# Chapter 3
# Stochastic System Dynamics Integrative Model:
## An Integrated Modeling Framework Spanning Policy Domains

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## ABSTRACT

*Although it is widely recognized that urban planning has a large implication on the provision of utilities, services and other urban infrastructures, it is usually undertaken in isolation. Increasingly over the last 15 years, various types of integrated models have been developed to support policy making in addressing specific problems related to the changing land-use and land-cover pattern and their effect on the land system. However, the deepening of the understanding of the implications of these changes on the land and social system, the increasing awareness of their strong interconnections with design and provision of large infrastructures (transportation, water and energy), and the fragmentation of the regulatory bodies and stakeholders, all compound the matter and call for integrative approaches and tools that can reconcile large process specific information and provide practical support for participated decision making. This chapter provides an extensive review of the latest work in the field and presents Stochastic System Dynamics Integrative Model (SSDIM), a modeling framework that improves upon the existing ones on some important respects. By modeling the interconnections between land use change, waste water infrastructures (drainage and treatment) and water quality in receiving water bodies through a chain of physically-based simulation models, it provides high level integration across important domains and detailed information across different physical and temporal scales to adequately support impact*

DOI: 10.4018/978-1-60960-156-0.ch003

*assessment of urban plans through the analysis of various influential factors. These include, but are not limited to, alternative planning policies at a local or regional level (for example, urban growth patterns), location and extent of protected areas, different demographic scenarios, refined characteristics of new developments, (for instance, maximum housing densities), alternative design and expansion options of the sewer network; provision of added treatment facilities or new treatment technologies. Examples of applications are presented through two case studies. The SSDIM framework is an effort to provide developers, regulators and water companies a common test bed to assess the impact of their decisions on the performance of existing assets and quality of water bodies, and devise coordinated plans.*

## INTRODUCTION

Although, traditionally, modeling frameworks have been developed within separate groupings of scientific domains, it is nowadays increasingly acknowledged that effective land-use planning cannot address the analysis of physical and human processes in isolation, but must rather focus on their interconnections and treat the land system in a holistic approach.

Lately, wastewater infrastructure planning and management (WIPM) is undergoing significant rethinking; sewer performance, asset maintenance, flooding due to sewer overflow and the costs associated with provision of acceptable wastewater infrastructure services are beginning to play an important role when proposed housing developments are being considered (WaterUK, 2005). The problems associated with deterioration of wastewater infrastructure and the consequences of inadequate maintenance plans are far from obvious; the occurrences of water pollution events are normally good indicators of sewer failures but the price to pay may be too high. Hence, there is a growing advocate that WIPM should be incorporated into land use plans. There is a strong case for sewerage service providers to demonstrate that their WIPM practices can deliver robust performance that meet regulatory requirements and that investment are sustainable as well as economically, socially and environmentally justifiable. There are still gaps in understanding the interrelationship of physical and economic behavior of the wastewater infrastructure, how to model the infrastructure, and the impact of different management strategies (Wirahadikusumah *et al*, 2001). Even less well understood is the relationship between proposed land development and risk of water pollution events such as flooding caused by wastewater infrastructure failure.

Air pollution modeling has developed considerably since the 1985 Helsinki Protocol (to reduce Sulfur emissions) and the 1988 Sofia Protocol (Nitrogen). However, in order to meet current policy objectives for air pollution it has become necessary to address "non-technical measures" for pollution abatement in addition to the technological measures already captured by Integrated Assessment Models. Such measures tend to provoke behavioral responses from individuals and society (ASTA, 2005; AQEG, 2005) and a challenge for quantitative integrated assessment modeling is to capture these qualitative socio-cultural dynamics in a way that informs the formulation of abatement policies designed to promote change through behavioral responses.

In this chapter, we describe a modeling framework that pushes further the cross-boundary integration between these land system domains. Through a dynamic integration of a land-use, a road-network and an air pollution model, this framework helps in investigating the combined long-term effects of land-use change, housing development, behavioral characteristics of populations and infrastructure design on roadside (traffic) emissions, and the resultant aerosol concentrations and Nitrogen deposition, and on sewer flooding and waste water pollution.