipalities (Federal Model I). The advantages of the system are the direct application of a standard allotment formula for all municipalities and the high number of market participants. However, the direct allocation has the major drawback of disregarding regional and spatial specificities of municipalities (see Section 3.1). Another possibility is that the national reduction goal has to be broken down to the federal states (States Model I). In this case, the states are responsible for setting the specific reduction goal, which the municipalities (the market participants) have to meet. A higher acceptance of the cap-and-trade scheme can be expected because the federal states can set reduction goals in specific regions or municipalities. Moreover Walz and Küpfer discuss a federal states model (States Model II) wherein municipalities can trade only within a federal state. However, due to the efficiency gains of the cap-and-trade system, Walz and Küpfer recommend the implementation of a national market. Nevertheless, since the federalism reform has strengthened the legislative power of the federal states, federal states models have become a subject of discussion (see also Köck and Bovet, 2008a). Legislative aspects will play an important role if the federation imposes binding goals on the federal states and if a trading system should be implemented.

Studies have analyzed regional differences that have to be taken into account when setting regional targets or reduction goals for the federal states. Hansjürgens and Schröter (2004) discuss how the federal states can allocate the certificates on the regional level. Based on the regional building law, the federal states can allocate the certificates to the region planning level. In these models, the final allocation of the certificates to the municipalities would be the task of the regional planning. Hence, the reduction goal is set by the administrative district or a supervisory planning authority. Depending on which institutional level the trading system would be implemented, two different types are possible (Regional Model I and II). Köck and Bovet (2008a) emphasize that the implementation of such models is less practicable and requires more legal adjustments than the direct allocation of the certificates. An advantage of this models is that the regional council can also take communal interests into account, which might facilitate the acceptance of the new instrument (principle of counterflow). However, it remains unclear if and how the regional council, which comprises communal representatives, is able to negotiate the allocation of certificates as well as fair allocation rules.

Two further models in which the market participants are the regional planning authorities are conceivable (Federal States Model III and IV). In these models, the superior authority is responsible for the trading and receives a basic budget to support the trading, auctioning and the implementation of planning tools. The drawback of this modeling is that the local authorities have to negotiate the land development plans with the respective supervisory authority and are not able to buy or sell certificates directly at the market. A data collection phase is necessary wherein the local authorities develop regional land development plans. In case a municipality is not willing to coordinate the development plans, the achievement of intended regional reduction goals is not possible and a renegotiation of the reduction goals between the federal states and the regions is necessary. Hence, high additional administration costs might appear if such Federal States Models will be implemented.

Model	# Market Participants	Compatibility with Interests of the Federation	Compatibility with Interests of the States	Compatibility with Interests of the Regions	Compatibility with Interests of the Municipality	Compatibility Constitutional Law
Federal Model I	high 1148	high	low	low	medium	low
States Model I	high 1148	medium	high	low	medium	medium
States Model II	medium 456*	medium	high	low	medium	medium
States Model III	medium 301	medium	high	medium	low	medium
States Model IV	low 17**	medium	high	medium	low	medium
Regional Model I	high 1148	low	medium	high	medium	high
Regional Model II	medium 456*	low	medium	high	medium	high

* average number of municipalities in a federal state
** average number of regions in a federal state

Table 2.5: Own Assessment of the Allocation Models

Table 2.5 compares the different models by evaluating the compatibility with the interests of the involved institutions, the number of the market participants and the compatibility with the German Constitutional Law. The advantage of Federal Model I, States Model I and the Regional Model I is the high number of market participants because a nation-wide trading system is implemented. In contrast, the low number of market participants is a drawback of the States Model IV wherein on average 17 districts would trade on a federal states market. The Federal Model I seems to be more compatible with the interests of the federation because no reduction targets have to be negotiated with the federal states, in contrast to high additional administration costs in the regional models. From the perspective of the federal states, the four states models seem to be appropriate. The federal states are able to set individual targets for regions and municipalities. Against it, regions and local districts could prefer the regional models. From the perspective of the municipalities, the States Model III and IV might be evaluated as inapplicable because negotiation with the superior planning authority is necessary and no direct transfer of certificates is possible.

The table points out that the more institutions are involved in the cap-and-trade scheme, the more individual interests can be considered. Hence, regional models ensure the highest compatibility with the German Constitutional Law by considering planning aspects from the regional planning authority as well as interests of the federal states. However, as mentioned above, this also results in higher administration costs. The table indicates that the states models and the regional models are more compatible with the interests of the involved institutions than the federal model. These models might guarantee a high acceptance of the new instrument and seem to be an appropriate approach to solve the regulatory choice problem. The table also indicates that the states and regional models have some pros and cons. However, arguing from an economic perspective, the Regional Model I and States Model I are beneficial due to the fact that they include a high number of market participants. In contrast arguing from a legal perspective, the Regional Models I and II are more appropriate because they are more compatible with the German law.

Köck and Bovet (2008a) also discuss various distribution criteria to break down the national goal to the federal states or local authorities. The federation calculates the necessary reduction for each underlying institution to reduce the total land development to 30 hectares. The procedure is similar to the burden sharing of the national allocation plan in the emissions trading scheme, wherein the member states have an individual reduction goal.

2.3.4 Monitoring by a Supervisory Authority

When introducing a cap-and-trade scheme, further tasks, such as monitoring the land development, arise. At the end of a planning period, the municipalities can use their development certificates to legalize their development plans. A regional development planning authority or a supervisory authority has to examine whether the regional developments are in accordance with the amount of certificates hold by the municipalities to monitor the municipal development. The supervisory authority is a regional planning institution or administrative district that is responsible for the coordination of the municipal land development plans. Furthermore, the federal states can also be interpreted as supervisory authorities due to their legislative power (Section 2.3.2). Another possibility of monitoring the land usage, is the municipal self-checking of the land development combined with a subsequent reporting to the supervisory authorities. Furthermore, a building plan can only be approved (§10 BauGB) if enough certificates are available.

In the case of a discord in land usage, which means that a municipality holds less certificates than required, the supervisory authority imposes sanctions. In the run-up of the certificates trading, the type or degree of these penalties must be specified. In general, sanctions are assessed by looking at the volume of trade affected. Bizer et al. (2008) note that these penalties must be proportionate, dissuasive, effective and admissible in terms of the German law. For instance, sanctions could be about ten times as high as the expected market price. By setting high sanctions, the participants will have incentives to prevent the realization of land development plans without having an adequate certificates coverage.

The advantage of a system with tradable development certificates is that the underlying regulation problem is solved by a market system. To establish a sustainable and efficient market system over time, a proper regulatory framework is needed. As discussed in Section 2.3.2, the regulatory framework has to make sure that the national targets are met. This includes the monitoring of the land development and the imposition of a special administrative penalty when a municipally has not enough certificates.

Both, a supervising authority and a supervised authority, are supposed to integrate the monitoring of the land development in their coordination processes of organization and administration to avoid additional transaction costs for the monitoring. However, monitoring is not only a special issue of the tradable development certificates system, it also would have to be executed if another policy instrument was introduced. To facilitate this task, a supervisory authority can gather information by means of databases for a faster and more flexible data management (see Chapter 4). All development plans would be stored in a central planning tool, which will be managed by a local supervising authority and which provides a comparison of these plans depending on the regional development. Furthermore, by using a specific frontend (calculation tool) to that database, private broker and unassisted municipalities (Section 2.2.4) could get access to the necessary data without knowing the detailed arrangement of specific planning strategies (Figure 2.3). Thereby, the private broker is able to determine appropriate development plans and will buy or sell certificates at the exchange depending on the current (or possible) market prices.

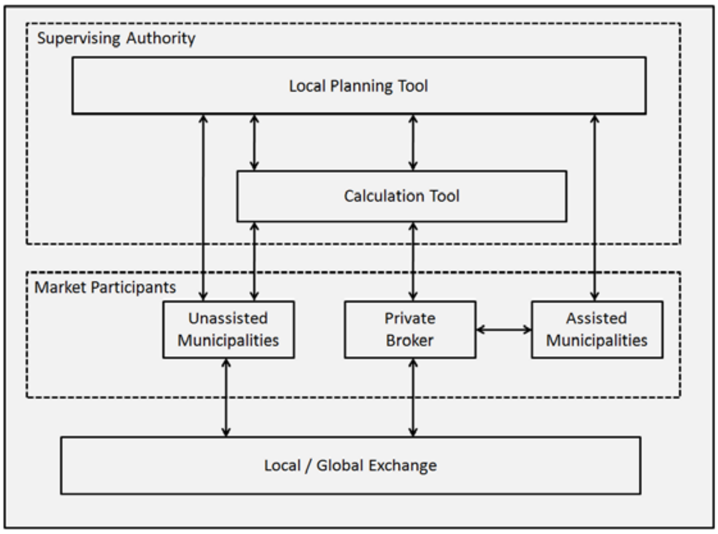

Figure 2.3: Market Participants and the Supervising Authority

2.4 Summary and Discussion

A system of tradable development certificates is a promising instrument to reduce the land usage in Germany. An appropriate design of a policy instrument, including the specialties of the respective policy area, the market design and the institutional design, can affect the success of the instrument in reality and has been discussed in many studies. Thus, different design options have to be carefully investigated before actually applying the instrument in practice. The introduction of a tradable development certificates system could give rise to several legal and other planning policy concerns. However, as discussed in Section 2.3.2, a cap-and-trade system for land usage is compatible with the legal framework currently in place and has to be consistent with the restrictions in spatial planning.

Furthermore, the national reduction goal has to be negotiated with the federal states. Establishing a national or federal exchange is possible by ignoring specific local aspects in regions. The continuous double auction in combination with a primary allocation that is based on an appropriate allotment formula is proposed in the literature as a market mechanism for a TDC scheme. Even when the market is illiquid, the market mechanism might support an effective certificate trading and ensure a fast price discovery process (Bizer et al., 2008). The biggest challenge when introducing a cap-and-trade system is the reliability of the regulatory framework that is responsible for monitoring and sanctioning. In this context, numerous practical challenges must be taken into consideration when implementing such a scheme, regardless of whether a federal states model or a regional model is implemented (Section 2.3.3). In case the position of a supervising authority can be strengthened, the realization of a suitable cap-and-trade scheme for land development is possible. Based on the findings from the last section, the following allocation process for tradable development certificates is proposed (Figure 2.4).[6]

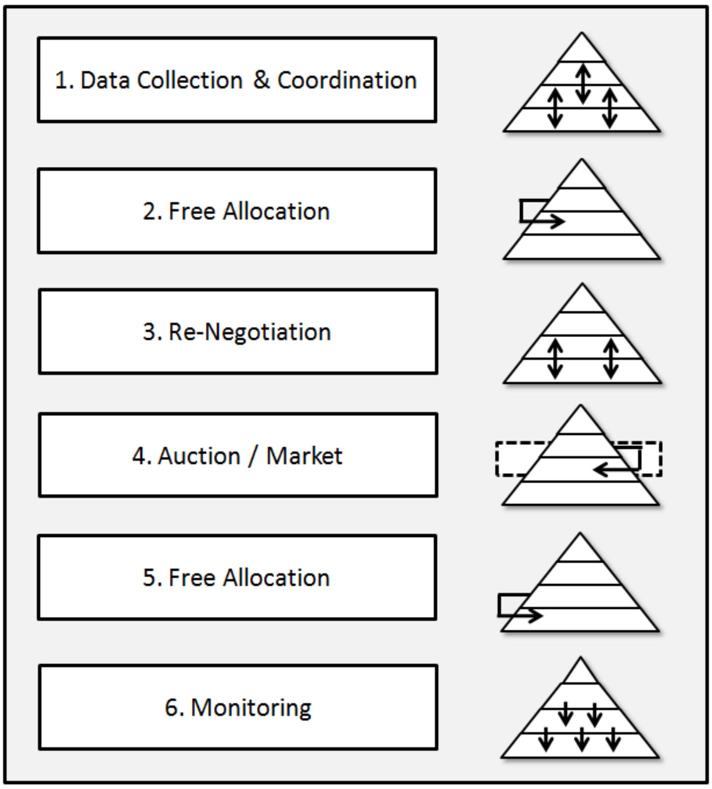

Figure 2.4: Allocation Process

[6]The process is the same regardless of whether a federal states model or a regional model is introduced.

First, the supervisory authority determines the demand for floor space and estimates an individual index for land development for each municipality. This procedure is already carried out by the regional planning institutions in Germany. Therefore, the regional planning institution collects the necessary data and coordinates the land development plans (Step 1). Hence, the superior institutions have to collect data about population, settlement and traffic areas, nature protection areas, and historical population growth in their region. In addition to this, the supervising authorities could also support the trading, auctioning and the implementation of planning tools (Section 2.2.4).

Based on the forecast for new settlement and traffic areas by the regional planning, the federal states could allocate the certificates to the regions (Step 2). Alternatively, the criteria discussed in Section 2.2.2 can be used. Based on basic endowment, the adaptation of land development plans has to be renegotiated (Step 3). In the next step, additional certificates can be auctioned or bought at the secondary market (Step 4). On the basis of the new endowment, further adoptions of land development plans can also be negotiated by repeating steps 3 and 4.

The allocation of the certificates to the municipalities is based on the basic endowment criteria (Step 5). Appropriate criteria for the final free allocation of the certificates would, again, be the combination of economic, ecological and social criteria. Afterwards, the supervisory authority has the task to monitor the land development plans and the municipalities have to hand in the certificates when developing new areas (Step 6).

Before introducing the new instrument, it is necessary for the government to analyze the economic impacts of a specific trading scheme for the involved parties. A system of tradable development certificates is a flexible policy instrument that takes local authority interests into consideration (Bovet, 2006; Senftleben, 2008). Furthermore, the government needs to know how a design influences the behavior of the market participants and the efficiency of the trading scheme. Hence, the incentives and interests of the involved institutions should be analyzed in detail, which is also the focus of the following chapters. It is possible that not every party will maximize its economic benefits due to incomplete information, lack of cost transparency and bounded rationality. The next chapter focuses on the decision making processes of local representatives and the main characteristics of their decision situation. The goal of the chapter is to design a decision framework that serves as a basis for the development of appropriate decision support tools. These tools can also support the data collection steps of the supervisory authority and can play an important role when introducing a cap-and-trade scheme in Germany.

3 Decision Making in Local Land Development

The closing discussion in Chapter 2 has emphasized the need to analyze municipal decision making and the decision situation in order to understand possible implications when introducing a tradable development certificates system. This chapter proposes a decision making framework that helps to understand municipal decisions in order to design appropriate decision support tools for municipal decision makers. Such decision support tools can facilitate the decision making of local representatives even if a system of tradable development certificates is not existing. The tool can also support the municipal and regional data collection and can provide planning assisting tools, as well as additional support tools for a tradable development right system. The implementation of regional planning tools, that accurately reflect all regional characteristics and data, is only feasible if the municipalities facilitate the regional data collection by providing their specific data (e.g. planned population growth or available brownfields) that cannot be collected precisely by other institutions. Whereas this chapter analyzes the municipal decision making, the design and the implementation of a decision support system based on the proposed framework will be described in Chapter 4.

Various participants are involved in the process of land development and have interests that depend on the regional community context and the type of the municipality. In the next sections, characteristics of the decision makers and the timing of decisions in land development within the regions will be presented. For a further description of the municipal decision situation, some municipal structures and their interdependencies in regional networks will be analyzed. A decision making framework will be developed by identifying characteristic dimensions of communities in terms of land usage and other relevant aspects (e.g. structure of the policy network). The structure of the regions is characterized along the following five dimensions: *Political Institution*, *Structure of Policy Networks*, *Structure of Spatial Areas*, the *Demand for Floor Space* and the *Community Context*. Furthermore, it will be discussed how the lack of cost transparency can considerably influence the decision situations, different modeling approaches for the decision situation will be shown, and the resulting *Cost Paradox*, *Development Dilemma* as well as cooperation concepts in land development will be described. The land development dilemma describes a situation wherein municipalities compete for households in a region and negative externalities (spillover effects by moving households and firms) impact the outcomes of the municipalities. As a negative consequence of an uncoordinated land development, municipalities develop more new land than actually demanded. Such a dilemma situation can be solved by introducing municipal cooperation concepts. Hence, a short overview about the research on municipal cooperation concepts will be given in Section 3.4, especially with focus on land development. Such cooperation concepts in land development are joint land development plans that are established between municipalities within a region. Within this context, it will be discussed how different cooperation concepts in land development might be influenced by structural aspects of the region and by incentives of the involved actors as well as their relationships. In the last section of this chapter, it will be discussed how the framework can be applied and how it can be used to combine methods from different disciplines in order to facilitate the transdisciplinary research in this domain.

3.1 Decision Making Framework in Local Land Development

Municipal decision makers determine land development decisions for future time horizons at specific points of time depending on the specific characteristics of the municipalities and regions. The main task of the decision makers is to provide floor space areas for settlement and commercial purposes by realizing development in the inner or outer areas of municipalities in the respective planning period. In the next sections, the different groups involved in the land use process and the timing of their decisions will be analyzed. The necessary properties of the institutions, the individuals, and the main environmental conditions in land development will be described to understand the decision situation and a decision making framework will be proposed. The characteristics of the framework facilitate the analysis of the decision making and the behavior of municipal representatives from different perspectives.

Several approaches for the classification of municipal decision making have been suggested in the literature depending on the particular perspective. Municipalities and regions typically can be differentiated by their spatial orientation, the constellations of political actors, the structure of the regional network, the level of institutionalization and the binding intensity between municipalities. Wilske (2007) mentions that basic aspects with regard to land use situations are the municipal data, such as the population trend or the structure of spatial areas, the spatial position of a municipality, the available development potential and the political framework. The structures of regional or metropolitan networks may influence the likelihood of voluntary solutions for different issues, e.g. regarding a coordinated land development as mentioned in the last section. If the likelihood is low, standardized and centralized solutions seem to be more appropriate for resolving different sets of externalities and interdependencies (e.g. negative effects by an uncoordinated land development). Hence the municipal decision making in the context of cooperation concepts may give insights which aspects have also an influence on the municipal decision situation. Feiock (2007) analyzes the decision making between municipalities in the context of cooperation concepts and proposes a distinction depending on the dimensions political institution, policy networks and community context. More specific, Gawron (2004) focuses on cooperation concepts in land development and distinguishes between dyadic neighborhood-based cooperation, metropolitan cooperation between cities and hinterland, and regional-orientated cooperation that includes all municipalities of one region. Each approach allows a different view on land use decisions and the institutionalization of cooperation concepts discussed in Section 3.4. Based on the approaches from the literature, the five dimensions *political institution*, *structure of policy networks*, *community context*, *structure of spatial areas*, and *demand for floor space* have been derived and will be described in the following sections. The five dimensions reflect the main characteristics of the decision situation from different vantage points within the scope of this book and define a framework wherein land decision of local authorities are made.

3.1.1 Political Institution (Vertical Policy Network)

Municipalities are represented by the elected local officials. These decision makers act in the interest of the municipality, but have also personal interests, which might affect their behavior as representatives. However, the process that leads to land development and land usage (land usage process) is characterized by an interaction of various groups of actors playing different roles (for an overview see Gutsche and Schiller, 2007). Next to individual decisions, coordinated group decisions are also made. Different actors and their specific decisions in this decision making chain make the task and the decision processes in land development even more complex. Wrong incentives or bounded rationality of decision makers can lead to wrong decisions with negative consequences for the municipalities. Depending on individual and institutional interests, local decision makers perceive the decision situation individually different and initiate further decision making processes based on their individual perception (see Kahneman, 2003).

On the one side, municipalities and owners of areas are the providers of areas. On the other side, households and firms are the consumers of areas and make location decisions. Moreover, actors between the two sides, such as project developers, business development agencies, or utility companies with other preferences, complicate the decisions as to where, when and how areas will be developed. Other actors, for instance agencies responsible for social and technical infrastructures or customers who pay for the service provision, are only indirectly involved in the land development, but might be affected by follow-up costs of the land development projects. Therefore, actions within the framework are influenced by many institutional and individual aspects.

In comparison to large municipalities, decision makers in small municipalities usually have limited resources to conduct and monitor a professional spatial planning because they work mainly on a voluntary or part-time basis for the municipality. As a result, these participants have usually no in-depth knowledge in the field of building and construction. Hence, the content of a land development plan that is transmitted to a development office is, in small municipalities, often determined by non-professionals. Therefore, it is possible that established concepts and strategies often will be used without carrying out more detailed fiscal analyses of different development alternatives. Hence, the basis of decision making for the private development offices are drafts of land development plans, construction plans, or municipality development concepts that only insufficiently reflect trans-regional and long-term development factors. The goal of the municipal commissioner is merely to have an affordable, legally covered development concept. The mayor decides in coordination with the local council which development plan is finally carried out by the rural municipality. In many cases, the most simple and easiest way of floor space provision is the development of new land. In urban municipalities, on the contrary, experts who can abstract from the overall development concept and personal motives are usually in charge of developing the basis for decision making.

Therefore, there is not only a strong discrepancy between the knowledge and incentives of the participants acting in municipalities and the possibilities that result out of the usage of innovative methods of modern spatial and urban planning sciences, but also between the interests and motives of the local participants within the framework. The location decisions within the land development planning are a complex process of individual decisions by heterogeneous actors in specific situations. The connection of all individual decisions might cause inefficient settlement structures with high infrastructure costs even in case all involved decision makers act cost-conscious (see Gutsche and Schiller, 2007). An overall planning, supported by a supervisory authority that collect all information and facilitate the decision making of each actor, could solve this problem.

The vertical policy network comprises all policy relationships between municipal decision makers in a municipality, influenced by personal incentives. The structure of the vertical policy network might have a major influence on land use decisions and also on the establishment of cooperation concepts. For instance, if municipalities have successfully developed a commercial area, the establishment of further cooperation concepts (e.g. a coordinated land development regarding housholds) seems to be more likely than in case the past cooperation has failed. In many countries, the state constitutions and the enabling legislation vary between the federal states. Local municipalities are embedded in the institutional framework of the states, but have planning authority over their territory (Section 2.3.2). Within the institutional framework, the elected officials and local administrators may establish collaborations with other municipalities for the coordination of land development in a region. The executive of the municipality can initiate and propose collaboration projects, but the city council has the function of a veto player in the political system (Tsebelis, 2002). Thus, before finalizing land development plans or fostering intercommunal cooperation, a council approval is necessary. If the council is elected with a high majority of votes, it is likely that the council has the same interests as the executive and that the executive gets an approval (Clingermayer and Feiock, 2001). Dissimilar interests between elected and non-elected officials can have a strong impact on the collective actions of an authority within its metropolitan area or region. Furthermore, agreements with neighboring municipalities often imply that local officials give up some power. Thus, strengthening a regional coordination of municipalities reduces the independence of municipalities and involves the risk for politicians that agreements are contrary to the interests of the local population. If the agreed regional policies and the preferences of the district constituent are different, it is difficult for municipal representatives to weigh up the benefits of the regional agreement and the risk of losing votes at the next election. Internal conflicts resulting from vertical interdependencies and diverging political priorities in the decision making chain can hinder or slow down the realization of intercommunal cooperation in land development.

Since cooperation in land development is usually a long-term agreement, short election cycles of the local representatives can influence the time horizon of a collaboration. Short-term gains from not coordinating the land development could be more important for local leaders than the benefits from a repeated cooperation in the long-term. The longer the terms of office for elected officials and administrative authorities are, the less selective benefits exist and the more likely are intercommunal agreements. Therefore, personal interests, like individual career incentives, can decisively influence the behavior of local officials and the decision as to whether entering into collaborative arrangements or not (McCabe et al., 2008). Although elected officials are mainly responsible for their own constituencies, decisions in land usage can also influence other regional constituencies. For example, if one municipality can attract households from neighboring municipalities by providing attractive building areas, a crucial effect on residential location decisions from other constituencies is possible. Hence, it is necessary to also have a closer look at the network relationships between municipalities (the horizontal policy network) and the structure of the regional policy network.

3.1.2 Structure of Policy Networks (Horizontal Policy Network)

Horizontal network relationships between neighboring municipalities with regard to a joint land development are typically voluntary and self-organized in Germany. Usually, relationships and agreements about land development form a complex regional structure, in which local decision makers act in a social network (Thurmaier and Wood, 2002). In large networks, the credibility of commitments is enhanced by receiving more information about the other municipalities' local policies, programs, and implementation problems (Feiock, 2009). Many European and American states enable local municipalities to enter or exit agreements without being reviewed or monitored by a supervising or coordinating agency. Thus, network agreements on regional and intercommunal land development can reduce the likelihood of uncoordinated land development plans by means of reputation, reciprocity, and trustworthiness. Moreover, political institutions and local decision makers with similar values, norms, and beliefs, called *Institutional Homogeneity*, tend to cluster each other in a specific region (Carley, 1991). Consequently, agreements about land development are more likely if representatives share similar interests.

The establishment of an appropriate joint land development plan in a region and the implementation of a regional decision support system requires information about the land development plans and the structure of the spatial areas in all municipalities. For the collection of the associated spatial and financial data a broad access to private information (e.g. the calculated costs and incomes of a land development plan) of municipalities is necessary to design a regional land development plan (see Section 3.4). The provision of crucial data and information about the costs or profits of planned development areas requires a high level of trust between the involved parties. Weakly-tied networks can offer solutions to coordination problems and strongly-tied networks can enable trust and credible commitment (Feiock, 2007). In both cases, the transaction costs of a joint action in land usage can also be reduced. Especially in strongly-tied or reciprocating networks, the incentive for free-riding or defecting from a cooperation is less present as municipalities receive information about the efforts and behavior of the other municipalities. Lubell (2007) has shown that strongly-tied relationships can increase mutual trust and the likelihood of compliance with the agreement when the relationship lasts over a longer time period. Municipalities can benefit from having a positive reputation and can use it as social capital for future negotiations in their network.

Feiock (2007) has shown that voluntary coordination mechanisms are mainly found in metropolitan areas with high fragmentation and complex institutional networks. The fragmentation of service responsibilities between country governments, agencies, and districts characterizes networks in metropolitan areas. Within these networks, decisions made by one community influence incomes and costs of others. The more complex such a network is (e.g. in regions with many municipalities), the more suitable are self-organizing coordination mechanisms with low transaction costs instead of complex standardized solutions (Section 3.4). By generating economies of scale in land development and internalizing spillover effects (e.g. negative externalities such as unused areas), the success of interlocal agreements between few municipalities can trigger collaborative agreements with more municipalities, which results in additional benefits by more efficient land usage for a region (Einig, 2003). These negative spillover effects are mainly influenced by the geographic position of municipalities in a region and the types of municipalities that are defined by the specific community context in a region.

3.1.3 Community Context

The community context of a municipality can be described by the spatial centrality, the level of integration into the regional network, and the distance to important central industry or commercial areas. The specific community context might influence the intensity of negative spillover effects of the uncoordinated land development, the suitability of intermunicipal cooperation concepts and the possible gains from cooperation by reducing the total new land development and urban sprawl. Feiock (2009) argues that homogeneity between the municipalities is important in order to establish intermunicipal cooperation. Agency costs for officials acting on behalf of citizens and the effort to aggregate the preferences of all actors are higher in heterogeneous municipalities. Studies in the area of metropolitan governance propose a classification of municipalities and institutions with similar characteristics by means of a cluster analysis (Siedentop, 2005; Wilske, 2007). The studies characterize municipality types by identifying relevant socio-demographic and structural residential criteria of municipalities. The main indicators for the clustering of municipalities are population density and age structure, centrality in terms of labor, population and employment dynamics, prosperity and tertiary education.

Figure 3.1 shows four municipality types and their relation to some municipal indicators as well as migration processes between these municipalities (the classification is derived from Siedentop, 2005). Municipalities in suburban and commuter areas (Types 2 and 3) are characterized by a high level of tertiary education. Young households, middle class households and socially mobile persons searching for building land are responsible for a disproportionate rise of prosperity and a decreasing average age in suburban municipalities. Employees, who use the increasing transport infrastructure, do not have to live close to their work place and can settle down in these areas. Due to the suburbanization and urbanization processes, the population and employment dynamics are higher in more central municipalities and city centers.

In many central cities (Type 1) a so called counter urbanization can even be observed. Counter urbanization means that the population moves away from urban areas into new smaller municipalities in rural areas or into other urban areas. Nevertheless, central cities in metropolitan areas have the highest level of centrality in terms of the labor market and a high population density. On the contrary, municipalities in rural areas (Type 4) tend to have a lower population density and an old age structure, and are characterized by less prosperity and low tertiary education. Only when a rural municipality is in closer distance to working facilities, a positive population growth is probable (Type 3). These commuter towns are primarily residential and can also be seen as peripheral suburbs of a nearby metropolis.

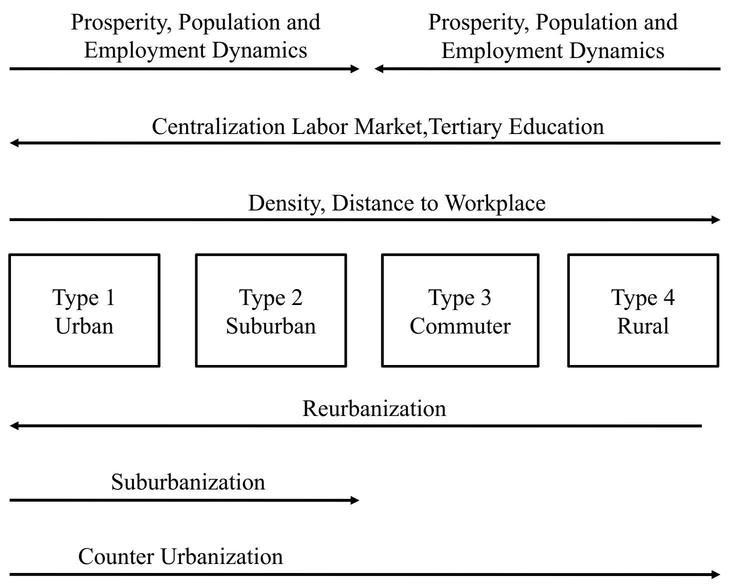

Figure 3.1: Types of Municipalities

The typification is mainly based on the spatial position and the size of a municipality. These two factors influence the strategies of a municipality considerably in terms of land development. Thus, municipalities can initiate different amounts of new settlement development. Dahm (2006) shows that small municipalities develop more new areas compared to metropolitan areas relative to their size. Thus, the smaller a municipality is the more land it develops. Although small municipalities develop more areas, the study reveals no significant population growth in these municipalities. Small municipalities are characterized by urban sprawl and an accumulation of unused areas.

As an example, the decision process in small, rural municipalities (Type 4) and in large, urban municipalities (Type 1) will be compared. The planning rhythms and the planning horizon of a land-need prognosis typically differ between small municipalities and larger cities, and also depend on the community context (Dahm, 2006): In small municipalities, a larger area development is often done in advance in order to offer demanders a continuing construction possibility. However, this procedure is linked to financial risks within the planning horizon in the case of non-usage of the areas and, consequently, missing tax incomes. While the provision of new areas and the land development or land use by the residents occurs simultaneously in larger cities, Dahm argues that a delay between the provision and the usage of the areas can be observed in smaller municipalities. Larger municipalities are, however, confronted with a large number of dimensions, such as commercial areas, with different qualitative and quantitative properties that have to be taken into account in the municipal land-use planning within a certain planning period.

The reasons for the growing land development in rural municipalities differ from those in urban agglomerations (see Dahm, 2006). Land development in small municipalities is triggered by the desire of private households to build a home. These households, however, have other preferences with regard to housing and location than households in urban areas. Single- or double-family-houses with gardens are the preferred housing types of households in rural areas (Gutsche and Schiller, 2007). Land saving and a resource-efficient land development is of little or no importance in small municipalities. Planning regulations on the national as well as on regional levels are less important in the case of small municipalities, as sufficient development potential is available in the outer areas of the municipalities. Municipal administrations and the actual land users, the owners or contractors, are in close contact on the political level in rural municipalities. As a consequence, the municipal representatives often take into account the personal needs of the respective land user. Especially, due to the proximity between political representatives and their voters, a certain degree of influence on the decision makers cannot be avoided when specifying development concepts.

In case municipalities share common borders, and, furthermore, residential or commercial areas are adjacent to each other, interdependencies and spillover effects between them tend to be higher. In case of a land use conflict (competition for households or firms), no municipality can avoid the conflict and the situation has the character of a dilemma situation (see Section 3.3). If a municipality would develop areas without regarding the needs of the other municipality in a specific time horizon, this can lead to retaliation in the future by the other municipality. Moreover, cooperation gains due to economies of scale in the bordering area can often be realized in these scenarios and a cooperative solution in land development (a joint land development plan) is more likely. These observations underline the need to carefully analyze the community context in order to understand how land use decisions in municipalities are made.

3.1.4 Structure of Spatial Areas

The structure of the municipal spatial area defines the decision making space regarding the possible land development strategies. A coordinated land development and a space-saving development in the inner area is only feasible if a municipality is able to align its development plans with the structure of the underlying spatial areas. The development of new areas or the recycling of brownfields can change the spatial structure and the density of land use. Measurement parameters for the density of land use can be floor-space indices, population density, or density of workplaces per hectare. Consequences are the utilization of transport systems, social infrastructures (e.g. schools, hospitals) and public infrastructure systems (e.g. roadways and sewage disposal).

In metropolitan areas, open spaces run short and, as a result, the development focuses on the inner areas of the municipalities. As a response to the public pressure of the constituent, open space is often used as green areas for recreation. The inner areas can be large brownfields or vacant lots between built-up areas. Additional floor space can also be created by increasing the maximum allowed urban density. On the contrary, rural-peripheral regions have no shortage of open space. Here, municipalities develop more new settlement areas and can easily increase the transport infrastructure in order to attract households and firms. The development of areas within the city is not necessary. In contrast to the development of new areas, development of inner areas leads to a more efficient utilization of the existing infrastructure and to overall cost savings. The comparison illustrates that the community context and the structure of spatial areas are closely linked.

In municipal planning, local actors calculate the expected demand for new floor space within a specific time horizon. In order to realize the given land-need forecast, the municipal decision maker has different alternatives for providing the necessary floor space. As mentioned above, settlement and commercial areas can be provided by revitalizing areas in the inner area of a municipality, or by developing new settlement areas in the outer area of the municipality. When deciding, the municipality has to take the objectives from the land-need prognosis into consideration. That means that the requested development objectives have to be met by a combination of inner and outer development in each planning period. The resulting expansion of settlement areas within a time horizon can differ according to the specific municipality type.

In large agglomerations, municipalities often use their development potential within their district. Using further areas affects the number of remaining recreation and open areas. Consequently, the development of new areas in the inner area is often impeded by the resistance of the local population. Thus, restrictions from the vertical policy network influence the available development potential. Frequently, increasing the maximum density in existing areas or concentrating on brownfield recycling are the only remaining options to provide additional floor space in the inner area. In many municipalities, the existing brownfields and gaps exceed the long-term demand for floor space. However, it is only rarely possible to develop settlement and commercial areas in the inner area with similar properties. For example, some areas could be partially contaminated and can, therefore, not be used for a considerable time because of high development cost. In practice, municipalities develop the cheapest available development options first. Typically, closing gaps between buildings is cheaper than recycling brownfields. Hence, the more land development is necessary in the inner area of a municipality, the more expensive the development per hectare becomes to meet the demand for floor space.

3.1.5 Demand for Floor Space

The extent to which a municipality uses new land and the locations of the new developments depend on various factors. Dahm (2006) classifies the essential aspects of land development into quantitative and qualitative aspects. A challenge is that many municipalities do not know the precise demand for space in the inner and outer zones. Many municipalities, even with a stagnating population, plan a demand for new areas despite an excess supply of space for living purposes exists in a region. The calculation of the municipal demand is based on both, estimates and empirical values of the recent past that are influenced by population movements of the (re-)urbanization process (Section 3.1.3). The overall size of the potentially settling population and industry can be considered as a proxy for the demand for new areas in a certain region. Thus, the expected land development of a municipality results from a prognosis estimating the population growth and an analysis of the preferences of the land demanders. Apart from the invariable topological factors of the location, the synergy of these factors influences the local demand, measured in floor space for living or commercial purpose, for development areas in the inner and outer zones. Therefore, the demand has a long-lasting effect on the settlement characteristic of a municipality over long planning periods.

Apart from the quantitative need of floor space for residential and commercial usage, the qualitative needs of the population and the industry (e.g. housing types, transportation connection, long-term extensibility) are further factors in land development. These factors might be important when households decide to move from an urban area to a rural area (counter urbanization process) and include housing density, the market price for housing, pollution levels, or crime levels. This qualitative demand depends on the regional characteristics, or even on the specific location. Therefore, demand for land in one location cannot simply be replaced by the provision of land in other locations or in other regions. Certain linkages between the demand and a location or a region have to be taken into account during the decision processes. Based on the total development of new areas and the demand for new areas in a region, new areas can cover the demand for floor space at different speeds.

The different dimensions of the political networks, the structure of regions and municipalities presented in this section define the context of decision making of the officials and influence their perception with regard to benefits and costs of joint actions in land development. To model the decision processes of local municipalities, generally two mechanisms, bilateral contracting and multilateral collective action for local units can be used (Feiock, 2002, 2007). In the next section, the aspects of the municipal decision making in the land usage domain will be discussed in order to elaborate an institutional collective action framework that describes the Cost Paradox as well as the Development Dilemma.

3.2 The Cost Paradox in the Decision Chain

The competition between municipalities for households and firms has led to an expansion of settlement and commercial areas and to a growing municipal infrastructure (Einig, 2005; Gutsche and Schiller, 2007). In spite of a stagnating or even decreasing population this trend still continues in many regions. However, many unused areas exist in the inner areas of municipalities that could be recycled for residential or commercial usage. Müller-Kleissler and Rach (2001) show that four out of five municipalities plan to cover the demand for floor space by developing new areas in the outer area. Many studies analyze why the development of new areas goes on, while the brownfields remain unrecycled and some new areas remain unused (Gutsche, 2006; Gutsche and Schiller, 2007; Siedentop, 2007). Within the scope of the debate about a sustainable and efficient settlement development, cost transparency in location and planning decisions of municipalities, households, and firms becomes more and more important: Only if all actors behave cost-consciously, more efficient regional structures will be possible. The understanding of the complex interdependencies between planning decisions of municipalities and location decisions of households and firms complicates the realization of cost transparency. The fact that incorrect estimates of the costs associated with land development result in inefficient land usage is often noted. However, in order to get a sufficient understanding of the complex structure of the decision chain within a municipality in land development, more comprehensive explanations and modeling approaches are necessary (see Section 3.3).

The heterogeneity of the different groups and decision makers in municipal development has been the subject of many research analyses (e.g. Feiock and Carr, 2001; Thurmaier and Wood, 2002; Evans, 2004). Empirical studies have shown how concrete instruments can be introduced in order to avoid the negative effects of the lack of transparency in land development (e.g. Einig, 2003, 2005). Actors which are involved in the land development process minimize their own costs, but due to the lack of transparency this results in inefficient regional structures regarding the land development and the associated costs. Other studies have analyzed the fiscal impact of the municipal development by comparing the recycling of inner areas and the development of new areas (Rothe, 2005; Billing, 2004; Mainz, 2005; Seiler, 2006; Preuß and Floating, 2009). Furthermore, increasing the transparency of the land use processes will demonstrate the fiscal impact of different land development plans and can lead to the reduction of new land development (Bodenschatz and Schönig, 2004; Reidenbach et al., 2007). Urban studies and studies on migration have revealed that next to economic aspects, non-economic aspects, such as preferences of households for specific residential areas, also play an important role for the decisions of the actors. Depending on the role of a group, different aspects and cost factors are more or less important. However, the studies show that economic aspects are usually predominant. For instance, Gutsche and Schiller (2007) create profiles for each group of actors in order to describe the characteristics of the specific decision making situation of each actor. The profiles help to analyze the impact of costs on the individual decisions. By systematically analyzing the actors and their motivations during decision making processes in more detail, the lack of transparency can be analyzed in more detail. The dimensions of the framework will be used as a guideline to explain the costs of land development and to identify false incentives in the decision chain.

Policy Network Political and financial considerations on the vertical policy network motivate municipalities to develop new land for commercial and residential use. As mentioned above, many actors are involved in the process of developing land. Thereby, the municipalities often pass costs for developing new areas on investors or the general public. If remaining infrastructure costs were negligible, a development project can be considered as appropriate and feasible. The calculation of potentially high follow-up costs is difficult and is therefore often ignored in this decision process. Distorted costs perception and bounded rationality of actors will lead to wrong decisions when an actor does not consider all indispensable costs. As a result, the total net value of development projects is often overestimated (Siedentop and Schiller, 2006; Gutsche and Schiller, 2007; Henger and Thomä, 2009). The studies have shown that the calculated increasing tax receipts by the settlement of new households are often not feasible. For the owners of the building lands, land speculations and expectations about future prices of their property play an important role. If the property tax is too low, the occurrence of speculation effects is increased. In this case, land owners have fewer incentives to sell unused property and are more patient, even passive, with regard to their dealings. The restrictions from the vertical policy network (Section 3.1.1) arising during the decision making of the actors might hinder the efficient usage of spatial areas and may exclude the realization of alternative development plans.

Spatial Structure Gutsche and Schiller (2007) examine various factors of the cost transparency in more detail by describing the impact of spatial structure in a region with homogeneous municipalities. Crucial for the costs are the regional location of the municipality and its spatial structure, especially the density of land. For instance, if a municipality is less dense, the specific costs per houshold, e.g. per schoolchild, tend to be higher than in denser, urban municipalities. Gutsche (2006) has shown that the costs for public infrastructure strongly depend on the density of use. As a rule-of-thumb, which proves to be true in many studies, Gutsche (2006) states: "Half the density of use, double the infrastructure costs for each unit." Therefore, small municipalities that develop large new settlement areas face high costs for the maintenance of the infrastructure. The development costs also depend on the regional location of the new areas. In case the new areas can be well integrated into the existing infrastructure, no new facilities are necessary and the municipality can save costs.

Community Context The community context of a municipality influences the costs for the maintenance of the social infrastructure partially covered by external utility companies (Section 3.1.4). The demographic trend in many countries can get municipalities in sparsely populated suburban or rural areas (Type 4) in financial difficulties when the population is declining. Consequences are even higher costs for the remaining residents. The resulting costs are reimbursed by all households of the municipality in the form of duties. Therefore, utility companies have less incentive to avoid long network sections per user or long facility lifetimes, as households bear the increased costs, regardless of whether they live in new or in existing areas (Gutsche and Schiller, 2007). Such a transfer of costs to other parties can cause problems in case the costs have no significant effect on the own decision, but impacts the outcomes of other actor groups included or excluded in the land use process. Another major challenge is to involve groups that are excluded during an individual decision making. For instance, the development of new residential and commercial areas determined by a municipality has negative consequences with tremendous costs for the general public in case the technical and social infrastructure in municipalities becomes more and more expensive.

Demand for Floor Space As mentioned in Section 3.1.5, the demand for floor space is characterized by the location decisions of households, firms, and investors. During the decision making process of the households and firms, the infrastructure costs play a less important role. The low land prices of suburban areas conceal the high costs in these areas, which are born by all households. However, Gutsche and Schiller (2007) have shown that the low living costs are outweighed by the additional mobility costs associated with these areas and the households often do not take the long-term costs into account when making their location decisions. The community context and the structures of the spatial areas influence the costs of the transport systems. For instance, households in suburban areas with few public transport services travel greater distances by car. Low land prices in suburban areas make these locations also attractive for investors and firms. From an individual perspective, the low price levels overcompensate the higher infrastructure costs for the development of these densely populated areas. However, the regional cost advantage of developing denser areas by a coordinated land development is not taken into account in the individual decision making process of local representatives (see Section 3.3).

The conflation of all individual decisions into the decision chain for land usage often leads to an inefficient settlement structure in regions even though actors believe to decide economically rational. Gutsche and Schiller (2007) describe this contradiction as a costs paradox wherein "actors involved in property development try to minimize their respective costs. However, the end result of these individual decisions is a highly cost-intensive regional settlement structure." Thus, a discrepancy between individual perception of costs and the observed regional costs characterizes this cost paradox. The cost paradox is enhanced by the lack of transparency within this complex decision making process of many actor groups. It should not be confused with the *building land paradox* (Davy, 1996), which has the character of a collective action problem.

The common characteristic of the two concepts is that the behavior and decisions of local actors in the land development process are uncoordinated. However, the cost paradox is based on the bounded rationality of the actors acting successively in the vertical decision chain. By contrast, within the scope of the building paradox, or dilemma in land development, actors on the horizontal level make uncoordinated decisions at the same time, which results in a higher land provision than actually needed. Nevertheless, both concepts entail urban sprawl and high follow-up costs for the infrastructure. By modeling the individual decision situations from a regional perspective, the cost paradox can be explained. The introduction of information systems and decision support systems to avoid the cost paradox should reduce costs for the community and the region, make the costs more transparent and avoid wrong incentives along the decision making chain. Awareness raising campaigns, for example, could help actors to take all costs into account during the location decisions. By doing so, the discrepancy between individual and collective efficiency in land development can be equalized.

3.3 The Development Dilemma in Land Usage

Local decisions about land usage and the development of new areas in a municipality are influenced by the relationships to other municipalities in the region. In many cases, municipalities compete with each other for new businesses or households: When one municipality wins, other municipalities loose (Einig, 2005). In such a scenario, the location of a firm or the settlement of households, are exclusive, meaning that there is rivalry between municipalities in a region and that a household or a firm settles in only one municipality. If all municipalities compete against each other for the settlements by providing new building land, the situation has the structure of a dilemma situation and negative spill-over effects between the municipalities exist. This dilemma situation is characterized by an inefficient infrastructure (caused by unused new land) and losses of tax receipts in these municipalities. Thus, the competition for new businesses and households and the expected increase of the municipal tax incomes characterize many land use decisions. The more serious the problem is and the more new land will be developed, the greater would be gains from cooperation and the more likely involved municipalities seek an agreement of a restricted use of a good (Ostrom, 1990; Ostrom et al., 1994).

The financial situation of municipalities plays an important role in land development and influences the probability of collective actions as well as the realization of coordinated land development plans. As coordinated land development plans are difficult to define, transaction costs for the coordination of joint actions in land usage tend to be relatively high (see Section 3.4). Moreover, coordinated land usage projects for long time periods can create mutual dependencies between the municipalities due to the necessary long term commitments. Thus, by coordinating their land usage strategies, it is possible that their individual flexibility is reduced to adapt land usage plans in case the demand for residential or commercial areas will change in the future. For instance, if demand increases in only one municipality participating in the cooperation, the municipality will have an incentive to develop more new areas than others within the cooperation. Consequently, this party might be tempted to resign on the contract, which incites the other participants to develop their own areas. For many municipalities, the development of new areas seems to offer possibilities to stabilize or improve their financial situation. In practice, however, this effect is often overestimated—in extreme cases, the financial situations of the municipalities may even get worse (Einig, 2005). As a result, the uncoordinated land development causes excessive costs by a high amount of unused new areas.

New information and decision support systems can enhance cost transparency during decision making, but cannot alone solve the collective action problem and the development dilemma. This section shows, how a lack of transparency of municipal costs or incomes may influence the structure of the decision situation and how it enforces a potential dilemma in land development. First, the characteristics of the development dilemma between two municipalities will be discussed from a game-theoretical perspective by presenting a competitive situation in two different games. Second, a more general game-theoretical approach will be introduced to model the situation in a region with more than two municipalities. If municipalities face a dilemma game with land development, intercommunal cooperation concepts are promising instruments to address the collective action problem. Hence, the section concludes with a discussion of cooperative concepts that may be helpful to achieve a cooperative solution of this collective action problem.

3.3.1 Competitive Situations between Two Municipalities

Game-theoretical models can be used to describe urban conflicts and to analyze cooperative solutions in a decentralized system of governance (Steinacker, 2004). Formal models usually depend on specific assumptions, which are critical for the model predictions. Therefore, it is necessary to consider the important drivers which are relevant in actual settings. By variation of the model parameters, the model can be applied to situations that differ between regions or that reflect particular municipal characteristics. In the following, a competitive situation between two homogeneous municipalities will be considered. The outcome of the competitive situation is calculated by the municipal decision maker depending on his perception of the related costs and is, thus, strongly impacted by the transparency of these values in a specific situation. In the following, the impact of cost transparency will be demonstrated by describing two exemplary games.

The first game models the structure of a bilateral intergovernmental conflict and has the structure of a dilemma situation. The payoff structure captures the competitive nature of the relationship between the municipalities (Rubin and Rubin, 1987). Two neighboring municipalities have the possibility to provide living space by recycling inner areas or by developing new land in the outer areas. The interaction of the two municipalities can be characterized as a non-cooperative game with two players. Each player has two pure strategies: Inner Development (I) and Outer Development (O). The recycling of brownfields in the inner area of a municipality (I) is associated with costs of 2 monetary units. In the example, the development of new areas in the outer area (O) costs 3 monetary units.

In the game, the migration of households and firms and the incomes by population dynamics will be also taken into account. The higher this value, the higher is the incentive for a municipality to develop new areas. Municipalities usually calculate that new areas will be entirely used (Dahm, 2006). In reality, however, oversupply of new areas can be observed, which leads to empty properties. In the example, if only one municipality develops outer areas, additional population settlement in the outer area increases the tax incomes by 4 in one municipality, and decreases the tax incomes by 4 in the other municipality. Considering the costs for the development of different areas in each municipality leads to a payoff of +1 for the municipality with the outer development (tax income of 4 minus development costs of 3) and to a payoff of -6 for the municipality that chooses inner development (development costs 2 and a tax decrease of 4). If both municipalities choose the same strategy in this example, no municipality has changes in tax incomes. The resulting payoff matrix is shown in Table 3.1.

		Municipality 2	
		I	O
Municipality 1	I	$-2,\ -2$	$-6,\ +1$
	O	$+1,\ -6$	$-3,\ -3$

Table 3.1: Payoffs Game 1 (Prisoners' Dilemma)

In such a classical dilemma situation, it is always better to develop outer areas, regardless of the other municipalitys' decision. As defecting (the development of new areas) is a (strictly) dominant strategy for both players, the game has a (unique) Nash Equilibrium (O,O) in dominant strategies: No player has an incentive to switch to a different strategy in this game independent of what the other does. However, the outcome in this equilibrium is not Pareto-optimal. If both municipalities would develop the inner areas, they would be both better off.

In practice, the outcome of the game depends on the individual perceptions of the decision situation, i.e. the estimates of associated costs and incomes. A careful calculation of infrastructure costs and social costs is necessary to define the outcomes of the game in a specific situation (Section 3.1). As mentioned in the last section, the structure of the vertical network mainly influences the distribution of the costs among the different actors and the existence of the cost paradox. In case, the municipalities have to bear the additional infrastructure costs caused by urban sprawl (and not the residents), the costs for the outer development tend to be higher. Hence, the infrastructure costs for developing new areas in the outer areas O are higher and the payoffs in the (O,O), (I,O) and (O,I) outcomes of the game change. Furthermore, if transparency is enhanced, a more detailed overview of all possible development areas in a municipality is possible.

Especially in urban municipalities of Type 1, a comprehensive overview of all available development options is not always present. Only if a municipality knows all brownfields and other development options within its territory, the development of the areas with the lowest costs will be possible. Therefore, the costs for inner development I decrease and the payoffs in the (I,I), (O,I) and the (I,O) outcomes of the game increase.

Hence, for the second game, a higher cost transparency by a correct cost calculation of all possible development options will be assumed. This will influence the individual perception of the game on the part of the municipalities and might change the structure of the situation. Table 3.2 shows the structure of the new game that assumes cost transparency. The difference to Game 1 is that the outer development is more expensive with associated costs of 7 monetary units, and the development of inner areas is cost neutral with associated costs of 0. In this case, the payoffs of the game will change and will reflect the fact that outer development is less attractive than formerly assumed. The game now reflects a situation with the absence of the cost paradox and wherein the preferences of the local representatives are completely convergent.

		Municipality 2	
		I	O
Municipality 1	I	+0, +0	−4, −3
	O	−3, −4	−7, −7

Table 3.2: Payoffs Game 2

In this game, the recycling of inner areas in both municipalities is still Pareto-superior but now I is a dominant strategy and the strategy profile (I,I) is a Nash Equilibrum in dominant strategies. Due to the fact that the Pareto Optimum is also a Nash Equilibrium (I,I), the development of inner areas in both municipalities is easier to establish in the new Game 2 than in Game 1. The new game has no longer a dilemma structure and the development in the inner area is more likely. The example points out that the analysis of costs is necessary to identify if a real development dilemma between municipalities exists or not. If cost transparency can be enhanced, the realization of cooperation concepts that establish intercommunal agreements and reduce the new land development are more likely.

Other aspects that were discussed within the proposed framework may have also an impact on the structure of the game and the existence of a dilemma situation. For instance, non-monetary aspects can influence the payoff structure. However, reputation aspects can work in two directions: On the one hand, the development of new areas is an indicator for the attractiveness of a municipality and increases its prestige. In this case, additional non-monetary values increase the valuation of the development of new areas. On the other hand, the initialization of sustainable land development concepts increases the reputation and might be an important driver for the strategy I. However, the question arises if and how these aspects can be valued by the municipal decision makers in practice.

The various aspects discussed in both games illustrate how the individual perception of the decision situation changes the structure of the game and may influences land use decisions of local representatives. The shortcoming of both modeling approaches is the assumed symmetry in the players' positions. Political and economic asymmetries can favor some municipalities in cooperation and involve problems when negotiating the fair division of benefits (Feiock, 2009). The dimension community context of the framework defines different municipality types and their relation to each other, and helps to understand how asymmetries in the players' positions may influence the outcomes of the games. In metropolitan conflicts between urban and suburban municipalities, the heterogeneity between the players is typically high. Both municipalities are interested in joint land development plan, but have different preferences with regard to the outcomes in this cooperation. In the following sections, the main focus will be on regions with homogeneous municipalities and only at some points aspects of heterogeneous municipalities will be discussed.

Next to the community context, the frequency of the interaction also has an impact on the possible game results over time and the stability of the Nash Equilibrium. Typically, the situation as presented in Game 1 can be found in practice as a repeated interaction between municipalities. By repeating the same interaction, an actor is able to reward or punish past actions of the other actor. Due to the folk theorem, a cooperation can be established in the infinitely repeated game (with no discounting or with a sufficient small discounting) by subgame perfect equilibria.[1] A possible strategy to establish such

[1] In this context, a discount rate close to 1 can be assumed, due to the high probability that the interaction continues in future periods.

an equilibrium, is the 'grim trigger' strategy. Here, the opponent will be punished when deviating in the game. For instance, both municipalities could try to establish the outcome (I,I) in Game 1. In a repeated interaction, a player could now punish the other one if he deviates from the solution (I,I) by applying the grim trigger strategy: If the other municipality would develop new areas, the municipality can punish the other one by choosing the outer development in all future periods so that no advantage of any player exists. In such a case, the additional incomes of the other player can be cancelled out. Furthermore, Steinacker (2004) discusses such a repeated game in the context of metropolitan conflicts, models a realistic repeated interaction between municipalities and analyzes further aspects of such a game. The author argues that the likelihood of cooperation depends on more factors, e.g. the number of rounds or risk aversion of the local representatives. Hence, a repeated interaction between municipalities can establish the Pareto-optimal solution (I,I) and may facilitate the coordination of their land development plans by reducing the outer development as observable in practical use cases (see Section 3.4).

3.3.2 Competitive Situations between Two and More Municipalities

In Germany, the development dilemma arises only rarely within the scope of dyadic relationships (Einig, 2008). Usually, more than two municipalities are involved in the land development process of a specific region. Hence, cooperation between municipalities and the coordination of land development plans among cities is typically a collective action problem in a competitive environment (Olson, 1971; Ostrom, 1990). Some collective action models (e.g. Steinacker, 2004) highlight that the major conditions having an impact on the likelihood of cooperation are the characteristics of the good and the heterogeneity of the actors. The discussed competitive situation between two municipalities and the impact of the framework on the presented games, show that there is still a need for new approaches to model collective land use decisions and the interaction of decision makers in the land use domain.

The following n person game helps to improve the understanding of intercommunal competition, similar to the examples presented in the last section. The game considers a region with $n > 1$ homogeneous municipalities competing for households in an one-stage game. Each municipality $i \in \{1, 2, ..., n\}$ is characterized by a given development goal

e_i, which determines the demand for new floor space for residential, commercial, and industrial purposes within a specific time horizon. The demand for floor space can be covered by recycling areas y_i in the inner area or by developing new areas x_i in the outer area of the municipality under the condition $e_i = y_i + x_i$. For all other municipalities in the region, the land development is summarized by $X_{-i} = \sum_{j \neq i} x_j$. Thus, the overall development of new land in the region is $X = x_i + X_{-i}$. When developing new areas, municipalities have to seal additional surfaces in their territory. In this case, forest or agricultural areas will be converted into residential or commercial areas. Typically, these new areas are generously developed and will be less densely populated than areas in the center of the municipalities (Section 3.1.4).

As mentioned in Section 3.1.5, one reason to develop new areas in the outer zone of the municipality instead of recycling existing areas is the high demand for new attractive building land on the part of the households and firms. Therefore, it is assumed that new land is developed in municipalities in order to attract a proportion of those households, which are willing to move from one municipality to another municipality in the considered region. The variable $m_i > 0$ defines the number of households in municipality i seeking for new building land within the region. In total, the number of regional households, that are willing to migrate is given by $M = \sum_{i=1}^{n} m_i$. The settlement of new households is associated with additional tax receipts of $\ell_i > 0$ per household. Accordingly, the higher the expected number of movers or tax receipts are, the higher are the incentives for the development of new residential areas and the more competitive is a region. In this approach, the tax income or loss, caused by the migration of households between municipalities in a region based on the individual share $\frac{x_i}{X} = \frac{x_i}{x_i + X_{-i}}$ of new land a municipality develops, is:

$$P_i(x_i, X_{-i}) = \ell_i \cdot (\frac{x_i}{x_i + X_{-i}} \cdot M - m_i) \tag{3.1}$$

If, for instance, there are two municipalities A and B in a region and only municipality A develops new areas, i.e. $X_{-A} = x_B = 0$, all households seeking new building land in the region will settle in municipality A. The additional tax incomes for municipality A would then be:

$$\begin{aligned} P_A(x_A, x_B) &= \ell_A \cdot (\frac{x_A}{x_A} \cdot (m_A + m_B) - m_A) \\ &= \ell_A \cdot m_B \end{aligned}$$

On the one hand, municipalities can attract households by increasing the amount of new development areas. On the other hand, the development of new areas also increases the infrastructure costs $S_i(x_i)$ (e.g. waste and sewage disposal, street cleaning, administration) by an amount of $c_i > 0$ per new hectare x_i:

$$S_i(x_i) = c_i \cdot x_i \tag{3.2}$$

As mentioned above, an alternative development strategy can be the recycling of inner areas. The costs for developing inner areas are influenced by the structure of the spatial areas and can be calculated by a given convex cost curve $C_i(y_i)$ for the inner development y_i, with $C_i'(y_i) > 0$ and $C_i''(y_i) \geq 0$. Furthermore, since $y_i = e_i - x_i$ any development of new areas x_i implicitly specifies inner development of $e_i - x_i$. Thus, the costs for the inner development given the development of x_i new areas are given by $C_i(e_i - x_i)$ and it holds $C_i(y_i) = C_i(e_i - x_i)$.

The decision problem of the municipality is to choose an appropriate amount of new areas and recycling of existing areas for a given demand. The main task for each municipality resulting from (3.1), (3.2), and the given cost function $C_i(e_i - x_i)$ is to maximize the total payoff R_i of the individual land development:

$$R_i(x_i, X_{-i}) = P_i(x_i, X_{-i}) - S_i(x_i) - C_i(e_i - x_i) \tag{3.3}$$

Inserting (3.1) and (3.2) into (3.3) leads to:

$$R_i(x_i, X_{-i}) = \frac{x_i}{x_i + X_{-i}} \cdot M \cdot \ell_i - c_i \cdot x_i - C_i(e_i - x_i) - m_i \cdot \ell_i \tag{3.4}$$

By derivating the formula with respect to x_i one obtains the following necessary condition of an inner solution for the Nash Equilibrium:

$$\begin{aligned} \max_{x_i} R_i(x_i, X_{-i}) &\Longrightarrow \frac{dR_i(x_i, X_{-i})}{dx_i} \stackrel{!}{=} 0 \\ \Longrightarrow \frac{x_i + X_{-i} - x_i}{(x_i + X_{-i})^2} &\cdot M \cdot l_i - c_i + C_i'(e_i - x_i) \stackrel{!}{=} 0 \\ \Longleftrightarrow \frac{X_{-i}}{(x_i + X_{-i})^2} &\cdot M \cdot l_i - c_i + C'(e_i - x_i) \stackrel{!}{=} 0 \end{aligned} \tag{3.5}$$

If all municipalities are homogeneous, the game is symmetric and $l = l_i = l_j$, $c = c_i = c_j$, $m = m_i = m_j$, $e = e_i = e_j$, $C(.) = C_i(.) = C_j(.)$ holds for all i, j. If concentrating on symmetric Nash Equilibria, i.e. $\tilde{x} = x_i = x_j$ and $\tilde{X}_{-i} = (n-1) \cdot \tilde{x}$, Condition 3.5 simplifies to:

$$\begin{aligned} \Longrightarrow \frac{n-1}{n^2} \cdot \frac{M \cdot \ell}{\tilde{x}} + C'(e - \tilde{x}) - c = 0 \\ \Longleftrightarrow C'(e - \tilde{x}) = c - \frac{n-1}{n^2} \cdot \frac{M \cdot \ell}{\tilde{x}} \end{aligned}$$

Resubstitution of M by $n \cdot m$ leads to:

$$\Longrightarrow C'(e - \tilde{x}) = c - \frac{n-1}{n} \cdot \frac{m \cdot \ell}{\tilde{x}}$$

The symmetric Nash Equilibrium is a strategy $\tilde{x} = x_i$ each player chooses, and which fulfills the above condition. For instance, if there are no movers ($m = 0$) or no taxes ($l = 0$), the infrastructure costs in a municipality should equal the marginal costs of inner development. Due to $C_i'(e - x_i) > 0$, also the right side of the condition is greater than zero, and $c - \frac{n-1}{n} \cdot \frac{m \cdot \ell}{\tilde{x}} > 0$ holds. This leads to the following property of the Nash Equilibrium:

$$\tilde{x} > \frac{n-1}{n} \cdot \frac{m \cdot \ell}{c}$$

Hence, the number of municipalities, the number of movers, the tax incomes, and the infrastructure costs influence the lower limit of the land development $\tilde{x}$. High tax incomes and a high amount of movers increase this lower limit in the Nash Equilibrium, while higher infrastructure costs decrease the limit of new land development within the model.

In order to analyse how a small change of m affects the value of $\tilde{x}$, the implicit function $H(.)$ can be written down:

$$H(n, e, m, l, c, \tilde{x}) := C'(e - \tilde{x}) + \frac{n-1}{n} \cdot \frac{m \cdot \ell}{\tilde{x}} - c = 0 \tag{3.6}$$

Using this function $H(.)$, it is possible to answer how changes in m affect the corresponding $\tilde{x}$. Since $H(.) = 0$ the implicit function theorem applies and one obtains:

$$\begin{aligned}
\frac{d\tilde{x}}{dm} &= -\frac{\frac{\partial H(.)}{\partial m}}{\frac{\partial H(.)}{\partial \tilde{x}}} \\
&= -\frac{\frac{n-1}{n^2} \cdot \frac{l}{\tilde{x}}}{-C''(e-\tilde{x}) - \frac{n-1}{n} \cdot \frac{m \cdot l}{\tilde{x}^2}} \\
&= \frac{\frac{n-1}{n^2} \cdot \frac{l}{\tilde{x}}}{C''(e-\tilde{x}) + \frac{n-1}{n} \cdot \frac{m \cdot l}{\tilde{x}^2}} > 0
\end{aligned}$$

This shows that an increase of the population dynamics by an increasing number of movers m in a region leads to an additional new land development. Hence, the higher population dynamics are, the less areas should be developed in the inner zone of the municipality. The impact of increasing n (assume for simplicity that n is a continuous variable) can be analyzed similarly by using the implicit function $H(.)$ and applying again the implicit function theorem:

$$\begin{aligned}
\frac{d\tilde{x}}{dn} &= -\frac{\frac{\partial H(.)}{\partial n}}{\frac{\partial H(.)}{\partial \tilde{x}}} \\
&= -\frac{\frac{2}{n^2} \cdot \frac{m \cdot l}{\tilde{x}}}{-C''(e-\tilde{x}) - \frac{n-1}{n} \cdot \frac{m \cdot l}{\tilde{x}^2}} \\
&= \frac{\frac{2}{n^2} \cdot \frac{m \cdot l}{\tilde{x}}}{C''(e-\tilde{x}) + \frac{n-1}{n} \cdot \frac{m \cdot l}{\tilde{x}^2}} > 0
\end{aligned}$$

Hence, for increasing discrete n the land development $\tilde{x}$ is positive and an increasing number of municipalities within a region, competing for households and firms, increases the amount of new land being developed.

The Pareto Optimum for the region can be calculated by maximizing the total outcome of all municipalities in the region. This can be done by the calculation of the optimal new land development $x_1, .., x_n$ in all municipalities:

$$\max_{x_1,..,x_n} \sum_{j=1}^{n} R_j(x_j, X_{-j}) \Longleftrightarrow \max_{x_1,..,x_n} \sum_{j=1}^{n} (\frac{x_j}{x_j + X_{-j}} \cdot M \cdot l_j - c_j \cdot x_j - C_j(e_j - x_j) - m_j \cdot l_j)$$

Representatively for each municipality in the region, the necessary condition in the Pareto Optimum will be considered for municipality i. From the perspective of a municipality i the overall payoff of all municipalities will be maximized if:

$$\frac{d \sum_{j=1}^{n} R_j(x_j, X_{-j})}{dx_i} \stackrel{!}{=} 0 \tag{3.7}$$

The derivation leads to:

$$\Longleftrightarrow \frac{X_{-i}^*}{(x_i^* + X_{-i}^*)^2} \cdot M \cdot \ell_i - c_i + C_i'(e_i - x_i^*) + \sum_{j \neq i} (\frac{-x_j^*}{(x_j^* + X_{-j}^*)^2} \cdot M \cdot \ell_j) = 0$$

If the tax incomes are the same in each municipality ($l = l_i = l_j$) it holds:

$$C_i'(e_i - x_i^*) = c_i$$

Hence, if the municipalities are homogeneous regarding the taxes, the marginal costs for the inner development should equal the infrastructure cost for new land development and each municipality develops the amount of $x_i = x_i^*, \forall i$ that fulfills this condition. In case the municipalities have different tax incomes per household or firm, a more divagating land development between the muncipalities can be expected due to the different tax incomes.

If the game is symmetric and the municipalities are homogeneous, it holds $c = c_i = c_j$, $e = e_i = e_j$, and $C(.) = C_i(.) = C_j(.), \forall i, j$. Thus, the land development $x^* = x_i = x_j$ is the same in each municipality and it holds:

$$\Longrightarrow C'(e - x^*) = c$$

Hence, in the Pareto Optimum each municipality develops the same amount of $x_i = x^*, \forall i$ that fulfills the condition that the marginal costs for recycling the inner areas equal the infrastructure costs of new areas. The cost relation between inner and outer development and the spatial structure determines how much inner area will be developed. If the infrastructure costs for the development of new areas are high, more inner areas should be developed. The comparison of the resulting equation in the Pareto Optimum and the equation in the Nash Equilibrium leads to:

$$C'(e-\tilde{x}) + \frac{n-1}{n} \cdot \frac{m \cdot \ell}{\tilde{x}} = C'(e-x^*) \tag{3.8}$$

Because the term $\frac{n-1}{n} \cdot \frac{m \cdot \ell}{\tilde{x}}$ is greater zero, the equation shows that $C'(e-x^*) > C'(e-\tilde{x})$. The variable $\tilde{y} = e - \tilde{x}$ determines how many areas should be recycled in the inner areas in the Nash Equilibrium and $y^* = e - x^*$ the amount of recycled areas in the Pareto Optimum. Due to the assumption that the cost function is convex, less new land should be developed in the Pareto-optimal solution than in the Nash Equilibrium, and more floor space in the inner areas $y^* > \tilde{y}$. Figure 3.2 illustrates this relationship and shows that the higher the number of municipalities, the tax incomes or number of movers is (summarized by $\Delta = \frac{n-1}{n} \cdot \frac{m \cdot \ell}{\tilde{x}}$), the higher is the difference between the Nash Equilibrium and the Pareto Optimum.

The resulting conditions of the proposed model outline the land development dilemma and give an idea how the structure of spatial areas, demand for floor space and the community context will foster urban sprawl. The simplified approach of the model also reflects some basic aspects that may be observable in real land development (Section 3.1). In order to adapt the model for regions with Type 2 or Type 3 municipalities, higher population dynamics can be modeled by increasing the number of households searching for new building land. The prosperity of the households can influence the expected tax incomes. Population density and centrality of a municipality determine the average infrastructure costs. For instance, centralized municipalities with high densities (Type 1) tend to have low costs for the maintenance of the infrastructure per hectare (Section 3.1.3). However, due to low population dynamics, municipalities of Type 1 and Type 4 tend to have more development options available in the inner area and more flexible development strategies. Furthermore, the analysis shows that the more municipalities compete in a region, the more differs the land development in the Nash

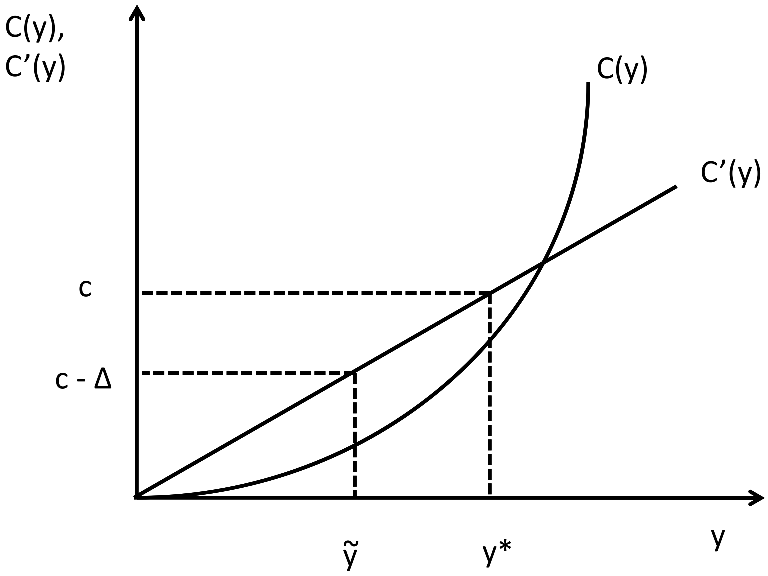

Figure 3.2: Theoretical Solutions and Abatement Costs

Equilibrium from the Pareto Optimum. Accordingly, Feiock et al. (2005) as well as Olberding (2002) found that the number of local municipalities in a region has a negative effect on the probability of collective action that is necessary to solve metropolitan conflicts.

3.4 Cooperation Concepts in Land Development

Case studies have shown, that by realizing coordinated land development plans amongst municipalities, the dilemma situation could be solved and more efficient land development plans in ecological and economical terms could be established (for an overview see Einig, 2008). However, this makes cooperation between municipalities necessary. In political science, forms of cooperation are considered to be the third way of social control after market-based and hierarchical approaches (Section 2.1.2). Usually, forms of cooperation are classified into coordination, negotiation and mediation (Powell, 1996). Issues of metropolitan governance and cooperative agreements have already been analyzed by researchers since the 1990s, without generating a comprehensive understanding of the conditions of how to achieve sustainable intercommunal cooperation. First studies that integrate diverse perspectives on development competition and cooperation solutions has been started in the last years (e.g. Feiock, 2002). The coordination of regional land development plans by establishing collaboration between municipalities have been proved as a solution to avoid the high usage of new land and has been realized in many regions (Einig, 2003; Spannowsky and Borchert, 2003).

Joint actions of the local units are feasible by consolidating functions of the local authorities, by establishing horizontal interlocal policy agreements and by overlaying nested services enabling a collective action (e.g. a joint municipal land development, Feiock and Carr, 2001; Thurmaier and Wood, 2002). However, a voluntary collaboration is not easy to establish in practice. Considering governmental fragmentation, it is often difficult to give concerted responses to problems like interjurisdictional competition (Downs, 1994; Katz, 2000). In many cases, self-organizing local units are incapable to deal with existing spillover problems (Lowery, 2001; Olberding, 2002) and a cooperative solution is necessary to coordinate the regional land use planning (Einig, 2008).

Cooperation concepts in land development can be established in many ways. On the one hand, legal agreements for coordinated land development are initiated by voting and participation procedures (in larger municipalities with a more complex administrative machinery), or by decisions of few elected officials (in small municipalities with more hierarchical structures). On the other hand, the coordination of land development can also be initiated on a voluntary basis. In the latter case, the institutionalization of cooperation is possible on the basis of weak-tied, non-hierarchical relationships that represent voluntary cooperation projects without legal commitments. In Germany, new weak-tied forms of cooperation on the regional level have been developed over the last years (see Gawron, 2004). The binding intensity is relatively low and legal agreements between the municipalities are very rare. In contrast to a hierarchical, vertical coordination of land development managed by a supervisory authority, the new approaches are based on the horizontal coordination principle. Weak-tied cooperations are often a preliminary stage of subsequent more binding relationships that involve binding agreements in order to strengthen the cooperation between local units (Gawron, 2004). Thus, the level of institutionalization is interpretable as a dynamic process with different developmental levels that are associated with changes in the complexity of the interdependencies between the municipalities. The regional context in which these interdependencies occur is determined by the characteristics of the framework presented in Section 3.1.

A cooperative solution requires a continuous interaction between the participants to establish agreements on structures and binding decisions of the group (Ostrom, 1990; Ostrom et al., 1994). Municipalities with a homogeneous community context and similar neighboring jurisdictions are more likely to start a cooperation including a higher interdependency due to the repetition of the interaction. By contrast, the more heterogeneous the community context is, the more difficult is it to foster voluntary intercommunal agreements even though no cost paradox exists. Moreover, in metropolitan areas with more frequent interaction the establishment of regional cooperation is more likely. Thus, whether a collective action by a coordinated land development is possible, depends mainly on the structure of the horizontal policy framework (Section 3.1.2).

The more political instruments and initiatives are combined to achieve a regional coordination of the development plans in such a scenario, the more complex is the resulting horizontal network (Einig, 2008). By analyzing regional coordination in different case studies, Einig proposes a framework for regional land development in Germany, that consists of a multistage phase model (Figure 3.3). In the stage *Regional Data Collection*, the collection of all municipal data in the region is necessary to estimate the future demand for floor space and the population dynamics. In the next step, the municipalities have to negotiate the regional goals and agreements. Based on the target agreement, the regional planning can design different regional land development plans. When an appropriate development plan is identified and realized, the regional planning has the task to monitor the land development in the region. The design of the framework for regional coordination is similar to the proposed TDC framework (Section 2.4), for instance regarding the data collection and monitoring, although the framework for regional coordination focuses only on coordination of the municipal development.

For the establishment of cooperation concepts, joint gains are essential (Steinacker, 2004). In case of a joint land development plan, the gains would be the reduced infrastructure costs of denser and more compact areas. A basic component when coordinating land development is the establishment of rules how to divide the gains between the involved municipalities. The coordination of development plans can reduce regional disparities in tax incomes and can weaken the competition for new development areas.

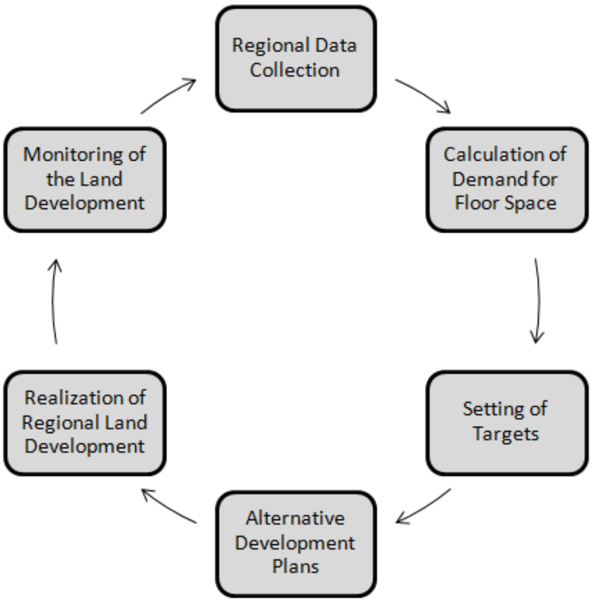

Figure 3.3: Framework for Regional Coordination (Einig, 2008)

Problems can occur if the municipalities are heterogeneous and some municipalities have more power than others, e.g. in urban-suburban conflicts (Wuschansky and König, 2006). Furthermore, if many municipalities are participating, the fair division of costs and incomes is very complex (Einig, 2008). However, Wuschansky and König have shown that in most regional coordination projects in Germany, two or three municipalities are involved. Due to the low number of participants, the transaction costs in these projects are not very problematic. The division of the tax incomes could follow simple rules (e.g. the proportional amount of new development areas) or could be negotiated in each specific use case. Nevertheless, these rules should be considered as fair by the participants (see Brams and Taylor, 1996). However, this makes the collection of required data and a further collaboration of all regional municipalities necessary.

The transaction costs of bargaining a cooperative solution are crucial for the establishment of self-organized cooperative solutions. Einig (2005) as well as Spannowsky and Borchert (2003) emphasize that a cooperative solution is only feasible if the payoffs of the agreement are higher than those of a non-cooperative solution. The larger the gains from an agreement, the more likely the transaction costs will be outweighed (Libecap, 1994; Ostrom, 1990; Lubell, 2007). Feiock (2007) distinguishes between four sources of transaction costs to coordinate the actions of local authorities: information costs, agency costs, negotiation costs and enforcement costs—all these costs must remain low in order to enhance the probability of cooperation and in order to avoid the development dilemma. Furthermore, a cooperative solution in building land politics is only possible if the transaction costs can be reduced (Einig, 2003; Gillette, 2001).

Information costs comprise the costs to inform all participants about the possible outcomes of the cooperation. Information asymmetry and incomplete information can impede recognition of potential gains from cooperative land development and cooperation between municipalities. The community context of the framework mainly affects the information costs of a joint action in land development. In municipalities with large policy networks (Type 1), gathering necessary spatial data is more expensive than within small municipalities. In regions with heterogeneous municipalities, information costs seem to be higher than in homogeneous municipalities with common interests (Section 3.1.2). Furthermore, the number of municipalities and the distance between them can have an impact on the information costs as well (Feiock, 2007).

In case public officials do not properly represent the interests of their constituents, principal-agent problems might arise and the likelihood of cooperative agreements decreases. Hence, the characteristics of the vertical policy network influence the amount of the arising agent cost in land development. For example, constituents will face higher taxes due to increasing infrastructure costs of non-cooperative land development initiated by their agents. Next to costs caused by the agreement negotiation, costs for dividing the joint benefits between the parties are also created. A fair division of the gains tends to be more problematic between heterogeneous municipalities than between homogeneous municipalities when both partners have similar bargaining strengths. If municipalities have different types (e.g. Type 1 and Type 4), it has to be negotiated how the benefits of the joint land development plan should be divided because their basic municipal criteria tend to be less homogeneous.

Enforcement costs are the costs for monitoring and enforcing the agreement. The costs depend on the characteristics of the horizontal policy network and might be reduced when the contracting municipalities make repeated creditable commitments to each other over long periods of time. However, the characteristics of vertical policy networks and preferences of constituencies or other interest groups should also be analyzed more systematically. The following discussion facilitates the analysis of new collective action frameworks that describe the decision making processes in land development and the effects of the cost paradox, as well as the existence of a development dilemma.

3.5 Summary and Discussion

The presented models reflect only partially the complex process of land use decisions. The proposed approaches mainly analyze how the structure of the spatial area, the demand for floor space, and the community can be modeled and how the cost paradox might influence land use decisions. The decision making framework was introduced to get a deeper understanding of land use decisions in local municipalities. For instance, in small municipalities the influence of vertical policy networks might have a higher influence on land use decisions of the local representatives than in large municipalities. Decision makers in small municipalities tend to have a lack of instruments and tools to develop land use plans that are efficient from an economic perspective. Due to the fact that land consumption is caused by small municipalities, the establishment of decision support tools and the training of the local decision makers in these municipalities might support more efficient land development in ecologic terms. As mentioned in this chapter, land development, which is efficient from an economic view, might reduce the development of new areas and, thus, counteract the ecological problem caused by urban sprawl.

This example highlights the importance of analyzing decision situations of local authorities and the timing of their decisions within this framework. Recent studies only provide limited views on decisions in land development and possible collective action problems. The framework serves as a basis for further analyses and a more interdisciplinary view on the topic. The characteristics of the framework have a crucial impact on the decision situation and the decision making of local authorities. It was shown that two effects can occur when local actors make decisions, the cost paradox and the development dilemma. Both effects can hinder intercommunal cooperation if competition exists, reinforce extensive land use and, thus, lead to urban sprawl. The decision making within this framework was discussed and it was shown how the structure of the framework, which classifies regions and municipalities, influences municipal decision making. The separation allows general statements about different effects on land use decisions in different types of municipalities from an interdisciplinary point of view.

Figure 3.4 depicts the framework and the integration of the decision chain in the land development process that entails the new land usage in a specific planning period. The framework for land use decisions highlights the link between structural aspects of municipalities and the municipal decision making. The calculation of land development plans, the development of new areas, and the local land use decisions of households and firms delineate the main decision steps. The calculation of alternative land development plans is the first step in the land use decision chain. The design of alternative development plans is mainly influenced by the structure of the spatial areas in the inner and outer zones of a municipality. Depending on the available area and the demand for new floor space, categorized into different segments like commercial or residential areas, a municipality might consider different development plans as feasible. Internal conflicts in the vertical network, including personal interests of local representatives, interest groups, or land owners, can influence which of the options are worked out and presented in more detail. The lack of cost transparency combined with bounded rationality of decision makers has an impact on the calculation of the associated costs and can raise the likelihood of a cost paradox in this step.

Alternative development plans are the result of the first step and represent the decision making basis for local representatives in the next step. For local representatives, the horizontal policy network and the structure of policy networks within the region play a more important role. Due to legal agreements and relationships between local representatives within a region, some development options that should be preferred considering economic criteria are sometimes not feasible. Therefore, municipalities with many established relationships and agreements might have fewer development options. Furthermore, the community context defines the balance of power within the regional municipalities. Well located municipalities and municipalities with a lot of property are in better negotiation positions and have more feasible strategies. Due to collective decisions amongst the municipalities, typical dilemma situations could occur in this step. By using game-theoretical models, different aspects of land use decisions can be analyzed. In order to solve the collective decision problem, the initialization of cooperative concepts and the strategic interaction between the municipalities are necessary. The more

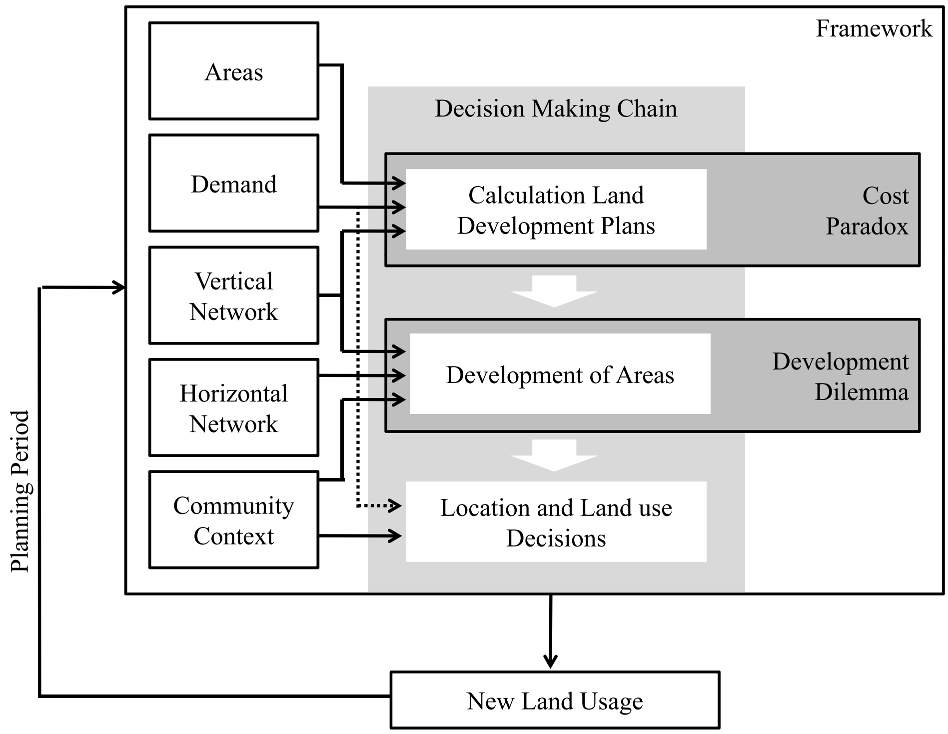

Figure 3.4: Framework of Land Use Decisions

serious the problem caused by high population dynamics is, the larger are the gains from solving it and the greater is the likelihood of a coordinated land development. As in other common pool resource situations, dramatic welfare losses resulting from the development dilemma can be expected depending on the specific scenario.

In the third step of the decision chain, households and firms make location and land use decisions. Based on the available areas within the region, households migrate to new municipalities and build new houses, and firms put up new large buildings, respectively. The usage of new areas is the output of this decision making process. The outcome directly modifies the initial situation of the planning process in later planning periods and also reflects changes of the framework. The framework can help to understand how local authorities in decentralized systems of governance compete and cooperate with respect to the use of land. Furthermore, the framework for land use decisions can serve as a basis for other modeling approaches, especially for the design of decision support tools. When modeling an information system and decision support tool, the focus should be on the structure of spatial areas, demand for floor space, and the community context. Based on the proposed framework, in the next chapter, the modeling and implementation of a regional information system and decision support tool that facilitates the municipal decision making is shown.

4 A Decision Support System for Land Development

The variety of problems regarding the municipal decision making in land usage highlighted in Chapter 3 underpins the need for new methodologies and tools to support these decisions. The presented decision making framework (see Section 3.1) strengthens the necessity to design new, more comprehensive decision support systems (DSS) that support local planners with respect to policy making and spatial planning. Modular components of decision support tools could cover interdisciplinary facets of the proposed framework and help to integrate the tools for specific use cases. Furthermore, the implementation of a system of tradable development certificates, as discussed in Chapter 2, implies additional requirements for such a system. Analyzing the interaction of real world actors with such a new decision support system in field studies or experiments (see Chapter 5) provides insights into decision making processes and can help to identify further requirements for designing new, more appropriate tools or to redesign existing systems to support land use decisions. In this chapter, an overview about Decision Support Systems for land usage in Germany will be given, and a model as well as an implementation of a decision support system that focuses on a TDC scenario will be introduced. The chapter will close with the application of the system in the Spiel.Raum field study, as well as a summary of the findings.

4.1 Overview of Decision Support Tools for Land Development

The development of tools that support policy-making for a sustainable management of land has been progressing in the last couple of years (for an overview see Matthies et al., 2007). The approaches include the modeling of ecological systems, as well as of economic and human subsystems (e.g. social and policy networks). Due to complex interdependencies of socio-political, ecological and economic aspects in environmental quality management, new environmental decision support systems (EDSS) or spatial decision support systems (SDSS) for spatial planning have been developed in the recent years. Interactive computer based information systems utilize environmental models and data, and provide user friendly graphical interfaces. Thus, the tools facilitate cost calculation and improve the decision making of local decision makers. With an EDSS, the decision maker can compare environmental scenarios, e.g. the actual state of a scenario in an use case, with the optimal theoretical state calculated by the EDSS. Especially in Germany, many EDSS and SDSS have been implemented and applied in regional field studies in the last few years (for an overview see Preuß and Floating, 2009). The next section will present the functionality and the modeling of some of these software tools.

4.1.1 Was-kostet-mein-baugebiet.de

Gutsche (2009) implemented different information systems to support the decision making of local representatives and private households. Local decision makers can compare different development scenarios and the software calculates the proceeds and costs, as well as the associated development of areas. The online software tool is free of charge and is available via the internet platform www.was-kostet-mein-baugebiet.de.

A particular module allows the user to calculate living and mobility costs, and facilitates land-use decisions of private households (www.womo-rechner.de). Another module provides estimates of the infrastructure costs of different development options. This module focuses on the follow-up costs of development scenarios and deliberately avoids the comparison of the technical infrastructure costs and possible municipal tax incomes. A comparison typically overestimates the expected incomes of new development areas as mentioned in Chapter 2. There are two versions of the module: a free internet application and an offline excel tool.

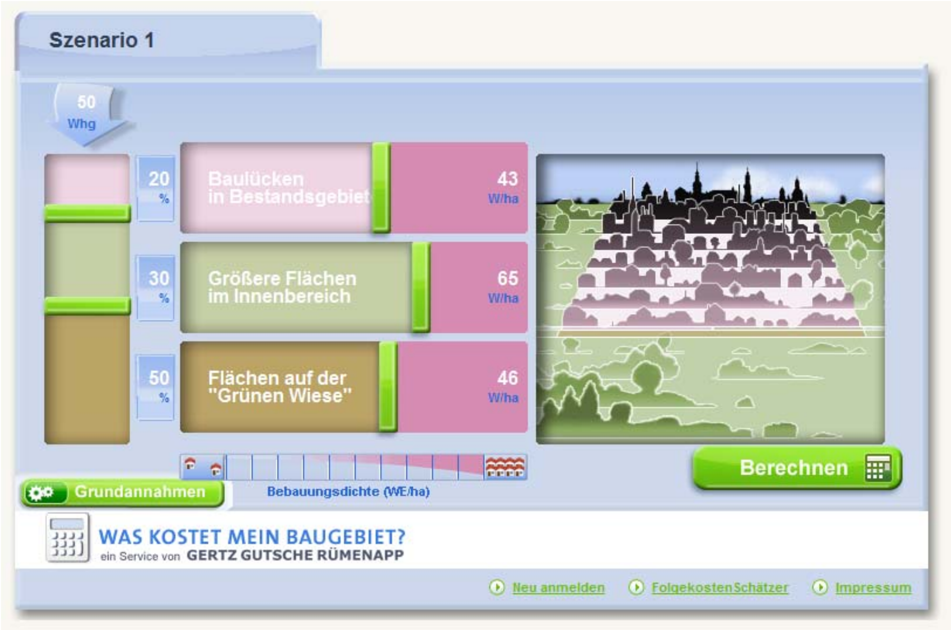

Figure 4.1: Specification of a Scenario with the Tool (Data Input)

The online tool demonstrates the main features of local land development and allows municipal decision makers to make a rough calculation of follow-up costs of different development options (Figure 4.1). The main purpose of the calculation is to simulate scenarios by defining how many gaps should be closed, and how many areas should be developed in the inner and outer areas in a municipality by setting an average building density for each area. Based on these inputs and reference values, the software displays the running costs for streets, sewage systems, water pipes and power supply lines (Figure 4.2).

For a more detailed calculation and a comparison of different planning scenarios, Gutsche (2009) recommends the offline tool. The excel tool precisely estimates the follow-up costs for maintaining the technical and social infrastructure, and also integrates a model for population forecasts. The software itself is also free of charge and facilitates the design of municipal and regional land development plans. However, due to its complexity, the usage of the complete module is only possible in combination with consulting services of the software provider. In contrast to the online tool, the user

Figure 4.2: Running Costs when Realizing the Specified Scenario (Data Output)

can define different development areas and the software calculates the total technical infrastructure costs, as well as the amount of traffic areas. When there is no detailed data available, the software provides benchmark values.

4.1.2 Fokosbw

The Institute for Applied Research of the Hochschule für Wirtschaft und Umwelt Nürtingen-Geislingen and the STEG Stadtentwicklungs GmbH Stuttgart developed, in co-operation with eight municipalities, a practice-oriented software tool to estimate the cost effectiveness of development projects. The cooperation with local actors from specialized disciplines, which are involved in the land development chain, facilitated the design of the software tool. This included the development of concepts for modeling the EDSS and the identification of necessary requirements for a practical implementation. Furthermore, based on an empirical study in 25 regions, characteristic values for different types of municipalities were derived. The classification was based on the calculation of the different costs and incomes, as well as on the structure of the spatial areas in the municipalities.

The design and usability of the software interface was also evaluated by the local decision makers and the feedback was used to redesign the platform. In addition to an offline version of the software, an internet platform is available (www.fokosbw.de).

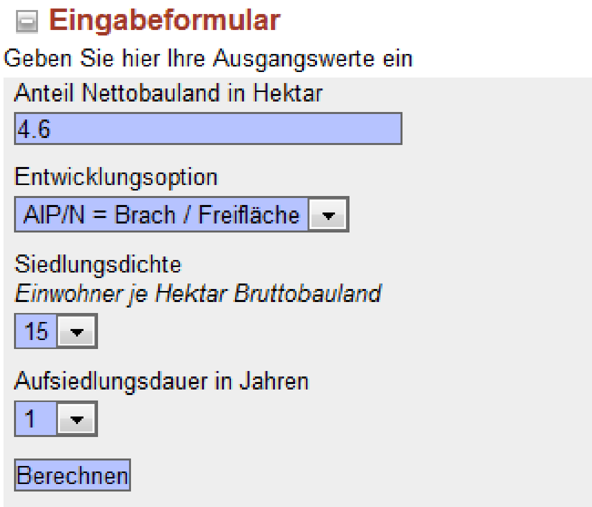

Figure 4.3: Specification of a Scenario by Area-related Inputs

The software calculates different development projects and compares them over a time horizon of 25 years. Municipalities can enter basic area-related data of the city planning (Figure 4.3). The software then calculates the associated costs. The costs are divided into 18 cost types, e.g. preparatory costs, development costs, running costs of the technical infrastructure, education costs, financing costs, or costs for buying and incomes from selling building land (Figure 4.4). The municipalities that participated in the study emphasized the importance of integrating financing costs and incomes associated with the building land (Hauerken et al., 2009). In contrast, education costs are rated as less important. For the calculation of social infrastructure costs, the estimated population growth is included in the analysis. On the basis of few data, the software calculates different costs of different development projects, allows the comparison of the projects and, thus, facilitates the decision making of local representatives. Most municipalities that were involved in this study appreciated the application of the tool because it enhances the cost transparency of the different development projects and improves municipal decision making. Hauerken et al. emphasize that the success of the tool and the realization of cost efficient regional land development, also depends on the structure of the horizontal and vertical policy network.

Kommunaler Anteil der Folgekosten			Folgekosten gesamt	
Innere verkehrl. Erschl.	9.100 €	45%	9.100 €	34%
Sonstige innere Erschl.	0 €	0%	0 €	0%
Äußere verkehrl. Erschl	4.600 €	23%	4.600 €	17%
Straßenbeleuchtung	700 €	4%	700 €	3%
Wasserversorgung	0 €	0%	2.000 €	7%
Abwasserentsorgung	0 €	0%	5.100 €	19%
Entwässerung öffentl. Flächen	3.500 €	18%	3.500 €	13%
Öffentl. Grünflächen	900 €	4%	900 €	3%
Kinderspielplatz	0 €	0%	0 €	0%
Sonderbauwerke	1.300 €	6%	1.300 €	5%
Kompensationsmaßnahmen	0 €	0%	0 €	0%
Summe	20.200 €	100%	27.200 €	100%

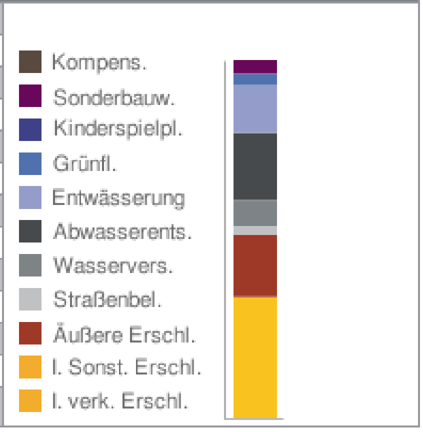

Figure 4.4: Output of Different Costs in the Specified Scenario

4.1.3 LEANkom

LEANkom is a software tool that aims at enhancing the transparency of costs and incomes of the municipal land development. The following institutions participated in the application-oriented, interdisciplinary project LEAN^2: Institut für Landes- und Stadtentwicklungsforschung GmbH, Stadt- und Verkehrsplanungsbüro Planersocietät, Institut für Raumplanung TU Dortmund (IRPUD), Ingenieurgesellschaft GmbH, Lehrstuhl für Planungstheorie und Stadtentwicklung RWTH Aachen, and nine municipalities as partners from practice. The implementation of the DSS is based on studies analyzing municipal decision processes from a theoretical perspective and on empirical case studies (e.g. Feldmann and Klemme, 2007; Krause-Junk, 2008). Furthermore, the authors have announced future versions of the software that will also support the analysis of communal interdependencies to facilitate a coordinated regional land development (see Preuß and Floating, 2009).

The two basic aims of the project are to design an user-friendly tool and to develop a detailed modeling of the municipal decision processes. A high user-friendliness can be realized by implementing a simple user interface that allows an easy data entry and data output. The detailed modeling of the municipal decision situation requires the specification of different development projects by entering data into the platform (see Figure 4.5). The main challenge is to implement a simple user interface with few input fields, which is also able to describe the structure of spatial areas with reasonable accuracy.

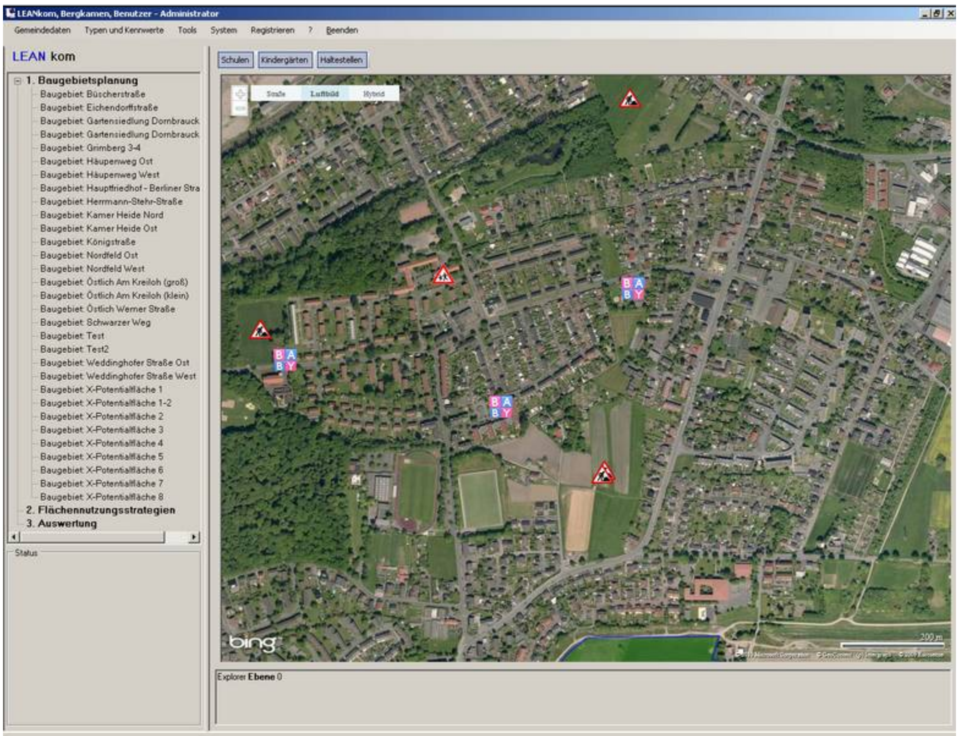

Figure 4.5: LEANkom Software

In LEANkom, the data is distinguished into basic data, municipal data and project data. Basic data are for instance property taxes or the amount of municipal financial compensation. Municipal data comprises more detailed information about the municipalities (e.g. level of income or number of train stops). Project data is a case-by-case description of municipal development projects on the basis of land development plans. To facilitate the data input, the software also provides an interface to import GIS-data of the plans. The software supports the calculation of the profitability of individual municipal projects, as well as the financial impacts of specific land development plans that result from the combination of different municipal projects. The costs are divided into development costs, education and social costs, financial costs and taxes within a time horizon of 20 years. Furthermore, population data is used to calculate the education and social costs based on the degree of utilization of facilities and municipal taxes (Krause-Junk, 2008). After the specification of the scenario, the software displays the resulting incomes and costs on a clear and transparent output page. Furthermore, the export of the data to Microsoft Excel is supported.

4.1.4 Fin.30 - Flächen intelligent nutzen

Similar to the above described projects, the goal of the project Fin.30 is to make costs of different development plans more transparent to decision makers. The result of the project is an excel tool for local decision makers based on the city planning that was tested in some case studies. The model includes location specific characteristics and calculates both one-time and running costs of the social and technical infrastructure. Furthermore, the model distinguishes technical infrastructure costs between inner and outer areas. Based on the estimated population growth, the software estimates the costs of the social infrastructure. Due to the fact that the land will be converted from agricultural into new building land, the model also considers increases in land values. Tax incomes resulting from the settlement of new households are not modeled. The software discounts all annual incomes and costs of a 15-year land development plan and outputs the ranking of different land development plans.

4.1.5 Regionales Portfoliomanagement

The realization of a more efficient regional land development is the central focus of the research project “Regionales Portfoliomanagement” supported by the Institut für Stadtbauwesen und Stadtverkehr der RWTH Aachen, the empirca Qualitative Marktforschung, Stadt- und Strukturforschung GmbH, as well as the Forschungsinstitut für Ökosystemanalyse und -bewertung. Different cooperation concepts have been analyzed in the region Bonn/Rhein-Sieg/Ahrweiler. Coordinated land development in the region is supposed to avoid the competition between municipalities and to reduce the negative fiscal impacts. An existing GIS-based information system has been extended by integrating additional modules for the calculation of costs and for the coordination of regional planning. The usage of the cost module allows the calculation of financial impacts of the regional development on the basis of reference values for a time horizon of 20 years. The regional information system can also be used to monitor the regional land development or to integrate additional policy instruments. Furthermore, different regional development strategies have been compared and evaluated in the case study by analyzing social, economic and ecological consequences of the regional land development.

4.2 Designing a Decision Support System for Land Use Decisions

In this section, three different designs of a decision support system for land use decisions are presented. To facilitate the task of selecting appropriate land development plans by local representatives, an adequate design of the DSS is necessary. First, a basic model will be presented which then will be extended to be used in the context of tradable development certificates. The extension of the DSS was applied in the Spiel.Raum field study (see Section 4.5) and was implemented as a part of the field experiment with the local representatives, which will be described in Chapter 5. The third model will extend the design of the DSS by considering competition for households and applies the game-theoretical model from Section 3.3.2. A comparison of the implemented DSS and the other decision support systems will be given at the end of this chapter in Section 4.6.

In order to model the decision situation of a municipal representative in the DSS, many variables come into question depending on the specific characteristics of the proposed framework. This chapter focuses on the decision making of municipal representatives, while location decisions of the households are only considered indirectly. As described in Chapter 3, the municipality type and the decision making of local representatives are influenced by different criteria. Basic criteria to define the municipality type and the community context are, for instance, population, number of employees, or the budget of the municipality. For instance, a criterion for measuring the prosperity is the municipal budget per capita or the unemployment rate, which can be entered into the database or can be imported from other information systems. Furthermore, an Environmental Decision Support System for land development should apply criteria that define the structure of the areas and the demand for floor space to provide a realistic basis for the decision making in municipalities.

For a more detailed description of municipal decision situations, the structure of the municipal territory, the settlement and traffic areas, as well as the associated floor space areas will be modeled. Table 4.1 shows the structure of spatial areas, which is the basis of the EDSS models described in the following sections (see Statistisches Bundesamt, 2008). The territory of a municipality is divided into settlement and traffic areas, as well as open space. Settlement and traffic areas include sealed surfaces as well as the associated free spaces. Further areas, such as graveyards, recreation and plant areas also belong to this category. Open space is defined as agricultural area, such as cropland or farmland, forest, and water area.

Settlement Area (sealed)
+ Settlement Area (unsealed)
+ Plant Area (no mining land)
+ Recreation Area
+ Graveyards
= *Settlement Area*
+ Traffic Area
= *Settlement and Traffic Area*
+ Open Space
= *Municipal Territory*

Table 4.1: Structure of Spatial Areas

While the settlement and traffic areas reflect the structure of spatial areas, the floor space is used as a measure to model the municipal demand for living space. Settlement and traffic area per capita is an indicator for space consumption, mainly influenced by the given floor space indices and site occupancy indices. Floor space is the total size of all floors of a building on a plot area. The total floor area of buildings on a settlement area can vary depending on the Floor Space Index (FSI).[1] If the FSI is 3.0, the total floor area of a multi-level building can be up to three times the sealed settlement area of a plot.

A municipal land development plan defines the conversion of open space into new settlement and traffic areas and determines structural changes of the spatial area. Furthermore, the land development plan of a municipality is based on the demand for floor space within the respective time horizon. Typically, land development plans are drawn for periods of 10 to 15 years. This time horizon is manageable for most municipalities

[1] In some states, the term Floor Area Ratio (FAR) is also used.

and similar time horizons (15 to 25 years) are also used in other decision support tools which have been presented in Section 4.1.

Furthermore, the decision support system used in the field study assumes that the time horizon is divided into planning periods, in which adaptations of land development plans are possible. Due to the slow adaptation of land development plans and the plans' long validity, longer planning periods than e.g. in emissions trading schemes seem to be appropriate. As mentioned in Section 3.1, it depends on the specific municipality type how often land development plans are revised. Hence, planning periods between one and five years appropriately reflect the decision making processes in municipalities, which are influenced by changes of the policy networks and the demand for floor space.

For the calculation or forecast of the requested floor space, the population development and the development of living space per capita can be used. The demand for commercial floor space can be determined by calculating the development of the working population and the predicted floor space per worker. In the following, the development goal of municipality i in a planning period j is defined by the total amount of new floor space $\bar{e}_{ij}$. The overall development goal of municipality i over all periods is $\bar{\bar{e}}_i = \sum_j \bar{e}_{ij}$. The demand for new areas is determined by floor space, whereas the land development is defined by the increase of settlement and traffic areas. In the next section, the relation of the two area types will be described by showing exemplary development options for a municipality.

4.2.1 Specification of Land Development Plans by Development Options

The task of a municipal decision maker is to design an appropriate land development plan to cover the demand for floor space in a certain planning period. Based on the current spatial structure of the municipality, a land development plan can be defined by a set of development options that restructure the areas of the municipality. By realizing a development option and restructuring spatial areas, a municipality can cover the demand for floor space by households and firms.

Municipalities can use two categories of development options to provide floor space: Development options that determine the new land development in the outer area by converting open space into new settlement and traffic areas, and development options that reuse or extend the usage of existing settlement and traffic areas in the inner areas without developing new land. The delimitation of the types is modeled according to §13a BauGB, which defines development plans for an internal development of municipalities. Therefore, the development of new areas for external development defines the development of areas on the edge of a settlement. For a further categorization in the DSS, it will be distinguished between five different development option types:

- Recycling of brownfields (in the inner area)
- Increase of floor space indices (in the inner area)
- Closing of gaps (in the inner area)
- Redevelopment of existing settlement and traffic areas (in the inner area)
- Development of new areas (in the outer areas)

In each municipality, a set L of development options is available from which a subset K is selected for a land development plan in a specific scenario. Each selected development option $k \in K$ of a municipality i is characterized by the provision of ν_{ijk} hectares floor space in planning period j. The specific provision of floor space can be determined for different planning periods. This is the case if large new development areas in the outer area provide floor space over a long time horizon and cover the demand of many planning periods. Thereby, the sum of floor space provided by the options over all planning periods is limited by the maximum amount of floor space $\tilde{\nu}_{ik}$, which an option can provide:

$$\sum_j \nu_{ijk} \leq \tilde{\nu}_{ik} \tag{4.1}$$

Furthermore, the total amount of floor space, which the selected development options provide in a planning period j is given by:

$$\bar{\nu}_{ij} = \sum_k \nu_{ijk} \tag{4.2}$$

Typically, the maximum FSI influences the building density of development options and the building density is higher in the inner areas than in the outer areas of a municipality. This is due to the fact that the usage of the inner areas is more intense. A higher floor space index in the inner area allows a municipality to provide more floor space, e.g. by closing a gap, than in outer areas with a lower floor space index. Furthermore, differences regarding the type and the degree of building and land use are being neglected by this tool, and new floor space in the inner and in the outer areas is regarded as being of equal value.

4.2.2 Structure of the Spatial Areas

Municipalities have different development options, which determine changes of the spatial structure of the municipal territory while covering the demand for floor space. Typically, development options in the inner area do not change the total amount of settlement and traffic areas. They only restructure a specific area. In contrast, the development of new areas increases the amount of settlement and traffic areas. For the definition of development options, the specific area, which is linked to the quantity of the provided floor space (Section 4.2.1), has to be specified.

A development option k is associated with total changes $\bar{\sigma}_{ik}$ in the spatial areas in municipality i (e.g. the increase in settlement and traffic areas). Changes in the settlement and traffic areas caused by a development option in a specific planning period j in municipality i are summarized by σ_{ijk}. Therefore, the total land development of all development options in a planning period j

$$\bar{\sigma}_{ij} = \sum_k \sigma_{ijk} \tag{4.3}$$

is the amount of new areas that has to be developed in order to provide $\bar{\nu}_{ij}$ floor space in this period. Thus, the average realized floor space index $\tau_{ij} = \frac{\bar{\nu}_{ij}}{\bar{\sigma}_{ij}}$ depends on the types of the selected development options. In case the options are not realized completely in one planning period, the amount of floor space provided in a planning period is divided by the maximum amount to calculate the proportional share $\frac{\nu_{ijk}}{\tilde{\nu}_{ik}}$ of total settlement and traffic areas $\tilde{\sigma}_{ik}$:

$$\sigma_{ijk} = \frac{\nu_{ijk}}{\tilde{\nu}_{ik}} \cdot \tilde{\sigma}_{ik} \tag{4.4}$$

This calculation emphasizes the connection between settlement and traffic areas as a measurement for new land development, and the floor space area as a measurement for the provision of living and working space. By summarizing the new settlement and traffic areas of all realized development options within the planning horizon, the total land development of a municipality calculates to

$$\bar{\bar{\sigma}}_i = \sum_k \sum_j \sigma_{ijk} \quad . \tag{4.5}$$

The realized land development plan is associated with different costs and incomes that are based on the individual costs and incomes of each development option.

4.2.3 Costs and Incomes of Development Options

The realization of a development option is associated with one-time costs C and incomes V, as well as running costs c and incomes v in the following periods. Table 4.2 summarizes the costs and incomes that characterize the development of areas. Incomes and costs that are linked to population dynamics, such as tax incomes or family compensations, are not considered in the basic model of the DSS (for an extended model see Section 4.4). The basic model is based on the assumption that the realization of the development goal is ensured, the municipal population is constant and that floor space in the inner and outer areas are considered as perfect substitutes. Hence, the basic model only includes costs that are associated with the development or restructuring of areas. In the following, the present value $\tilde{PV}_{ik}$ is used to summarize the costs and incomes of option k in municipality i (interest rate $r \in [0, 1]$):[2]

$$\tilde{PV}_{ik} = (V - C) + \frac{v - c}{r} \tag{4.6}$$

[2] The present value includes the present value of the perpetuity, which is an annuity with periodic payments that start on a fixed date and continue indefinitely.

	Incomes	**Costs**
One-time	• Revenues from selling properties, V	• Planning Costs, C_P • Purchase Costs, C_U • Development Costs, C_D • Costs for Demolition Work, C_W • Costs for Renovation, C_R • Other Costs, C_O $C = C_P + C_U + C_D + C_W + C_R + C_O$
Running	• Property Tax B, v	• Direct and Indirect Operating Costs, c_O • Maintenance Expenditures, c_M • Levies, c_L $c = c_O + c_M + c_L$

Table 4.2: Costs and Incomes in the Basic Model

If a development is stretched over many periods, the proportional present value for the realization of a development option providing $\nu_{ijk} \in [0, \tilde{\nu}_{ik}]$ ha floor space in a planning period can be calculated as follows:

$$PV_{ijk} = \frac{\bar{\nu}_{ijk}}{\tilde{\nu}_{ik}} \cdot \tilde{PV}_{ik} \tag{4.7}$$

The total present value $\bar{PV}_{ij}$ of a land development plan in planning period j is:

$$\bar{PV}_{ij} = \sum_k PV_{ijk} \tag{4.8}$$

4.2.4 The Decision Problem in the Basic DSS

The task of a local decision maker is to cover the demand for floor space in each planning period by choosing development options and an appropriate land development plan. The tool supports this decision making by a comparison of incomes and costs of the land development plans in different scenarios. The decision situation is similar to the described situation in Section 3.5 (framework of land use decisions), in which local representatives evaluate different, alternative land development plans. By using the interest rate $r \in [0,1]$ in a planning period, the discount rate δ_j for each planning period j can be calculated:

$$\delta_j = \frac{1}{(1+r)^j} \tag{4.9}$$

The discount rate must be included, when calculating the net present value of a land development plan $\bar{\bar{PV}}_i$ for municipality i:

$$\begin{aligned} \bar{\bar{PV}}_i &= \sum_j \sum_k \delta_j PV_{ijk} \\ &= \sum_j \delta_j \bar{PV}_{ij} \end{aligned}$$

As mentioned above the amount of floor space provided by the realization of development options in a planning period j should cover the demand for floor space $\bar{e}_{ij}$ in all planning periods:

$$\bar{e}_{ij} = \sum_k \nu_{ijk} \tag{4.10}$$

From an economic perspective, development options that provide floor space with a high net present value should be developed first. However, in practice other aspects during the selection of a land development plan could be relevant (e.g. the policy network, see Section 3.1). For instance, surveys within the Spiel.Raum study have shown that non-economic criteria are also important. The preferences of the participants during the selection of development options in the field study will be described in Chapter 5. A simple approach to select the development options from an economic perspective is to calculate the ratio of net present value per hectare floor space ϱ_{ik}:

$$\varrho_{ik} = \frac{\tilde{PV}_{ik}}{\tilde{\nu}_{ik}} \tag{4.11}$$

Then, it is possible to sort all options according to the specific ϱ_{ik} in order to determine the optimal land development plan: A development option $a \in L$ would be preferable to an option $b \in L$ ($a \succeq b$) if the ratio of a is higher than the ratio of b ($\varrho_a > \varrho_b$). The application of such a selection maximizes the financial outcome of a land development plan that assumes a land usage of the new areas and disregards population dynamics. Before an extension of the basic model with additional cost parameters including population dynamics (Section 4.4) is presented, the next sections introduce necessary extensions of the model if a TDC scheme is introduced as described in Chapter 2.

4.3 Designing an EDSS for a TDC Scheme

As mentioned in the last section, municipal decision makers realize the given development goal by developing areas in their municipality. The land development can include the conversion of open space into settlement and traffic areas. When introducing a TDC scheme, a municipality has to submit a corresponding amount of certificates to a supervisory authority for cancellation. An EDSS for a TDC scheme that supports the decision making of local representatives in such a scenario will be presented in this section. Such a DSS was also implemented as a prototype within the Spiel.Raum study and will be presented in more detail in Section 4.5.

As defined in Chapter 2, a tradable development certificate legitimates the conversion of one hectare open space into new settlement and traffic areas. The total amount of initially allocated TDCs limits the development of new areas in all municipalities. For the conversion of recreation areas with specific characteristics, exemption regulations can be applied, so that certificates are not necessary to develop these areas, even though they are considered as settlement and traffic areas.[3] The municipalities can trade TDCs

[3] As discussed in Chapter 2, areas that may not require certificates could be parks, zoological gardens, game enclosure or botanical gardens.

amongst each other. The inner development is characterized by planning measures that improve the usage of existing settlement and traffic areas. Inner areas can be developed within the limits of §13a BauGB or §34a BauGB Abs. 4 Satz 1 Nr. 1 and Nr. 2. As a result, no new settlement and traffic areas have to be developed and no certificates are necessary for the development of inner areas.

As mentioned in Chapter 2, a supervisory authority can set a reduction goal in the TDC system and allocate a total number of certificates in a planning period. The total amount of allocated certificates $\bar{z}_j$ limits the total land development in a planning period. Without the possibility to trade certificates, the municipal land development $\bar{\sigma}_{ij}$ would be limited by the number of certificates $\bar{z}_{ij}$ allocated to a municipality i in a planning period j. Due to the fact that a central market place is implemented in a TDC scheme, municipalities can buy or sell certificates to realize the specific land development plan. Furthermore, if banking is allowed (Section 2.2.3), the remaining certificates $\bar{z}_{ij} - \bar{\sigma}_{ij}$ will be added to the municipalities in the next planning period.

4.3.1 The Decision Problem in a DSS for TDCs

In contrast to the decision problem discussed in Section 4.2.4, a municipal decision maker has to take into account even more aspects during his decision making. For instance, the available amount of certificates or the current market price might influence the selection of the development plan and the trading strategy (the timing of selling and buying certificates at the market). To facilitate decision making in a TDC scheme, the implementation of further functions in the decision support tool is needed. Furthermore, the tool should be tailored to the task of the participants and the available data.

The DSS should also facilitate the comparison of alternative development plans, for instance if the planned municipal development is not feasible due to a shortage of certificates. By comparing different land development plans, abatement strategies that facilitate an efficient achievement of the total reduction goal as described in Chapter 2 can be elaborated. Therefore, the proposed EDSS allows a comparison of different land development plans and enables the calculation of a theoretical price for the TDCs (the so called indicator price). The indicator price of TDCs enables the comparison of planning alternatives to support the elaboration of an appropriate abatement strategy. In the next paragraphs, the calculation of the indicator price in the tool will be demonstrated by comparing two alternative land development plans.

The calculation of the indicator price is based on a comparison of the present values $\bar{\bar{PV}}_i^A$ and $\bar{\bar{PV}}_i^B$ of two alternative scenarios A and B in a municipality i. The values $\bar{\bar{PV}}_i^A$ and $\bar{\bar{PV}}_i^B$ reflect all incomes and costs associated with the land development discounted over all periods at the time of the decision. The planning tool allows a comparison of the two planning scenarios A and B. In this example, planning scenario A is the current scenario and B is an alternative scenario, which is associated with less new land development. The software calculates the present value of the land development plan $\bar{\bar{PV}}_i$ in the municipality i by adding up the discounted present values (discount rate δ_j) of each development option k in each period j (Section 4.2.4):

$$\bar{\bar{PV}}_i = \sum_j \sum_k \delta_j (PV_{ijk}) \tag{4.12}$$

In order to compare the two planning scenarios also the additional incomes and costs for developing a specific amount of area σ_{ijk}^B and σ_{ijk}^A (the difference of the new settlement and traffic areas), given a price for the TDCs of p_i per hectare, have to be discounted for the calculation of the indicator prices. Hence, the values $\sum_j \sum_k \sigma_{ijk}^B \cdot p_i$ and $\sum_j \sum_k \sigma_{ijk}^A \cdot p_i$ will be discounted for a land development plan. Due the fact that for a specific indicator price both scenarios have the same monetary outcome, the following equation holds:

$$\bar{\bar{PV}}_i^A + \sum_j \sum_k \delta_j (\sigma_{ijk}^A \cdot p_i) = \bar{\bar{PV}}_i^B + \sum_j \sum_k \delta_j (\sigma_{ijk}^B \cdot p_i)$$

Based on these values, the EDSS calculates the indicator price $p_i^{A,B}$ associated with the two land development plans in a planning period:

$$\iff p_i^{A,B} = \frac{\bar{\bar{PV}}_i^B - \bar{\bar{PV}}_i^A}{\sum_j \sum_k \delta_j (\sigma_{ijk}^A - \sigma_{ijk}^B)}$$

The indicator price signals for which price a participant should change its current abatement strategy A to a new alternative abatement strategy B. That is the case, when the marginal costs of the land development plan B are equal or less than the value of the certificates needed to realize the planning strategy A. When the price is negative, abatement strategy B is always more profitable even without a certificate system. Hence, the planning tool enables an economic comparison of two land development plans with different abatement strategies and supports the selection of development options during each planning period.

4.4 EDSS Design with Intercommunal Competition

The following game-theoretical model will extend the basic model by aspects of intercommunal competition and additional costs related to the usage of the new development areas. As mentioned in Section 4.2.3, the basic DSS does not include changes in tax incomes or other population-based values by assuming a constant population and disregarding population movements. The demand for floor space is still given, but the usage of the areas by the settlement of new households is assumed to be uncertain. Depending on the development of all municipalities in a region, determined by all municipalities simultaneously, the settlement in each municipality varies. For this, the game-theoretical approach, presented in Section 3.3, will be used to extend the basic model of the EDSS. The EDSS model can be used to solve the described collective action problem by enhancing the cost transparency in a region or to establish cooperation concepts, which have been also discussed in Chapter 3.

In this model, the demand for floor space in a planning period j is determined by the number of households m_{ij} that make new location decisions in a municipality i.[4] Table 4.3 shows the incomes v and costs c per capita that are associated with the settlement of a new household. In order to calculate the average additional incomes in municipality i, the present value l_i for a given interest rate r will be calculated in the DSS. The value of a perpetuity is used by assuming that the descendants of a household will live in the municipality for an indefinite period of time and, hence, the annuity continues indefinitely:

$$l_i = \frac{v - c}{r} \tag{4.13}$$

[4]For simplification purposes, only households and the demand for floor space in living spaces are considered. The interpretation for firms, or other dimensions of floor space, is similar.

	Incomes	**Costs**
Running	• Share of income tax, $v_S^\sharp$ • Subsidies and levies, $v_I^\sharp$ • Family compensations, $v_F^\sharp$ $v = v_S^\sharp + v_I^\sharp + v_F^\sharp$	• Operating costs, $c_O^\sharp$ • District levy, $c_D^\sharp$ $c = c_O^\sharp + c_D^\sharp$

Table 4.3: Running Costs and Incomes per Capita

The total number of households that are willing to migrate (so called movers) within a region in one planning period j is $M_j = \sum_i m_{ij}$. In the following, it will be distinguished between the provision in the inner area $\bar{\nu}_{ij}^I$ and floor space associated with the development of new areas in the outer area $\bar{\nu}_{ij}^A$. The development of new areas in the other municipalities within the region are summarized by S_j. If no information about the population dynamics in a region is given, the incomes of a municipality can be estimated in the model by using the proportion of the new floor space $\bar{\nu}_{ij}^A$ of the total new land development $\bar{S}_j = S_j + \bar{\nu}_{ij}^A$ in the region. The development of new areas influences the changes in tax incomes, determines the net present value in a municipality and reflects population dynamics:

$$\bar{PV}_{ij}^M(\bar{\nu}_{ij}^A, S_j) = l_i \cdot \left(\frac{\bar{\nu}_{ij}^A}{S_j + \bar{\nu}_{ij}^A} \cdot M_j - m_{ij}\right) \tag{4.14}$$

As mentioned in Section 4.2, a municipality is able to cover the given demand $\bar{e}_{ij}$ for floor space in one planning period by realizing different types of development options. The demand for floor space can be covered by developing floor space $\bar{\nu}_{ij}$ in one planning period. By developing more areas at the edge of the municipality than before, a municipality is able to attract new households and firms. Thus, the quotient of these two area types can be interpreted as a criterion for the attractiveness of the total land development plan of a municipality. If a municipality develops more new areas, the settlement of new households and firms is more likely. Furthermore, this differentiation enables the usage of costs and yields functions for these two area types.

In the following, it is assumed that the development options are realized according to economic criteria and that municipalities develop the cheapest options first (Section 4.2.4), in order to model the costs curve for the total inner development instead of calculating the costs for each development option individually. For instance, the costs of providing floor space of $\bar{\nu}^I_{ij}$ in the inner area, e.g. recycling brownfields, can be approximated by the following quadratic cost function:

$$\bar{PV}^R_{ij}(\bar{\nu}^I_{ij}) = a_i \cdot {\bar{\nu}^I_{ij}}^2 + b_i \cdot \bar{\nu}^I_{ij} + d_i \tag{4.15}$$

The parameters $a_i, b_i, d_i > 0$ enable the individual adjustment of the cost function for each municipality in the DSS. If no floor space in the inner area is provided, no recycling costs exist ($\bar{PV}^R_{ij}(0) = 0$). Typically, closing gaps between buildings is cheaper than the recycling of brownfields (Section 3.1.4). This means, that the more areas $\bar{\nu}^I_{ij}$ will be developed in the inner areas, the higher are the marginal costs for restructuring the inner areas:

$$\bar{PV}^{R'}_{ij}(\bar{\nu}^I_{ij}) > 0 \tag{4.16}$$

$$\bar{PV}^{R''}_{ij}(\bar{\nu}^I_{ij}) \geq 0 \tag{4.17}$$

However, the more areas will be developed in the outer areas, the higher are the costs of maintaining the social and technical infrastructure. As in the basic model, the average floor space per hectare of new settlement and traffic areas is specified by the realized floor space index τ_{ij} in municipality i within planning period j. If no detailed data about additional technical and social infrastructure costs for one hectare of new areas resulting out of the development of one hectare of new land is available, the costs should be estimated (e.g. education costs) by reference values from studies (see Section 3.2). Thus, the total infrastructure costs $\bar{PV}^C_{ij}$ of a municipality depend on the total development of new settlement and traffic areas $\bar{\sigma}_{ij}$ and increase with the costs of c_i per hectare:[5]

$$\bar{PV}^C_{ij}(\bar{\sigma}_{ij}) = c_i \cdot \bar{\sigma}_{ij} \Longleftrightarrow \bar{PV}^C_{ij}(\bar{\nu}^A_{ij}) = c_i \cdot \frac{\bar{\nu}^A_{ij}}{\tau_{ij}} \tag{4.18}$$

[5] As introduced in Section 4.2.2: $\tau_{ij} = \frac{\bar{\nu}_{ij}}{\bar{\sigma}_{ij}}$.

4.4.1 The Decision Problem in the Game-theoretical Model

As mentioned at the beginning of this chapter, the calculation of the demand for floor space is derived from the expected population development. However, due to the population dynamics the provision of a specific amount of floor space does not necessarily mean that a certain number of households will settle in the municipality within this model. Within the game-theoretical approach, a municipal decision maker reflects a player $i \in \{1, 2, ..., n\}$, who has the task to select a development plan and an appropriate inner $\bar{\nu}_{ij}^{I}$ and outer development $\bar{\nu}_{ij}^{A}$ of areas to cover the given demand for floor space of $\bar{e}_{ij}$. Hence, each player has to choose simultaneously an amount of $\bar{\nu}_{ij}^{A} \in [0; \bar{e}_{ij}]$. Such a decision situation was described in more detail within the proposed framework of land use decisions in Section 3.3. Depending on the realized land development more or less households will settle in the municipality and Equation 4.14 is used to reflect the location decisions of the movers. Furthermore, the different cost and yield functions presented in the last section have to be considered. Under the prerequisite that the given demand has to be covered ($\bar{e}_{ij} = \bar{\nu}_{ij}^{A} + \bar{\nu}_{ij}^{I}$), the yield and cost functions (4.14), (4.15) and (4.18) result in the overall function $\bar{PV}_{ij}^{\sharp}(\bar{\nu}_{ij}^{A}, S_j)$ which represents the basis of the decision making for a municipal decision maker within this model and determines the outcome for a player depending on the own land development $\bar{\nu}_{ij}^{A}$ and the new land development in other municipalities S_j within the region:

$$\bar{PV}_{ij}^{\sharp}(\bar{\nu}_{ij}^{A}, S_j) = \begin{cases} -\bar{PV}_{ij}^{R}(\bar{e}_{ij}) + \bar{PV}_{ij}^{M}(0, S_j) & \text{if } \bar{\nu}_{ij}^{A} = 0 \\ \bar{PV}_{ij}^{M}(\bar{\nu}_{ij}^{A}, S_j) - \bar{PV}_{ij}^{C}(\bar{\nu}_{ij}^{A}) & \text{if } \bar{\nu}_{ij}^{A} = \bar{e}_{ij} \\ -\bar{PV}_{ij}^{R}(\bar{e}_{ij} - \bar{\nu}_{ij}^{A}) + \bar{PV}_{ij}^{M}(\bar{\nu}_{ij}^{A}, S_j) - \bar{PV}_{ij}^{C}(\bar{\nu}_{ij}^{A}) & \text{if } 0 < \bar{\nu}_{ij}^{A} < \bar{e}_{ij} \end{cases} \quad (4.19)$$

If municipalities cover the complete demand for floor space by the development of outer areas ($\bar{\nu}_{ij}^{A} = \bar{e}_{ij}$), no costs for inner development have to be calculated within the DSS. This is likely in case the costs for increasing the infrastructure are relatively low or the costs for inner development are very high. In case the costs for recycling are low compared to infrastructure costs, the development of areas in the inner area is more appropriate. In an extreme case, the total floor space is provided by the recycling of areas in the center of a municipality and no floor spaces have to be developed in the outer area ($\bar{\nu}_{ij}^{A} = 0$). Due to the fact that the costs for the development of inner areas are extremely variable, a mixed development strategy is more likely ($0 < \bar{\nu}_{ij}^A < \bar{e}_{ij}$). In practice, the optimal development strategy is often a mix of development options in the inner and outer areas: Cheap inner development options, for example the closing of gaps and cheap area recycling, will be developed first. Costly recycling of areas might not be necessary if the demand for floor space is covered by already realized options. The incomes of the new areas depend on different factors, such as the number of movers M or the total development of new areas in a region. From this perspective, the development of new areas is risky. Sometimes fewer households settle in a municipality if the total development in a region is too high and more floor space is provided in the outer areas than actually needed. In contrast, the development of inner areas is a more conservative development strategy and the areas will be used. In the next section, the calculations of the theoretical solutions of this model within the EDSS are shown and some specific implications resulting from the chosen model design are discussed.

4.4.2 Theoretical Solutions

The Pareto-efficient solution represents a reference point for the game-theoretical model. A solution of the proposed model can be derived under the assumption of homogeneous municipalities. As described in Chapter 3, in most metropolitan conflicts homogeneous municipalities are involved. Hence, the theoretical solutions have been derived under this assumption in Section 3.3.2. Inserting (4.18) and (4.14) into (4.19) leads to the following equation, which is the basis for the calculation of the theoretical benchmark:

$$\bar{PV}_{ij}^{\sharp}(\bar{\nu}_{ij}^A, S_j) = -\bar{PV}_{ij}^R(\bar{e}_{ij} - \bar{\nu}_{ij}^A) - \frac{c_i}{\tau_{ij}} \cdot \bar{\nu}_{ij} + l_i \cdot M_j \cdot \frac{\bar{\nu}_{ij}}{S_j + \bar{\nu}_{ij}^A} - l_i \cdot m_{ij} \tag{4.20}$$

The equation has the same structure as the game-theoretical equation, which was introduced and discussed in Section 3.3.2. Hence, the calculation of the theoretical benchmark is similar. Based on this equation the maximum overall present value in the region can be calculated. The necessary condition in the Pareto Optimum leads to:[6]

$$\bar{PV}_j^{R\prime}(\bar{e}_j - \bar{\nu}_j^{A*}) = \frac{c}{\tau_j} \tag{4.21}$$

[6]The detailed derivation is shown in Section 3.3.2.

The result shows that the marginal costs of recycling inner areas should equal the infrastructure costs per realized floor space in the optimal solution. By calculating the derivation of the quadratic cost function the equation can be transformed as follows:

$$\bar{\nu}_j^{A*} = \frac{1}{2} \cdot \frac{2 \cdot a \cdot \bar{e}_j + b + \frac{c}{\tau_j}}{a} \tag{4.22}$$

This is the optimal amount of floor space $\bar{\nu}_j^{A*}$ each municipality should develop in the outer area in one planning period. If the required data is entered into the decision support tool, the tool can calculate the optimal land development plan for a region. The theoretical solution is independent of the amount of municipalities in a region and the tax receipts of the households. Corresponding to the assumption that a specific floor space has to be provided by developing inner and outer areas, the optimal amount of floor space in the inner area $\bar{\nu}_j^{I*} = \bar{e}_j - \bar{\nu}_j^{A*}$ can be determined for a planning period. However, due to the fact that land development decisions are made at the same time and competition for households and firms exists, the deviation from this land development strategy is likely. Thus, municipalities have an incentive to develop more new land, which can be determined by calculating the Nash Equilibrium of the model (see also Section 3.3.2). For determining the symmetric Nash Equilibrium, the Equation 4.20 has to be maximized. In the Nash Equilibrium a municipality provides the amount of floor space $\bar{\nu}_j^{A\sim}$ that fulfills the following equation:[7]

$$\bar{PV}_j^{R\prime}(\bar{e}_j - \bar{\nu}_j^{A\sim}) = \frac{c}{\tau_j} - \frac{n-1}{n^2} \cdot \frac{M \cdot l}{\bar{\nu}_j^{A\sim}} \tag{4.23}$$

Hence, the individual net present value of a municipality resulting from the provision of floor space in the inner areas will equal the infrastructure costs per realized floor space ($\frac{c}{\tau_j}$) less the incomes of moving households per provided floor space in the outer areas ($\frac{M \cdot l}{\bar{\nu}_j^{A\sim}}$), and is influenced by the number of municipalities within the region. For the given cost function 4.15, the decision support tool calculates the Nash Equilibrium:

$$\bar{\nu}_j^{A\sim} = \frac{2 \cdot a \cdot e_j + b + \frac{c}{\tau_j} + \sqrt{(-2 \cdot a \cdot e_j - b - \frac{c}{\tau_j})^2 + 8 \cdot a \cdot \frac{n-1}{n^2} \cdot M \cdot l}}{4 \cdot a} \tag{4.24}$$

[7]The detailed derivation is shown in Section 3.3.2.

The comparison of this solution and the Pareto Optimum (Equation 4.24), as well as the impact of the parameters on the solution have also been presented in Section 3.3.2. For instance, for a convex cost curve it has been shown that more new areas will be developed in the Nash Equilibrium than in the optimal solution.

The adaption of the model presented in Section 3.3.2 into the EDSS provides additional functionality for municipalities as well as for a supervisory authority. By enhancing the cost transparency of each municipality the expected (lower) incomes for developing new areas could be displayed for a municipality depending on the planned outcome of the other municipalities in the region and could reduce the new land development. Hence, by displaying more detailed estimates about the possible incomes when developing new land the monetary incentives for the municipalities in the region could be reduced. Due to the fact that the EDSS for TDCs does not include tax incomes, the game-theoretical model can be used to extend the EDSS for TDCs and can be implemented as an additional software module into the existing prototype. Furthermore, the implementation of this EDSS model can be used to calculate possible gains of a collective action for a supervisory authority within a region to establish cooperation concepts.

4.5 Implementation of an EDSS Prototype: The Spiel.Raum Study

The previous sections have shown the structure of a decision situation in order to support the decision making of local representatives by a DSS, whether population dynamics exist or not. First, the decision situation and the associated decision problem of local representatives was presented on the basis of a basic model (Section 4.2.4). This decision problem is characterized by selecting land development options to cover the demand for floor space. Second, if a TDC system is introduced, further aspects might influence the decision making of local representatives and the DSS can be extended by an additional indicator price module (Section 4.3.1). Results of case studies can be helpful to estimate the specific model parameters, e.g. the demand for floor space or the infrastructure costs of new land development, of the proposed models in different regions. Finally, the game-theoretical model can be integrated into the DSS that reflects the impacts of competition for households and metropolitan conflicts in different community contexts or analyzes the decision making of local representatives.

In this section, the implementation of an EDSS that is based on the basic model and that addresses further aspects of a TDC system will be presented. As mentioned in Section 1.3, a cap-and-trade scheme for land development was investigated with local authorities by means of the field experiment. Within the Spiel.Raum field study, which was conducted with 14 German municipalities, a first EDSS prototype with TDCs was implemented in practice. The EDSS was implemented as an internet tool, in which the participants were asked to enter municipal data. After the implementation of the EDSS and the collection of field data, a TDC field experiment was conducted with the municipalities. In Chapter 5, the design of the field experiment will be presented and the decision making of local representatives will be analyzed and evaluated.

4.5.1 Field Data Collection

Within the Spiel.Raum study, the design of the TDC scheme and the software tool were discussed with the participating municipalities and communal interest groups on several workshops before the field experiment was conducted. Afterwards, the local representatives collected data of their municipalities regarding the time period between 2008 and 2022, divided into five planning periods each lasting three years. In order to facilitate the field data collection and to provide technical assistance on how to enter the data into the platform, two workshops with the participants were conducted in 2007 and 2008, respectively. These workshops also included reports on past experiences with experiments for emission allowances and a discussion of the results with the participants.

The first workshop focused on different design parameters of the EDSS. This included the discussion of the necessary real world data (e.g. costs and spatial areas), the structuring of data at the software platform (as described in the Sections 4.2.2 and 4.2.1) and the design of decision support tools. Basically, it was distinguished between two types of development options: development options in the inner area and options in the outer area of a municipality (see Section 4.2.1). A development option specified a potential development project in a municipality and the associated development costs and areas (see Figure 4.6). The realization of development options in the outer area required an amount of certificates specified by the baseline scenario. However, for the realization of options in the inner area[8] no certificates were needed. Typically, these development options should allow a denser city development and were more expensive (see Section 3.2). It was possible that inner development required a negative amount of TDCs, which meant that participants received certificates for implementing the project.

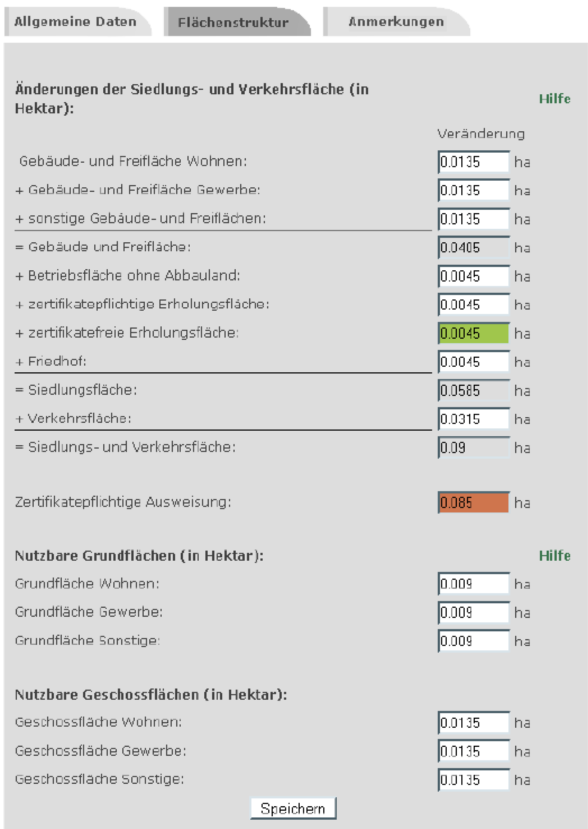

Figure 4.6: Specification of a Development Option in the Spiel.Raum DSS

At the second workshop, a first test run with the participants using fictitious data was carried out to collect feedback and suggestions for an improvement of the EDSS. The test run included the definition of development options, the specification of the development goal and a test of the trading platform. In the next step of the study, the participants collected data with respect to their cities' inner and outer-city potentials for further development including associated costs. The municipal data was entered in

[8] As defined in the German law §13a BauGB or §34 BauGB Abs. 4 Satz 1 Nr. 1, 2.

a structured and comparable format into the EDSS. The participants entered the main data that determined the community context, such as the number of population, number of employees, the budget of the municipal household and the detailed structure of the spatial areas (Section 4.2.1).

Possible changes of the spatial areas were determined by the specification of development options. A development option was specified by its name, its type, its net present value, the structure of the spatial areas, and an informal, textual description.[9] Predefined forms for the area structure, which were based on the structure of spatial areas in Germany, were provided to simplify this task for the participants. An online help, which included a comprehensive description of the area types as defined in the cataloguing of the German Federal Statistical Office, was available. The participants could enter as many development options as available in their municipality. The territory, the settlement and traffic areas, and the total floor space was used to calculate the settlement and traffic area per capita and the realized floor space and site occupancy indices. The software automatically calculated some key indicators, for instance the municipal budget per capita. Furthermore, the EDSS automatically calculated the amount of certificates that was necessary for realizing a development option in the field experiment based on the spatial structure of the area.

At the end of the data collection, the EDSS also asked the participants to specify targets in terms of the provision of living space and industrial real estate and to define a baseline scenario representing the actual planning in a city for the next 15 years if there were no restriction for the development of new land.[10] The representatives decided which options would be developed in a planning period. This implied that an individual demand for new floor space was set in each planning period. The demand for floor space determined the development goal of a municipality in the two dimensions living space and floor space for commercial use. The participating representatives determined these development goals of the municipalities in the EDSS. The scenario was used as the reference scenario (baseline scenario) of the field experiment. Furthermore, the baseline

[9] When no data was available, estimations from studies were used to complete the database (Reidenbach, 2007).

[10] As discussed at the beginning of this chapter, 15 years are the general time horizon of a land use plan in Germany.

scenario showed the total amount of new settlement and traffic areas that a municipality planned in each planning period to cover this demand for new floor space.

4.5.2 Scenario Analysis in the EDSS

During the field experiment, alternative development plans could be analyzed by the participants (e.g. regarding the amount of TDCs, see Chapter 5). The participants' task during the field experiment was to cover the development goal by combining development options in the inner and outer area of their municipality in each planning period. To facilitate the task for the participants, the DSS allowed a comparison of two land development plans (Section 4.3). In addition to the decision in which planning period the development option would be developed, the participants could specify a priority for each option. Options declared with a higher priority were automatically developed first by the system. When a development option was not fully realized in a planning period, the development option had the highest priority in the next period. This should facilitate the task for the participants of selecting appropriate development options. The participants could test different scenarios by altering the timing of the land usage or the order of the development options.

When the participants selected a development option, the platform calculated the proportional incomes and costs for the specific planning period as presented in Section 4.2.3. Therefore, the participants could consider economic aspects in their planning strategy to provide floor space in each planning period at minimal costs (see Figure 4.7). Development options that were not fully realized until the end of the planning horizon were considered in the respective proportions. The planning tool calculated all net present values and compared the scenarios from an economic perspective. The comparison of the demand for TDCs and the resulting indicator price were also displayed. During the simulation, the Decision Support System was made available to the participants, which simplified the adaptation of the land development plan by displaying price signals for selling or buying development certificates on the market place on the basis of two different planning strategies (Section 4.3.1).

At the end of a planning period, the DSS delivered an overview of the new developed areas in a municipality. The certificate stocks for the different planning periods and

Szenarioanalyse:

Periode:	2008-2010	2011-2013	2014-2016	2017-2019	2020-2022
Bedarf Geschossfläche:					
Wohnen (Baseline):	5 ha	5 ha	5 ha	0 ha	0 ha
Gewerbe (Baseline):	5 ha	5 ha	5 ha	0 ha	0 ha
Sonstige (Baseline):	5 ha	5 ha	5 ha	0 ha	0 ha
Beitrag Geschossfläche oben getesteter Maßnahmen:					
Wohnen	M156: 3 ha Sum: 3 ha	M6: 5 ha Sum: 5 ha			
Gewerbe:	M156: 3 ha Sum: 3 ha	M6: 5 ha Sum: 5 ha			
Sonstige:	M156: 3 ha Sum: 3 ha	M6: 5 ha Sum: 5 ha			
Zertifikatebedarf:	0 ha	15 ha	0 ha	0 ha	0 ha
verfügbare Zertifikate:	12 ha	12 ha	12 ha	0 ha	0 ha
Über(+)/Unterdeckung(-):	12 ha	-3 ha	12 ha	0 ha	0 ha
Einmalige Einnahmen:	0 Tsd. €	100 Tsd. €	0 Tsd. €	0 Tsd. €	0 Tsd. €
Einmalige Ausgaben:	1200 Tsd. €	100 Tsd. €	0 Tsd. €	0 Tsd. €	0 Tsd. €
lfd. Einnahmen (Summe):	62 Tsd. €	137 Tsd. €	137 Tsd. €	137 Tsd. €	137 Tsd. €
lfd. Ausgaben (Summe):	62 Tsd. €	137 Tsd. €	137 Tsd. €	137 Tsd. €	137 Tsd. €

Barwert der Maßnahmen (2008): -1200 Tsd. €

Figure 4.7: Scenario Analysis in the Spiel.Raum DSS

the payment transactions were traced in separated accounts and could be monitored by the local decision makers. The municipality could use this information to adapt the trading strategy, for example initiating the purchase of more certificates when there was a shortage. This feature should reduce the risk of paying sanctions and enhance the calculation of land development plans by monitoring the stock during the planning simulation.

4.5.3 Results of the Field Data Collection

The municipal representatives gathered 263 development options for the field study. 209 of these options were selected for the realization in the planning horizon and defined the baseline scenario. Depending on the size of the municipality, the amount of development options differed between 7 and 69 per municipality. Table 4.4 depicts the characteristics of the development options gathered from the municipal representatives.[11] On average,

[11] A more detailed description of the field data is already given by Ostertag et al., 2010.

a development option provided 6.97 ha of floor space. Options that are defined in the baseline scenario are associated with the development of 7.46 ha floor space each. In contrast, not preselected (alternative) options only provide 5.08 ha, which are mainly smaller projects in the inner area. The baseline scenario includes many new development areas in the outer area. Due to fact that new development areas are large residential or commercial areas, new development areas can be seen as indivisible and tend to provide more floor space. The average amount of new settlement and traffic areas in the baseline development is also higher. Development options in the baseline are connected with an average increase of 6.54 ha settlement and traffic areas, whereas the alternative options have an average new development of 0.57 ha. Most of the alternative development options are options in the inner area and do require less or no development of new areas.

	All Options	Selected Options (Baseline)	Unselected Option
Provided Floor Space (in ha)	6.97	7.46	5.08
Settlement and Traffic Areas (in ha)	5.31	6.54	0.57
Realized Floor Space Index (in ha)	0.76	0.88	0.11
Present Value (in mu)	279.55	489.52	-533.11

Table 4.4: Main Characteristics of the Development Options

The division of the new settlement and traffic areas by the provided floor space delivers a value for the efficiency of land development (Section 4.2.2). The realized floor space index makes clear how many new areas have to be developed on average for the provision of a hectare new floor space. In the baseline scenario, the municipalities plan the realization of 0.88 ha new settlement and traffic areas per one hectare floor space (see Table 4.4). The alternative options have a quotient of 0.11 ha, which means that the realization of alternative options would be linked to the development of denser areas and allows more sustainable development in terms of land consumption. However, the alternative options are linked to cuts in the municipal incomes and have on average a lower present value. The average net present value of development options defined in the baseline scenario is 489.520 monetary units on average, which means that the development of new areas is associated with incomes. The data gathering was conducted from the point of view of the municipal representatives and reflects results from many studies. As mentioned in Chapter 3, recent analyses have shown that the perception of costs and incomes of development options might be influenced by a lack of transparency during the data collection.

4.6 Summary and Discussion

In this chapter, the design and the implementation of a decision support system for tradable development certificates was presented. The definition of municipal land development projects is a central requirement in order to make an accurate comparison of different municipal development plans possible. For the definition of different development options, the software includes specific online forms and a comprehensive online-help. Compared to other decision support systems, the dimension floor space was introduced as the central value for an appropriate comparison of different development strategies. Furthermore, the decision support system determines the structure of the areas that are linked with a 15-years land development plan and with the demand for floor space. Similar to other planning tools, the presented DSS includes a basic model without considering population movements and distinguishes area-related costs and incomes. However, by using the introduced extended modeling approach, these incomes can also be included. Table 4.5 compares the characteristics of the decision support tool with the modeling and implementation approaches of the other EDSS.

The internet-based platform also provides a market module that enables the implementation of a TDC market. A planning tool signals the price, for which a specific development scenario is linked with higher incomes, and facilitates the municipal decision making. The platform for TDC schemes also supports the municipal accounting. At the end of a planning period, the platform delivers an overview of the total new developed areas in a municipality. The certificate stocks for the different planning periods and the payment transactions will be calculated in separate accounts and can be monitored by the local decision makers. The municipality can use this information to adapt the trading strategy, for example initiating the purchase of more certificates if there is a shortage. The system will reduce the risk of paying sanctions and enhance the calculation of land development plans and the stock over a long time horizon.

Tool	Software	Case study	Time Horizon (years)	Incomes	Costs
Was-kostet-mein-baugebiet.de	Excel Tool, Internet Tool	-	10-100	-	Technical and social infrastructure
Fokosbw	Excel Tool, Internet Tool	25 regions	25	Taxes, financial compensation	Technical and social infr., financial
LEANkom	Excel Tool	9 municipalities	20	Taxes, financial compensation	Technical and social infr., planning, financial
Fin.30	Excel Tool	3 municipalities	15	Revenues by selling property	Technical and social infr., financial
Portfolio-management	Excel Tool	One region, Regional cooperation	20	(Estimation of utility)	Social infr., planning, ecological
Spiel.Raum	Internet Tool	14 municipalities, TDC scheme	15	Revenues by selling property	Technical infrastructure, planning, financial

Table 4.5: Comparison of the EDSS

In the field study, the 14 municipalities entered their municipal data into the web-based platform. This data collection was the basis for simulating a system of tradable development certificates. The next chapter will introduce the design and set-up of the field experiment and will present the results of two simulation runs. Furthermore, the chapter analyzes the trading strategies of the local decision makers as well as the abatement strategies that were elaborated on the basis of the implemented decision support tool.

5 Tradable Development Certificates in a Field Experiment

In the previous chapter, the model and the implementation of a decision support system for tradable development certificates in Germany were described. Based on the proposed data model, the design of a software platform as well as the data collection in a field study with actual municipalities were presented. In the data collection phase of the presented field study Spiel.Raum, the task of the participants was the specification of development options in the inner and outer areas of their municipalities on the software platform, as well as the determination of a baseline scenario. By defining a baseline scenario, a municipality set the development goal determined in floor space for each planning period in an actual scenario without the presence of a TDC system. The total development of new settlement and commercial areas, which would be developed in the baseline scenario, was the basis for the amount of TDCs allocated in the field experiment. However, in the field simulation a reduced amount of TDCs was emitted to the municipalities. The reduced amount of TDCs determined the reduction goal in the simulation that was set in order to limit the development of new areas and to reduce new land development.

In this chapter, a field experiment within the scope of the field study Spiel.Raum will be presented. The local representatives of the municipalities which also participated in the field data collection, simulated a system of tradable development certificates in two subsequent simulation runs. Hence, the field experiment is based on the collected data of the field study. First, the design of the field experiment and the task for the participants in the preparation phase of the field experiment as well as in the simulation runs will be presented. Second, theoretical benchmarks and hypotheses about expected abatement strategies, price discovery processes and trading strategies of the participants will be shown. The hypotheses serve as a guideline for analyzing the field data in the simulation run and are investigated in the third section. The analysis is based on the main results of the Spiel.Raum study (Müller et al., 2010; Ostertag et al., 2010, as well as a so far unpublished working paper). The chapter concludes with a short summary and a comparison of the simulation results.

5.1 The Field Experiment Spiel.Raum

In addition to classical laboratory experiments, more realistic field experiments with a specific contribution to economic policy making have been carried out over the last years (see Cardenas and Carpenter, 2005; Carpenter et al., 2005; Harrison and List, 2004; Sturm and Weimann, 2006). Furthermore, some of the national and regional emissions trading systems in the US were simulated in experiments prior to the actual implementation to test selected properties of new policy instruments (e.g. Holt et al., 2007). This experimental methodology makes it possible to assess the validity of results from theoretical models (see Eckel and Lutz, 2003; Loewenstein, 1999). The explorative approach can also lead to new findings which, because of the complexity of the environment, could not have been derived from theory. The simulation game SET UP on emissions trading combined the advantages of a field experiment and a controlled lab experiment, and simulated an emissions trading scheme with actual companies in a controlled environment (Schleich et al., 2002; Ehrhart et al., 2003).[1] Companies that participated in the ex-ante simulation also took part in such a system in reality. The artificial testing environment developed for SET UP allowed the controlled analysis of the participants' actual decision processes and strategies.

The study Spiel.Raum (engl. "Spatial.Game") was conducted as a first experiment with tradable development certificates with 14 German cities and municipal syndicates from 2007 until 2009. Similar to the SET UP study, the main goal of Spiel.Raum was to design a cap-and-trade scheme for land development and to analyze efficiency gains of the new instrument in a field experiment with actual decision makers as well

[1] For publications in English see also Schleich et al. (2006).

as to analyze the behavior of the local representatives.[2] Furthermore, both studies applied a two-stage approach: During the first stage (Section 4.5), the participating municipalities collected data on necessary floor space, fallow land, development areas, as well as possible development alternatives including the respective short- and long-term costs and benefits.

During the second stage, the participants simulated the time period from 2008 until 2022 in two subsequent simulation runs under the assumption that a TDC system was in place, which limited the total development. While the field experiment was run over the Internet, several accompanying workshops were conducted, in which the data collection, the rules of the experiment or the calculation of the value of a TDC were explained, and the possible consequences of a TDC system on municipal planning processes were discussed. After each of the two simulation runs, the results were presented to the participants and their feedback was collected, to identify their strategic behavior. Furthermore, it was examined whether difficulties had arisen during the simulation runs in order to collect improvement suggestions for further decision support tools. In addition, surveys and interviews were conducted focusing on the strategies applied by the decision makers as well as the influences of the system on other planning objectives (see Ostertag et al., 2009, 2010).

The design of the field experiment can be characterized as follows by using the terminology of List (2003):

The main *subjects* of the study were urban and spatial planners. In the following, they are also called the field subjects. Being experts in land use management these participants are non-standard subjects in the language of experimental economics. In order to obtain an empirical benchmark for the results, each simulation run was repeated in the lab with a student control group, so-called standard subjects, using the same municipal data. The results of the real planners were compared to both, the theoretical predictions (Section 5.1.2) and the results of the control group. Both groups acted independently from each other and the participants interacted within a group only by trading certificates on the internet platform (Section 4.5).

[2]Within the study, additional laboratory experiments have also been conducted, which are not the focus of this book. For the results of the laboratory experiments see Müller et al., 2010a and Müller et al., 2010b.

Both groups received a guideline, containing detailed *information* about the field experiment as well as the *task and the trading rules* (Section 5.2.1). The participants were also provided with calculation tools and an online help functionality. Moreover, a telephone hotline was available in case of questions. One week prior to the experiment, a short test run for each subject group was conducted in order to verify that everybody had understood the *task and the rules of the game* as well as handling the software. This aimed at guaranteeing that – regardless the very different background – both groups had the same level of information with respect to how the field experiment was run. The context of the experiment, the municipal development planning, was thoroughly explained to the participants.

The *commodities* in the experiment were TDCs as defined in Section 2.2.1 rather than abstract goods. At the first workshop, it was discussed with the participants which area types did require TDCs and which did not require (for example various recreation areas). The resulting structure of the spatial areas was presented at the beginning of Section 4.2.

The *stakes* were different for the two subject groups. There was no explicit incentive for the field subjects. The cities were only reimbursed for their travel expenditures related to participating in the workshops. The students of the control group received a graduate course attendance certificate, but were not paid. Thus, either for both groups the payoffs were independent from the individual performance in the simulation.

During the experiment, both groups could use additional media (e.g. calculators, laptops) for decision support. Hence, the *environment* was not strictly controlled. The experts participated in the experiment (including the field simulation) via the internet, whereas the simulation with the student group was run in a computer lab. However, both groups operated on the same platform. After the field data collection with the local representatives, the experiment was run in parallel with both groups and with each group the time period 2008–2022 was simulated twice. The simulation runs were divided into five planning periods consisting of three calendar years each. The targets for residential and commercial floor space as specified in the baseline scenario were imposed separately for each three-year planning period. Since the set of development options was fixed at the beginning of the simulation, the participants could not search for new, potentially cheaper options and add them to the platform.

5.1.1 Allocation of Certificates

In each period, a certain amount of TDCs was allocated to the municipalities. In the first simulation run, the total reduction potential was 119 ha (27.6%) compared to the baseline scenario. For the simulation run, only 375 ha of the total demand of 431.4 ha in the baseline scenarios were emitted, i.e. overall emitted to all municipalities and municipalities obtained 13.1% less certificates than in the initial baseline development. At the beginning of the experiment, all municipalities were informed about the individual amount of certificates they would receive in each planning period. However, the total amount of certificates was not announced at the beginning of the experiment. Banking of certificates was permitted and therefore unused certificates could be transferred into the next planning period. In contrast, borrowing was not permitted.

	Baseline 1	Simulation 1	Baseline 2	Simulation 2
Planning Period I	77.2 ha	100.1 ha	74.3 ha	129.8 ha
Planning Period II	125.0 ha	88.5 ha	127.2 ha	79.4 ha
Planning Period III	84.4 ha	75.0 ha	100.9 ha	54.1 ha
Planning Period IV	52.2 ha	61.5 ha	53.9 ha	39.0 ha
Planning Period V	92.6 ha	49.9 ha	83.1 ha	28.7 ha
Sum.	431.4 ha	375.0 ha	439.4 ha	331.0 ha

Table 5.1: Planned Development vs. Primary Allocation of TDCs

Due to the fact that the municipalities could adjust the baseline scenario between the two simulation runs, the two baseline scenarios vary slightly. In the baseline scenario of the first simulation, about 431.4 ha new land had to be developed; in the second simulation run, the planned total land development was 439.4 ha. Moreover, the overall reduction goal was increased to 24.7% in the second simulation run and only 331 hectares certificates were allocated. In addition, the certificates were emitted asymmetrically with respect to the municipalities' reduction potentials (e.g. development options for recycling brownfields). The total reduction potential in the second run was 238 ha. Thus, the municipalities had the possibility to reduce the development of new areas by 54.2% compared to the baseline scenario. Furthermore, the allocation of the certificates was done unevenly so that there was a surplus of certificates in the beginning and a shortage in the last periods in both simulation runs (Table 5.1).

5.1.2 Theoretical Benchmark

In the field experiment, the efficiency of the TDC system can be measured by comparing the simulation results with an optimal scenario, specified by individual land development plans, in which the development goal is achieved at the lowest possible costs. To calculate the cost-efficient optimum measured in monetary units (mu)[3], the development options of all municipalities were considered and the overall cheapest development options were realized to achieve the required global reduction goal.

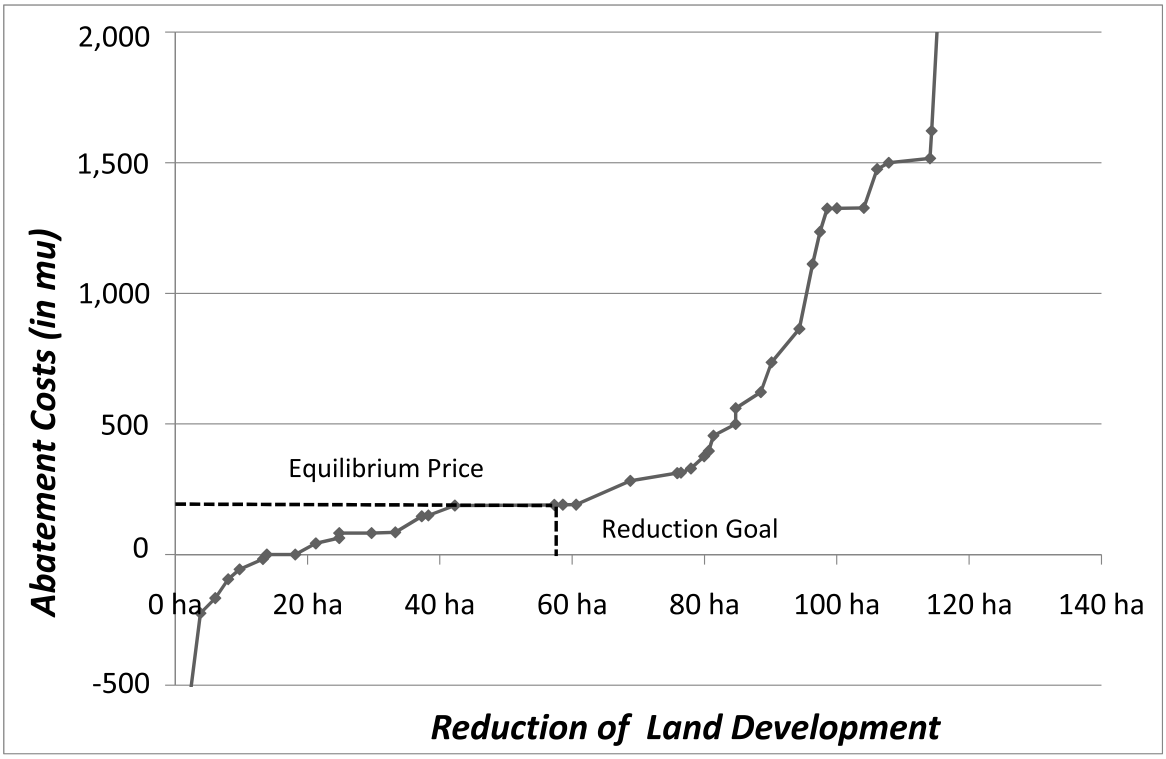

Figure 5.1: Marginal Cost Curve for Simulation 1

Figure 5.1 depicts the marginal cost curve in the first simulation run of the field experiment.[4] In theory, the market price should reflect the marginal costs of achieving the cost-efficient reduction of new land use. Figure 5.1 also shows the theoretical market price (equilibrium price) of 191 mu/ha in the first planning simulation based on the field

[3]In the following, all costs and incomes are represented by monetary units.
[4]A negative value indicates that the realization of development options is linked to incomes.

data gathered by the participants. In the second simulation run, the theoretical market price was 429 mu/ha.

Municipality	Baseline	Optimum
1	9.50	8.50
2	32.30	32.18
3	13.90	7.26
4	20.67	3.39
5	11.55	10.95
6	21.00	21.00
7	72.02	66.01
8	20.00	20.00
9	48.16	43.28
10	11.80	9.84
11	92.00	87.90
12	55.80	49.08
13	16.00	8.00
14	6.70	6.70
Sum.	431.40	374.10

Table 5.2: Land Development (in ha) in the Baseline and Optimal Scenario

In Table 5.2, a comparison between the land development of the baseline and the optimal scenario is shown. All municipalities had to reduce (or at least not extend) their land development in such a scenario to achieve the overall reduction goal. Furthermore, 0.9 ha less than the total amount of certificates allocated to the municipalities should be developed in the optimal scenario. To realize this reduced land development, the municipalities had to trade a minimal amount of certificates (minimal trading volume) depending on the distribution of certificates determined by the primary allocation.

The reduction of land development should also be associated with additional costs. Table 5.3 depicts the net present values of the land development plans in the baseline and in the optimal scenario for each municipality in monetary units. In total, the achievement of the environmental goal enhances the overall net present value by 13,619.486 mu in the optimal scenario, which indicates that the land development plans in the baseline scenario were not optimal from an economic point of view. In five municipalities, the adaptation of the land development plans leads to a lower income regarding incomes

Municipality	Baseline	Optimum	Diff
1	-418.027	-586.195	-168.167
2	59,191.871	72,393.984	13,202.113
3	3,325.439	2,799.265	-526.174
4	-38,541.336	-42,225.745	-3,684.410
5	0.000	0.000	0.000
6	43,726.585	43,726.585	0.000
7	7,123.810	7,203.774	79.965
8	11,081.154	11,081.154	0.000
9	3,771.389	3,202.064	-569.325
10	22,473.105	22,740.982	267.878
11	24,586.697	25,935.661	1,348.964
12	4,485.807	9,562.767	5,076.959
13	11,776.961	10,275.268	-1,501.693
14	3,768.787	3,862.164	93.376
Sum.	156,352.243	169,971.729	13,619.486

Table 5.3: Net Present Values (in mu) in the Baseline and Opt. Scenario

of the land development plans. Hence, the calculation of the optimum reveals that the land development in the municipalities could be reduced without resulting in additional costs for the municipalities. The land development, the theoretical market price and the total net present value of the calculated optimal scenario are the basis for the further evaluation of the simulation runs, which is explained in the following sections. The theoretical scenario represents the cost-efficient land development in the field experiment. In the next sections, the simulation results of the first simulation run will be examined and compared with the calculated theoretical cost-efficient optimum scenario as well as the initial baseline scenario.

5.2 Evaluation of the Field Experiment

In this section, the decision making of local representatives and the causes and effects that influenced the simulation outcome in the first simulation run are analyzed. Particularly, the land development, the price discovery, and the trading strategies of the participants are analyzed in more detail. The analysis is based on the results of the simulation runs as well as the results of surveys among the participants subsequent to each simulation run. These surveys provide further insights into their decision making. Due to the fact that the initial baseline scenarios of the municipalities were slightly adapted for the second simulation scenario, the analysis focuses on the first simulation run and the initial baseline scenario determined by the municipalities.

5.2.1 Decision Situation

At the beginning of each period, the participants had to decide which of their potential development projects they wanted to implement. Hence, the participants could adopt their development plans, as long as they provided the floor space originally defined in their targets. In order to facilitate the task for the participants, the Spiel.Raum software provided a decision support tool (Section 4.3) which facilitated the economic analysis and the pairwise comparison of different planning strategies. In order to reduce the huge amount of planning strategies, the number of feasible strategies was restricted in the first simulation run, and 179 of 264 development options were predetermined (Table 5.4).[5] On average, the participants could choose from 6.1 development options (minimum 4, maximum 14). However, in the second simulation a much larger set of feasible development options was possible and more than half of the options were disposable (on average 9.9 options).

	Simulation 1	Simulation 2
Total number of development options	264 (100%)	268 (100%)
Predetermined options	179 (67.8%)	129 (48.1%)
Number of selectable options	85 (22.2%)	139 (51.9%)
Min. / Avg. / Max. per participant	4 / 6.1 / 14	6 / 9.9 / 18

Table 5.4: Development Options

After the participants had decided which development options they wanted to realize in the current planning period, they could trade certificates among each other on the online market place.[6] The software recorded all transactions as well as all costs incurred

[5]This step was intended to provide a realistic scope of action to all participants, which was manageable and transparent during the experimental sessions.

[6]To preclude market power of the three largest municipalities (Munich, Nürnberg and Heidelberg/Mannheim) during the trading phase, these municipalities were scaled down by the factors

by the participants. At the end of a planning period, the software canceled an amount of certificates according to the development of new areas in the period. For each missing TDC, a participant had to pay 1,000 monetary units. In addition, missing TDCs were automatically subtracted from the allocation of subsequent planning periods.

In each planning period, the local representatives made decisions on development options and selected a scenario based on criteria, which seemed to be important to them. One might expect that a participant would carry out development options in the ascending order of their net present values. However, the results across all participants suggest that the choice of the development options was not always done to minimize costs. Some low-cost development options were not realized, whereas more expensive measures compared to the optimal scenario were realized (Section 5.1.2).

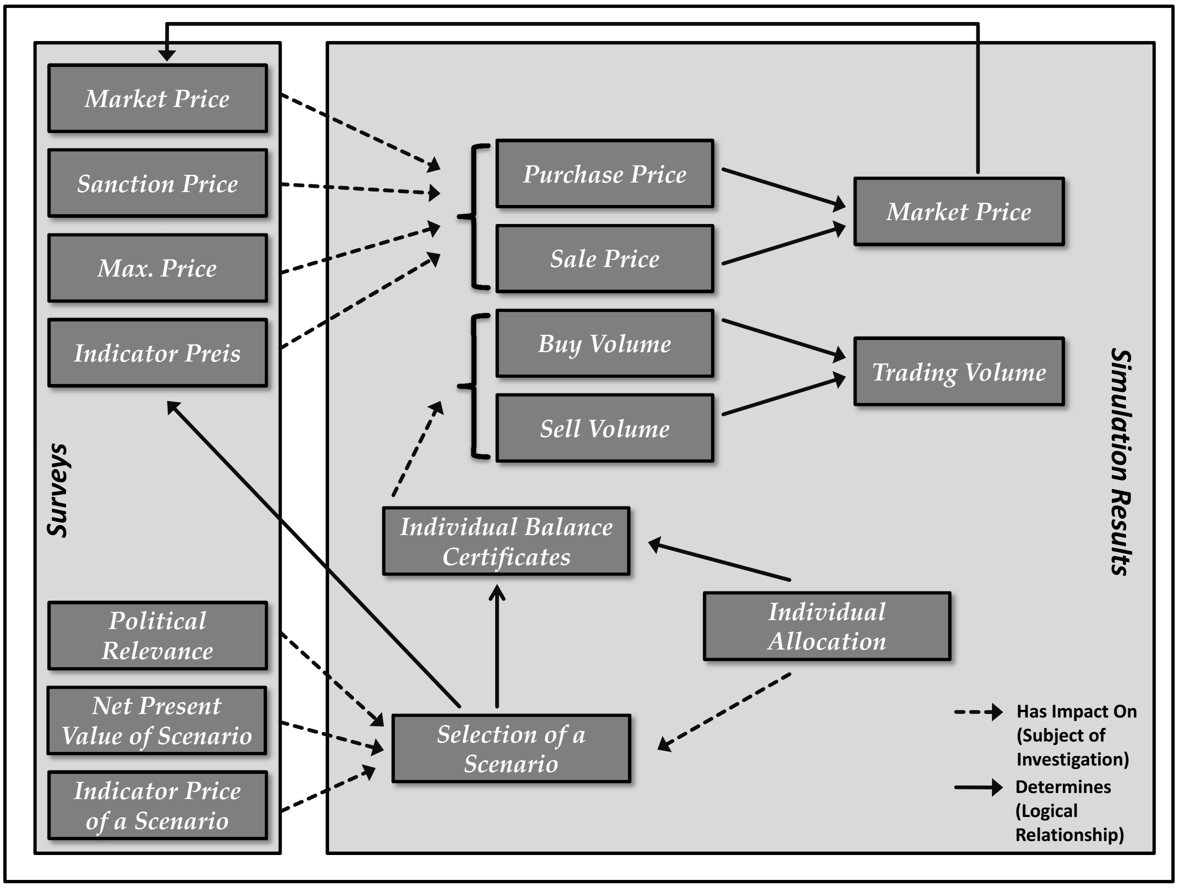

Figure 5.2: Relations of Cause and Effect

10:1, 5:1 and 3:1. The adjustment was necessary because of the heterogeneous pool of municipalities in this study.

Figure 5.2 shows the relevant data that will be analyzed in the following sections. The arrows hypothesize the relations of cause and effect during the simulation runs and further logical relationships between the data, which will be the subject of investigation. The figure outlines that the amount of allocated certificates, the political network (survey item ‘political relevance’) and economic criteria (survey items ‘net present value’ and ‘indicator price’) could have influenced the selection of the scenario which will be evaluated in Section 5.2.3.

The figure also depicts the logical relationships between order prices (purchase and sale prices) and the market price, as well as some other items (sanction price, max. price, indicator price) that might influence the market price. In theory, the orders should equal the respective indicator price in a municipality, which was introduced and described in Section 4.3. The resulting market price should reflect the scarcity of certificates and should help to achieve the global optimum. The survey results can give insights into what was relevant for the participants when trading certificates in the simulation. Hence, the survey examines issues such as the price of last transactions and the orders in the order book, the sanction payments, the indicator price, and the maximum price (see Section 5.2.4). The trading volumes are analyzed in Section 5.2.5. The subject of investigation is the impact of the individual balance of certificates on the observed trading volumes in the simulation.

5.2.2 Methodology

In order to analyze the causes and effects presented in the last section, relationships between the variables (survey and simulation data) are analyzed by calculating the correlation coefficients and the impact of different variables on specific simulation results. Since the survey data are ordinal scaled, the Spearman rank correlation coefficient is used. The Spearman correlation coefficient ρ shows the correlation between the variables and interprets the strengths of the relationship by a value between -1 and 1.

A positive correlation is linked to a positive correlation coefficient, and a negative correlation coefficient characterizes a negative correlation. The stronger the relationship, the more differs the correlation coefficient from 0. Therefore, if there is no correlation the correlation coefficient is 0.[7] A further interpretation of the correlation coefficient depends on the specific context and varies from study to study. Therefore, with respect to the presented hypotheses, the correlation coefficients are classified into the categories as shown in Table 5.5.[8]

Corr. Coefficient	Interpretation
$\rho = 0$	uncorrelated
$0.30 > \rho$	weakly correlated
$0.50 > \rho \geq 0.30$	medium correlated
$\rho \geq 0.50$	strongly correlated
$\rho = 1$	perfectly correlated

Table 5.5: Correlation Coefficients and Interpretation

The correlation analysis of the data is used to identify variables for a regression analysis. By means of the regression analysis, a set of variables should be identified, which can help to explain some of the simulation results. The linear regression models the relationship between a simulation result and one or more variables (e.g. the results from the surveys). In the following sections, only the final regression model will be presented and some other, excluded variables will only be discussed (the p-value limit for excluding variables from the regression analysis was 0.2). Due to the small amount of observations, the impact of a variable is described as significant if the p-value is less than 0.1.

The correlation coefficient is calculated between the items and the difference between the simulation and the baseline results. For instance, high political restrictions of local representatives could hinder the adaption of the land development plan from an economic point of view. In this case, it could be more likely that local representatives choose land development plans which are similar to the plans in the baseline scenario. Furthermore, the current market price and a comparison to the costs for inner development of the municipalities could play a less important role for these decision makers. In contrast, pure economic decisions without political restriction (e.g. basing on the indicator price)

[7]Due to the fact that the correlation coefficient is restricted to the analysis of linear correlation, a correlation coefficient of 0 does not mean that a non-linear correlation does not exist. Therefore, some of the data will be depicted in a scatter diagram to obtain first-hand impressions of the correlation.

[8]When comparing the individual results over all planning periods, the sample size is $n = 14$ and equals the number of participants. When using the individual results from each of the five planning periods $n = 70$.

can lead to a more flexible abatement strategy and to an adaptation of land development plans in the simulation. Moreover, the items of the survey are compared with the absolute differences in the different scenarios within the regression analyses. No significant influence of the municipality size on the presented results could be identified within the analyses.[9] However, this does not necessarily mean that the size of a municipality have no impact on a system which would be introduced in reality (a discussion of different factors that affect land uses decisions is given in Section 3.1). Furthermore, general implications on the basis of the simulation data will be only made in some of the following sections—the external validity of some results is influenced by the field data which was entered by the municipal representatives, as well as the specific experimental design and the design of the software platform.

In the surveys the participants indicated whether an item was not relevant ($\bar{X} = 1$), relevant ($\bar{X} = 2$), or highly relevant ($\bar{X} = 3$). Furthermore, it was possible that a representative did not answer a question ($\bar{X} = 0$). Hence, a result from the survey and the associated variable $\bar{X}$ is coded by two dummy variables X and $X^{\sharp}$ within the regression analysis.[10] The linear regression analysis allows a quantification of the strength of the relationship between variables, and analyzes which of the variables are related to a simulation result, as well as which of the subsets of variables contains redundant information. The resulting variables comprise the regression model that should help to explain some simulation results in more detail. In the next sections, the abatement strategies, the price discovery, and the trading strategies of the participants are analyzed in more detail by the correlation and regression analysis. Afterwards, a discussion of the results regarding the causes and effects in the simulation results will be given.

5.2.3 Evaluation of the Abatement Strategies

The realization of the baseline scenario specified in the preparation phase was associated with a development of 431 ha new settlement and commercial areas (Table 5.1). By the substitution of development options in the outer areas with options in the inner areas, the municipalities could reduce the total amount of new areas by a maximum amount

[9] This could be the result of the scaling of the municipalities in the experimental study.

[10] If $X = 0$ and $X^{\sharp} = 1$ the item was rated as very relevant, if $X = 1$ and $X^{\sharp} = 0$ the item is relevant, and if $X = 0$ and $X^{\sharp} = 0$ holds the item was not relevant.

of 119 ha. In comparison to the baseline scenario, this corresponds to a total reduction potential of 27.6%. In the first simulation run, 56.4 ha less than the demand determined by the individual baseline scenarios were allocated to all municipalities. This implies that the municipalities obtained 13.1% less certificates than in their initial baseline development and had to reconcile their development strategies accordingly.

	PP1	PP2	PP3	PP4	PP5	All
Baseline Scenario	77.18	125.02	84.41	52.18	92.62	**431.40**
Allocation	100.12	88.52	75.00	61.48	49.88	**375.00**
Simulation Scenario	64.57	98.29	60.01	47.23	74.97	**345.07**
Transfer +/-	35.55	25.78	40.77	55.02	29.93	-

Table 5.6: Allocation, Transfer and Usage of Certificates (in ha)

Table 5.6 shows the development of new areas in the first simulation run and a comparison with the baseline scenario in each planning period. In the simulation run, the municipalities developed only 345.07 ha new land in the outer zone, which corresponds to an actual reduction of 20% compared to the baseline scenario. In comparison to the baseline scenario, the municipalities reduced the total amount of newly developed areas in each planning period. Due to the fact that banking was allowed, surplus certificates could be transferred into the subsequent planning period. In each planning period, certificates were transferred from period to period, resulting in a final stock of 29.93 ha certificates at the end of the simulation.

As discussed in Chapter 3, the land development decisions and the abatement strategies of local representatives are influenced by many factors. The initial individual balance of certificates in each planning period, based on the primary allocation of certificates and the baseline scenario, could influence the adaptation of the scenario regarding the land development in each planning period. The higher the balance of certificates in a planning period, the more areas should be developed in the simulation.

Figure 5.3 depicts the initial certificate stock of each planning period in each municipality ($n = 70$) and the periodical difference between land development in the simulation run and land development in the baseline scenario by adaptation of the land development plans. The weak positive correlation of $\rho = 0.213$ between the two values indicates that the initial allocation of certificates does not strongly influence the abatement strategies of the participants. Hence, when participants had more certificates, not necessarily more new land was developed in each planning period compared to the baseline scenario.

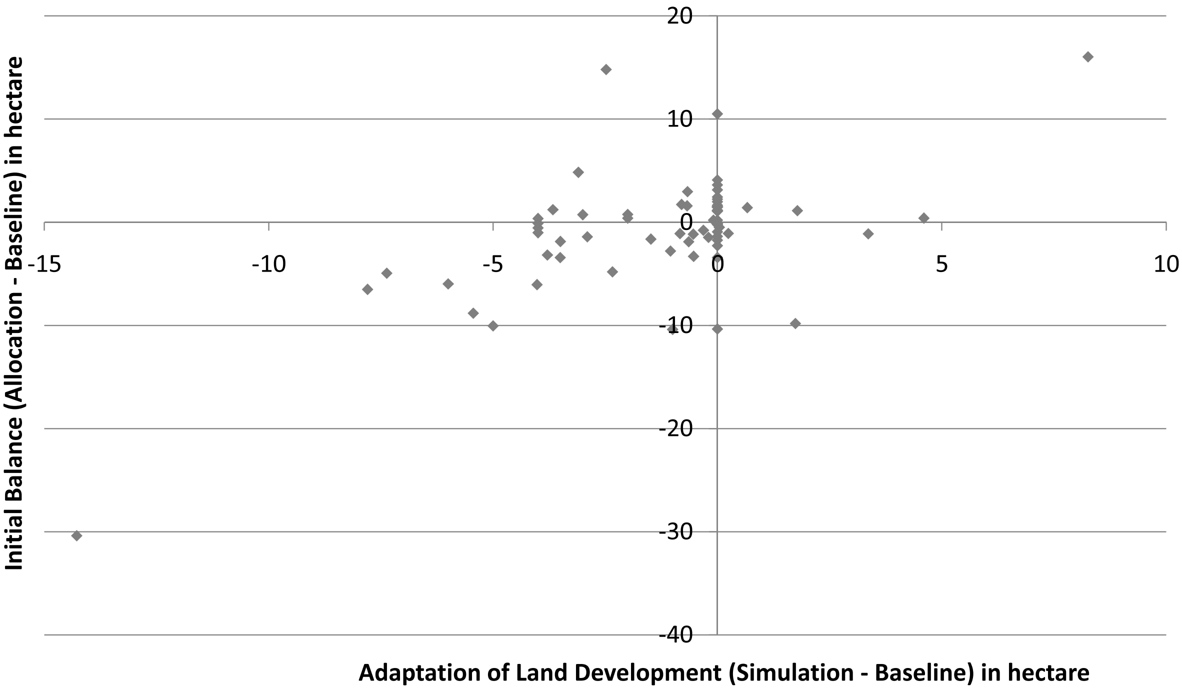

Figure 5.3: Allocation of Certificates and Adaptation of Land Development

The initial required adaption of land development (the difference between the primary allocation of certificates and the baseline scenario) and the observed adaptation of the land development plan in the simulation (land development in the simulation minus baseline) for each municipality is shown in Table 5.7. Again, the correlation coefficient is weakly positive with a value of $\rho = 0.101$. The results emphasize the supposition that the initial allocation of certificates does not strongly influence the adaptation of the land development plan. Thus, other factors than the initial allocation trigger the adaptation of land development plans.

During the simulation, the participants could adapt their land development plans and reduce the development of new areas. The selection of a scenario and the abatement strategy in the simulation run can also be influenced by the policy networks, the net present value and the indicator prices of a scenario compared to alternative scenarios. If political relevance is an important criterion for decision making, purely economic decisions should be less likely. As a result, the net present value, the land development,

Municipality	Initial Adaptation	Adaptation in Simulation
1	-1.324	-2.925
2	-4.502	0.832
3	-1.938	-4.550
4	0.849	-15.129
5	-1.610	-4.938
6	-2.927	0.000
7	-10.039	-5.476
8	-2.788	-16.200
9	-6.713	-9.460
10	-1.645	0.000
11	-12.823	-9.900
12	-7.778	-7.441
13	-2.230	-10.000
14	-0.934	-1.140
Sum.	-56.402	-86.327

Table 5.7: Adaptation of Land Development Plans (in ha)

and the indicator price of the scenario will differ considerably from the reference values of the optimal solution. An abatement strategy of a participant, which is based on the indicator price, might include the net present value of the development options. Hence, if the item net present value is more relevant, the net present value of the simulation scenario compared to the baseline scenario should be higher. The development of new residential and commercial areas could be encouraged by the policy network and the relevance of this network can impact the new land development (see Section 3.1.1 and Section 3.1.2).

Hence, the participants were asked after simulation run 1 (S1) and simulation run 2 (S2) what the main criteria for their decisions were and a survey concerning five items was conducted (see Figure 5.4).[11]

The selection of development options in the group of the local representatives was mostly driven by non-economic criteria. Most of the participants preferred to develop specific areas because they had a high political priority. Next to development options

[11]The results of the second simulation are also listed because a short discussion of the second simulation follows at the end of the chapter.

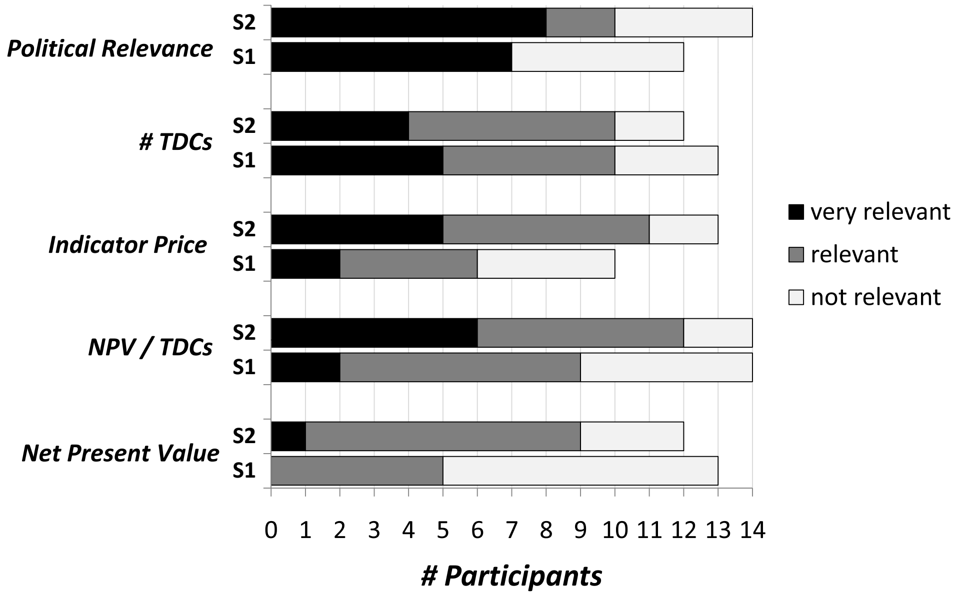

Figure 5.4: Criteria for Decisions on Options

with high political priority, options that did not require any certificates were also relevant to the subjects. Furthermore, some participants in the workshop pointed out that they reduced the demand for certificates in order to be independent from the market and to reduce the risk of paying high certificate prices in later planning periods. These participants hoarded certificates at the beginning of the planning simulation. Furthermore, the participants had difficulties in analyzing the scenario from an economic perspective and it is astonishing how little relevance the most important economic criteria, the indicator price and the net present value of the development options, had for the municipalities in the first simulation run.[12]

Preferences During the Adaptation of a Land Development Plan

Based on the simulation and the survey data, the strategic behavior of the participants will be analyzed in more detail. As mentioned in the last section the amount of allocated certificates had only little impact on the abatement strategy of the participants. By

[12] A comparison between the subjects pools is given by Ostertag et al., 2010. It shows that the student control group was driven more strongly by economic criteria, which had a positive impact on their overall incomes in the simulation. Due to the fact that the control group had an economic background these differences are not surprising.

combining the simulation results with the survey results further insights into municipal decision making are possible. The consideration of the criteria from the surveys allows an analysis of the preferences during the adaptation of a land development plan. Therefore, the main focus of the abatement strategy analysis is on the link between the individual simulation results and the importance of the items for each participant identified in the surveys.

Municipality	NPV	NPC	IP	SAV	POL
1	1	2	1	2	3
2	2	1	2	2	3
3	2	3	3	1	3
4		2			3
5	2	2	3	3	1
6	1	2	1	1	3
7	1	1	1	1	1
8	2	1		2	
9	1	2	2	3	1
10	1	2	1	2	3
11	2	1		2	3
12	1	3	2	3	1
13	1	1	2	3	1
14	1	2		3	
Avg.	1.38	1.79	1.80	2.15	2.17

Table 5.8: Preferences of the Participants

Table 5.8 shows the results of the survey for each of the 14 municipalities as well as the five items, net present value (NPV), net present value per certificate (NPC), indicator price (IP), saving of certificates (SAV), and political relevance (POL).[13] The results show a strong correlation between the net present values and the indicator price ($\rho_{NPV,IP} = 0.732$). Thus, participants who have considered the net present value during the selection and adaptation of the land development plan have likely also considered the indicator price by comparing the new scenario with the previous one. Furthermore, the net present value is positively correlated with the political priority of development options ($\rho_{POL,NPV} = 0.311$). However, the indicator price is negatively correlated with

[13] 1 = no relevance, 2 = relevant, 3 = highly relevant.

the political priority ($\rho_{POL,IP} = -0.298$). This result indicates that a high political relevance of a development option can trigger a land development plan which is not efficient from an economic perspective.

Preferences and the Development of New Areas

Table 5.9 compares the land development of the simulation run with the baseline scenario for each municipality. In the following, the items of the survey are compared with the land development in the different scenarios. The item NPV is weakly correlated with the land development in the baseline scenario and the simulation runs ($\rho_{NPV,BL} = 0.085$ and $\rho_{NPV,SIM} = -0.042$). Thus, choosing development options according to these economic criteria in the experiment is not linked to a specific amount of new land development. In contrast, municipalities have determined less new land development when the participants chose options that are politically relevant ($\rho_{POL,BL} = -0.220$ and $\rho_{POL,SIM} = -0.057$). As explained in Chapter 3, especially in small municipalities the policy networks have a high relevance for local decision makers when selecting a land development plan. Furthermore, participants who used the indicator price during their decision making developed less new land in their scenarios ($\rho_{IP,BL} = -0.270$ and $\rho_{IP,SIM} = -0.208$).

The correlation coefficient between the three items and the difference between the simulation and the baseline scenario in terms of land development (Difference Land Development, DLA) can provide information about the individual preferences. By means of the linear regression analysis, the relationship between the land development and the variables from the surveys is investigated. The regression model is shown in Equation 5.1 and includes the variables net present value, the indicator price, and the political relevance.[14]

$$DLA_i = \beta_0 + \beta_1 \cdot NPV_i + \beta_2 \cdot IP_i + \beta_3 \cdot IP_i^{\#} + \beta_4 \cdot POL_i^{\#} \quad (5.1)$$

The results of the regression analysis are shown in Table 5.10. Local representatives who adapt the scenario on the basis of the net present values tend to increase the

[14] For the regression analysis, the variables from the survey were subdivided by dummy variables as explained in Section 5.2.2, e.g. the survey results of the item indicator price were coded by the variables IP (relevant) and $IP^{\#}$ (very relevant).

Municipality	Baseline (BL)	Simulation (SIM)	Difference (DLA)
1	9.500	6.575	-2.925
2	32.300	33.132	0.832
3	13.903	9.353	-4.550
4	20.666	5.537	-15.129
5	11.550	6.612	-4.938
6	21.000	21.000	0.000
7	72.020	66.544	-5.476
8	20.000	3.800	-16.200
9	48.160	38.700	-9.460
10	11.800	11.800	0.000
11	92.000	82.100	-9.900
12	55.802	48.361	-7.441
13	16.000	6.000	-10.000
14	6.700	5.560	-1.140
Sum.	431.401	345.073	-86.328

Table 5.9: Land Development (in ha)

development of new land by 7 ha on average ($\beta_1 = 6.939$). A negative correlation between the usage of the indicator price and the changes of the land development in the simulation ($\rho_{IP,DLA} = -0.312$) is underpinned by the regression coefficients $\beta_2 = -4.721$ and $\beta_3 = -8.867$ of the indicator price variables. Thus, the higher the relevance of the indicator price, the less land a municipality developed in the simulation. If a decision maker rated the indicator price as relevant the reduction was 4.7 hectare on average, and if the item was rated as very relevant even 8.9 hectare were developed less. In contrast to the economic aspects, high political priority is positively correlated with a medium correlation coefficient of $\rho_{POL,DLA} = 0.417$. The influence of political aspects on the adaptation of the municipal land development plans is also reflected by the positive regression coefficient of $\beta_4 = 2.858$, which means that on average 2.9 ha more land was developed if a decision maker rated political priority as relevant. However, due to the p-value of 0.119 the impact of the political priority is identified as not significant within the regression analysis.

Variable	Regression Coefficient	Standard Error	t-value	p-value
$Constant$	-4.246	1.422	-2.986	0.031
NPV	6.939	2.483	2.795	0.038
IP	-4.721	1.728	-2.733	0.041
$IP^{\#}$	-8.867	3.103	-2.858	0.036
$POL^{\#}$	2.858	1.520	1.880	0.119

Table 5.10: Regression Land Development

Net Present Values of the Land Development Plan

Table 5.11 lists the net present values of the land development plans associated with the realization of the development options for each municipality. The data is used to calculate the correlation coefficients with the items of the survey. The item NPV is weakly positively correlated with the net present values of the baseline and simulation scenario ($\rho_{NPV,BL} = 0.085$ and $\rho_{NPV,SIM} = -0.085$). Thus, the results of representatives, who have considered the net present value while selecting an appropriate scenario, are not related to a high net present value of a land development plan in the simulation. The item political relevance is also weakly positively correlated with the net present value of the scenarios ($\rho_{POL,BL} = 0.171$ and $\rho_{POL,SIM} = 0.269$). Furthermore, the item indicator price is negatively correlated with the net present values ($\rho_{IP,BL} = -0.091$ and $\rho_{IP,SIM} = -0.337$). However, the medium correlation coefficient between the land developed and the net present value of the baseline scenario $\rho = 0.417$ underpins that the development of new land is generally linked to additional incomes.

The table also shows the difference between the net present value between the simulation scenarios of the baseline scenarios (DNP) by the adaptation of land development plans in the simulation, which is the subject of investigation in the correlation and regression analysis. Equation 5.2 summarizes the variables of the regression model that had a significant influence on the change of the net present value in the simulation runs.

$$DNP_i = \beta_0 + \beta_1 \cdot NPV_i + \beta_2 \cdot NPC_i^{\#} + \beta_3 \cdot IP_i + \beta_4 \cdot IP_i^{\#} + \beta_5 \cdot SAV_i^{\#} \qquad (5.2)$$

The influence of the item NPV ($\beta_1 = 26,138.380$) shows that the higher the importance of the net present value was, the higher was the result in the simulation

Municipality	Baseline	Simulation	Difference (DNP)
1	-418.027	-2,634.372	-2,216.344
2	59,191.871	78,214.502	19,022.631
3	3,325.439	2,953.672	-371.767
4	-38,541.336	-43,822.747	-5,281.412
5	0.000	-3,601.887	-3,601.887
6	43,726.585	43,726.585	0.000
7	7,123.810	6,133.992	-989.817
8	11,081.154	-1,580.528	-12,661.682
9	3,771.389	1,887.334	-1,884.055
10	22,473.105	22,473.105	0.000
11	24,586.697	18,521.811	-6,064.886
12	4,485.807	10,271.183	5,785.376
13	11,776.961	9,100.532	-2,676.429
14	3,768.787	2,579.315	-1,189.472

Table 5.11: Net Present Value (in mu)

compared to the baseline scenario (see Table 5.12). On average, a municipality had a net present value that was 26,238 mu higher than in the baseline scenario if the local representative rated the item NPV as relevant. The relevance of the indicator price during the adaptation of the land development plans led to additional costs and reduced the net present values of the plans in the simulation by 6,314 mu, respectively 33,774 mu ($\beta_3 = -6,314.210$ and $\beta_4 = -33,774.235$). In case the participants used the net present value per hectare of the development options during the decision making (displayed by the decision support system) the total net present value was 8,066 mu higher ($\beta_2 = 8,065.625$). Furthermore, if participants rated the item SAV as very relevant, a significant influence on the land development plan can also be observed ($\beta_5 = 4,835.505$). In contrast to the economic items, a high political priority has no significant influence on the outcome in the simulation and the item was also excluded in the regression analysis ($\rho_{POL,DNP} = -0.074$).

Hence, political relevance indicates that a municipality has higher incomes in the baseline, but not necessarily that the incomes are optimal after introducing a system of development certificates. Other factors, such as an economic comparison of differ-

Variable	Regression Coefficient	Standard Error	t-value	p-value
$Constant$	-801.540	476.705	-1.681	0.168
NPV	26,138.380	2,335.369	11.192	<0.001
$NPC^{\#}$	8,065.625	1,167.685	6.907	0.002
IP	-6,314.210	2,184.538	-2.890	0.045
$IP^{\#}$	-33,774.235	3,661.642	-9.224	0.001
$SAV^{\#}$	4,835.505	1,783.668	2.711	0.053

Table 5.12: Regression Net Present Value

ent scenarios and the usage of the indicator prices, seem to be more relevant for the achievement of higher net present values of land development plans.

5.2.4 Price Discovery

Similarly to the analysis of the abatement strategy, the price discovery process is analyzed by combining the results of the surveys with the observed transaction prices in the simulation. The market price in the simulation and the theoretical market price in the optimal scenario are shown in Figure 5.5.[15]

In the simulation, the market price was generally higher than the theoretical market price with a high price variance in the first planning period. A high price fluctuation can be an indicator for an intensive price discovery process in the first planning period (Table 5.13). In the following periods, the market price starts to rise continuously with a lower price fluctuation. Hence, in the following planning periods II and III, consistently high transaction prices of the TDCs can be observed. At the end of planning period IV, the certificate price decreases again, resulting in a high price variance in the last period with prices between 500 and 1,500 monetary units per hectare. Thus, a bubble-shaped price path over the planning periods can be observed, which ends in a complete price collapse in the last period.

Table 5.13 also shows the difference between the average market price and the price in the optimal scenario. Reacting to the high prices, the participants might realize

[15] According to the Hotelling-rule, the theoretical market price increases at the rate of the interest rate (here 4%).

[16] For the calculation of the average price, the transactions are weighted with the trading volumes.

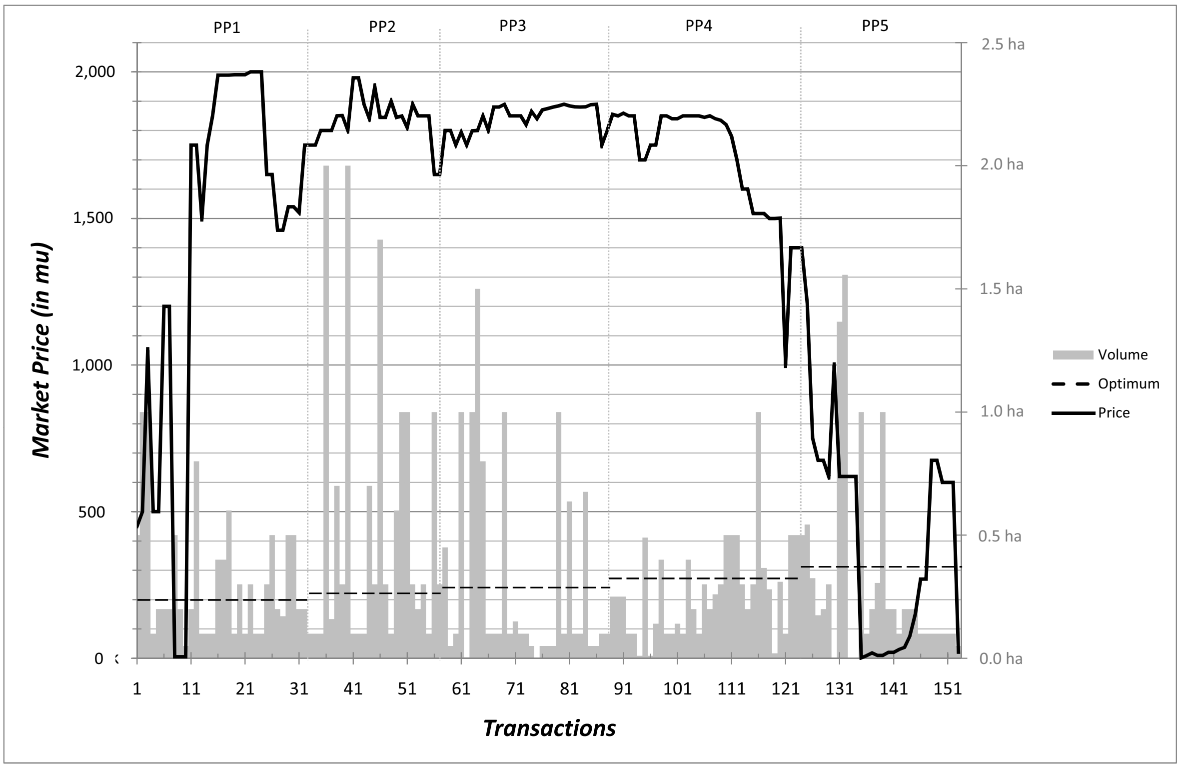

Figure 5.5: Price Discovery Process in Simulation Run 1

many expensive development options that presumably would not have been activated following a correct price development. Even though no details about the total amount of certificates were given, some participants argued at the final workshop that they hoarded surplus certificates for speculation purposes instead of selling them on the market. The high supply of certificates in the last planning period and the decreasing demand for certificates might have led to the price collapse. In the last period, the market price came back down to a lower level, since unused certificates had a final book value of 80% of the average market price in the last planning period.[17]

[17]It can be noted that the price discovery process in the student control group differed from the price discovery of the expert group. The market price in the student group was lower than in the expert group, but also above the theoretical price with a high price variance at the beginning. In response to the observed high market prices, this could also lead to the initiation of more costly development options in the student group. The analysis of the student group is not focus of this book. A more detailed comparison of the two groups is already given by Ostertag et al. (2010).

	PP1	PP2	PP3	PP4	PP5	All
Standard Deviation	665.60	62.92	64.39	131.84	449.16	635.81
Avg. Price[16] (in mu)	1,312.74	1,814.41	1,818.82	1,730.26	583.06	1,455.68
Opt. Price (in mu)	189.98	213.70	240.39	270.40	304.16	243.73
Difference (in mu)	1,122.76	1,600.71	1,578.44	1,459.86	278.89	1,211.96

Table 5.13: Market Price

Preferences of the Participants when Selling Certificates

In order to analyze the price discovery process in more detail, the participants were asked which criteria were important when selling or buying certificates on the market after the simulation run. The participants could rate how relevant the criteria last transaction price (TRA), current buy orders (CBU), current sell orders (CSE), maximum price (MAX), sanction price (SAN), and indicator price (IND) were when trading certificates. Figure 5.6 depicts the survey results of the first (S1) and the second simulation run (S2).

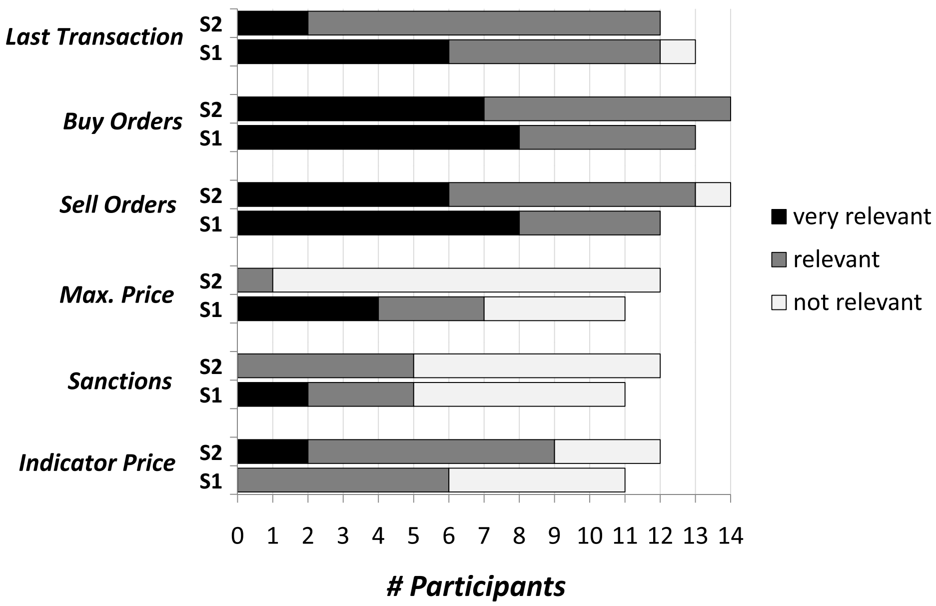

Figure 5.6: Criteria in the Price Discovery Process

Due to the fact that this section focuses on the first simulation run, the results of the first survey are of importance at this point.[18] The figure indicates that the last transactions and the current order prices influenced the price discovery process. In the following, the analysis focuses on the observed transaction prices and not the individual order prices. An analysis of the correlation of the individual order prices and indicator prices has been conducted by Ostertag et al. (2010). The study shows that the order prices are affected very little by the indicator price and correlate with the prices of the last transactions. About half of the participants rated the criteria as very relevant. Almost all participants rated the criteria at least as relevant. In contrast, the maximum price and the sanction price were perceived less important. Noticeably, also the indicator price was of less importance than the last transactions and only six participants considered it during the trading. Furthermore, Table 5.14 lists the results of the surveys for the sell orders of the six items.[19]

Municipality	IND	SAN	MAX	CSE	CBU	TRA
1	2	3	1	2	2	2
2						
3	1	1	2	3	3	3
4						
5		1	1	3	3	3
6	1	2	3	2	2	3
7	1	1	3	3	3	3
8	2			3	3	3
9	2	1	3	3	2	2
10	2	1	1	3	3	2
11	2	2	2	3	3	2
12	1	3	2	2	2	3
13	1	2	3	3	3	2
14	2	1	1	2	2	1
Avg.	1.55	1.64	2.00	2.67	2.58	2.42

Table 5.14: Price Discovery Preferences (Sell Orders)

[18] The results of the second simulation are also listed because a short discussion of the second simulation follows at the end of the chapter.

[19] 1 = no relevance, 2 = relevant, 3 = highly relevant.

The item indicator price is strongly negatively correlated with the prices of the last transactions and the maximum price ($\rho_{IND,MAX} = -0.590$ and $\rho_{IND,TRA} = -0.638$). Thus, local representatives who had based their decisions to sell certificates on the indicator price, rated the maximum price and the prices of the last transactions as not relevant. The weak correlation between the two items maximum price and the prices of the last transaction shows also the existence of a link between these items ($\rho_{TRA,MAX} = 0.298$): If local representatives take the maximum price of 2,000 mu into account when selling certificates, they also tend to take into account the last transaction price. However, due to the fact that almost all transactions are close to the maximum price of 2,000 mu, the fact that both items are positively correlated is evident.

Price Discovery of the Participants when Selling Certificates

Table 5.15 lists the data for the further analysis of the price discovery process. The average selling prices (ASP) are weighted average transaction prices. The table also contains the weighted average abatement costs (AAC) for each participant. The value shows the average financial effort of each municipality to reduce one hectare of settlement and traffic area. Municipalities which have low average abatement costs, have also low indicator prices when comparing different scenarios.

In the following, the variables that influenced the average sell price of the participants are discussed. The correlation analysis identifies that the importance of the maximum price had a medium influence on the average prices ($\rho_{MAX,ASP} = 0.339$). Thus, participants who sold certificates at high prices considered the maximum price within their trading strategy. However, within the regression analysis of the resulting regression model no significant influence could be observed:

$$ASP_i = \beta_0 + \beta_1 \cdot MAX_i + \beta_2 \cdot MAX_i^{\#} \tag{5.3}$$

The estimated regression coefficients are shown in Table 5.16. Due to the p-values, the relevance of the maximum price, identified in the surveys, had no significant influence on the high prices in the simulation run. The item may have a positive impact on the transaction prices, but this impact was not statistically significant within the analysis.

Municipality	ASP	AAC
1	1,559.260	757.725
2		22,863.739
3	1,524.500	81.707
4	1,041.210	349.084
5	1,552.630	729.422
6		
7		180.742
8	1,817.510	781.585
9	1,939.900	199.160
10	658.070	
11	1,880.890	612.615
12	1,471.840	-777.479
13	1,287.160	267.643
14	902.730	1,043.397

Table 5.15: Price Discovery Sell Orders (in mu)

The influence of other variables analyzed within the scope of the regression analysis, had no significant influence on the average sell prices. Between the item sanction payments and the average price only a weak correlation can be observed ($\rho_{SAN,ASP} = 0.166$). Furthermore, the indicator price had only little impact on the average sell price and a weak correlation between these indicators ($\rho_{IND,ASP} = 0.274$) exists. This shows that the more relevant the indicator price was for a participant, the higher are the average prices—even though the correlation was identified as not significant in the regression analysis.

Variable	Regression Coefficient	Standard Error	t-value	p-value
$Constant$	1,040.022	223.072	4.662	0.006
MAX	585.722	315.471	1.857	0.122
$MAX^{\#}$	573.508	352.708	1.626	0.165

Table 5.16: Regression Sell Price

Preferences of the Participants when Purchasing Certificates

Table 5.17 shows the results of the survey that are used to analyze the trading behavior of the participants when purchasing certificates.[20] In contrast to the preferences when selling certificates, the correlation between the indicator price and the maximum price, as well as the correlation between the indicator price and the price of the last transaction are $\rho_{IND,MAX} = -0.204$ and $\rho_{IND,TRA} = -0.335$. Furthermore, the correlation between the two items is again weakly positive ($\rho_{TRA,MAX} = 0.265$). Thus, the more relevant the maximum price was, the more relevant was also the price of the last transaction.

Municipality	IND	SAN	MAX	CSE	CBU	TRA
1	2	3	1	2	2	2
2						
3	1	1	2	3	3	3
4						
5		1	1	3	3	3
6	1	2	3	2	2	3
7	1	1	3	3	3	3
8	2			3	3	3
9	2	1	3	3	2	2
10	2	1	1	3	3	2
11	2	2	2	3	3	2
12	1	3	2	2	2	3
13	1	2	3	3	3	2
14	2	1	1	2	2	1
14	1.36	1.60	1.56	2.50	2.50	2.50

Table 5.17: Price Discovery Preferences (Buy Orders)

Notably, the indicator price and the sanction payments are positively medium correlated ($\rho_{IND,SAN} = 0.345$). In contrast, only a weak correlation between the two items when selling certificates was observed. A possible explanation is that the participants also considered the sanction payments when buying certificates. An efficient land development plan is only realizable if a municipality has enough certificates. If enough certificates are available, the influence of the sanction price should be lower, because

[20] 1 = no relevance, 2 = relevant, 3 = highly relevant.

losses of interest by hoarding certificates should be low compared to the high sanction payments. Therefore, a relevance of the sanction price only arises in case not enough certificates are available. Furthermore, the payment of sanctions could even be beneficial if the price drops more than the sanction payments between the two periods. Both effects could explain why participants, who consider the indicator price as relevant, also rated the relevance of the sanction payment high.

Price Discovery of the Participants when Purchasing Certificates

Table 5.18 lists the average transaction prices when purchasing certificates (ABP) and the average abatement costs (AAC).

Municipality	ABP	AAC
1	762.380	757.725
2	1,435.970	22,863.739
3	1,095.730	81.707
4		349.084
5		729.422
6	620.260	
7	1,092.930	180.742
8	1,755.730	781.585
9		199.160
10	1,804.760	
11	1,668.280	612.615
12	1,796.020	-777.479
13	381.840	267.643
14	1,408.850	1,043.397

Table 5.18: Price Discovery Buying Order (in mu)

For explaining the observed data and the price discovery process, the influence of the items on the average buy price is being analyzed in the regression analysis. The items sanction price and transaction price are identified as the variables that significantly influenced the price discovery process:

$$ABP_i = \beta_0 + \beta_1 \cdot SAN_i^{\#} + \beta_2 \cdot TRA_i^{\#} \tag{5.4}$$

The regression coefficients of $\beta_1 = -817.080$ and $\beta_2 = -781.771$ show that participants who considered the last transactions and the sanction price tend to buy certificates at lower price levels (Table 5.19). If a participant rated the sanction payment (1,000 mu) as very relevant during the price discovery process, the individual weighted transaction price was 817 mu lower on average, and if a participant rated the last transaction prices as important, the prices were 781 mu lower. In contrast to the average sell prices, the maximum price only had little impact and was excluded in the regression analysis. The relevance of the maximum price when purchasing certificates is positively correlated with the average transaction prices with a weak correlation coefficient of $\rho_{MAX,ABP} = 0.261$. Similarly to the analysis of the behavior when selling certificates, participants who rated the indicator price as relevant, realized higher average transaction prices but with no significant influence on the transaction prices. Here, a medium correlation can be observed with a correlation coefficient of $\rho_{IND,ABP} = 0.418$.

Variable	Regression Coefficient	Standard Error	t-value	p-value
$Constant$	1,579.461	142.704	11.068	<0.001
$SAN^{\#}$	-817.080	319.096	-2.561	0.043
$TRA^{\#}$	-781.771	201.814	-3.874	0.008

Table 5.19: Regression Buy Price

5.2.5 Trading Strategies

In order to analyze the trading strategies of the participants, the observed trading volumes will be compared to the certificate balances and the minimal trading volumes of the optimal scenario (see Section 5.1.2). However, in contrast to the analysis of the price discovery processes and the abatement strategy, no survey data was available for the evaluation.

If a municipality does not have enough certificates in a planning period to realize the land development, a purchase of certificates on the market will be necessary. In case of a positive individual balance, TDC sales can be expected. The same applies to the balance of certificates when regarding the remaining periods of the realized land development plan. If a municipality needs additional certificates until the end of the simulation, the likelihood of an additional purchase volume in a specific planning period should be higher. Municipalities with surplus certificates should sell certificates on the market.

	PP1	PP2	PP3	PP4	PP5	All
Trading Volume in the Simulation Run	10.02	12.56	7.87	8.68	10.53	**49.66**
Optimal Volume	15.68	19.15	2.61	3.43	10.58	**51.45**
Control Group	15.68	16.40	7.35	19.23	11.71	**70.37**

Table 5.20: Comparison of Trading Volumes (in ha)

Furthermore, the trading volumes could be conform to the minimal trading volumes of the optimal scenario. The minimal trading volume necessary to achieve the optimal solution in the simulation is a TDC amount of 51.45 ha (Table 5.20). Compared to this theoretical benchmark, the experts have traded 2.21 ha less in the simulation run. This fact shows that the municipalities have not traded enough certificates to provide a cost effective solution, whereas the trading volumes in the student group are sufficient for an optimal market result.[21]

Figure 5.7 compares the observed individual trading balance in each planning period (sell volume minus buy volume) of the simulation run (TVS) with the minimal trading volumes in the optimal scenario (TVO). The Pearson correlation coefficient of $\rho_{TVS,TVO} = 0.318$ shows that the simulation results are positively correlated with the trading volumes in the optimal scenario.

The trading volumes of each municipality in each planning period (sell volume minus buy volume) and the individual certificate balances in the planning periods (DEP) are depicted in Figure 5.8. The correlation coefficient $\rho_{TVS,DEP} = 0.569$ shows a strong correlation between these values, and strengthens the supposition that the trading volume was mostly driven by the individual demand in each planning period. Hence, if a municipality has a positive balance of certificates, also a positive trading volume is observable.

Figure 5.9 depicts the correlation between the trading volume and the cumulated demand for certificates of all municipalities until the end of the simulation (DES). The strong correlation coefficient $\rho_{TVS,DES} = 0.510$ outlines that the local representatives

[21] The control group traded certificates of 70.37 ha in the simulation.

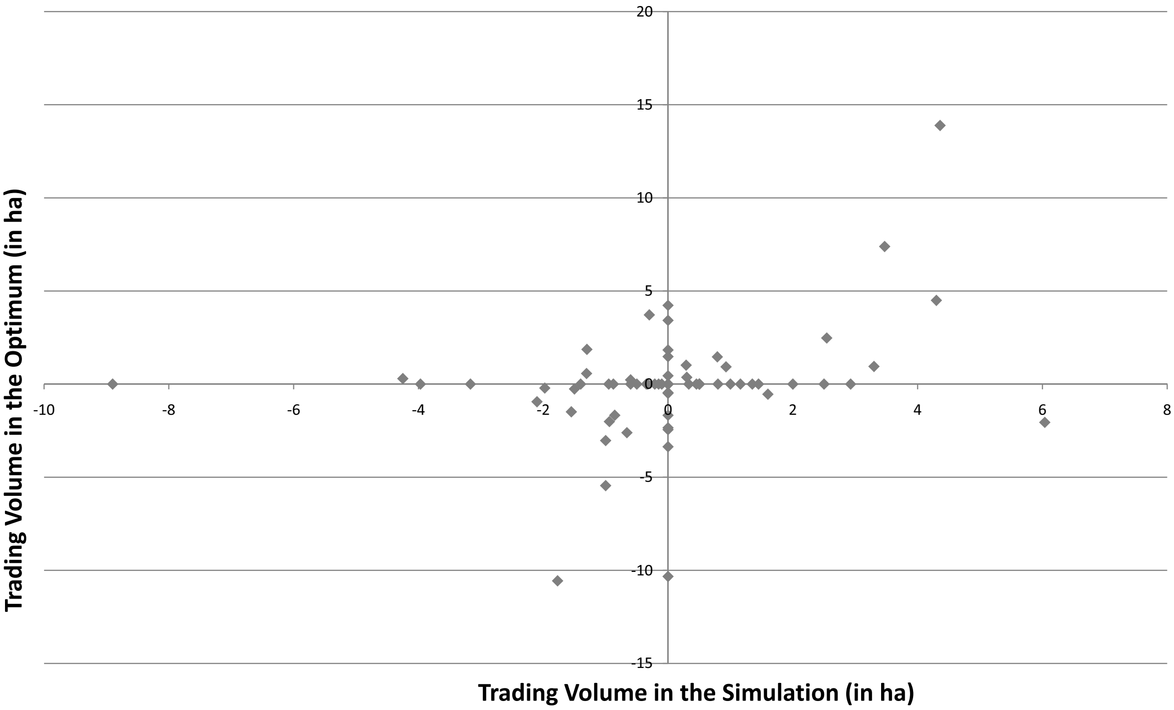

Figure 5.7: Trading Volumes in the Optimal Scenario and in the Simulation

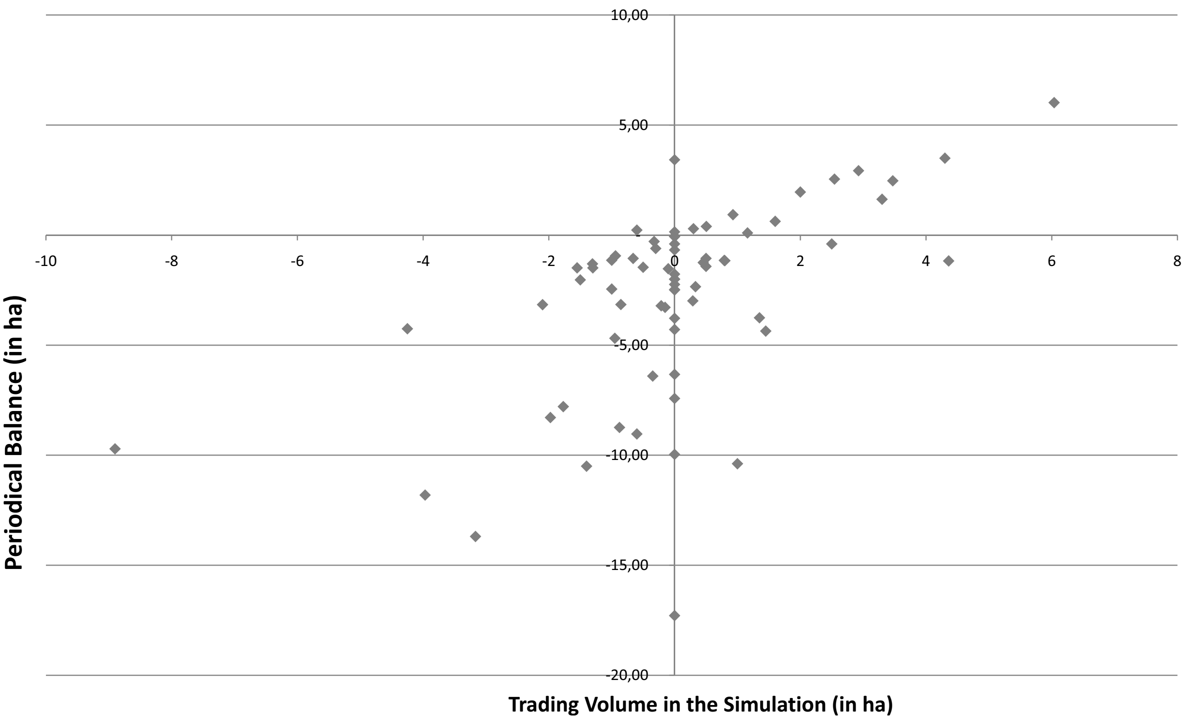

Figure 5.8: Trading Volumes and Balance in each Planning Period

also considered their demand for certificates until the end of the simulation, and adapted their trading strategy based on this value.

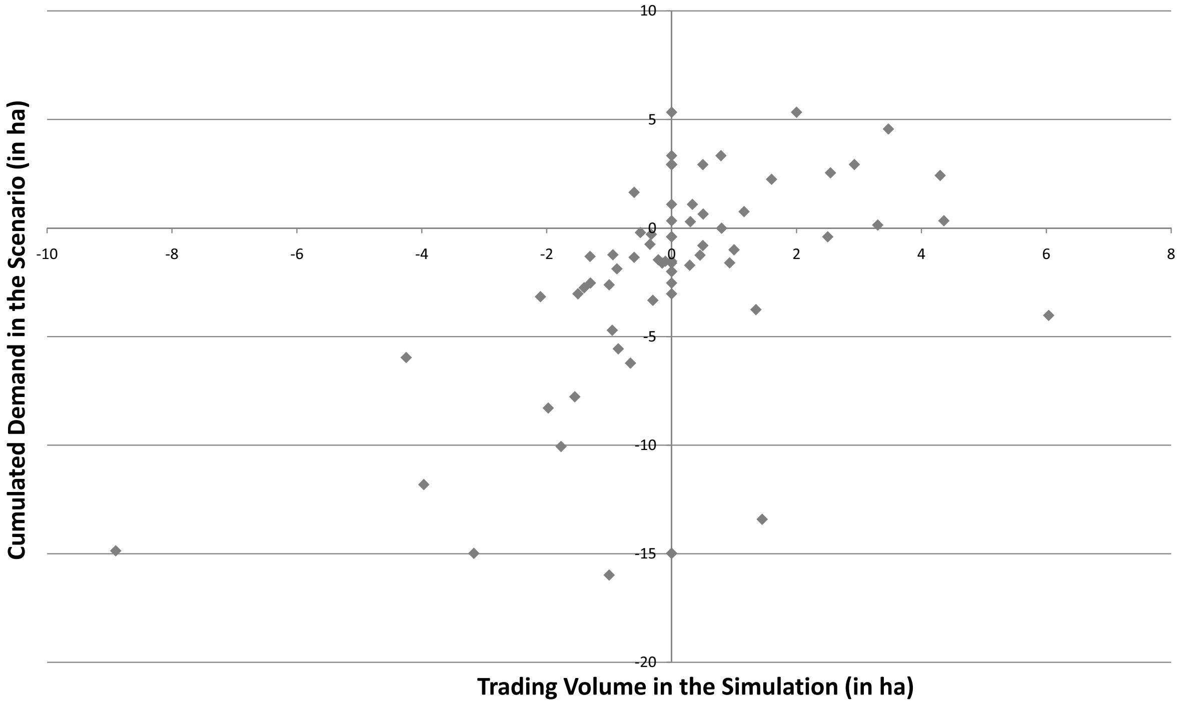

Figure 5.9: Trading Volumes and Demand for the Scenario

The regression analysis identifies that the DES and DEP have the highest impact on the trading volume in the simulation:

$$TVS_i = \beta_0 + \beta_1 \cdot DEP_i + \beta_2 \cdot DES_i \tag{5.5}$$

The results of the regression analysis are shown in Table 5.21. The highest impact on the observed trading volume in the simulation has the periodical need of certificates with a p-value < 0.001 and a regression coefficient of $\beta_1 = 0.200$. In comparison, the cumulated need for certificates until the end of the simulation has a lower impact on the trading volume (p-value of 0.008 and $\beta_2 = 0.120$). Nevertheless, both variables significantly influence the amount of certificates the participants traded in each planning period.

For a better understanding of the connection between the trading volumes and the price discovery process, the average transaction prices and the individual balance of

Variable	Regression Coefficient	Standard Error	t-value	p-value
$Constant$	0.822	0.230	3.567	0.001
DEP	0.200	0.052	3.817	<0.001
DES	0.120	0.044	2.754	0.008

Table 5.21: Regression Trading Volumes

certificates are listed in Table 5.22. The table shows the average transaction prices when selling certificates for each municipality in the five planning periods. The regression analysis has shown that if a negative periodical balance (a negative periodical balance is labeled in the table as P) or a negative scenario balance for the remaining land development plan (S) exists, the likelihood for transactions (purchasing certificates) is higher. Furthermore, if there is a negative balance in a planning period, there is a need to buy the certificates in order to avoid sanction payments.

	PP1	PP2	PP3	PP4	PP5	All
K1	^{P,S}762.38	^{P} -	-	-	-	**762.38**
K2	^{S} -	^{P,S}1,815.00	^{S} -	^{S}1,630.51	^{P,S}1,077.43	**1,435.97**
K3	-	-	-	1,637.52	614.81	**1,095.73**
K4	-	-	-	-	-	**-**
K5	-	-	-	-	-	**-**
K6	^{P,S} -	^{S} -	^{S} -	^{S} -	^{P,S}620.26	**620.26**
K7	^{P,S}1,552.08	^{S} -	^{S}1,853.70	^{P,S}1,839.22	7.96	**1,092.93**
K8	1,832.95	-	-	1,500.53	-	**1,755.73**
K9	-	-	-	-	-	**-**
K10	^{P,S}1,540.00	^{P,S}1,898.12	^{P,S}1,823.89	^{P,S}1,833.06	-	**1,804.76**
K11	^{S}450.00	^{P,S}1,845.12	-	1,517.00	-	**1,668.28**
K12	^{S} -	^{S}1,798.85	^{P}1,793.97	-	-	**1,796.02**
K13	-	-	-	1,700.00	372.43	**381.84**
K14	827.50	^{P,S}1,851.00	1,850.00	1,600.40	-	**1,408.85**

Table 5.22: Weighted Transaction Prices in the Simulation Run (in mu)

The table shows that most of the trading activities were triggered by the need of municipalities to buy certificates in order to have enough certificates for realizing the land development in a planning period or the total land development plan. If a municipality has a negative balance in a planning period, the purchasing of certificates is more likely and the weighted transactions price will be shown in the table. For instance, six out of the nine municipalities that bought certificates in planning periods II and III needed certificates in order to avoid sanction payments. Only one local representative bought certificates without a periodical need and a negative scenario balance. Furthermore, the analysis of the price discovery process (Section 5.2.4) shows the influence of the sanction payments when purchasing certificates on the market. The results underpin the supposition that the trading strategy was mainly influenced by the individual balance within the planning period and by possible sanction payments.

5.2.6 Outcomes in the Simulation Run

The previous analyses have focused on the impact of different items on the total net present value of the land development plans, the price discovery process and the trading volumes. In this section, the influence of the different items on the main simulation outcome, the game result in monetary units is analyzed. If incomes and costs from trading certificates as well as sanction payments are added to the net present values of the land development plans (see Section 5.2.3), the total net present value of the simulation scenario (the so called individual simulation outcome, ISO) for each participant can be calculated (Table 5.23).

By means of the regression analysis the regression model identifies which variables have influenced the individual simulation outcomes of each player compared to the baseline scenario. Four factors have been identified that had an impact on the difference of the net present value between the outcome in simulation run and the baseline (DNP), which results in Equation 5.6. Other variables, for instance the item NPV that is correlated with the individual simulation outcome of each player (positive correlation coefficient of $\rho_{DNP,NPV} = 0.296$), had no significant influence on the outcome. Similarly, political priority is only weakly correlated with the total net present value and has no impact on the simulation outcome ($\rho_{DNP,POL} = 0.024$).

$$DNP_i = \beta_0 + \beta_1 \cdot IP_i + \beta_2 \cdot IP_i^{\#} + \beta_3 \cdot POL_i^{\#} + \beta_4 \cdot MAX_i. \tag{5.6}$$

The item indicator price has a significant impact on the simulation outcome (see Table 5.24), which is also underpinned by the positively correlated medium correlation

Municipality	Baseline (BL)	Simulation (ISO)	Difference (DNP)
1	-418.027	2,873.658	3,291.685
2	59,191.871	67,690.877	8,499.006
3	3,325.439	7,083.640	3,758.201
4	-38,541.336	-33,229.963	5,311.372
5	0.000	623.683	623.683
6	43,726.585	35,522.266	-8,204.320
7	7,123.810	-7,167.631	-14,291.441
8	11,081.154	30,043.002	18,961.848
9	3,771.389	9,618.402	5,847.013
10	22,473.105	7,690.297	-14,782.807
11	24,586.697	5,839.648	-18,747.049
12	4,485.807	-11,059.370	-15,545.177
13	11,776.961	16,050.527	4,273.565
14	3,768.787	1,634.040	-2,134.748

Table 5.23: Outcomes in the Simulation Run (in mu)

coefficient of $\rho_{DNP,IP} = 0.402$. Therefore, if local municipalities include the indicator price of land development plans into their abatement strategies, additional incomes for the municipalities are more likely: If a participant rated the indicator price as relevant, the individual simulation outcome was 21,008 mu higher on average compared to results of participants that rated the indicator price as not relevant (regression coefficient of $\beta_1 = 21,008.319$). If the participant rated the indicator price as very relevant, the outcome increases by 21,541 mu ($\beta_2 = 21,541.479$).

Thus, by including the indicator price into the abatement strategy, a higher simulation result and a significantly higher net present value can be expected. Moreover, the regression analysis shows the impact of the items political relevance and maximum price on the individual game result in the simulation scenario ($\beta_3 = 12,143.863$ and $\beta_4 = -15,635.700$). However, due to high p-values, a statistically significant influence of these variables can not be proved.[22] As an overall result, the regression analysis proposes that the overall game result was mainly influenced by the usage of the indicator price supported by the planning tool. Therefore, the usage of the decision support

[22] Due to the fact that the variable $MAX^\sharp$ had no significant impact on the net present value of the scenario, another reason for the rejection of the hypothesis that the maximum price has an impact on the outcome is given.

tool enhanced the decisions in the simulation run and facilitated the development of an appropriate land usage scenario.

Variable	Regression Coefficient	Standard Error	t-value	p-value
$Constant$	-17,604.618	6,629.587	-2.655	0.057
IP	21,008.319	8,958.745	2.345	0.079
$IP^{\sharp}$	21,541.479	8,060.500	2.672	0.056
$POL^{\sharp}$	12,143.863	7,314.785	1.660	0.172
MAX	-15,635.700	7,571.521	-2.065	0.108

Table 5.24: Regression Simulation Outcomes

5.3 Discussion of the Simulation Results

The results of the previous section have shown that the indicator price was relevant for some local representatives during their decision making in the simulation runs. The decision support tool allowed the economic comparison of different scenarios by signaling an indicator price. If a municipal decision maker considered the indicator price, which was provided by the decision support tool, a higher outcome was observable. The more relevant the indicator price and the net present values of the development options were for a municipal decision maker, the higher were the total incomes for the municipality in the simulation. Hence, the implementation of the decision support tool and the implementation of the indicator price tool facilitated the decision making and supported the determination of an appropriate individual abatement strategy in the simulation run. Municipalities that based their decisions on economic criteria, also pursued a reduction in new land development. In contrast, the political priority had only little impact on the overall monetary result. When local representatives selected development options depending on political priority, the total land development was higher. Furthermore, the results showed the low impact of the primary allocation on the adaption of the initial land development plan, which was determined in the baseline scenario.

The analyses of the trading strategies in the first simulation run revealed that municipalities took the maximum order price into account, especially when selling certificates, and that the indicator price was irrelevant for them. If local municipalities rated the indicator price as more relevant, they bought and sold certificates at prices that reflected the average abatement costs in the simulation more likely. When purchasing certificates, the sanction prices were also of importance and influenced the trading behavior of the local municipalities. The analyses of the trading strategy revealed that the trading volumes were mainly influenced by the balance of certificates in a planning period and not by minimal trading volumes in the optimal scenario. Furthermore, in planning periods, wherein the price was relatively high, most municipalities only traded certificates to avoid potential sanction payments at the end of the trading period.

Due to the fact that only some participants used the indicator price during the adaption of the land development plans and when transferring certificates, additional training courses were conducted after the first simulation run. The training courses with the planning tool were carried out during the second workshop to point out the importance of this instrument due to the findings from simulation run 1. As a result, the surveys showed learning effects for the second simulation run regarding the trading strategies, which, however, could be overcompensated by the more complex task in simulation 2.

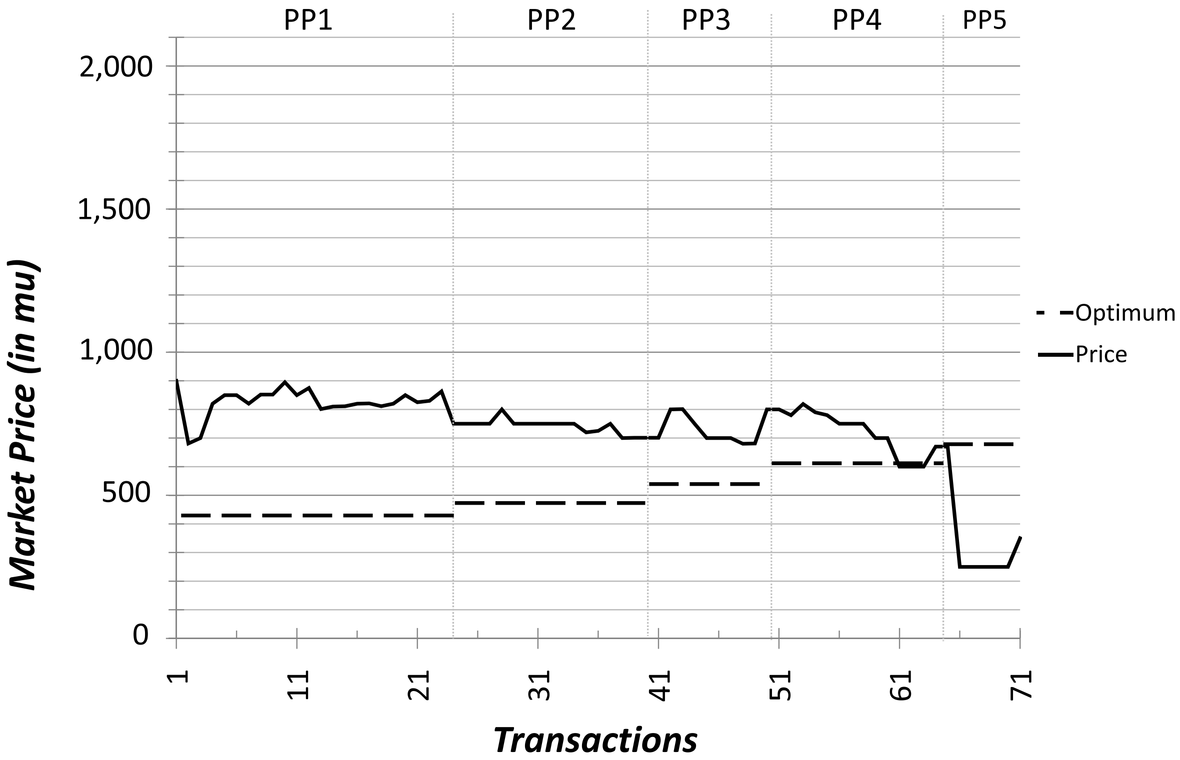

Figure 5.10: Development of the Market Price in Simulation Run 2

In the second simulation run, lower market prices than in the first simulation run could be observed (see Figure 5.10). A reason for this might be the surplus allocation of TDCs in planning periods I and II or learning effects by the additional training courses. Furthermore, transactions have been observed that are closer to the theoretical price level in this simulation run. Some experts initiated more costly development options, potentially in response to the high market prices at the beginning of the simulation run. Therefore, supply was still sufficient and the price level was not increasing in the last planning periods.

As shown in Section 5.1.1, a total amount of only 331 ha TDCs was allocated in the second simulation run and the reduction target was more ambitious than in the first run. Nevertheless, the expert group exceeded the required reduction in land development and developed 309 ha. In comparison, the student control group reduced the development of new areas only to 337 ha and developed more new areas than the total amount of certificates allowed. Due to the finiteness of the planning simulation, it was possible to develop new areas in the last planning period without handing in the missing certificates in the next period. In practice, the surplus certificates would have been removed from the initial allocation in the next planning period in order to realize the reduction goal. As the participating municipalities expect overall profits from new outer-city developments, limiting urban sprawl was linked to cuts in the cities' incomes.

Table 5.25 lists the outcomes in the simulation runs and various scenarios of the field experiments on the basis of the initial net present values of the baseline scenario (100%). The table also shows the outcomes in a no-trade optimum, which represents the optimal solution if no trading is possible (see also Ostertag et al., 2010). When comparing the simulation results of both groups with the optimal market results, it can be observed that the simulation results are quite far from the optimal solution. In both simulation runs, the net present values in the control group are closer to the optimum than the results in the expert group. The net present value in the first simulation run was 87% of the baseline scenario in the student and 75% in the expert group. In the second simulation run, the participants were confronted with the more challenging task. Due to the ruinous results of three participants, the expert group performed poorly in this simulation run (-35%). One reason for this result could be that only a few development options had been predetermined in the second simulation run and hence the task was much more complex. However, the result of the student control group (60%) is higher than the no-trade optimum and efficiency gains could also be realized in the second simulation run by trading certificates.

The net present value in the first simulation run is higher than in the virtual case, the so called no-trade optimum, in which all municipalities had to reduce their new development individually by the required 13% without a trading system. Thus, the simulation results have outperformed this no-trade optimum in the first simulation run. However, in the second simulation run different results can be observed. Here, only the results of the student group outperformed the no-trade optimum.

Scenario	Simulation 1	Simulation 2
Baseline	100%	100%
Experts	75%	-35%
Control Group	87%	60%
Theoretical Optimum	109%	76%
No-trade Optimum	64%	39%

Table 5.25: Comparison of the Net Present Values

For a comparison of the experimental results and the efficiency gains postulated by theory, the efficiency level of each experimental session is calculated. The efficiency measures how much of the efficiency gains, generated by an optimal trading compared to the no-trade solution, have been realized in the planning simulation:

$$Efficiency = \frac{\textit{Simulation Result - No-trade Solution}}{\textit{Theoretical Optimum - No-trade Solution}}$$

The efficiency equals one, when the participants behaved according to the optimal scenario and realized the cheapest overall reduction potentials. When the efficiency is zero, the simulation result is equal to the no-trade solution and the participants were not able to use cheaper reduction potentials by trading certificates. A negative efficiency means that the participants were not able to improve an inefficient no-trade solution by trading certificates in the simulation runs. However, by choosing the optimal no-trade solution as the worst-case reference point, a conservative approach for the calculation of the efficiency level is used.

	Experts	Control Group
Simulation 1	0.49	0.93
Simulation 2	-0.82	0.68

Table 5.26: Efficiency of the Simulation Runs

Table 5.26 depicts the efficiency levels in the four experimental sessions. The students realized efficiency levels of 0.93 and 0.68, which means that they have realized 93% and 68% of the theoretical efficiency gains. Previous planning simulations in other domains have shown similar efficiency levels (see Cronshaw and Brown-Kruse, 1999; Schleich et al., 2006). The negative efficiency level of the municipalities in the second simulation could be a further indicator that actual decision makers have other preferences during the selection of development options compared to the student group, which focused on economic aspects when selecting development options.

In spite of the artificial character of the simulation, the selection of development options within the simulation was rated as realistic by the participants. The simulation results of the field experiment show that a TDC system can be an appropriate instrument to reduce the development of new land efficiently. An efficient reduction of land usage can be enabled by new decision support tools that facilitate the municipal decision making. However, the existence of decision support tools does not necessarily mean that the instrument works efficiently and that gains are always feasible when using the new instrument. The differences between the simulation runs, as well as the differences between the subject pools, in the field experiment are an indication that the participants need to be familiar with the usage of such DSS.

However, it is questionable whether a purely economic evaluation as an overall criteria to measure the efficiency of the new instrument, is appropriate in this context. Since the DSS might not map all relevant values, e.g. political priority or complex population dynamics, the results from this experiment as well as results from similar experiments should be considered cautiously. For instance, if a municipality ignores the policy network within field experiments and bases decisions on economic criteria, high outcomes in experiments are more likely, but an implementation in reality could be complicated and might lead to additional costs for other actors within the horizontal and vertical policy framework (Section 3.2). In future field experiments, policy aspects should be included into the modeling of the decision situation in order to evaluate the results of field experiments in land development by those non-economic criteria. For this, the different aspects of the framework proposed in Section 3.1 can be used as a guideline for future studies.

6 Conclusion and Outlook

In this book, theoretical and empirical methods have been used to investigate the design of a cap-and-trade scheme for land development in Germany. The results give insights into how a cap-and-trade scheme can be implemented and reveal how real world decision makers behave in such a system under close-to-real conditions. Within the Spiel.Raum study (see Ostertag et al., 2010, Müller et al., 2010) the experimental methodology was used in the field to gain new insights into the behavior of actual decision makers, which are difficult to obtain by conducting only theoretical analyses (e.g. Walz et al., 2006, Köck et al., 2008, Walz et al., 2009) due to the complexity of the subject of examination. In the field experiment of the study, the decision making of local representatives was observable and was analyzed in two different experimental treatments. For supporting the decision making process of local representatives, a decision support tool was designed, which was based on real data stored in an information database. The field study points out the complexity of land use decisions, and emphasizes that causes and effects of urban sprawl should be investigated in transdisciplinary studies, which may also bring local representatives into the researchers' laboratory to analyze the decision making within other experimental designs and stylized data. In order to answer the four research questions, the main contributions and the implications of each chapter will be presented in the following four sections starting with the last chapter and finishing with the first chapter to discuss the consequences for the underlying chapters, respectively the research questions. Afterwards, this chapter concludes with an outlook on future work.

6.1 Results of the Field Experiment (Chapter 5)

In order to gain real life experience for municipalities regarding the new instrument, a potential system with TDCs covering local authorities in Germany was analyzed by using the experimental methodology. The experiment was conducted as a field experiment with spatial planners of 14 German cities and municipal syndicates and was based on real world data of the participating municipalities. The experiment was run with different scheme designs regarding the allocation of the certificates and the complexity of the task. By analyzing the market outcomes in the two simulation runs, factors that influenced the market outcome, such as the usage of the decision support tool and the complexity of the task, could be identified. Compared to the local representatives, a student control group achieved a higher efficiency level. The cost difference between the simulation results and the theoretical benchmarks may indicate additional costs of non-quantifiable monetarily goals or the realization of economical inefficient land development plans. The question as to whether representatives of planning authorities acted 'less efficient' than, for example economic experts, was further investigated in laboratory experiments.[1] Of course, all these findings are based on a simplified experimental setting. However, most of the participants stated in additional surveys that the land utilization and the exercised development plans in the simulation are realistic.

Despite the fact that most of the local representatives were skeptical about this new instrument, the field experiment has shown that the local authorities were able to reduce the development of new land in the simulation runs. Some participants realized more expensive infill projects and partly financed these projects with the revenues from selling unused development certificates. Moreover, even though one should be careful with the absolute amount of the cost estimates used for the simulation, the results demonstrate that the flexibility introduced by the tradability of the development certificates allowed overall cost savings as postulated by theory. The results demonstrated that a suitably developed TDC system can be efficient as well as operational. However, the realized net present values were further away from the theoretical benchmark than the results in a student control group. This is an indicator that not all the possible cost potentials were realized by the local representatives in the field experiments. For a more detailed investigation, the results of the simulation were combined with available data from surveys, which had been conducted after the simulation runs. This method allowed a further analysis of the individual decision making of the participants.

[1] Further laboratory experiments which were conducted in addition to the field experiment underpin these results. The laboratory experiments show that the economics students acted closer to the theoretical optimum than the spatial planning students, which means that the economics students reached the reduction goal at lower cost (Müller et al., 2010a,b).

According to economic theory, the primary allocation of the certificates should not affect the efficiency of the trading system. If the initial allocation is inefficient, the secondary market should correct this situation by reallocating the certificates to the 'right' municipalities. How fast the market can achieve a constellation, wherein no transaction is possible which enhances the Pareto-efficiency, depends on the design and the trading rules of the secondary market, as well as on the trading behavior of the participants. The results of the data analysis indicate that the primary allocation of the certificates had only little impact on the adaption of the land development plan. Moreover, some participants used the flexibility of the trading system to adjust the amount of certificates in order to realize a specific scenario and bought the necessary certificates at the market place. Hence, it was possible for the participants to realize the initial baseline scenario and to balance the periodical demand for certificates by purchasing additional certificates on the market.

Some results of the field experiment indicated that the implementation of the proposed scheme will not automatically result in the expected cost savings and efficiency gains. In all simulation runs, the overall incomes were lower than in the optimal solution. Furthermore, the results from the simulation runs with the student control group showed that efficiency gains can be realized when focusing on economic criteria during the simulation. Possible reasons for inefficient abatement strategies include incomplete information about the scarcity of certificates in the future, wrong price signals from the market, risk aversion of the participants, as well as the consideration of non-economic criteria during the selection of development options. The analysis shows that the usage of the decision support tool supported the economic comparison of different development plans and led to higher incomes in municipalities if a TDC scheme is introduced. Local political goals and economic cost minimization are not necessarily congruent. When participants based their decisions on the economic criteria, political relevance was less important. Hence, the measurable economic optimum must not be validated as the only reference point in the planning process. A strategy evaluation that compares market results with the monetary optimum is only partly convincing for the comparison of the two subject pools, and the results of the simulation must be interpreted carefully. As described in the presented framework for land use decisions, political constraints could hinder economic decisions of local representatives.

Wrongly chosen development options, in economic terms, as observed in the field experiment, can also support high market prices, slow down the price discovery process and reduce the efficiency of the trading system. The field experiment replicated some of the typical features of environmental and experimental markets. A gap between observed prices and optimal prices was observed particularly in the first simulation run and significant learning effects in the second simulation run. In the first simulation run, the market price was mainly influenced by the maximum price and the sanction price. Market prices that are not based on the abatement costs may influence the trading strategy of municipalities, and can lead to a significant decrease of the municipal profits and to a lower efficiency of the allowance system. Only if the participants base their order prices on fundamental values, the market price can correctly reflect changes in demand and in costs between municipalities. Otherwise, the market prices cannot adequately reflect scarcity and the abatement costs.

The dispersion during the price discovery process can have some important policy implications in the domain of land development. Price fluctuations can lead to the reduction of new land development in municipalities with high abatement costs, which foster inefficient market results. Due to the fact that a land utilization plan determines the development of cities for a long period (in German municipalities usually 15 years), a high price variance in this illiquid market can influence the long-term planning of the municipalities. This convergence process is critically important for policy applications, because it can complicate long-term decisions of the municipalities. In emission rights schemes, various derivative instruments have been developed to hedge long-term purchases and sales of emission rights (e.g. options, swaps, futures, etc). Such instruments are essential for the calculation of inter-temporal strategies and make an individual calculation of the price discovery possible. A similar development could be expected for TDC systems. This would facilitate the handling of volatile prices and increase the acceptance of the new instrument.

6.2 Design of a Decision Support Tool (Chapter 4)

The participants reported at the workshops of the field study that they well received the structured data collection and the comprehensive decision support tool, which supported their decision making in the field experiment. The decision support tool reflects the municipal decision situation by describing the municipal land development on the basis of different development options and the associated areas, as well as the related costs and incomes. Many local representatives stated that their sensibility towards costs, related to development options, was growing when collecting and entering the data into the online platform. Furthermore, the tool supported the strategic planning and served as the basis for policy making and development planning in the simulation. Learning effects on the part of the participants between the two simulation runs, especially with regard to strategy finding and pricing, were observable between the two simulation runs and the participants became more familiar with the usage of the decision support tool.

The design of the platform and the decision support tool enabled the calculation of follow-up costs for maintaining the infrastructure. Help windows and tool tips were available to support the decision making over the internet and were integrated into an user friendly graphical interface. This functionality is an advantage of web based tools that combine a front end with a database. Against it, offline excel tools, which are used in most of the current studies, offer only a limited functionality. Similar to other decision support tools for land development, the implemented tool focused on the actual demand for floor space, and did not include population dynamics. Moreover, due to the geographical distance between the municipalities, the modeling of migration and the associated effects were of lower importance. However, a game-theoretical modeling extension of the decision support system that allows the reflection and estimation of population dynamics in different regions and metropolitan areas was also proposed.

The observed trading and avoidance strategies highlight the necessity of supporting information tools, as well as a thorough preparation and training of the decision makers within a TDC system. Regardless of whether a TDC system is introduced, the simulation also showed that there is a need for supporting methods and tools in order to precisely record costs, especially long-term costs. The planning is very complex and depends on various factors, which cannot be quantified, or are difficult to quantify. Before the new instrument can be implemented in practice, it is necessary to enhance the acceptance for the instrument and the expertise among the market participants. The participants' lack of experience with this new instrument stresses the need for local authorities to acquaint themselves with the rules and the range of possible strategies in a system with TDCs as a supplement to the existing planning regulation systems.

In contrast to other decision support systems, the implemented decision support system focused on the structure of the areas and the integration of a TDC scheme. The tool distinguished between two categories of development options that can cover the demand for floor space in a municipality. First, development options which are associated with new land development by converting open space into new settlement and traffic areas could be specified. Second, development options in the inner areas, which allow the reuse or extended usage of existing settlement and traffic areas, could be defined in the tool. Based on this model, the decision support tool calculated the total amount of TDCs that was necessary to realize a new land development plan in a planning period. In order to enable the simulation of a system with TDCs, the implemented decision support system had to reflect the structure of the municipal boundaries, the settlement and traffic areas, as well as the associated floor space areas very accurately. However, the decision support tool can also be used without the introduction of a TDC system. For instance, the implementation of a decision support tool on the regional level can be used to create an efficient regional land development plan by coordinating the municipal land development.

The participants in the field experiment, and respectively the local representatives, considered further aspects apart from just cost minimization when using the decision support tool. The decision support tool only reflected the recorded costs of the development options chosen by the municipal participants, which only partially reflected the preferences of the participants. For instance, priorities in local politics, which were not explicitly modeled in the field experiment, were relevant for their choice of development options. Hence, local political priorities were the dominant criterion for the choice of development options in the strategy finding of the municipalities. Although municipalities could enter additional textual descriptions of development options, for instance the relevance of a development option in the political context, a monetary quantification of the data was not possible. Politically and sociologically caused costs are difficult to quantify monetarily and were not included in the tool. Economic criteria, on the contrary, are insignificant for some municipalities, which emphasizes the importance of displaying the information comprehensibly to the participants. By analyzing the trading strategies of the participants, it became clear that the individual marginal costs displayed on the internet platform by the indicator price tool (which is an economically rational criterion for price bidding levels) was of little importance to the participants although the participants received assistance in marginal cost calculation.

6.3 Decision Framework for Land Usage (Chapter 3)

The results of the field experiment and the limits of the presented modeling approaches for decision support systems show that more work needs to be done to elaborate institutional collective action frameworks for land development in more detail. The proposed framework provides a guideline for the integration of new policy instruments into the land use decision chain. For a more comprehensive understanding of the interdependencies in the decision process, a multi-step modeling of the decision process is helpful. Only if the characteristics of the decision process, including the incentives of the decision makers in different environments become clear, a suitable integration of the new policy instruments into the planning processes is possible. Modeling approaches from other domains, such as common-pool resource games used in the fishery or water usage domain, might enrich the modeling approaches in land usage by introducing competition for households and firms. Furthermore, the analysis of the vertical and horizontal policy framework can be investigated within the scope of social network analysis. New theoretical modeling approaches in this area can provide further insights into other aspects during the decision making in land development.

The proposed framework for land development decisions shows that relationships on the horizontal level can influence the ability of local bargainers for coordinated collective actions in land usage and can hinder the realization of some development plans. As mentioned above, the policy network primarily limits the feasibility of municipal development strategies or leads to an overestimation of tax incomes. Furthermore, political relevance of specific development options in the decision process will increase the valuation of options that are unfavorable from a purely economic perspective. The introduced model can serve as a basis for analyzing the policy network among governmental and non-governmental actors for the coordination of land usage in different regional scenarios.

The decision framework for land usage points out that there still exists a lack of cost transparency during land development decisions in Germany. By enhancing the cost transparency, the development of land development plans, which are preferable with regards to economic, ecological and social aspects, will be more likely. For instance, in many municipalities the demand for floor space is overestimated, which leads to an inadequate development of new areas depending on the community context. In order to solve the related collective action problem, it is necessary to solve the dilemma of uncoordinated land development plans. A planning institution as a supervisory authority in a region should be able to provide a regional database that enables local authorities to store municipal data to compare the efficiency of different development plans and to coordinate the land development. However, this makes a mapping of the regional and municipal structure of the spatial areas necessary. Some of the recent studies, presented within this book, have also directed their attention to the impact of regional structures on the likelihood of local agreements. Furthermore, the platform supports an accurate estimation of the municipal demand for floor space and can support the solution of development dilemmas.

Vertical and horizontal policy networks can hinder the efficiency of newly designed market-based instruments, such as property rights systems. Recent studies have analyzed the design of property rights allocation to different regions. The acceptance of these new instruments is mainly influenced by whether the introduction is considered to be fair for the participants. For instance, in a property rights scheme, the design of the initial allocation of certificates to the municipalities is crucial for the acceptance of the new policy instrument. An allocation rule implies requirements for the functioning of the new instrument and can determine how far the result deviates from the optimum. Depending on the criteria that are taken as the basis for the allocation, the property rights scheme leads to considerable redistribution effects between the municipalities and influences the acceptance of the new instrument.

The findings have implications for a variety of issues in land development. The framework points out that the understanding of the regional and municipal structure is a necessary condition but, in order to gain more detailed insights into land development and urban sprawl, a more transdisciplinary analysis of the decision making of local actors is necessary. Furthermore, the analysis shows that the structure of a region has a crucial impact on the decision situation of a municipality in land development. Based on the specific decision situation, however, other factors can play an important role. Timing of decisions, personal interests, or cognitive abilities of decision makers can have a greater impact on the land use decision than the characteristics of the underlying collective action framework. Therefore, it is necessary to analyze the decision making and the behavior of the local actors in more detail than currently done in theory. A theoretical analysis of all complex decision making processes is almost impossible.

6.4 Design of a TDC Scheme (Chapter 2)

A TDC system can be described as an instrument intended to effectively reduce the development of new settlement and commercial areas. In the field experiment, this ecological target was met. Due to the chosen experimental design (borrowing was not allowed but effectively possible by paying sanctions), the quantity restriction was surpassed in the second simulation run in the control group. As the simulation ended after the fifth planning period, the obligation of handing in certificates in the last round, in case of expansive area development, was outside the planning horizon. In case of continued trading, the sanctioning regulations and the obligation to hand in missing certificates later on guarantees that the global reduction goal will be achieved. Hence, exceeding the reduction goal is partially a simulation artifact and a TDC system can be seen as an effective instrument for quantitative control.

Independent from these results, it is important to point out that a TDC system alone does not guarantee compliance with qualitative goals. The reduction goal was even undercut in the simulation runs of the field experiment. It is necessary to consider economic and ecological aspects along with the institutional and legal requirements when choosing a market design for tradable development certificates in Germany. The new instrument rather complements existing spatial planning, ecological, and landscaping instruments. It is, thus, a challenge for policy makers to identify the crucial design elements that facilitate the trading system and lead to desirable outcomes in social, ecological, and economic terms. Therefore, different aspects of the market design for the new environmental instrument were presented, that were also the basis for the design of the field experiment and the implementation of decision support tools in the first part of this book.

By means of the field experiment, the applicability of the settlement and traffic areas, as the central indicator for measuring the land consumption and as the reference value of the TDCs, is proven to be suitable within a first application scenario. Therefore, tradable development certificates are goods that legitimate municipalities to develop new residential and traffic areas in the outer area of a city. In contrast, the central reference value to define a municipal development target, which has to be ensured in each scenario, was the demand for floor space. In the simulation, it was distinguished between two different targets, the required floor space for commercial purposes and the required floor space for residential purposes. In order to reduce the complexity of the task to coordinate the land development in two different dimensions, the modeling of different development goals for separated settlement and traffic areas seems to be more favorable. Due to the fact that many studies show differences between the costs and incomes of areas for commercial and residential purpose, high abatement costs in one dimension can influence the price in the other dimension if universal certificates exist. Hence, a market differentiation by land-use criteria and two specific submarkets for commercial and residential TDCs should be analyzed in further experiments.

An allocation model was proposed in this book that implements a market at the federal states level with municipalities as the market participants. The reduction goal is set by the federal states to the administrative district, and the supervisory planning authority allocates the certificates to the municipalities afterwards and coordinates the regional land development. Such a model, which is compatible with the interests of the involved institutions, includes a high number of market participants and is most compatible with the German law. The federal states can set binding reduction goals in subordinated local authorities in the interest of a sustainable federal land development and planning. Studies have shown that the federal states are able to limit the development of new settlement and traffic areas and consider quantitative restrictions on new land development as feasible. However, the German Federation has to negotiate the reduction goals with the federal states to prevent a deviation by concurrent competences. The proposed model should guarantee a high acceptance of the new instrument and seems to be appropriate to solve the described regulatory choice problem.

In a TDC scheme, the task of the supervisory planning authority is to coordinate land development plans, to allocate the certificates to the municipalities and to monitor the land development plan. As mentioned above, a regional database can facilitate all these tasks and allows the calculation of the primary allocation of the certificates. Due to the fact that the initial allocation should have little influence on the efficiency of the system, the allocation should aim at solving the acceptance problems potentially arising from the different interest groups within the vertical policy framework. Thus, the criteria *population*, *settlement and traffic areas*, *nature protection area* and *historical population growth* were identified as appropriate, because they combine economical, ecological and social aspects. Furthermore, the platform can provide different access rights to the supervisory authorities and to the municipalities. Regional planning authorities can get restricted access to the data and only request information about the structure of the municipal areas for allocating the certificates, while municipalities get full access to the entire data such as sensible costs and incomes. Thus, the database can support the cost calculation of the municipalities, facilitates the calculation of the initial allocation of the certificates and enables the monitoring of the land development plans.

6.5 Outlook

In order to provide more empirical results in different regions, further experiments and field studies should be conducted with focus on a cap-and-trade mechanism for land usage. The participation in such experiments can lead to an augmented acceptance of the real world actors towards the new instrument. For this reason, additional surveys and field studies should be conducted, which focus on the mentioned observations, and investigate and test tradable development certificates in other planning simulations. Alternative scenarios with municipalities that are in a regional association could give further insights into how to design an appropriate TDC scheme. Consequently, issues of rivalry and allocation between municipalities could also be reflected. Future research projects should especially examine possibilities of combining regional planning and TDC systems, or should analyze various aspects of intercommunal competition between municipalities for households and firms. This would mainly influence the costs of development options, because, for example, commercial tax or personal income tax revenues, financial subsidies from the federal states, or costs for infrastructure developments and municipal facilities would be affected.

The observed strategies in the field experiment and the discussed market design for TDCs also have different implications for the design of future planning and decision support tools. First, in future decision support tools, different actor groups should have access to the data. A prerequisite is that municipalities should get unlimited access to the planning tools and should be able to decide which data is passed on to other actors, like brokers and economic experts, who support the trading of certificates, or the supervisory authority. However, further legal aspects in terms of privacy arise with the implementation of these regional decision support tools. Secondly, due to the regional consequences of local land development decisions, the implementation of regional planning tools is favorable. Small municipalities have only limited resources to implement and manage local information systems and decision support tools. Thirdly, the results of the field experiments have shown that the design of the tools has to be carefully elaborated with municipal decision makers. A user friendly interface that reflects the decision situation accurately and shows economic, ecological and social consequences is indispensable. Fourthly, the decision support tool has to reflect the municipal decision making processes. This includes the setting up of alternative development plans, the realization of a land development plan as well as land use decisions of households and firms as outlined in the proposed framework for land use decisions.

National studies suggest that a holistic consideration of all decision processes in land usage is very unlikely. Therefore, future research should focus on specific facets of the proposed framework. Context choice modeling might predict how actors (e.g. households and municipalities) behave within the land use decision chain. This will help to further analyze decision processes of local representatives in a particular context. By conducting choice experiments and conjoint analyses, probabilistic predictions about human decision making behavior in a particular situation are possible. In this context, the consideration of psychological factors, which influence the cooperative behavior of the local decision makers, also plays an important role. Studies emphasize that the risk aversion of the participants has an impact on negotiation processes and influences the success of intercommunal cooperation concepts. Trust, candor, altruism, and goodwill of the representatives are further factors that determine the probability of achieving a cooperative solution in the second decision step, and the structure of the policy networks. A more interdisciplinary view on the collective action problem in land development will help to understand the way different local representatives in diverse types of municipalities and regions make decisions.

Recent studies have shown that, apart from the spatial structure and the community context, the policy network and the restrictions of spatial planning should also be taken into account when allocating property rights. Non-economic criteria, such as the structure of the described horizontal and vertical policy network, are difficult to quantify and, therefore, can hardly be considered during the primary allocation. The number of non-economic criteria, which will be taken into account in the initial allocation, influences the distance of the created allocation from the optimal economic allocation. The design of market-based instruments in land use depends on restrictions from other instruments, which have binding land goals as well. This enhances the necessity for a differentiated consideration of the goals and instruments within the scope of scientific and political discussions. Future research projects should especially examine the interaction with policy restrictions, for instance constraints from a superior regional planning, and the design of economic instruments. The proposed framework for land development decisions can also be used to discuss important aspects and interdependencies of the actors when introducing new policy instruments to achieve a sustainable land development. Furthermore, the framework outlines that cooperation concepts are necessary to avoid the cost paradox and the development dilemma. Without considering all these aspects, even a market-based instrument that is rooted in economic values will not be able to efficiently solve the main environmental problem.

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