Gaming the Interrelation between Rail Infrastructure and Station Area Development: Part 1 – Modeling the Serious Game 'SprintCity'

Nefs, M., Gerretsen, P., Dooghe, D., Mayer, I.S., Meijer, S.

Abstract—**The authors discuss and analyze the complex interplay between rail infrastructure development and land use development of railway station areas in the Netherlands. They argue that although this interrelation has been theorized and studied in the academic literature, the underlying complex and dynamic mechanisms, and the appropriate planning and management responses, are still insufficiently understood. This is particularly relevant for local, regional and national policymakers in the various subsystems, because a lack of network understanding and interconnectedness may produce suboptimal, unsustainable spatial and rail infrastructure planning. In order to better understand and manage the dynamic interrelations between rail infrastructure and urban development in the Delta Metropolis, the serious game SprintCity was developed. The game is played with the real stakeholders (administrators, planners, politicians, interest groups, experts and consultants, etc.). In this paper, the authors describe and analyze why and how the complexity of the real world system was modeled into a serious game.**

I. Introduction

In a small but densely populated country like the Netherlands, space is at a premium. It is therefore important to achieve a high level of spatial quality and connectivity. In this paper we analyze the interrelation between infrastructure networks and urbanization.

The structure of this paper is as follows. We first examine urban growth in the Delta Metropolis of the Netherlands, and present the central problem definition and research questions concerning the interaction between rail infrastructure and station areas. On the basis of existing models of the interaction between mobility and land use, we construct a model that describes the specific situation in the Delta Metropolis, with the variables and actors involved. We then develop the model that underlies the serious game SprintCity [1]. With this game we further investigate the interaction between the development of rail infrastructure and station areas, and at the same time make this clear to policymakers and develop starting points for future policy. We end with our main conclusions on the insights that the development of the model has provided up to now. In an accompanying publication [2] we present the serious game SprintCity, the validity and provisional results in more detail.

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Authors Nefs M., Gerretsen P. and Dooghe D. are with Vereniging Deltametropool, The Netherlands (e-mail: SprintStad@deltametropool.nl)
Authors Mayer I.S. and Meijer S. are with TUDelft (e-mail: i.s.mayer@tudelft.nl and sebastiaan.meijer@tudelft.nl)

II. Urban Growth in the Netherlands

The Delta Metropolis, also known as the Randstad, is the main agglomeration of the Netherlands. It is made up of a ring of urban centers situated roughly between the four large cities of Amsterdam, Rotterdam, The Hague and Utrecht, with a central green and rural area at its heart. The Delta Metropolis also contains the most important mainports, such as the Port of Rotterdam (PoR) and Amsterdam Airport Schiphol, and has a high level of density of line infrastructure, such as water, road and rail networks. Figure 1 presents a map of the Delta Metropolis and its main rail corridors.

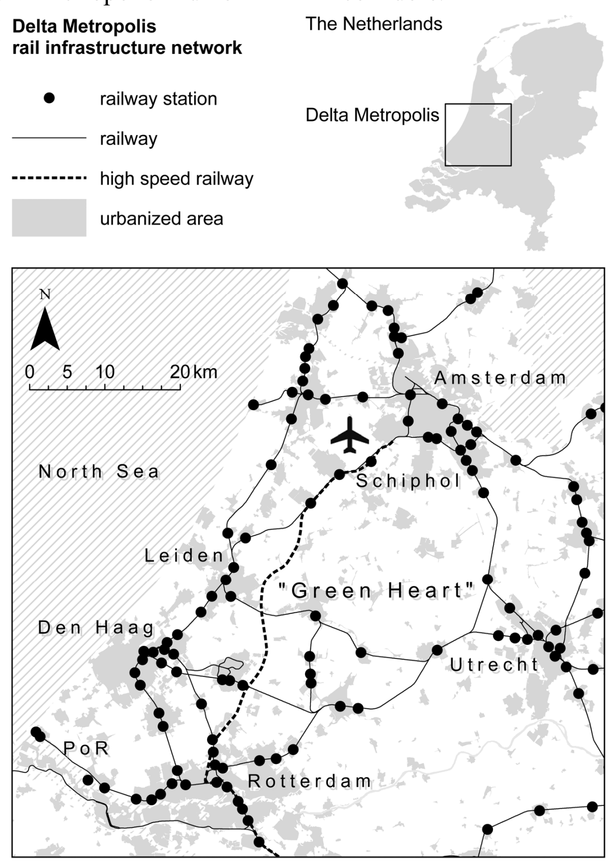

Figure 1: Rail corridors in the Delta Metropolis

In recent decades the Delta Metropolis has developed from a series of separate urban regions into a single integrated urban (metropolitan) area. The Delta Metropolis continues to attract new inhabitants and businesses. In order to accommodate new urban activities and remain economically competitive with other metropolitan regions such as Paris, Frankfurt and London, significant new-build development has to be planned in the region, with high-quality options of regional and international mobility [3]. Low-density Greenfield development in most parts of the Delta Metropolis, including the protected Green Heart, has ceased to be an option due to lack of building space and legal and environmental constraints [4]. There is more and more interaction between the various cores and functions (working, living, recreation, nature, etc.) in the Delta Metropolis, creating a growing need for mobility. The existing road network has insufficient capacity for this end, and the development of the regional public transport has not kept pace with the growth of the urban area.

For these reasons the Ministry of Spatial Planning (VROM) formulated the ambition to create a significant proportion of future urban developments within the existing urban perimeter. At the same time, the Ministry of Transport (V&W) has the ambition to create a public transport network of 'Olympic' quality before 2028 [5]. The Ministry of Transport, in close collaboration with the Dutch Rail Network Manager 'ProRail' and the Dutch Railways (NS), wishes to introduce non-timetabled train services from 2028. This means six Intercity trains (trains that only stop at the main stations) and six 'Sprinters' (trains that stop at all stations) per hour in large areas of the Randstad, comparable to a Metro system. The shift from transport flows on the roads to public transport, particularly by rail, has positive sustainability effects, for example in terms of energy use, CO2 emissions, quality of life, etc. The development of rail infrastructure creates opportunities for urban development, especially around station areas, and conversely, the spatial development of the station areas leads to greater transport flows and more intensive use of the infrastructure networks. The resulting quality of life and connectivity of the region would enhance the competitive position of the Delta Metropolis.

III. PROBLEM DEFINITION

To achieve the above-mentioned goals of sustainable quality of life and mobility in the current economic situation, new forms of interaction between stakeholders are required. At present, there is a lack of instruments to identify and investigate these new forms of multidisciplinary cooperation between governmental institutions, housing corporations, real estate investors, public transporters etc.

Even though the Delta Metropolis can be seen as one coherent urban system, in reality multiple transportation systems are under development at the regional level in the provinces of Zuid-Holland, Noord-Holland and Utrecht, concerned with the optimization of their regional public transport system, based on a more frequent use of the rail infrastructures. In general, however, municipalities do not prioritize spatial development around railway stations due to financial and institutional constraints. Greenfield development is often more financially attractive in the short term. This view is shared with the private building industry, which still focuses on low-density development on the urban fringe. Furthermore, municipalities mostly plan within their own boundaries without regard for the wider region, resulting in competition between cities, oversupply of certain functions and undersupply of others. Instead of focusing on the specific qualities of each station area and the productive diversity of the network as a whole, to many conflicting and counterproductive developments have taken place around railway stations in the Delta Metropolis.

In theory, everyone will only gain by cooperation and by channeling the urban densification task to the station locations of the Delta Metropolis, since both land-use development and public transport will benefit. In practice however, integrated development is more of an exception than the rule. In general, stakeholders lack an overview of the complex situation, conscience of their position in the network and knowledge of the most important existing and potential factors at station locations.

On the basis of the above analysis, there is a threefold necessity for more insight into integrated development of rail infrastructure and station areas.

A. Socio-economic necessity

The rapidly expanding and dispersing Delta Metropolis region faces a growing need for mobility that is not met by a significant increase in infrastructural capacity. Sprawling development in recent decades has led to traffic congestion and a decreasing quality of mobility, living space and the green environment, which in turn reduces the competitive position of the Delta Metropolis on the European level. Urban densification and public transport policies are underway to reverse these trends. However, one cannot neglect the context of the current economic crisis, limiting investments in new infrastructure. Only an integrated strategy of spatial concentration around railway stations and a more efficient use of existing infrastructures can properly address both sides of the problem. This means implementing new stations and higher train frequencies on existing corridors, and bringing new passengers within range of the system, by the development of urban programs around the station.

B. Institutional necessity

This strategy is only possible through a paradigm shift, leading to multidisciplinary and integrated development. Many government bodies and other stakeholders do not share this priority, and lack the instruments and knowledge of the relevant factors and potentials in station locations to engage in complex decision-making processes. While the actual form of collaboration and integration of policies is still unclear, a trend toward the integration of relevant scale levels and themes can already be identified. The integration of transport and spatial development on an inter-regional level can be seen as a precursor to this institutional trend.

C. Scientific necessity

New methods need to be developed to facilitate and guide complex decision-making processes in the field. A platform is needed to exchange experience between scientific research and practice, and to test abstract models and scenarios in the real world. Not only tools and knowledge about integrative strategies are needed, but also a new playing field in which these tools can be used, and in which governments and other stakeholders can cooperate in a coherent way. Serious gaming is likely to function as such a playing field, and as a catalyst in the necessary paradigm shift leading to new types of cooperation and integrated development.

IV. MULTI-ACTOR PROBLEM

The optimization of rail infrastructure and its interaction with the spatial development of station areas can be typified as a complex, socio-technical and multi-actor problem [6]:

1) Logistic-spatial-infrastructure dimensions of the problem are deeply interwoven with political-social dimensions, such as experience and emotions, political decisions and strategic behavior.
2) A large number of interdependent actors are involved, who operate in a variety of overlapping policy networks: some actors or networks do not interact, or only moderately interact, with each other.
3) The behavior and performance of the total rail infrastructure/spatial system cannot be inferred from the behavior and performance of the individual actors. The system is emergent (greater than the sum of its parts), and therefore largely unpredictable and poorly understood.

Although the interrelation between infrastructure networks and urban development has been theorized and studied in the academic literature, the underlying complexity of dynamic mechanisms and the appropriate planning and management responses are still insufficiently understood. This is particularly relevant for local, regional and national policymakers in the various infrastructure and urban planning subsystems, because a lack of 'integral' or 'systems' understanding may lead to suboptimal, unsustainable spatial and rail infrastructure planning. This problem is manifested by symptoms such as planning delays, deadlocks and stalemates, low quality urban development, and a mismatch between supply and demand in terms of rail transport or living and office space, etc. The chronic deadlock of the interaction between infrastructure and space, as well as a lack of insight into the complex situation, lead to traditional intensive construction on poorly accessible peripheral agricultural land. This has a negative effect on the quality and accessibility of the urban area. Impasses can only be overcome by good management and interdisciplinary action, on the basis of knowledge and understanding of the processes and possibilities. The lack of insight into the connection between infrastructure and urban development also leads to missed opportunities when the spatial development alongside the railway line as a whole is considered. Individual municipalities on a rail corridor can take decisions that are mutually competitive or conflicting on the level of the corridor or network.

As well as knowledge of the complex mechanisms of the space-mobility issue, there is also a lack of an instrument with which, on the one hand, knowledge can be validated by testing in practice and, on the other, knowledge can be applied in the real world.

In our view, gaming-simulation or 'serious gaming' could provide such an instrument. The serious game SprintCity [2] was developed in order to better understand and manage the dynamic interrelations between rail infrastructure and urban development.

V. THE SERIOUS GAME SPRINTCITY

The serious game SprintCity was initiated in 2009 by Delta Metropolis Association and developed in a joint project with the Serious Gaming Centre of TU Delft and the Next Generation Infrastructures (NGI) foundation. The name of the SprintCity game is inspired by the conceptual city of train station environments that are linked by frequent short-distance train services. In the Netherlands the trains that stop at every station along the train line are known as 'Sprinters'; therefore the SprintCity is the city that is not limited by geographical distances, but by traveling times between train station areas.

In short, SprintCity can be best characterized as a computer-based, multi-player (6-12 players), strategic planning game. The game has a high level of realism, and is based on actual data and a (simulation) model which is an adaptation and extension of the ***transport land use feedback cycle*** and ***the place-node model*** (explained below). The game is intended to be played with the real stakeholders with some expert or background knowledge on the subject matter (administrators, planners, politicians, interest groups, experts and consultants, etc.). A playable prototype version is available and, at the time of writing, has been used 9 times with around 70 participants from various stakeholder organizations. A game version 1.0 – with an improved and extended simulation model and more features – is currently under construction and will be released around autumn 2010.

The prototype game simulates an existing railway corridor in the Delta Metropolis, connecting the cities Leiden and Schiphol. The corridor contains 6 stations, 2 of which have in reality not yet been implemented. Real world data of the transport network and the area within a 1200 meter radius around each station were loaded into the game.

The objective of each game player is to develop their station area in phases of 4 years from the year 2010 to 2030, according to previously chosen ambitions and a functional master plan, drawn up by the player himself. In game version 1.0 a rail transporter player is to be introduced as well, who has the goal of improving the public transport system (higher frequency) and attracting more passengers.

Available infrastructure and demand for urban program in a certain period of time are limited, like in reality. These difficulties have to be overcome by the players to realize their ambitions. During the game, strategic cooperation and negotiation are required to achieve better results for each individual player and for the result of the whole corridor.

Due to limitations of space, a detailed description of the serious game SprintCity, the main results and insights so far , are not presented here but discussed in an accompanying paper [2]. In the remainder of this paper we will focus on the development of the underlying model – called ***public transport mobility – land use feedback cycle*** - that was used to model and design the game.

VI. Research Questions

The development and application of the ***public transport mobility – land use feedback*** model and game will be scientifically investigated with reference to three central questions:

1) What is the validity of generic models concerning the interaction between mobility and spatial development when applied to the rail infrastructure and station areas in the Delta Metropolis?
2) What can we learn about the integrated, long-term development of rail infrastructure and station areas when stakeholders interact with these models in a serious game?
3) Is serious gaming an effective research and learning method for validating and improving these models, generating policy-relevant knowledge and transferring this to policymakers?

Research question 1 is the central question in this paper. It is a methodological question concerning the modeling of the interaction between infrastructure and space. Research question 2 is the main content-based and policy-relevant question of the investigation, which will be answered at the end of the project. Research question 3 is a methodological question that is relevant for the professional field of gaming and policy analysis. This question will be answered in an accompanying publication [2].

VII. Modeling the Interrelation Between Rail Infrastructure Network and Urban Development

The mutual relationship and reciprocal influence between transport systems (car, public transport, etc.) and urban growth, among other things, is described in the 'transport - land use feedback cycle' [7] [8].

Figure 2 is a representation of this cycle, whereby the transport system influences land use via the factor of accessibility, and land use influences the development of the transport system via socio-economic activities. Various exogenous (cultural and socio-demographic) and endogenous (policy, demand, land, etc.) factors have an influence on the nature, the direction and the speed of the reciprocal influence.

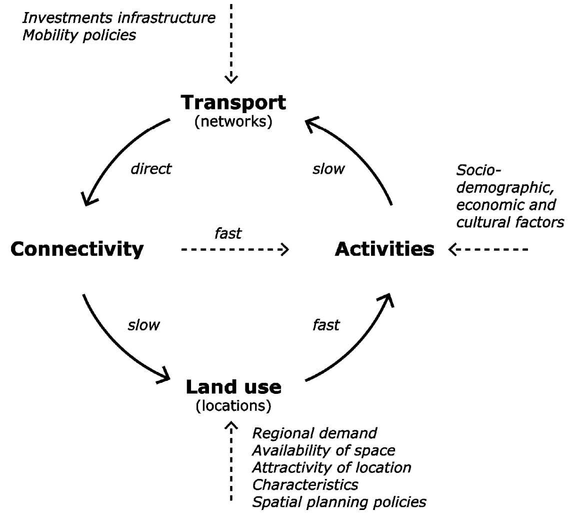

Figure 2 Transport land use feedback cycle [9]

Figure 3 is a representation of the model for the analysis of rail infrastructure development and land use at station locations. In this way the model forms the basis for the development of the SprintCity game. The main additions and amendments of this model are:

1) Physical delineation of the system: the transport corridor is the smallest transport-land-use unit in which all variables and actors are active. The Delta Metropolis is made up of more than 10 transport corridors.
2) Land use is primarily focused on 'density', and public transport mobility on 'intensity'.
3) High frequency use of the rail network stimulates the demand for the urban program in station areas.
4) Denser land use around stations stimulates the demand for public transport mobility.
5) A well functioning feedback cycle, where the factors influence each other in a positive way, has favorable effects on a sustainable, accessible living environment and the competitive position of the Randstad in Europe.

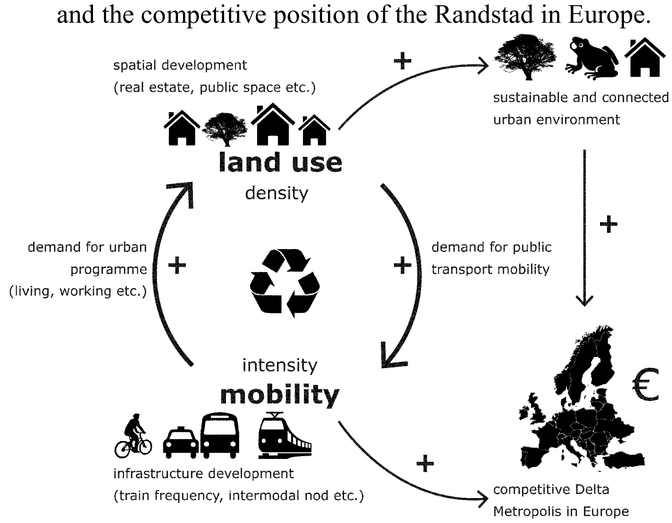

Figure 3 Public transport mobility – land use feedback cycle

In practice, there are various barriers or disruptive factors in the feedback cycle, so that the cycle does not function well, with unfavorable effects for sustainability, accessibility and the competitive position of the Delta Metropolis.

The spatial policy and infrastructural policy – which are drawn up in bodies at various levels of scale, each with their own interests and policy structure – remain in waiting for one another. Possible causes of this are risk avoidance or insecurity reduction by the actors involved. After policy, plans are made. Spatial and mobility plans are not always effectively attuned to one another between central and local government, infrastructure managers and the various transporters. Changes in course and disruptions and delays in the implementation of plans are also not unusual.

Developments depend on the available financial resources, the capacity of the infrastructure and spatial capacity around the stations. Bottlenecks, lack of space and economic crises have a negative effect on the feedback cycle. The interaction between infrastructure and spatial development can be operationalized in the manner shown below. This is important for the analysis of the actual situation, but also for the development of the game.

Figure 5 below presents the adapted, extended land use and public transport model as a multi-actor system. The model is concentrated on the situation in the Delta Metropolis by adding the variables and actors which have a direct influence on the feedback cycle.

VIII. NODE/PLACE MODEL

The factors to be influenced and the effects that the relations have on each other must be made 'measurable' in order to be able to play with them. It is thereby important that the underlying simulation model is based on scientific insights, validated calculations and realistic data. The realistic data in the serious game include regional demand for urban programs, available development space, existing numbers of workers and inhabitants (all within a 1,200m radius around the railway station), transport modalities, timetables, strategies and plans in progress, etc.

The relationship between the present transport infrastructure of a transport node and the activities around this node are expressed in Bertolini's node/place model [9]. This model is intended to determine the functionality of a station location. A station is functionally in balance when the node and place value correspond to one another. If the place value is high, while the node value is low, there are opportunities for mobility development. With a high node value and a low place value there is potential for spatial development.

Node value refers to the available supply of infrastructure and transport systems: the frequency and the number of directions of the public transport that makes use of the node, the extent of the network that is connected to the node, and the transport modalities that the node can reach. The place value is determined by the land use of the functions and activities in and around the node: living, working, public functions, recreation, and the degree to which these functions are intermingled.

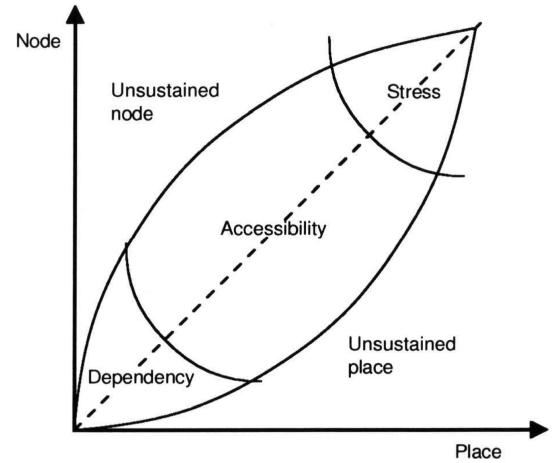

Figure 4 Node/place model [9]

The node/place value model is presented in the model in the manner shown below (figure 5).

On the mobility side, a ***Network Value*** is assigned to the stations, calculated with reference to the modalities, frequencies and transport directions. This value is influenced during the game by changes in the transport system.

On the land use side a ***Place Value*** is assigned to the station areas, resulting from the number of inhabitants and employees in that area (R=1200m) and the ratio between these two numbers (functional mix). This value is influenced during the game by the implementation of urban programs.

IX. THE RELATION BETWEEN MODEL AND SERIOUS GAME

The model portrayed in figure 5 came about in steps. By developing, playing and discussing the prototype of the game, missing variables were highlighted and relations between actors became clear. A better model of the real situation now makes possible a better version the game, which will hopefully in its turn lead to new insights while playing the game.

The model connects the most important variables and actors to the transport-land-use feedback cycle. It shows that a large number of policy actors are important players in the cycle. They interact on various components of the spatial policy, and give form to and implement infrastructure policy. Municipalities particularly manage issues via the implementation of the program for station areas. ProRail and Dutch Railways (NS) particularly manage issues via the frequency of trains. The interaction and attunement within the spatial network (the municipalities), within the rail infrastructure network and between the policy networks is not optimal, however. The game can be helpful in analyzing and reflecting on the networks and interactions, trying out new forms of interaction and drawing lessons from these for the situation in reality.

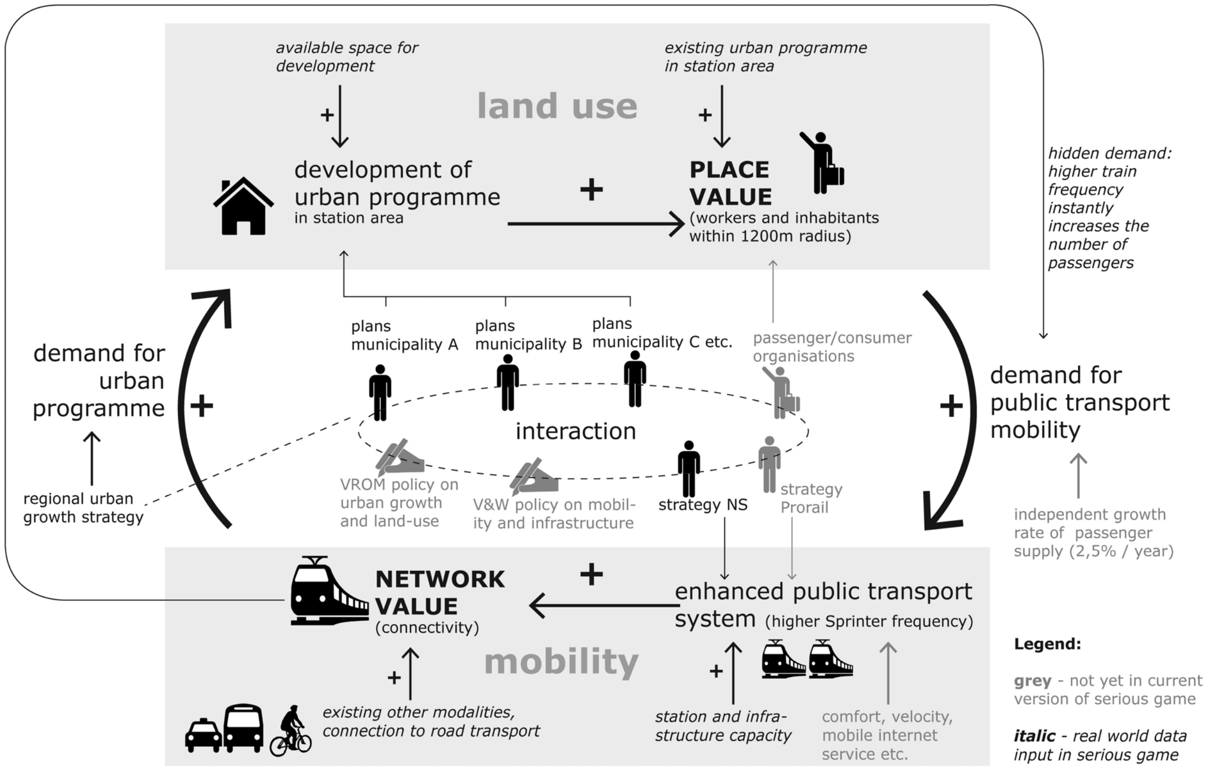

Figure 5: Land use and mobility as a multi-actor system in the serious game SprintCity

X. Conclusion and discussion

The development and play of the serious game SprintCity has contributed to a better understanding of the interaction between rail mobility and spatial development in the Delta Metropolis in a variety of ways. The serious game has enabled the adaptation and application of scientific models:

1) The creation of the game forces the concretization, elaboration and adaptation of several scientific theories and models concerning the interplay between rail infrastructure and spatial development, to describe the specific context and problems of the Delta Metropolis.
2) The game makes it possible to validate/test the model itself and the hypotheses that can be derived from it in the real world, and to take a step in the direction of the application of this knowledge in practice.
3) By playing the game the stakeholders become familiar with the underlying formal model, and can contribute to the improvement of the model with their feedback.
4) In the game the content-based research questions (see research question 2) concerning the relationship between land use and mobility can be demonstrated to stakeholders in practice. The results of this are not yet measurable at this stage.
5) The game makes the model of reality playable. In this way possibilities can be freely explored without this having direct consequences in the real world.

XI. Acknowledgements

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