Strategic Decision-Making in Asset Management:

An Approach to Study Long-Term Strategic Decisions in Water Cycle Infrastructures

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Preface and Acknowledgements

My studies at the Engineering and Policy Analysis MSc at TU Delft come to an end with this thesis. These two years provided me truly unexpected experiences and challenges. I learned more about myself, the complexity of the world, but also how much we can do to make it better. It has been a wonderful time that has given me the opportunity to meet diverse, interesting and smart people and making good friends. These new friends, as well as older friends and family members, have supported me enthusiastically, provided me constructive criticisms and shared other forms of attentions in this process.

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Abstract

Climate change, population growth and increasing consumption patterns of water and increasing urbanisation are challenges and future uncertainties that place stress upon urban water infrastructures. These urban challenges, along with the complexities of asset-intensive systems and socio-economic structures, make the development of efficient long-term strategies for the asset management of urban water cycle systems (WCS) problematic. Vitens - the largest drinking water company in the Netherlands - has considered changing their risk based asset management approach from input oriented short term, to an outcome oriented long-term approach in line with the institutional environment, which could lead to the development of efficient long-term strategies that would help cope with the complex characteristics of drinking water systems and uncertainties of the future. However, there are related complexities to effectively study the strategic decision-making process for asset management.

This thesis aimed to develop a methodological framework that links the complexities of studying long-term strategic decision-making processes for asset management at water companies. The case study research shows that the strategic decision-making process of asset management can be studied by applying an integrated and systematic methodological framework based using the systems diagram method with a different approach. The approach manages three articulated complexities to study the strategic decision-making process: 1) the contentious concept of the asset management process, as it varies within industries, strategic asset management maturity and institutional arrangements; 2) the complex functions of the assets in Water Cycle Systems, and the norms governing them, that are hard to define and quantify; and 3) the difficulties in characterising the interrelations between the internal and external context that constitute the decision-making process. As a result, knowledge relevant to Vitens' needs was gained in terms of: 1) the decision-making process to develop long-term strategies and strategic objectives; 2) the alignment within in the levels of the asset management process; and, 3) the integration of society needs, institutional arrangements, the environment and the business functions in the decision-making process.

Executive Summary

Urban Water infrastructures are essential for a functioning society and they depend upon their infrastructure assets in order to deliver and guarantee the water supply. Stress in the water infrastructure is expected to continue to increase due to: 1) the complexities in maintaining the capability of long-lived assets; 2) demanding requirements of organisations, society and institutions; and, 3) the impact of future challenges by internal and external factors (such as asset deterioration, climate change, population growth, and increased consumption of water and urbanisation).

A central element to confront these challenges is the management of the asset-based infrastructure to sustain the functionality of the water supply. Infrastructure Asset Management is a systematic approach (or process) that involves policies, strategies, plans and day-to-day activities that aim to bring the best value to assets in all lifecycle phases. Within the discipline, Infrastructure Asset Management involves a strategic decision-making process with a long-term view of the infrastructure performance, risk and cost focus in efficiency to maximise the value of capital investment as well as operations and maintenance expenditure.

Vitens - the largest drinking water company in the Netherlands - has identified a need to enhance their strategic asset management practices to cope with the complex characteristics of asset-intensive water supply systems. Vitens considers that, changing their risk-based asset management approach from short-term input oriented to an aligned long-term outcome oriented could lead to an infrastructure that couples the technical and external challenges to efficiently and effectively deliver the best value of the asset, and a high quality and reliable water supply. To investigate the feasibility and consequences of these changes, Vitens wants with this research to learn from other water companies – and other public infrastructure industries - working in other institutional environments.

Gaps in the current research of Strategic Decision-Making for Asset Management

Vitens' objective to learn from other companies is contested by complexities that are involved with the urban water infrastructure, asset management and decision-making process. First, urban water infrastructures are water cycle systems defined as the technical (drinking water and waste water) system and the environmental and physical systems directly related to the actors involved as part of the system. Second, there is a defining contentious state of what constitutes asset management for a water organisation. Third, the decision-making process that governs the asset management process in water companies is influenced by internal elements of the organisation (business objectives, asset capacity, resources, policies) and embedded elements (culture, institutional arrangements, asset conditions).

The research objectives of this thesis are to deepen the understanding of the long-term strategic decision-making process of asset management in a UK water company (Thames Water, the London's Water Company), and their interrelation with the socio-technical context, to contribute Vitens objective of learning from other water companies. Thames Water fits Vitens' intent due to their shift to an outcome-based asset management process. To reach the research objectives, this case study research developed a methodological framework that coupled with the complexities of studying the long-term strategic decision-making process for asset management at water companies. The framework was developed by applying principles of asset management and policy analysis, that resulted in a new approach for using the system diagram method. The capability of the methodological framework to study the strategic decision-making process is tested on the strategic asset management process at Thames Water.

Methodological Framework

The development of the methodological framework was conducted by conceptualising the decision-making process as a system and its interrelation with the socio-technical context. This conceptualisation

process led to a methodological framework that is based on a two-step approach. First, an evaluative framework was used to conceptualise the strategic asset management process which is based on principles of asset management and the standard Publicly Available Specification- *Optimal management of physical assets* (PAS-55). Along with the evaluative framework, five thematic factors were defined as the influential factors of the decision-making process. These influential factors Risk Management, Business Objectives, Performance Requirements, Stakeholder Requirement and Regulations – were used as indicators on how the asset management process is affected by internal decisions and external factors.

Second, the review of methodologies related to policy analysis led to conceptualise the decision-making process as a system that interrelates with the strategic asset management process and the socio-technical context. The result was an analytical framework based in applying the system diagram to the decision-making process to characterise the linking mechanisms and influences between the strategic asset management process, influential factors and socio-technical context. The systems diagram developed provides an analytical framework that conceptualises the system boundaries on the decision-making process and the interrelation with the socio-technical context, strategies and objectives and steering factors. In addition Adaptive Policymaking (Walker, 2001) is used as an analytical perspective to identify what the threats and opportunities of the effectiveness for the strategic decision-making system which operates in an external context and is susceptible to changes and uncertainties.

Application of the Methodological Framework

The strategic asset management structure at Thames Water is examined by applying the Evaluative Asset Management Framework. The Asset Management Evaluative framework reached the objective of understanding the internal process of asset management at Thames Water. Based on the description of this evaluative process, the five influential factors were indirectly identified (Performance Requirements, Business Objectives, Stakeholder Requirements, Risk Management and Regulations)

as part of the asset management process.

Then, the analytical framework was applied to analyse the strategic asset management process and to identify the interrelations and influences of the decision-making process based on the influential factors which characterise the decision-making process. The 5 elements proposed as the internal influential elements on the system diagram were identified through the evaluation of the strategic asset management process for long-term strategies. In the case of Thames Water, the structure is the product of the Common Framework established by Ofwat on all UK water companies. This framework is based on standardised asset management guidelines such as PAS-55 and the United Kingdom Water Industry Research (UKWIR). Therefore a structure that incorporates those elements was expected, if the influences of Ofwat were strong on the asset management procedure of Thames Water.

This led to a strategic asset management process that considers the impact of Thames Water Infrastructure on the customers, environment and shareholders, now and in the future. Therefore, the strategic asset management framework contains the criteria for the outcome-based structure, where aligned long-term strategies are linked to the business objectives by sustaining the long-term value of the infrastructure assets to the stakeholders. This implies that the decision-making process links the knowledge from the assets, business objectives, regulators and stakeholders to influence the asset management process.

The final stage of the study analyses the decision-making process by defining the interrelations and influences of Thames Water's socio-technical context. The socio-technical context was evaluated based on the elements of Physical Characteristics, Cultural Embeddedness, Institutional Arrangement and Governance Characteristics. The institutional arrangement in the UK shows that they have a large influence on establishing interrelations between the socio-technical context and the decision-making process. The Water Services Regulatory Authority (Ofwat) is in charge of designing the involvement with customers and integrating the requirements of other regulators. The mechanisms used, such as the regulatory report, risk management guidelines and engagement with customers, are responsible for making

the long-term strategies in line with the needs of society. Regulators have determined that the outcomes for the water industry are based on customer and societal needs for the UK and have pushed the asset management process to be an outcome-based approach. This shows that there is a strong interrelation between the socio-technical context and the strategic decision-making process.

Conclusions on the Methodological Framework

The developed methodological framework provides knowledge relevant to Vitens' needs in terms of: 1) the decision-making process to develop long-term strategies and strategic objectives; 2) the alignment within the levels of the asset management process: and, 3) the integration of society needs, institutional arrangements, the environment and the business functions in the decision-making process. Selecting a suitable methodological framework to study the strategic asset management process is dependent on the context and nature of the problems, the content and objectives of the organisation and the decision-making process and stakeholder involvement. This thesis finds that the strategic decision-making process of asset management can be studied by applying an integrated and systematic methodological framework based on the systems diagram method when the decision-making process is conceptualised as a system.

The proposed methodological framework combines asset management principles and policy analysis methodologies. With the developed framework, three articulated complexities to study the decision-making process were manage: 1) the contentious concept of the asset management process where it varies within industries, strategic asset management maturity and institutional arrangements; 2) the functions of the assets in WCS are complex and norms governing are difficult to define and quantify; and, 3) the difficulty to characterise the interrelation between the internal and external context that constitutes the decision-making process. The developed framework provides more transparency for the investment choices that are behind the WCS and an approach that considers the effects of exogenous factors. A more transparent and structured asset management system represents good business practice by justifying decisions for expenditure, and also demonstrates the delivery of

efficient investment over the long-term. This transparent and structured asset management system should benefit stakeholders, shareholders, customers and the environment at large.

Steering Factors and Recommendations

The application of the systems diagram method led to the identification of steering factors on the decision-making process of Thames Water. The definition of the steering factors is based on the actions of the strategic team that mitigate or manage the complexities identified in the long-term strategic decision-making process. Based on the analysis of the steering factors and research results, nine recommendations are proposed that focus on the strategic decision-making process for risk-based asset management approach that is long-term outcome oriented. The table below provides a summary of the complexities and recommendations.

Table 0.1: Summary of Complexities on the Strategic Decision-Making Process and Recommendations

Complexities on the Strategic Decision-Making Process	Strategic Asset Management Segment	Recommendation
Ranges of context specific factors that influence criticality of the assets for achieving long-term level of service	Risk Identification	*Apply an integrated long-term risk-identification framework*
Imperfect knowledge of the conditions/capability of the assets to identify risk, criticality and impact		*Integrate information management*
High-level objectives that are difficult to operationalize at the service and asset level and link to activities	Asset Management Framework	*Develop an outcome performance measure matrix*
Alignment between infrastructure objectives, situation and intervention and timeframe		*Design a specific procedure to develop service long-term strategies*
Uncertainties created by climate change, water demand and infrastructure capability		*Develop a monitoring system specific for the long-term strategies*
Management of multiple actors with different interests		*Integrate beneficiaries and other stakeholders in the decision rules of the strategic asset management process*
Trade-offs between: cost, performance and risk/ preventive; investment versus reactive investment; flexible versus robust	Optimisation of Strategies	*Define a structured approach for the delivery of strategies based on the uncertainties of the future*

Optimise strategies based on multiple criteria and interests and whole lifecycle of assets		*Develop a long-term strategic framework for the optimisation the long-term strategies*
Justify investment decisions in the present for the benefit of future needs		*Stress the decision-making process to develop organisational long-term strategies and integrate other authorities responsible of the WCS*

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Chapter 1

Introduction

1 Introduction

1.1 Research Background

Vitens is a public water utility company that has identified a need to enhance their long-term strategies to cope with complex characteristics of asset-intensive water supply systems and future uncertainties. The company is the largest drinking water company in the Netherlands. The company owns and operates -as a monopoly- the production of drinking water and the distribution to consumers and businesses in several Dutch provinces and municipalities. Their most important water resource is groundwater. Vitens' company objective is to increase the efficiency and effectiveness of their drinking water infrastructure system to provide a sustainable system with the highest quality of drinking water at the lowest price, which will increase the value of water for the society and reduce its social costs. The main challenges to reaching their objective arise from the complexity of these asset-intensive systems and the influence of external factors such as water scarcity, climate change, institutional changes and economics.

These challenges to water infrastructure can be framed in three main areas: maintaining capability of the water infrastructure, the requirements of the infrastructure by the organisation, society and institutions, and the impact of change by internal and external factors (such as asset deterioration, climate change, population, etc.) (See also Heather et al., 2007).

First, the water infrastructure capability is defined as the asset characteristics (asset condition, capacity, and performance) required to achieve service level targets (Heck, 2008). The capability of the water infrastructure is then underpinned by an intensive amount of assets with an independent physical and functional identity and

age (e.g., pump, motor, sedimentation tank, main) (USEPA, 2008). These assets are part of structured networks of interdependent entities that enable the service delivery capability of physical assets that are inherent to the water infrastructure (Stapelberg, 2011). Size of the infrastructure, interdependence and large capital investment (with long-term return and economy of scale) require long lead times, significant planning and the involvement of many stakeholders (Too, 2010; Mardiasmo et al., 2008; Aikman et al., 2008; Neumann et al., 2004). As a result, the maintenance, renovation and reconstruction of the assets are a constant and challenging task for water companies such as Vitens to achieve and sustain the capability and efficiency now and in the future (Marlow et al., 2010).

Second, across the world the performance of infrastructure networks (e.g. transportation, water supply, and sewerage systems) strongly affects the economic viability and social welfare of nations (Schraven et al., 2011). In the case of water infrastructures this interdependency with society has begun to be conceptualised with a holistic approach that is not limited to specific drinking-water or wastewater responsibilities, but with interconnection between the infrastructure and society. In the case of Vitens, the company recognises that their actions are part of a Water Cycle System (WCS), which is critical and imperative for the proper functioning of society.

WCS[1] is the conceptualisation of operational urban water infrastructures as an integration and interoperation of the individual function of the water value chain by simulating the natural water cycle. The system is defined as the structure related to the production of drinking water, the water use, and the collection, purification and

[1] Activities of the management of WCS under the Integrated Urban Water Management (IUWM) include the following:

- Improve water supply and consumption efficiency
- Upgrade drinking water quality and wastewater treatment
- Increase economic efficiency of services to sustain operations and investments for water, wastewater, and stormwater management
- Utilise alternative water sources, including rainwater, and reclaimed and treated water
- Engage communities to reflect their needs and knowledge for water management
- Establish and implement policies and strategies to facilitate the above activities
- Support capacity development of personnel and institutions that are engaged in IUWM

discharge of the wastewater (Figure 1.1). As a result, WCS are socio-technical systems that require social and technical elements engaged in an environment to reach a shared goal (Nikolic, 2009). This intertwined relationship creates a socio-technical context where the effectiveness of the system requires the joint optimisation of technological and social variables (Bauer and Herder, 2009). This results in a multi-actor setting where requirements, objectives, strategies and mutual relations change constantly. This continual dynamic causes strategic and institutional uncertainties (Enserink et al., 2010).

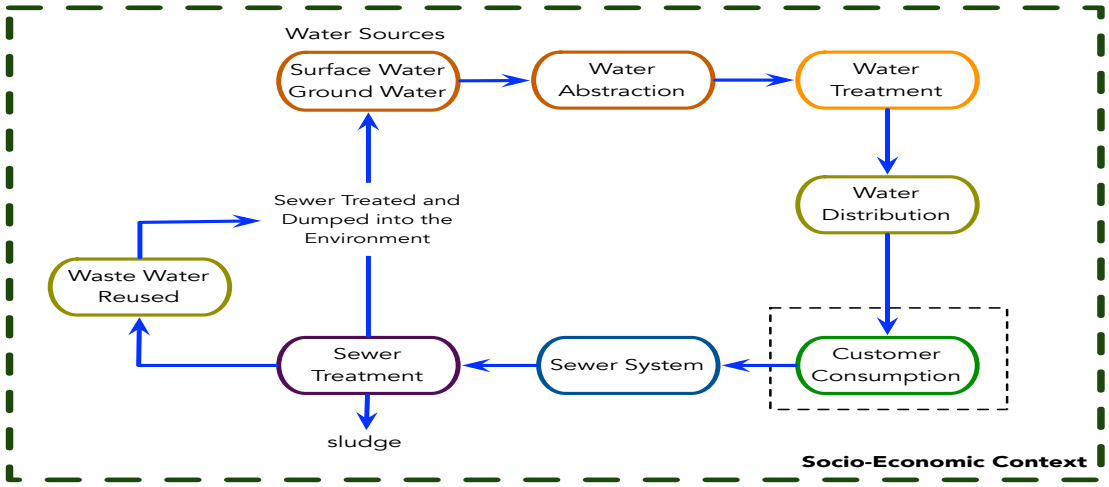


Figure 1.1:Simplified Overview of Water Cycle System

Third, the WCS is affected by internal and contextual changes of which the impact is uncertain but it is expected to affect the resource availability (supply) and augment the water use (demand), increasing the stress on urban water infrastructure. Some of these factors are: a limited budget, deterioration of the assets base, population growth, climate change, and increasing allocations for water conservation (Leeuwen et al., 2011; Heather et al., 2007). As a result, these future scenarios intensify the risk on infrastructure and long-lived assets. These increase the challenge to achieve efficiency (reach service targets) and effectiveness (stakeholder requirements) in these complex asset-intensive systems.

Infrastructure asset management has emerged as a discipline in the sector of

utility infrastructure, which promises to cope with these described challenges and achieve more value for the infrastructure with fewer resources (Moon et al., 2009; Velde et al., 2012). Within the discipline, the strategic asset management approach has gained recognition across the infrastructure of asset-intensive utilities. This approach brings a long-term view of the infrastructure performance, risk and cost focus in efficiency to maximise the value of capital investment as well as operations and maintenance expenditures (USEPA, 2008; Too and Too, 2010). Notwithstanding the widespread interest in strategic asset management, scant attention has been paid to the governance of the process and the challenges that the asset managers face when striving for improved effectiveness of their decision making (Schraven et al., 2011).

Vitens recognises the need to change the existing strategic asset management approach of their physical assets, to improve their working methods and investment decisions, and to guarantee the water supply despite future challenges and uncertainties. Their intent is to shift their risk-based asset management approach from short-term input oriented, to long-term outcome oriented to align their strategic decision-making process with societal and institutional arrangements and contextual scenarios. Vitens considers, as do other authors, that the efficiency and effectiveness of asset management is to be reached with the alignment of policy goals, infrastructure objectives, performance measures and intervention selection criteria (Iniestra and Gutierres, 2009; Malano et al., 1999; Neumann and Markow, 2004; Schraven et al., 2011). The objective of efficient and effective asset management practices is to focus and increase the value of the infrastructure assets to society.

This strategic asset management approach would incorporate long-term and asset system level strategies at an outcome level that considers the effects of the external context. By adapting this approach, determination of criticality and prioritisation on investment decisions to improve and enhance the water infrastructure is based on an internal need to maintain the operation of the infrastructure, not only from the company perspective, but also from a financial, social and environmental perspective. As a result, the decision-making process of Vitens would shift to a

holistic approach that extends the decision criteria and creates a more complex system that could be difficult to manage and optimise Then, emphasis in understanding the decision-making process could provide relevant information to manage complexity and facilitate the development of long-term strategies that help the organisation cope with the characteristics of WCS and the uncertainties of the future.

Decisions that govern over the strategic asset management process are defined in this thesis as the strategic decision-making process. Strategic decision–making in organisations is formed by a multiplicity of factors such as specific characteristics of the strategic process, management, contextual factors, and the internal context of the organisation (Papadakis et al., 1998). These make strategic decision-making unique on WCS and interdependent of multiple internally and externally factors.

Vitens' aims through this research to gain knowledge on steering factors, asset management structures and long-term strategies that can help them improve the efficiency and effectiveness of the decision-making process by managing the complexity of the asset management system. Exploring and analysing how long-term strategic decision-making for asset management of water companies – and other public infrastructure industries – working in different institutional environments can provide insights that could be relevant to Vitens' intent to change their asset management process.

The strategic asset management process of the United Kingdom's (UK) water companies, specifically Thames Water Utilities Ltd (London), is examined in this research. After the privatisation of the water utilities in the UK, regulators have driven the implementation of an asset management framework to regulate their investments on their assets, efficiency and effectiveness. As result, the water companies have implemented a risk-based framework that enable companies to demonstrate the need for future investment in terms of customer serviceability, quality and environmental enhancement and supply/demand balance (Heather et al., 2006). Thames Water forms an adequate case study due to its implementation of risk-based asset

management that assimilates an outcome-based approach.

1.2 Research Objectives

The research objectives of this study are to deepen the understanding of the decision-making process of asset management in Thames Water and to support Vitens' interest with their feasibility study of engaging with an outcome-based approach (Figure 1.2). For this purpose, the thesis examines and analyses the strategic asset management process in Thames Water, and the accompanying internal interrelations within the asset management levels and external interrelations with the socio-technical context. Subsequently, knowledge is obtained of outcome-based strategic asset management in term of: 1) the decision-making process to develop long-term strategies and strategic objectives; 2) the alignment within in the levels of the asset management process, and; 3) integration of the user needs, institutional arrangements, environment and the business functions in the decision-making process.

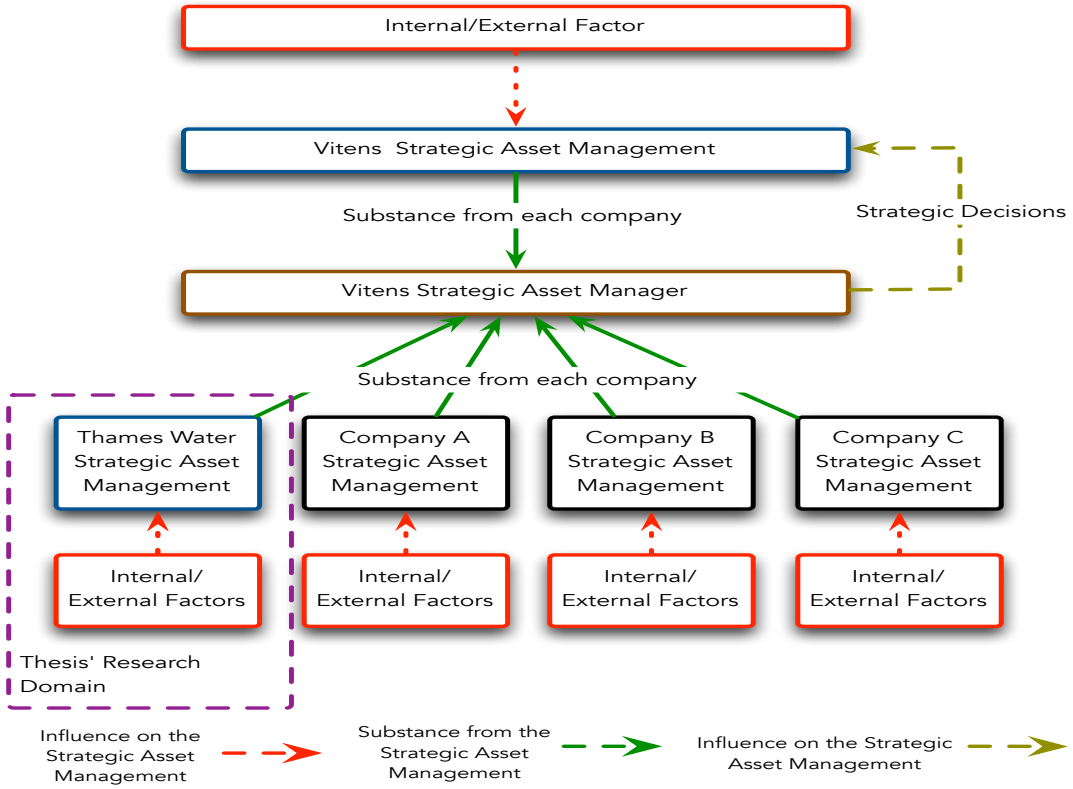


Figure 1.2: Thesis' research domain in relation to Vitens' overall research domain

1.3 Problem Statement and Research Questions

The main challenge in analysing the strategic asset management of WCS is to conceptualise the decision-making process that governs the process and the interrelation with external elements. The challenge results from the complexities caused by technical, economic, environmental, political and social factors that are described in the above subsections as part of incorporating an outcome-based approach asset management process (Badurdeen et al., 2011; Godau, 1999; Schraven, et al., 2011). These complexities can be summarised in three main areas: 1) the functions of the assets in WCS are complex combination of "nodes and link" which are complementary to each other, hence norms governing them are hard to define and

quantify; 2) the contentious concept of the asset management process where it varies within industries, strategic asset management maturity and institutional arrangements, and; 3) the difficulty in characterising the interrelation between the internal and external context that constitute the decision-making process.

In order to confront the challenge to study a long-term strategic decision-making process on asset management, a methodological framework that provides a systematic structure was needed. This led to the main research question:

> What methodological framework could be used to study the long-term strategic decision-making process for investments in water infrastructure assets within companies and in relation to the socio-technical contexts?

In answering the main research question and addressing the challenges associated to the study of the strategic decision-making process a first sub research question was necessary to examine and analyse the decision-making process involved in the development of long-term strategies. The determined approach considered that decision-making process to be: 1) characteristic of each organisation, 2) influenced by internal elements of the organisation (such as business objectives, asset capacity, resources, internal policies, etc.) and 3) with embedded elements (such as culture, institutional arrangements, asset conditions, etc.). The following sub-question was formulated:

> a) How can a long-term strategic decision-making process for investment in assets be examined and analysed?

After sub-question (a) was addressed, the next step in the research was related to applying the methodological framework on the case study in order to generate the knowledge intended by studying the decision-making process in Thames Water. The first step was to apply the framework to examine Thames Water's asset management

process and answer sub-research question b:

b) What are the asset management long-term strategies and objectives of Thames Water for investment on water supply physical assets?

Asset management strategies, developed as part of risk-based asset management with an outcome approach are expected to balance between factors such as assets, the organisation and stakeholders. To balance these interests, the decision-making process considers different elements, both in the present and in the future. Elements in the present can be contradictory making them difficult to balance within multiple criteria (asset capability, operational and capital costs, willingness to pay, regulations). In addition, the impact of future scenarios on those elements needs to be considered to define long-term strategies that will achieve future outcomes. As a result of this complexity, it is important to analyse the decision-making process by defining the influences on a risk-based outcome-led approach to develop the long-term strategies. Keeping this in mind, it was necessary to embody the decision-making process on a risk-based outcome approach. The second step in the research aimed to apply the methodological framework with the intent to answer the following two sub-research questions:

c) What is the asset management process of a company that applies a risk-based outcome approach?

d) What are the influences on the decision-making process on accomplishing aligned outcome-based long-term strategies?

The next step was to apply the methodological framework to analyse the impact of the socio-technical context on the decision-making process and complete the knowledge needed in order to finally answer the main research question. The analysis was conducted by understanding the influences of these external elements

and was led by the two final sub research questions:

e) What are the interrelations between the decision-making process and the socio-technical context?

f) What are the influences of the external context on the outcome based asset management decisions at Thames Water's Strategies and Asset Management Policies?

1.4 Approach and Outline of the Thesis

This subsection describes the high level research approach and method of analysis used in this thesis to address all the research questions (Subsection 1.4.1). A more detailed description of the application of the methods is provided in subsections 1.4.2.1 to 1.4.2.3. The outline of the thesis is provided at the end with the intent to provide a guide to the reader to follow and understand the research approach.

1.4.1 Research Approach

The overall research strategy was to study the asset management process utilising policy analysis methodologies. Policy analysis methodologies are practically used with the objective to study the content of policy, the processes of policy and the effects of policy in their political and societal context (Enserink et al., 2010; De Haan and De Heer, 2012). The methodologies manage similar complexities to conceptualise decision-making, problem solving and implementation processes in wide-ranging disciplines. The logic behind this research strategy was that infrastructure asset management processes share similar complexities to be studied as policy-making, -process and -implementation. Justification is expanded in Chapter 2 and a comparison of the complexities are summarised in the below table.

Table 1.1: Comparing Complexities to Study between Policy and Strategic Asset Management

Policy-Making Process	Strategic Asset Management Process
Problems definition are unclear and contested with not defined solutions	Functions of the assets in WCS are complex and norms governing are hard to define and quantify
Multi-actor setting with different requirements and view on problems and change overtime	Multiple interest and influences by users, government, general public and executives/investors
Research area are unique with limited or unclear information to conceptualise the settings and systems	Contentious concept of the asset management process where it varies within industries, strategic asset management maturity and institutional arrangements
Uncertainties, multiple-interrelations and dynamics systems	Difficulty to characterised the interrelation between the internal and external context that constitute the decision-making process

The research approach in four steps:

1. Development of a theoretical framework
2. Collection of data related to Thames Water based on the methodological framework
3. Analysis of the data by applying the theoretical framework
4. Concluding and reflecting on the analysis and theoretical framework

The research approach can be synthesised in three stages. Each stage illustrates how the study is constructed and the diversity in the methods of data collection and analysis adopted. The three stages include Conceptual Analysis and Methodology, Case Study Examination and Analysis, and Synthesis and Reflection (Table 1.2). In each of these stages different activities are undertaken that fit with the strategy to analyse the decision-making process for Thames Water and generate relevant knowledge to the empirical study.

Table 1.2: Stages in research construction and methods of data collection and analysis adopted

Stage 1	Stage 2	Stage 3
Conceptual Analysis	**Examination and Analysis**	**Synthesis and Reflection**
Asset Management Standards	Strategic Asset Management Process	Conclusion
Policy Analysis Methodologies		
Methodological Framework	Evaluative Framework: Internal Context Strategic Asset Management Process	
	Analytical Framework: Internal Context Decision Making Process – Internal Influential Factors on Asset Management Process Decision Making Process – Internal Influential Factors on the Long-term Strategies and Objectives	Analytical Framework-Steering Factors and Recommendations
	Analytical Framework: External Context Socio-technical Context- External Influential Factor on the Decision-Making Process	Reflection

In the first stage, the Conceptual Analysis, the concept of strategic asset management is explored with the intent to conceptualise the decision-making process and its interrelation with the internal and external context (Chapter 2). The exploration is based on information from a theoretical, literature-based, exploration of: 1) articles and standardised publications of asset management; 2) theories of the socio-technical context and public policy, and; 3) methodologies of policy analysis. The exploration results in the development of a methodological framework based on system diagram methods that conceptualise the decision-making process of long-term strategies as a system. This framework is a two-steps approach that combines an evaluative framework and an analytical framework. With this methodological framework, the complexities identified to study the decision-making process are intended to be managed.

The second stage is the application of the methodological framework in the

Case Study Research to conduct the Examination and Analysis. Application of the methodological framework has two main objectives. First, applying the framework allows for an in-depth analysis of the strategic asset management process at Thames Water. The framework systemizes and structures knowledge that could be useful to Vitens to confront their challenges related to asset management. Second, the framework approach is based on using the system diagram method in a different way, where in practise it is used as a decision-making tool as part of the decision-making process of the policy-analysts and decision-makers. Then, its capacity to manage complexities in analysing the long-term strategic decision-making on asset management for WCS is tested in this stage of the research.

This second stage is divided in three chapters (Chapters 3-5) to: 1) describe the components of asset management in Thames Water; 2) analyse the decision-making process that governs the asset management process, and; 3) analyse the interrelation of the socio-technical context with the decision-making process. In Chapter 3, the case study is examined by using the evaluative framework to define the components of the asset management process, and long-term strategies and objectives. The evaluative framework is primarily filled with the analysis obtained from interviews and public documents of Thames Water. This analysis includes thematic coding analysis and stakeholder analysis.

In Chapter 4, the analytical framework is applied to the strategic asset management process for a more in-depth analysis that enables this research to identify the internal mechanisms that are part of the strategic asset management process. The analysis is divided in two main parts: the analysis of the process and the analysis of the long-term strategies. In both parts, the focus of the analysis is the influence of the decision-making process. For the analytical stage, information is based on the results from the evaluative framework and explorative open interviews conducted at Thames Waters in relation to the asset management process (See also Sec. 1.4.2.1). Methods used for the analysis are based on thematic coding and soft methodologies such as causal diagrams and goal tree analysis. The latter methods were used for the

identification of connections and mechanisms of the process and components of asset management.

The interrelation and influence of the socio-technical context on the decision-making process is described by re-applying the analytical framework (Chapter 5). The analysis is conducted by first describing the socio-technical context, and second characterising the interrelation between the decision-making process and the external elements: Cultural Embeddedness, Physical Characteristics, Institutional Arrangements and Governance Characteristics. The interrelation and influences defined are based on a combination of analysis from the previous analysis, literature-based theories and research articles, and official documents related to the water environment in the UK. The analysis is based on organising the data using the defined external elements and explanatory schemes to reveal the concepts and relationships.

The final stage is the Synthesise and Reflection section, of which the main objective is to conclude on the knowledge obtained during the analysis and the challenges for the analysis of the strategic decision-making in asset management. This stage begins with the development of a final input-output-outcome model of Thames Water based on the information obtained during the analysis stage. Then, the concluding chapter answers the research questions (Chapter 6) and then synthesises the capability of the framework. The analytical framework is then applied to characterise actions that Thames Water applied to confront their challenge on the strategic asset management process (Chapter 7). Based on this analysis, recommendations are offered to Vitens for improvements on their asset management practises. Finally, a reflection on the methodology applied, the limitations of the research and future research is discussed in Chapter 8.

1.4.2 Description of Methods of Data Collection and Analysis

In this subsection the methods used for data collection and analysis are explained and justified in more detail. The research object was the long-term strategic decision-

making for asset management in Thames Water.

1.4.2.1 Interviews and Data Collection

The interview process comprised of 5 steps: 1) Design of interview questions on the basis of the Asset Management Evaluation framework and Context Variables; 2) Evaluation of the questions with Vitens; 3) Re-adjustment of the questions based on additional information and data obtained from reports, diagrams and presentations from Thames Water; 4) Conduct of interviews and adjustments based on the respondents' feedback and on the better understanding of the company structure; and, 5) Conduct of a presentation of the findings at Thames Water that included four of the participants interviewed. This last step was used as the validation of the interpretation of the system.

The intended outcome from the qualitative interviews was allowing for exploratory questions for in-depth understanding of ideas and concepts of the decision-making system following the methodological framework (Cohene and Easterbrook, 2005; Broom, 2005). Interviews were conducted utilising two approaches: semi-structured and open questions.

Interviews of a semi-structured nature were designed to collect information to fill the Asset Management Evaluative Framework, which is focused on concepts of asset management and decision-making. Typically, semi-structured questions are used to reflect on opinion and experience of the participant. In this research, the semi-structured questions were used with a different intent; information obtained was limited to factual context. However, semi-structured interviews were needed since the researcher did not have no previous knowledge of Thames Water's asset management structure, specific roles of the interviewed and governance . Open-ended questions allowed the researcher to follow relevant concepts and factors that resulted from the interview framework, and still provided the opportunity for identifying new ways of seeing and understanding the strategic asset management process. Without previous knowledge of the asset management system, using structured interviews would have

increased the possibility of missing critical information to this research. Questions used during the interviews are included in Appendix 10.8.

Non-structured interviews were used for a second round of interviews with key participants identified during the semi-structured interviews. The main intent was to explore the asset management process in more detail and capture the meaning of the process. These interviews were fully focused on factual data.

The interviews took approximately 30 minutes and pre-defined questions used for the interviews were pre-selected depending on the roles of the participants and their relation to the levels of the Evaluative Framework. These questions were forwarded in advance to the participants. In most of the cases, the questions did not provide a structure for the interview but were used as a guide for areas relevant to the research.

The main limitation encountered during the interviews was time; and confidentiality issues of the company to provide specific details related to the actual interrelation between the levels (executive level, asset management level, planning level, activity level, etc.), criteria of optimisation, and some topics due to the in-process change of procedures to an outcome-based approach (defined outcomes and performance indicators). As an outsider, there was no access to internal documents and policies to verify if some of the information provided was influenced by personal bias. Therefore, individual opinions or personal perspectives were not used without documented support.

1.4.2.2 Participants

The interviews were conducted primarily with members of the service directorate steering group; specifically, the strategic water planning section for the water business, and other direct areas such as maintenance strategies, optimisation and strategy, and regulation. The group is engaged in the strategic direction of the company by providing recommendations on where to invest, and they provide

solutions and strategies (short-term to long-term) from an assets perspective. Within this group, there is a strategic water planning section that is responsible for the development of strategies for the business plan and long-term plans related to the assets. The group covers the entire process of developing Asset Management Strategies, Objectives and Planning. The group is divided in Asset Strategies, Network Deterioration, Water Treatment Work, Asset Planning and Water Modelling.

A total of 11 people were interviewed, and the list with the reference numbers is provided in Appendix 9.8. Participants were of the strategic water asset planning section and included: the manager of the section, the strategic managers for water treatment and water distribution, the modelling manager, the ground water group manager and the asset planning manager. In addition to the personnel of the strategic water asset planning section, a participant from the regulation and strategic department and a participant from the optimization department were interviewed. Another participant interviewed was from outside of the company: the scientific director of a consultant company for strategic asset management in UK.

1.4.2.3 Desk research

Since Thames Water is a private company and not the sponsor of this research, limited internal documentation was provided for review. The desk research comprised of public documents from Thames Water, regulators and associated agencies; published articles in scientific journals; and, online research on topics related to the changes in regulations in the UK water industry. The core of the documents utilised from Thames Water was from the published statutory reports and from the economic regulator. The data from the desk research was used to underpin interview generics and develop the scientific intent of the research.

1.4.3 Data Analysis

The analysis process was based on data collected from the interviews and literature review. The process was based on three main rounds of codification and a final round

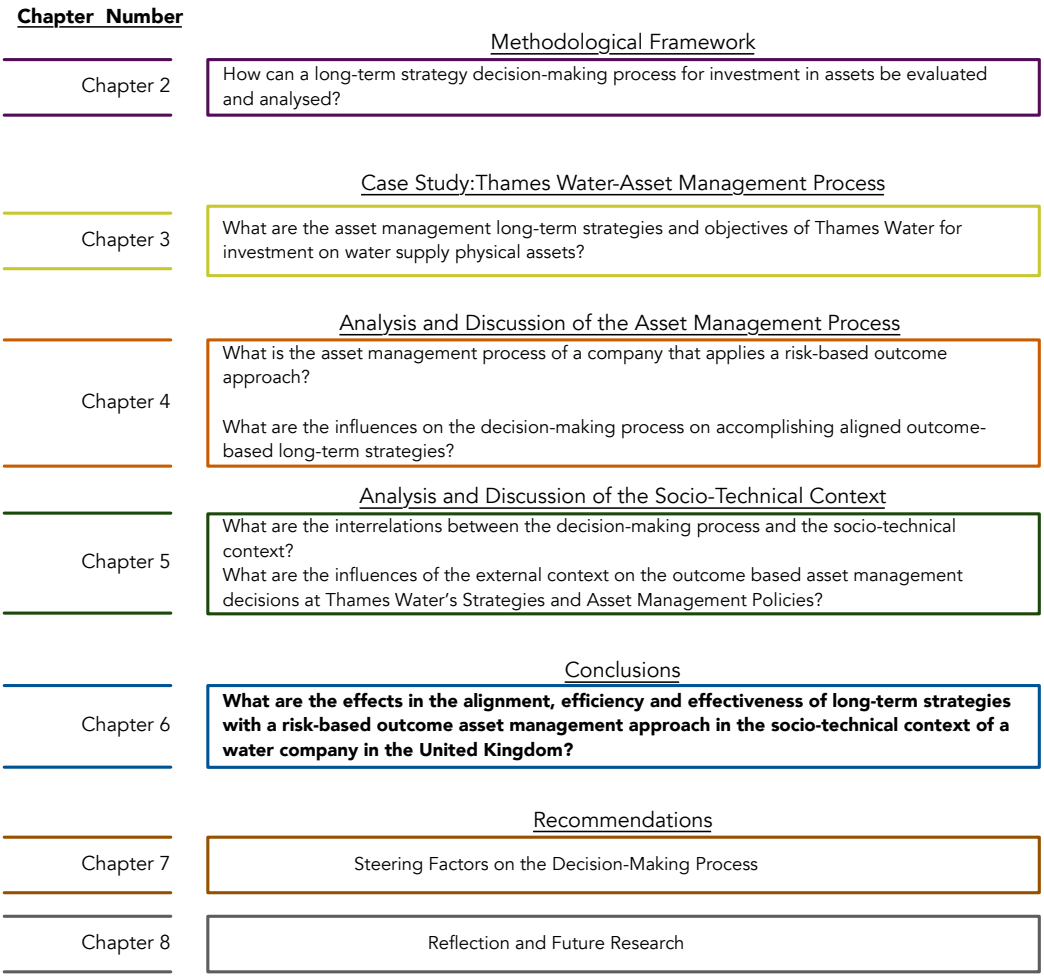
to define connections, mechanisms and relations.

All the interviews were transcribed and codified based on a thematic coding approach using manual framework techniques as described in Ryan and Bernard (2003) and Wang and Roulston (2007). In the first round of coding, the content was grouped based on the overall areas of this research: the evaluative framework, the system diagram and the external context. The second round was more specific, separating the content by the levels of the evaluative framework (Organizational Strategic Level, Asset Management Policy Level and Asset Policy Level). The final round of coding was based on the components of the system diagram (Business Objective, Risk Management, Performance Requirement, Regulation and Stakeholder Requirement). The codification was predominantly supported by the semi-structured interviews and literature review.

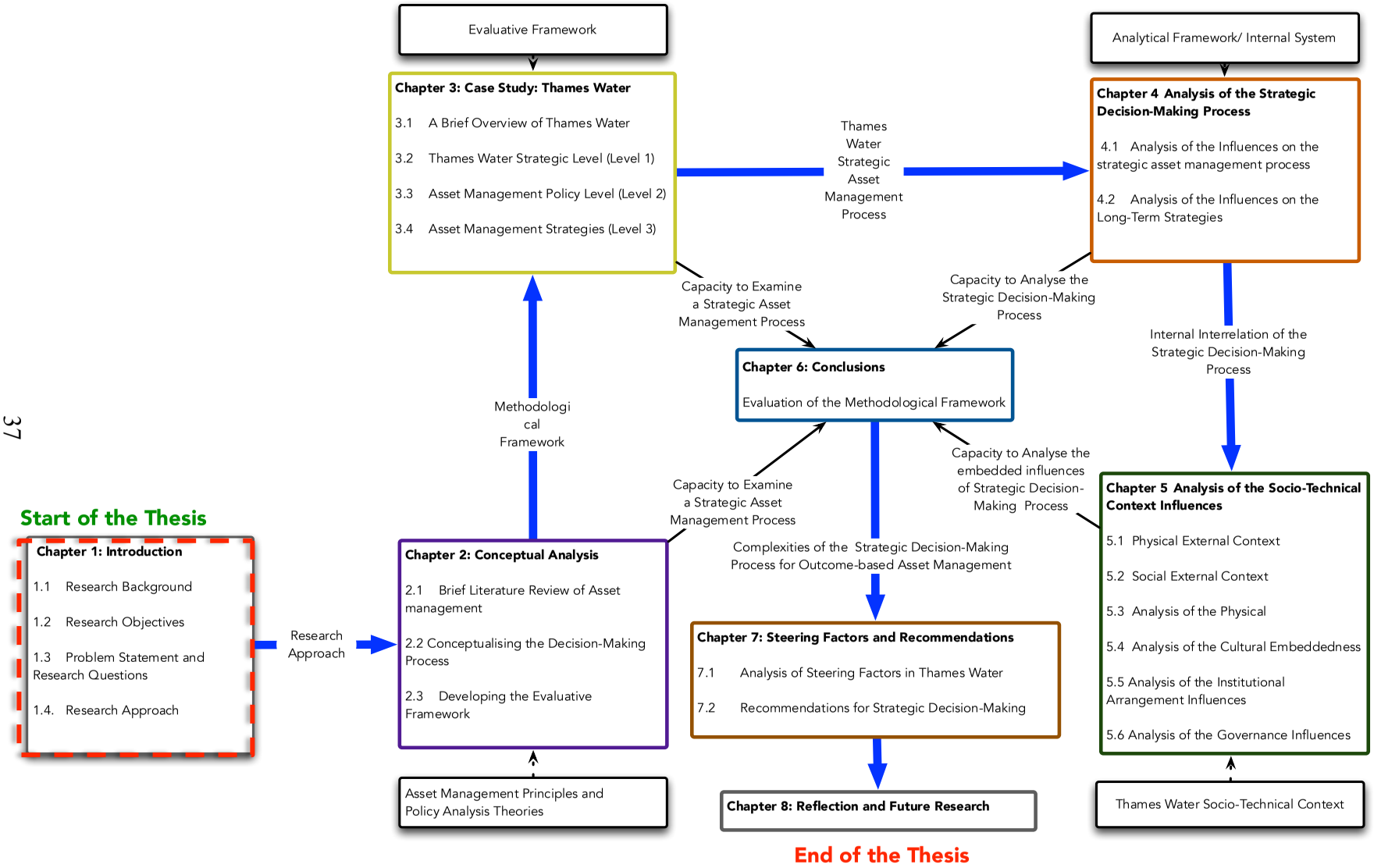
Defining the relations and interconnection for the analytical framework was conducted using analytical methods from soft system methodologies. The main method was the system diagram method combined with supplementary methods such as objectives hierarchy, means-ends analysis, causal diagramming, stakeholder analysis and input-output-outcome model (Bryson et al., 2002; Checkland, 2000; De Haan et al., 2012; Enserink et al., 2010). Relations and interconnections were based on non-structured interviews. The results from these analyses were the characterisation of the decision-making process system, the steering factors and the external context (Physical Structure, Cultural Embeddedness, Institutional Arrangement and Economic Characteristics).

1.4.4 Thesis Content Outline

Thesis findings are reported following the sub research questions order in the following chapters as outlined below. Conclusions, Recommendations and Reflections and Future Research chapters sum up this work.



This thesis consists of multiple concepts that are analysed in depth at each chapter and sub-chapter. These individual analyses could interrupt the understanding flow of the thesis and would increase the difficulty of the reader to follow the story line of the research. To reduce this difficulty a conceptual map to guide the reader through the research was developed. The conceptual map provides a visualisation of the research approach and can be found in the next figure.


Start of the Thesis
Chapter 1: Introduction
1.1 Research Background
1.2 Research Objectives
1.3 Problem Statement and Research Questions
1.4. Research Approach
Research Approach
Chapter 2: Conceptual Analysis
2.1 Brief Literature Review of Asset management
2.2 Conceptualising the Decision-Making Process
2.3 Developing the Evaluative Framework
Asset Management Principles and Policy Analysis Theories
Methodological Framework
Evaluative Framework
Chapter 3: Case Study: Thames Water
3.1 A Brief Overview of Thames Water
3.2 Thames Water Strategic Level (Level 1)
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3.4 Asset Management Strategies (Level 3)
Thames Water Strategic Asset Management Process
Analytical Framework/ Internal System
Chapter 4 Analysis of the Strategic Decision-Making Process
4.1 Analysis of the Influences on the strategic asset management process
4.2 Analysis of the Influences on the Long-Term Strategies
Capacity to Examine a Strategic Asset Management Process
Capacity to Analyse the Strategic Decision-Making Process
Internal Interrelation of the Strategic Decision-Making Process
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Capacity to Examine a Strategic Asset Management Process
Capacity to Analyse the embedded influences of Strategic Decision-Making Process
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Chapter 5 Analysis of the Socio-Technical Context Influences
5.1 Physical External Context
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5.3 Analysis of the Physical
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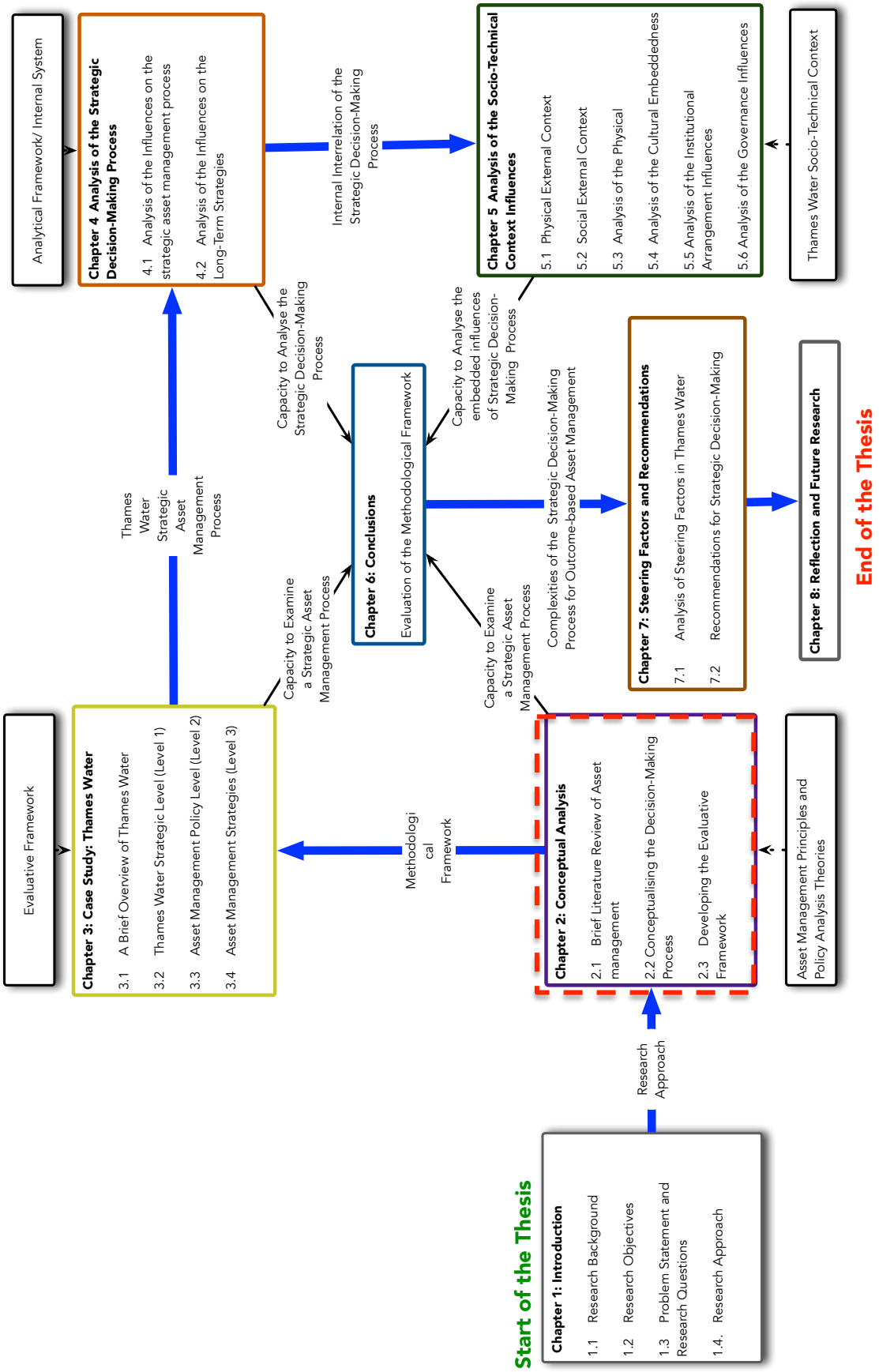
Thames Water Socio-Technical Context
Chapter 7: Steering Factors and Recommendations
7.1 Analysis of Steering Factors in Thames Water
7.2 Recommendations for Strategic Decision-Making
Chapter 8: Reflection and Future Research
End of the Thesis

Chapter 2

Conceptual Analysis:

Literature Review and Methodological Framework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2 Conceptual Analysis

The objective of this chapter is to develop a methodological framework to examine and analyse the decision-making process for investment in assets. The framework comprises conceptualising the decision-making process as a system and its interrelation with the socio-technical context. The chapter will focus on answering the first sub research question:

> How can a long-term strategy decision-making process for investment in assets be evaluated and analysed?

The chapter is structured by first conducting a brief literature review of the concepts of asset management based on actual theories and standards (Sec. 2.1). Then, a review is conducted to conceptualise the decision-making process that governs a long-term outcome-based asset management process (Sec. 2.2). The review of the two subsections led to the development of an evaluative framework to conceptualise the strategic asset management process (Sec. 2.3). Next, the review of methodologies related to policy analysis led to conceptualise the decision-making process as a system that interrelates with the strategic asset management process and the socio-technical context (Sec. 2.4). The chapter concludes with a discussion and an answer to the sub-research question.

2.1 Brief Literature Review of Asset management

Asset management is defined at the Publicly Available Specification (PAS) standard 55 (2008, p. V) as *"systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its*

organisational strategic plan". Asset life-cycle refers to the design, construction, commissioning, operating, maintaining, repairing, modifying, replacing and the decommissioning/disposal of assets. There are different types of assets that integrate the asset management system in an organisation. Examples are physical assets, human assets, information assets, financial assets and intangible assets. Although there is interdependency between the different assets, this research focuses on the evaluation of physical assets that are required to meet the optimisation level of the drinking water services from WCS.

As a holistic approach to manage infrastructures, asset management is devoted to a very broad range of concerns that combines engineering principles with sound business practices, information management and economic theory as well as the more traditional operational concerns related to the maintenance of assets (USEPA, 2006). Then, the principle of the asset management process is essentially in two levels: operational and strategic (Too, et al., 2006).

Operational infrastructure asset management deals with the practical business of keeping the infrastructure in working condition. The strategic level involves the integration of the user needs, the environment and the business functions of the organisation. The core of the strategic level is the optimisation of cost, risk and performance at the design, procurement and decision-making of the infrastructure based on the whole life cycle cost (Too et al., 2006). Whole life cycle cost encompasses economic, social and environmental aspects associated with design, construction, operation, decommissioning, and where appropriate, the re-use of the asset or its constituent materials at the end of its useful life (Mootanah, 2005).

Strategic asset management is aimed at achieving organisational long-term goals and effectiveness through dynamic alignment of the required infrastructure assets to meet and confront changing scenarios (LGV, 2004; Too et. al, 2006). Despite the difference in emphasis and perspectives of the strategic asset management process, some common themes can be identified and can be categorised based on the work from Too (2006) in strategic asset management. The concept 1-4 are reproduce

from Too (2010, p.33) and concept 5 is based from the literature review:

1. **Alignment of assets and operations with corporate objectives**: The key goal of asset management is the creation of value to the organisation stakeholders from infrastructure asset. It is about understanding and managing the trade-offs between financial performance, delivered operational and service performance and risk exposure. Hence, asset management provides a structure for driving and integrating customer expectations, legislative requirements, operating requirements, and financial objectives throughout an organization.
2. **It links decision-making and action with information**: Asset management is about obtaining the knowledge needed to optimise trade-offs among financial performance, operational performance and risk exposure. It is about decision-making, rather than the blind pursuit of technical performance (Humphrey, 2003). Decisions are driven by the actual condition and performance of assets individually and collectively as well as by the risks to corporate objectives from asset failure. Analytical methods and information integration are central.
3. **Life-cycle costing is a key concept:** Costs are minimised, starting with the initial investment, continuing through operation and maintenance, and ending with disposal. The connections between the choice of assets and the implications for the cost stream from maintaining those assets are critical.
4. **It is a process:** To understand asset management, we need to identify and define the activities involved. Asset management is about designing and implementing a new business process that can deliver higher value to the infrastructure's beneficiaries. One of the precepts of the discipline is that all business units should make decisions based on the same criteria. A sound strategic asset management process ensures that business units do not sub optimise by emphasising parochial criteria at the expense of overarching optimal service delivery.
5. **Strategic asset management framework** - The asset management framework represents a long-term view of

infrastructure combined with a risk-based systematic analysis of life-cycle costs and risk/criticality assessment to set priorities and make better decisions about assets and resource allocation. It provides a transparent and accountable methodology to allocate the limited resources amongst diverse objectives and is pressured by society, governmental agencies and investors (Too et. al 2006) for the long-term value of the infrastructure. The framework links strategies for addressing infrastructure's needs to service goals, operating budgets and capital improvements plans (Urquart, 2006).

Strategic asset management can thus be defined as: "a strategic and systematic process of optimising decision-making in resources allocation with the goal of achieving planned alignment of infrastructure assets with service demand throughout its lifecycle" (Too et al., 2006; p. 5). Based on Too et al., (2006), there is an importance in the implementation on the above concepts in the strategic asset management process to optimise the decision-making process.

Schraven et al., (2011) adds the importance of the decision-making process that interacts with the strategic asset management process by defining policy goals, infrastructure objectives, assessment of the infrastructure situation, thresholds, and the delimitation of assets and geographical areas. Decision-making process in asset management differs from the traditional management practices. Previous work by Flintsch and Bryant, (2009) describes the particularity of the decision-making process for asset management with the following four characteristics:

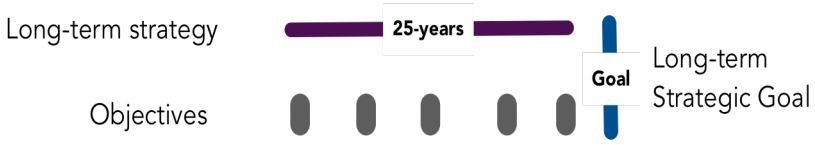
1. Addresses decisions in a network, system-wide fashion rather than at a project level.
2. Integrates existing individual infrastructure systems and databases in a common interoperable environment.
3. Introduces and incorporates financial and economic performance measures, ideas, and theories and treats the infrastructure management process as a business, which requires efficiency and effectiveness.
4. Models internal and external processes

The strategic decision-making process that is based on reaching outputs and

outcomes is developed on the basis of diverging requirements from different stakeholders (such as asset owners, local authorities, regulatory bodies and customers) and at different decision levels within an organization. This produces a complex decision-making process that balances contradicting inputs with decision criteria (Nordgård, and Gjerde, 2007). This process reaches a higher level of complexity when decisions are considered in different planning timeframes (short, medium, long term).

Intermezzo: Strategic Goals, Long-Term Strategies and Objectives

It must be provide a definition of strategic goals, long-term strategies and objectives that it would be used for this thesis. A strategic goal is the criteria or goals that a long-term strategy wants to achieve in the long term. In other words, the strategic goals act as the ends toward which effort and action are directed at by the asset management process. Long-term Strategies refers to the "how this will be achieved", and the strategic objective as the measure parameters of this approach. This interrelation occurs at each level of an organisation. Figure below illustrate a simple interrelation between the three concepts.



2.2 Conceptualising the Decision-Making Process

2.2.1 Model of Decision-Making Process

Analysing the strategic decision-making of asset management could provide relevant information to manage its complexity and facilitate the development of long-term strategies that help the organisation to cope with the characteristics of a socio-technical system and the uncertainties of the future. However, the complexity in evaluating the decision-making process on long-term outcome-based asset management increases when decisions on WCS are based on a multi-sectorial, multi-interest and multi-objective analysis in a broad societal context, involving social,

economic, environmental and ethical considerations (Savenije, 2001).

The logic model (also called the input-output-outcome model) has been a simple framework used in multiple applications, particularly in the public sector, for the evaluation of the efficiency and effectiveness of interventions on programmes or organisations (Julian, 1995; Schoenmaker, 2011). This simple model provides a conceptual framework to link inputs, outputs and outcomes while considering the impact, the actions and the influences of the external context. Pollitt and Bouckaert (2004) extended the logic model into a closed-loop framework that interrelated the needs of society, the objectives of an organisation and the impact of the external environment with the outcomes in the short and long-term (Figure 2.1.).

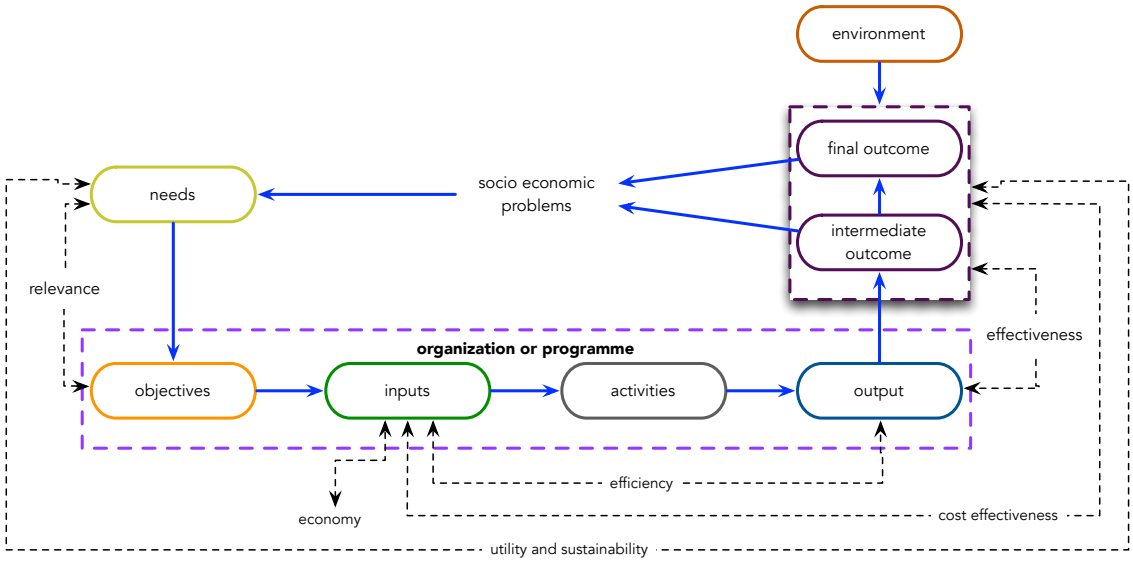


Figure 2.1: Logic model adapted from Pollitt and Bouckaert (2004) (Source: Schoenmaker, 2011, p. 80)

Efficiency is defined in the model as the extent in which time, efforts, or costs are adequately used for the intended purpose. The relation between the inputs and outputs of the system represents the operationalization of efficiency. Effectiveness is the relationship between the intended and the actual effects achieved, and it is the measure that indicates the extent to which the objectives have been achieved. Therefore, efficiency refers to the effect of the water infrastructure within the organisation, while effectiveness relates to the impact with the external context.

At the organisational or programme level are the elements of the model over which organisations have direct influence. This level outlines the relevance of an organisation's objectives that are based on their relation to the needs of society. The relationship between needs and objectives is defined as the relevance of those objectives. With a given *input* (resources, assets, people), *activities* (processes, throughput) are conducted to create a certain product, service, or good (*output*). The *output* consists of the products of the processes being carried out. This *output* interacts with the environment and leads to short and long-term effects (*outcomes*) (Pollitt and Bouckaert, 2004 cited in Schoenmaker, 2011, p. 79). *Outcomes* are short and long-term effects that were both intended and unintended. Table 2.1 summarise the main facts related to input, output and outcomes.

Table 2.1 Summary of main facts on Input, Output and Outcome (Source : Adapted from Ofwat 2011a)

Measure	What it is	Examples
Outcomes	• Higher-level objectives than company actions, activities and achievements are intended to help deliver • Things that a beneficiary values. • Delivered through outputs.	• Reliability/availability/safety of supply. • Customer satisfaction. • Environmental sustainability. • Fair, transparent and acceptable bills. • Compliance with legislative requirements. • Reducing carbon emissions.
Outputs	• Observable and measurable activities, actions and achievements needed to deliver outcomes. • May be high level or lower level (Strategic goals, key performance indicators). • Should help to achieve outcomes.	• Reductions in sewer flooding. • Maintaining/restoring serviceability. • Pesticide removal. • Meter installation. • New billing system. • Compliance with discharge consents. • Reducing service interruptions.
Inputs	• Resources an organisation needs to deliver outputs. • Includes money, people and products.	• Money spent on reducing sewer flooding (Opex/Capex). • Number of people employed on operating a water/sewage treatment works. • Length of new pipe needed to comply with drinking water standards.

The purpose of the input-output-outcome model is to evaluate the performance of the organization, not its structure. Therefore, if an organisation is input oriented,

output oriented or outcome oriented, that would not change the structure of the model. An organisation with input-based objectives focuses on obtaining the best economy value of their resources. This approach more likely considers the external context as less relevant; which can lead to less efficiency in reaching output. On the other hand, output-based objectives will aim to reach the most benefit from their input in order to reach certain outputs; however, it may lack effectiveness by not reaching the desired outcomes. Nonetheless, outcome-based objectives intend to be effective and efficient and reach forecasted outcomes in the short-term and the long-term.

Intermezzo II: Input-Output-Outcome Model (Logic Model)

It must be noted that asset management strategies are not part of the system. The aim of these strategies is to provide a framework for input, activities and output. With this in mind, it is important to more precisely define those concepts.

Outcomes are defined as the result of an impact on a particular subject or beneficiary (Schoenmaker, 2011). A single metric will not meaningfully reflect the extent to which it is being delivered. For example, the UK Water Services Regulatory Authority (Ofwat) uses as an example an outcome that aims for sustainability. The criterion will reflect, not only the quality of the water environment, but also the sustainability of the solutions used to deliver it, such as the carbon footprint of new asset schemes.

Outputs are goods and service delivered by the water company. They are observable and measurable activities; actions or achievements that the company needs to deliver in order to achieve the outcomes.

Inputs are the resources that the company has to deliver for its activities or for a particular output. These could be specific resources (such as goods, services, energy, labour or capital), or they could be enablers (such as the skills based).

The input-output-outcome model also provides a high-level framework were the interrelation between an internal and external system can be illustrated. An internal system is the process that occurs within the organisation to deliver the service of the infrastructure. The external systems are the elements that influence the organisation and are impacted by the service provided from the WCS. In the system under study, Thames Water, the strategic decision-making process acting over the strategic asset management interrelates with an internal context that represents its organisation system (business operation, asset system, asset management process, etc.) and the

external context that represent factors such as society needs, institutional arrangements, physical environment (Figure 2.2). Based on the model, the asset management strategies will be defined as a framework to allocate necessary resources and define the activities needed to achieve the desire outputs and outcomes. Then, the decision-making process that governs the strategic asset management process interacts among factors that are part of the organisation (internal context) and the socio-technical characteristics (external context).

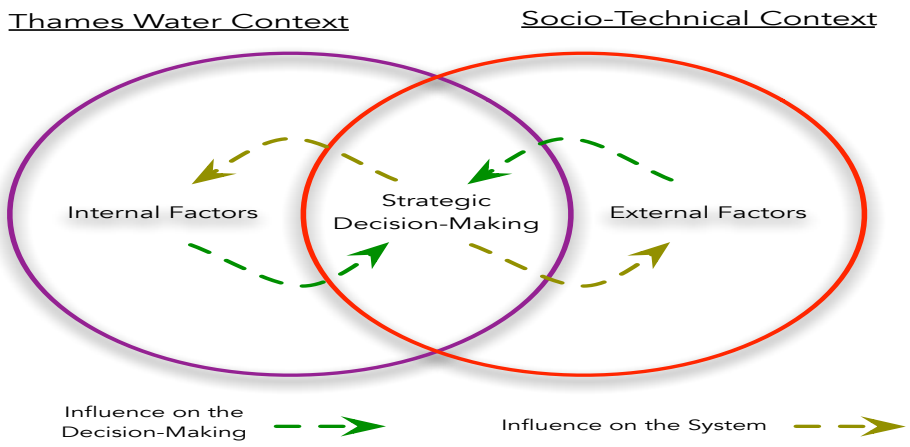


Figure 2.2: Strategic Decision-Making process as intermediary between Internal and External Factors

The contentious state of what constitutes asset management (Too, 2010) makes what constitutes the internal and external context of the decision-making process rather unclear. Then, the decision-making process for the strategic asset management is conceptualised by defining the internal context and the external context of the decision-making process. Section 2.2.2 and 2.2.3 would describe the conceptualisation of defining the internal and external context of the process.

2.2.2 Internal Context of the Decision-making Process

The decision-making process for strategic asset management is not a structured list of tasks that are conducted to produce a specific product or result. The configuration of asset management is normally embedded in a company and integrates both a number of interfaces within an organisation and external elements (Nordgård, and Gjerde,

2007).

In light of the complex nature of asset management, different publications on infrastructure (Humphrey, 2003; Woodhouse, 2003; Too and Too, 2010; and Velde et al., 2012) and PAS-55 advocates that the complexity of managing an asset intensive infrastructure business be reduced by dividing responsibility among three key entities: the asset owner, the asset manager, and the service provider. The clear demarcation of roles and responsibilities are summarised by Humphrey (2003) and Too and Too (2010) as follows:

1) **Top management**- sets the business values, corporate strategy and corporate structure. They provide guidance to the asset manager by delineating the asset costs; the risk the organisation is prepared to accept and the level of performance it expects.

2) **Asset manager**- focuses on asset strategies and decision-making. The basic function is to optimise the value of the assets in line with the stakeholders' objectives. The asset manager decides how and where money is to be spent, sets policies and standards the service provider will follow.

3) **The service provider-** responsibility is frontline execution of the day-to-day activities. This includes scheduling people and resources to deliver service efficiently at the level defined by the asset manager.

Along with the identification of the roles on asset management, a standard way to address asset management is by process models that are meant to guide asset managers into following stepwise activities and making rational choices. Decisions are not always clearly pointed out in these models, and the number and kind of decisions mentioned differ between models (Schraven et al., 2011). Different scholars only include a few decisions and relate them in a linear fashion (Vanier, 2001; Rouse and Chiu, 2009), whereas other authors offer models with multiple decisions and several feedback and feed-forward loops (Neumann and Markow, 2004; Haffajee and Brent, 2008). Within these different models, Schraven et al., (2011) identified three

general areas of decision-making on asset management that intertwined, and point out that this interrelationship makes asset management decision making complex and dynamic. The three main areas are:

1) Decisions with regard to the infrastructure objectives of public agencies;

2) Decisions with regard to the performance-related situation of the agency's infrastructure; and,

3) Decisions with regard to the interventions applied by the agency to the infrastructure.

PAS-55 (2008) provides a systematic structure on risk-based asset management practises (Parsons, 2008; Herder et al., 2012). PAS-55 describes the asset management system as coordination between different levels such as the organisation's *asset management policy, asset management strategy, asset management objectives, asset management plan* and the activities, processes and organisational structures necessary for their development, implementation and continual improvement. From a high-level perspective, the system can be described and illustrated using a three level scheme: the Organisational Strategic Level, the Asset Management Policy Level (Planning/Tactic) and the Operational/Implementation Level.

The Organisational Strategic level is the strategic plan developed by the asset owners that is derived from their vision, mission, values, business policies, stakeholder requirements, objectives and risk management. The Asset Management Policy provides principles and mandated requirements derived from the organisational strategic plan, providing a framework for the development and implementation of the asset management system. The asset management policy level and the interrelation with the other levels is the main responsibility of the asset managers. The Operational Level relates to the implementation and the day-to-day activities related to the operation of the assets, where the service providers conduct the main activities.

The Asset Management Policy Level contains three internal levels: the Asset

Management Strategy, Objective and Plan (Figure 2.3). The Strategy level describes the long-term optimisation approach for the management of the physical assets. The Objective level is the operationalization of strategic goals to quantify and/or demonstrate the achievement of an objective, and includes the defined Key Performance Indicators. The Plan Level comprises specific tasks and activities (actions) required to deliver and implement the asset management strategy and deliver the asset management objectives. Within these levels, the physical assets can be categorised into two levels: system or object.

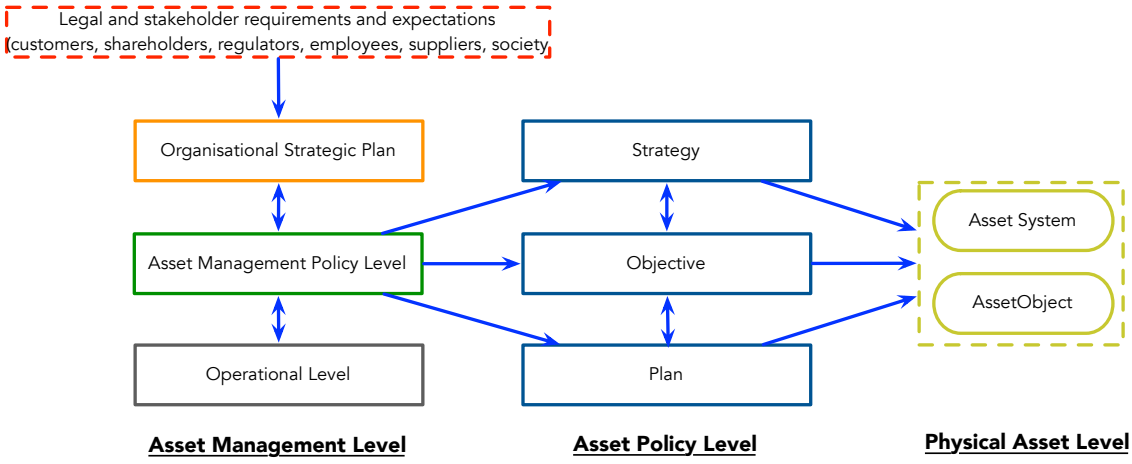


Figure 2.3: Asset Management System Definition (Source: Adapted from PAS-55 and Velde et al., 2012)

The study of the decision-making process on the asset management system is focused on the long-term strategies for investment at the system level of the assets. This decision process is part of the activities and elements that comprise the Organisational Strategic Level down into the Asset Policy level. At these levels the strategic asset management processes occur, the results of which are the long-term asset management strategies of the organisation.

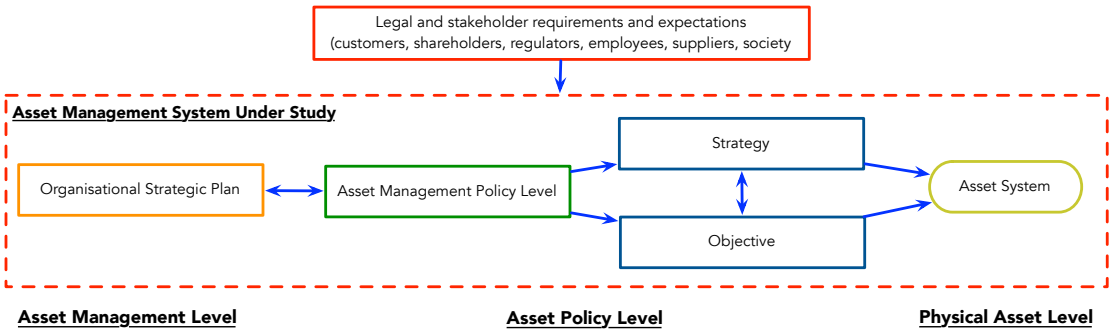


Figure 2.4: Defined Internal Context of the Decision-Making Process: Strategic Asset Management System

The above figure (2.4) illustrates the conceptualisation of the internal context within an organisation where the decision-making process to develop long-term strategies takes place. The figure is the result of re-arranging the asset management system defined in Figure 2.3, which is based on the systematic conceptualisation of asset management (See also, PAS-55, 2008; Velde et al., 2012). By conducting this conceptualisation, the system boundaries of the asset management process to be analysed at Thames Water are defined. Then, the analysis would be focused on elements related to the Organisational Strategic Plan, the Asset Management Policy Level and the Strategic Level of Physical Assets.

2.2.3 External Context of the Decision Making-Process

The external context of the decision-making process at Thames Water is defined by the determination that WCS are socio-technical systems. A socio-technical context can be described using the four-tier transaction costs economics model of Williamson (1998). The model provides a structure to explain the integration between social and institutional aspects occurring in a multi-layer system with a top-down and bottom-up causation interaction (Williamson, 2000; Bauer and Herder, 2009). In these causal relations, the upper levels enable and impose constraints on lower levels and vice versa.

The Williamson Model has been utilised in the energy sector (Bauer and Herder, 2009; Correljé and Vries, 2008; Koppenjan and Groenewegen, 2005) and the water sector (Broekhans and Correljé, 2008; Ploeg, 2011). According to Bauer and

Herder (2009), the Williamson Model can be a useful model that allows for the examination of different types of social and institutional arrangements, while the approach can be expanded to model the technical and social sub-systems (Table 2.2).

Table 2.2: Layers and time scales in socio-technical systems (Source: Bauer and Herder (2009, page 604))

Time scale	Social subsystem	Technical subsystem
Embeddedness Changes 10^2 to 10^3 years often non-calculative	Informal institutions, customs, traditions norms, religion	Informal conventions embedded in the technical artifacts
Institutional environment Changes 10 to 10^2 years, institutional setting	Formal rules of the game (property, polity, judiciary, etc.)	Technical standards, design conventions technological paradigms
Governance Changes 1 to 10 years design of efficient government regime	Play of the game (contracts, governance of transactions)	Protocols and routines governing operational decisions and (best available) technology
Operation and Management Continuous adjustments	Prices, quantities incentives	Operational choices

Williamson's framework characterises each of the layers using the criteria of: the purpose, the frequency of change of institutions and the level of analysis (Kunneke, 2010). The Embeddedness Layer represents the informal institutions, customs, traditions, norms and religion. Changes in this layer occur slowly, with timeframes between one hundred and thousands of years, and are typically undertaken in the analysis of institutions. There are different types of embeddedness (cognitive, cultural, technical tactics). From a water infrastructure perspective, the physical embeddedness (water and soil) provides constrains and enables the lower layer in the social and technical subsystems. The next layer down explains the institutional environment, which considers the formal rules of the game. The institutional environment includes arrangements such as national and international standards and legislations, property rights and water-specific regulations. Changes and dynamics in

this layer range from 10 to 100 years. One layer down is the governance structure of the system. This layer is based on economic transactions and represents the play of the game. It describes interactions related to hierarchies, methods of regulation and ownership decisions. These decisions are based on elements related to responsibilities under the sub-systems of the Water Cycle System: water demand, technology, internal protocols and routines of the organisation. The dynamics and changes in this level occur in a range from 1 to 10 years. The last level represents continuous decisions regarding operation and resource allocation; changes at this level occur constantly.

Based on the characteristics of each level (dynamics, aspects addressed, the way they evolve and the extent to which they can be influenced) and WCS, four main factors will be used to evaluate the external factors of Thames Water. These four factors are Physical Structure, Cultural Embeddedness, Institutional Arrangement and Governance Characteristics. Table 2.3 summarises expected elements for these factors based on Bauer and Herder's (2009) expanded model in relation to the decision-making process in asset management.

Table 2.3: Socio-technical elements emerged in the external context for decisions on Asset Management on Water Industries (Source: Bauer and Herder (2009)

Time scale	Social subsystem	Technical subsystem
Cultural and *Physical Embeddedness* Changes 10^2 to 10^3 years	Stakeholder vs. Shareholder, Individualism vs. Collectivism, Relation to Authority	Climate, (geo) hydrological system, water availability
Institutional Arrangement Changes 10 to 10^2 years	Property Rights Regulations and Legislation	Architecture and Condition of the System Structure
Governance Changes 1 to 10 years design of	Regulator Interaction Price of Water Ownership	System Borders Supply Demand Balance

Operation and Management Continuous adjustments	Out of the Area of Study	Out of the Area of Study

The availability of the resources is dependent on the (geo) hydrological system and climate of the region where it operates supply water infrastructure. Changing the availability of resources to produce portable water occurs in a timeframe that is almost non-calculative. The Physical Structure will reflect these embedded characteristics of the region where water companies operate. Cultural Embeddedness reflects elements from non-formal interactions, perceptions, and actions and values that impact the decision-making in asset management for drinking water; examples are Stakeholder vs. Shareholder, Individualism vs. Collectivism, Relation to Authority and Managerial Background. Institutional Arrangement reflects elements from the regulatory structures, arrangements and responsibilities over the Water Cycle System, such as Property Rights, Ownership, Architecture of the System Structure, and Regulations and Legislation. Governance Characteristics are elements considered from a macroeconomic perspective in the decision-making process of Asset Management and includes system borders, supply demand balance, regulator interaction and the price of water.

These four main external elements (Cultural Embeddedness, Physical Characteristics, Institutional Arrangement, and Governance Characteristics) comprise the external context of the decision-making process. These high-level elements are representative of external factors that are influential on WCS and the asset management process. Therefore, the external context outside of Thames Water is characterised based on a description of these elements.

2.2.4 Characterising the Strategic Decision-Making Process as a Governing System

The decision-making process to develop asset management long-term strategies is a complex process as defined in previous subsections. PAS-55 standards, International Standards Organisation for asset

management and other standards have influenced the infrastructure of the industry to standardise asset management, particularly infrastructures that are heavily regulated such as water, electricity and gas in the UK (Parson, 2006). These infrastructures apply risk-based approaches to make decisions for investments related to their assets.

The standardisation of the asset management process by these standards conceptualises the strategic asset management process into frameworks, but implementation and interpretation to develop long-term strategies relies on the decision-making process of the asset manager. This brought the idea that the decision-making process could be characterised as a separate layer influencing the asset management process. Similar characterisation is done in the public policy sector by Kooiman, Bavinck et al., (2005), Scharpf (1997) and Cuppen (2012) where they distinguish between a system-to-be-governed (asset management process) and a governing system (decision-making process). This layer lies in between the socio-technical context (external context) and the asset management process (internal context). Figure 2.5 illustrates the effect of these influential layers over the asset management process.

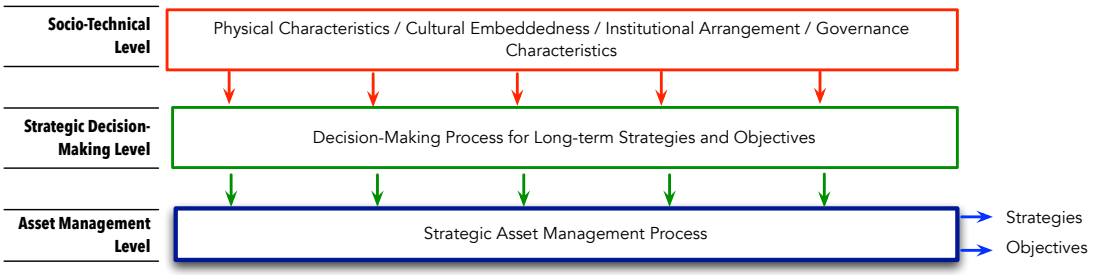
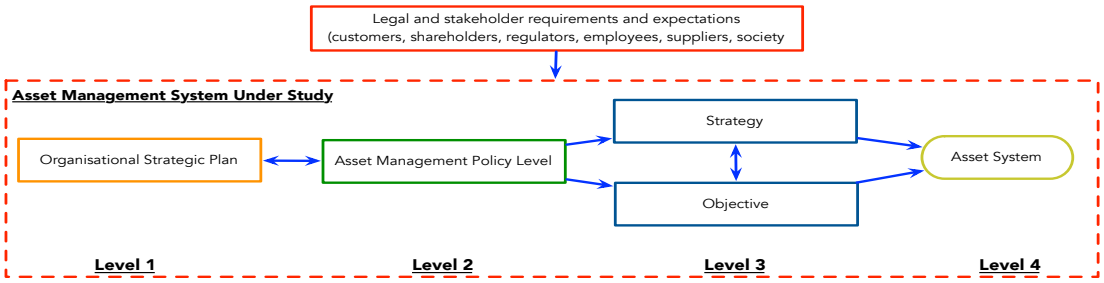


Figure 2.5: Influential Layers over the asset management process

2.3 Developing the Evaluative Framework

The development of the evaluative framework is based on the standardisation and characterisation of the asset management process defined in the above subsections. PAS-55 is used as a starting point to develop the evaluative framework of the

decision-making process due to its acceptability and its consideration of an asset management process in relation to stakeholders. Based on the asset management system defined, the framework portrays the strategic asset management process using the Organisation Strategic Level as a starting point and moving forward to the level of Asset Management Strategy and Objective (Figure 2.6).



LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
		Strategy	
		Strategic goals	
		Methods of optimisation and decision-making	
		Consider requirements of relevant stakeholders	
		Identify functions, performance and condition of asset systems and critical assets	
		State the desired future function(s), performance and condition of existing and new asset systems and critical assets	
		Describe criteria for optimising and prioritising asset management objectives and plan	
Organisational Strategic Level	Asset Management Policy		Asset System
Overall long-term plan for the organisation	Based on Organisational Strategic Plan	Objective	
Company's vision, mission, values	Risk Management Framework	Operationalization of strategic goals to quantify and/or demonstrate the achievement	
Business policies	Actions to comply with current applicable legislation, regulatory and statutory requirements	Target Values	
Stakeholder requirements	Identification and involvement of relevant stakeholders	Models and techniques that are used	
Objectives	Overall intentions/principles and framework for control of asset management	Improvement opportunities of new technologies and asset management tools, techniques and practices	

Figure 2.6: Asset Management Evaluation Framework (Based on PAS-55)

The main purpose of the Asset Management Evaluative framework was to structure the information in order to understand the internal decision-making process that leads to the determination of strategies and strategic objectives under the internal context at Thames Water. The framework provides a different structure compared to the framework defined by PAS-55 to focus in the strategic asset management process. The components described under each level are the main concepts defined in PAS-55 and asset management theories. Therefore, there the Asset Management Evaluative framework does not derive that much from the content of PAS-55. The components established under each level were determined using PAS-55, which led to an understanding of the influential factors in the decision-making process. The framework provided a guide to design the research methods, and to structure the information to develop and to analyse the decision-making process.

According to the PAS-55 standard, the physical asset management system is inside of a vital context, which is defined by the total business of the organization (PAS-55, 2008). This context can be classified under five categories: Stakeholder Requirements, Business Objectives, Regulations, Performance Requirements and Risk Management. These five categories represent the constraints or the internal context of the asset management process in the system under study. The categories were considered as the internal influential factors on the decision-making process for long-term strategies and objectives (Figure 2.7.). Changes on any of the categories influence the decision-making process and the development of asset management long-term strategies and objectives. Following the Evaluative Framework, these influential factors were captured for further analysis with the analytical framework.

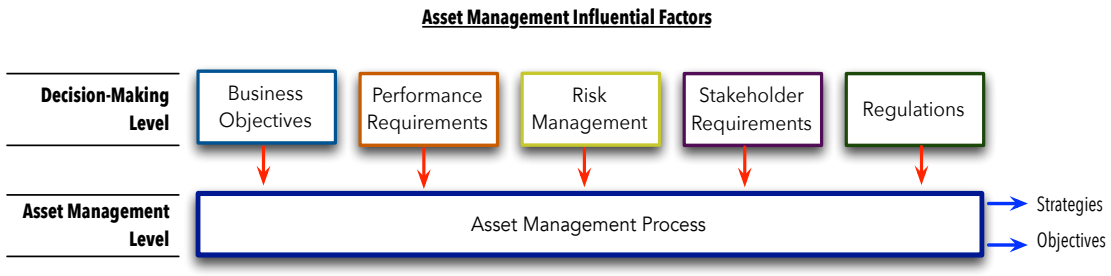


Figure 2.7: Influential Factor on the Decision-Making Process of Asset Management

Figure 2.7 illustrates two levels in the internal context as part of the characterisation: the asset management process for long-term strategies (the structure) and the level of internal influential factors acting over the asset management process. The decision-making process represents the governance of these five influential elements that are part of the asset management process. The decision-maker will not have control over some of these factors but does have control of the level of integration and consideration (governance) within the decision-making process. This illustrates a limitation of the evaluative framework, which would not characterise the impact of the decision-making process on the asset management system, and the need for an analytical framework.

2.4 Development of the Analytical Framework

Three different methodologies were evaluated to develop the analytical frameworks to conceptualise and study the long-term strategic decision-making for asset management of Thames Water. These methodologies were used because they are based on policy-making and policy-process analyses under a policy context that involves complex systems, uncertainties of long-term planning and multi-actor complexities. These three systematic and stepwise methodologies are Adaptive Policymaking, Dynamic Adaptive Policy Pathways and Systems Diagram.

First, Adaptive Policymaking is an approach to policy formulation and implementation by developing a basic plan and contingency planning to adjust as the world changes and as new information becomes available (Walker et al., 2001). Second, Adaptive Policy Pathways is a structured approach for designing a dynamic adaptive policy based on the concepts of Adaptive Policymaking and Adaptation Pathways (Folke et al., 2005; Haasnoot et al., 2013). Adaptive Pathways is an approach that provides insight into the sequencing of actions over time, potential lock-ins and path dependencies (Haasnoot et al., 2012). Finally, there is a seven-step approach that utilises System Diagram as the core concept to represent a structured view of a problem situation (van der Lei et al., 2010). This methodology focuses on the construction of a system diagram

as a process to provide structure to the conceptualisation of a complex problem situation.

It is important to understand that the policy described in the methods below does not refer to government policies, such as regulations, but refers to asset management strategies of an actor that owns the system infrastructure. In the context of Adaptive Policymaking and the asset management systems, described in the prior section, strategies contain actions that prepare the infrastructure system for the future without directly changing the institutional structure of the system (Kwakkel et al., 2010). This approach contrasts with traditional policy analysis in which policies are a set of forces within the control of the actors within the policy domain, which affects the structure and performance of the system (Walker, 2001; Kwakkel, et al., 2010). Tables 2.4 to 2.6 describe the steps that each of the methodologies entail.

2.4.1 Adaptive Policymaking

Adaptive Policymaking proposes a generic framework to manage uncertainty and changes. The framework is based on the principle that learning, overtime, mitigates uncertainties. The framework defines a stepwise process to develop a basic policy that enables this learning process, which can be adapted in light of new information and/or changes (Walker et al., 2001).

A review of this methodology is worthy since it does not assume that the future can be predicted, and it proposes a different alternative to cope with the uncertainties of the future. This method is part of a scientific body of work in adaptive policies that proposes that under deep uncertainties of the future, dynamic adaptive strategies need to be developed (Albrechts, 2004; Haasnoot et al., 2011; Haasnoot et al., 2011; Hallegatte, 2009). The application has been described using different cases such as airport strategies (Walker et al., 2001, Kwakkel, et al., 2010), transportation (Pas, 2013), energy policies (Hamarat, 2012), government policies (Swanson et al., 2012) and water resources (Kwakkel, 2012).

The process is split into two phases: a thinking phase and an implementation

phase. Over the thinking phase, the adaptive policy is designed and analysed for vulnerabilities, and a monitoring system is developed. The next step is to screen the identified vulnerabilities based on the level of uncertainty, and classify them as certain vulnerabilities and uncertain vulnerabilities. Certain vulnerabilities are taken into account in the basic policy by including mitigating actions that should be taken at the beginning of the implementation of the basic policy.

In the case of uncertain vulnerabilities, hedging actions are implemented to make the basic policy more robust. The monitoring system is created to manage the uncertain vulnerabilities, and actions are prepared in order to know how to proceed when the monitoring reveals that specific vulnerabilities have manifested. At the implementation phase, the policy is implemented, its performance monitored, and the policy modified if necessary. The implemented policy remains active as long as the signposts signify that the policy is on course to achieve its intended outcomes. In case the policy is no longer expected to achieve its intended course, a reassessment of the policy is conducted (Table 2.4).

Table 2.4: Adaptive Policymaking (Based on Walker et al., 2001 and Kwakkel et al., 2010)

	Title	Description
Step 1	Setting the stage	Identification of the Important objectives, constrains, available policy options and definition of success
	Thinking Phase	Specification of the outcomes in terms of the stated objective and constraints that the participant will find acceptable
Step 2	Assembling the basic policy	Specification of a promising policy
	Thinking Phase	Identification of the conditions that must be met in order to succeed and the way in which these objectives will be achieved

Step 3	Robustness	An analysis is conducted to determine vulnerabilities and opportunities, and actions needed to make the plan more robust
	Thinking Phase	Four types of action: mitigating actions, hedging actions, seizing actions (actions taken to seize likely available opportunities) and shaping actions (actions taken to reduce failure or enhance success).
Step 4	Contingency Planning	Definition of a monitoring system of the plan's performance and to take action if necessary
	Thinking Phase	Identification of the necessary conditions for successful signposts (specify information that should be tracked in order to determine whether the plan is meeting the conditions for its success) and triggers (critical values of signpost variables beyond which additional actions should be implemented)
Step 5	Defensive Actions	Determination of actions that can triggered by a signpost
	Thinking Phase	These actions can be classified into four different types of actions: defensive actions; corrective actions; capitalising actions; and, a reassessment of the plan
Step 6	Implementation of Policy	Implementation of actions to be taken immediately (from Step 2 and Step 3) and monitoring system (Step 4)
	Implementation phase	Implementation of other actions (from Step 5) is on hold until a trigger event occurs

2.4.2 Dynamic Adaptive Policy Pathways

The intention of the Dynamic Adaptive Policy Pathways is to combine the strengths of the Adaptive Policymaking approach and the Adaptation Pathway Approach. The Adaptation Pathway Approach has demonstrated to be applicable in practice and is currently used by the Delta Programme in the Netherlands to develop its water policy for the future (Haasnoot and Middelkoop, 2012). Nevertheless, a combination of these methods has not been used in a real case scenario. Its efficacy has only been demonstrated using a virtual application of planning concepts to a real world

decision-making problem currently faced by the Dutch National Government (Haasnoot et al., 2013).

There are four key characteristics to the Dynamic Adaptive Policy Pathways approach: (1) the use of transient scenarios representing a variety of relevant uncertainties and their development over time; (2) anticipating corrective actions to handle vulnerabilities and opportunities; (3) development of several Adaptation Pathways describing sequences of promising actions; and, (4) a monitoring system with related actions to keep the plan on track on a preferred pathway to reach the main objectives (Haasnoot et al., 2013). This approach allows for a dynamic exploration of a wide variety of relevant uncertainties that connects short-term targets and long-term goals, and identifies short-term actions while keeping the future options open (see Table 2.5).

Table 2.5: Dynamic Adaptive Policy Pathways (Based on Haasnoot et al., 2013)

	Title	Description
Step 1	Describe the study area	Description of the system's characteristics, the objectives, the constraints in the current situation, and potential constraints in future situations
		Development of a definition of success specifying the desired outcomes in terms of indicators and targets that are used in subsequent steps to evaluate the performance of actions and pathways, and to assess the 'sell-by dates' of the actions
Step 2	Problem Analysis	Current situation and possible future situations are compared to the specified objectives to identify whether there are any gaps
		Possible future situations are 'reference cases' that consist of (transient) scenarios that span the uncertainties identified in step one, where a gap indicates that actions are needed
		Possible *opportunities* and *vulnerabilities* are identified based on the condition of success

Step 3	Policy Actions	Determination of actions to address the identified vulnerability and seizing the identified opportunities
		Classified into shaping actions, mitigating actions, hedging actions, and capitalising actions
Step 4	Evaluate the Actions	The efficacy of each of the policy actions is assessed in light of the definition of success which can presented using scorecards
		Results will be used to identify the *sell-by date* for each action, previously identified vulnerabilities and opportunities are reassessed, and only the promising actions are used in the next steps as the basic building blocks for the assembly of Adaptation Pathways
Step 5	Assembly of Pathways	Pathways are a concentration of actions in which a new policy action is activated once its predecessor is no longer able to meet the definition of success
		Pathways can be assembled by exploring all possible routes with all available policies
		Result is an adaptation map, which summarises all logical potential pathways in which 'success' (as defined in Step 1) is achieved
Step 6	Preferred Pathways	Develop a manageable number of preferred pathways that fit well within a specified perspective
		Preferred pathways will form the basic structure of a dynamic adaptive plan (like the basic planning the Adaptive Policymaking framework)
Step 7	Contingency Planning	Define actions to get each of the pathways on track for success
		Distinguish between three types of contingency actions from Adaptive Policymaking: corrective, defensive, and capitalising actions, which are associated with a monitoring system (specifies what to monitor) and trigger values (specify when a contingency action should be activated)
Step 8	Dynamic Adaptive Plan	A plan that is capable of answering the following question: Given the set of pathways and the uncertain ties about the future, what actions/decisions should we take now (and which actions/decisions can be postponed)?

Step 9	Implementation and Monitoring	Implement actions needed immediately and establish the monitoring system
		Time starts running, signpost information related to the triggers is collected, and actions are started, altered, stopped, or expanded in response to this information, and other actions are suspended until a trigger event occurs

2.4.3 Systems Diagram Method

A systems diagram is a method derived from soft-analytical methodologies to make explicit complex multi-actor problems, conceptualise relevant factors as a system and rationalise robust alternatives (Haan and Heer, 2012). This 7-step systematic approach is based on a combination of existing, relatively straightforward analytical methods including objectives hierarchy, means-ends analysis, causal diagramming, stakeholder analysis and contextual scenarios (van der Lei et al., 2011). Table 2.6 describes a summary of the 7-steps that involve the development of a systems diagram.

Table 2.6: Systems Diagram (Based on van der Lei et al., 2011)

	Title	Description
Step 1	Why should the problem be solved?	A policy problem is the gap between an existing or expected situation and a desired situation (a principle, or norm)
		A clear understanding of what really matters to the problem owner
		Problem level determination diagram
		Why would the problem owner want this problem to be solved?
		Why is it important to satisfy this need or to solve the problem as initially articulated?

Step 2	What determines success for the problem owner?	Objectives tree - split objectives in the intermediate level of directional objectives, and these are further specified until they can be expressed in measurable indicators/ criteria
		Criteria are found by asking the 'What is - question'
Step 3	What are the means or tactics available to the problem owner?	What are the means/actions of the problem owner to solve it and/or to make it smaller?
		Means-ends diagram or means-ends objectives hierarchy by reasoning backwards from the objectives stemming from the previously developed objectives
		How (by using which means) can the objective(s) be achieved?
		Systematically reasoning backwards from a chosen objective, a number of means are mapped out that may contribute to the realisation of the objective
Step 4	What is the system of interest?	System of interest represented with causal diagram
		Factors and the influence relationships between these factors represents key attributes
		Causal diagram portrays the causal mechanisms linking the tactics with the criteria - these mechanisms are derived from established theories, definitions, expert knowledge, and/or beliefs of the author(s) of such a diagram
		External factors to consider are represented by the socio-technical context described in the above section
Step 5	Who else is involved and what are their means to affect the interests of the problem owner?	Stakeholder/actor analysis and basic network analysis serve to identify relevant social, institutional, and political attributes of the problem situation
		Focus on the wider policy arena in which the problem owner has to solve their problem
		The interests, objectives, problem perceptions and interdependencies

		of the listed actors are determined
		Studying the formal legislation, procedures, policy pieces
		Actors that might have an interest in the issue are identified, including formal tasks, authorities, and relations of actors
Step 6	How might the problem change in future?	Changes from within the system and in the context or environment of the system
		Contextual scenarios to map the effect of the driving forces that have an influence on the system
		Context scenarios are generally used to investigate the robustness of the proposed policies and are usually qualitative in nature
Step 7	What further steps, including possible research, are recommended?	Identify a plan of action to be recommended to the problem owner
		Two types of actions can be identified: Process Actions, for example, to start talking to, or negotiating with, critical actors, and Research Actions, targeted at resolving specific crucial knowledge gaps

2.4.4 Comparing Methodologies and Method

Overlapping and complementation can be identified between the three approaches. Adaptive Policy Making and Dynamic Adaptive Policy Pathways aim to provide a supporting structure for decision makers, emphasising the need for adaptability in order to couple with uncertainties and changes in long-term planning. Both approaches provide support to identify short-term actions in the near future that will keep the possibility open to modify, extend, or alter the plans to how the future unfolds.

The difference is in the way both approaches provide decision support. Adaptive Policymaking provides steps to design a policy, but does not provide clear guidelines beyond each step. Dynamic Adaptive Policy Pathways is an extension of the Adaptive Policy Making that takes into account how vulnerabilities can be identified, how actions should be sequenced, how one decides whether to hedge

against vulnerability or to specify a monitoring system with actions to handle the vulnerability in the future if and when it arises (Haasnoot et al., 2013). This is done by including transient scenarios representing a variety of relevant uncertainties and their development over time, and by developing Adaptation Pathways describing sequences of promising actions.

The aim of both approaches is aligned with Vitens' objective of moving from an existing asset management system that reacts to Vitens' internal context, to a system that adapts to changes of the external variables taking into consideration the internal structure. This shift in their existing asset management system can be reached by including a long-term plan that considers future changes internally and externally. Dynamic Adaptive Policy Pathways would attain Vitens' goals by providing a more adaptive and efficient Asset Management Policy that would guarantee water supply in the future. However, designing the Asset Management Policy goes beyond the scope of this research. The main objective of this research project is to study the decision-making process as a system, not to provide advice in strategies and actions for Vitens.

The Adaptive Policymaking methodology was used as analytical framework of the decision-making process of Thames Water. As mentioned, this method did not provide specific guidelines, and was too broad for the research objective, which was a systematic analysis of the decision-making process and its influences from the external context. A Systems Diagram Structure complements the substantive systematic method of the Adaptive Policymaking framework. This method combines analytical modelling techniques with actor analysis to construct an internally consistent and integrated system, wherein content and process aspects are connected (van der Lei et al., 2010).

Combining System Diagrams and Adaptive Policymaking approaches provides a systematic framework to study the asset management decision-making process at Thames Water, the influences it received from the external context and the relevant elements to be considered by Vitens. The combined approach details interrelations within and in-between the internal context and external context, and description of opportunities,

vulnerabilities and steering factors based on the Adaptive Policymaking Framework. A new combined methodology was developed based on an eight-step process (Table 2.7).

Table 2.7: Combine Methodology Process

	Adaptive Policymaking	System Diagram
Step 1	Setting the stage/ Assembling the Basic Plan	Why should the problem be solved?
Step 2		What determines success for the problem owner?
Step 3		What are the means or tactics available to the problem owner?
Step 4		What is the system of interest?
Step 5		Who else is involved and what are their means to affect the interests of the problem owner?
Step 6	Increasing the Robustness of the Basic Plan	How might the problem change in the future?
Step 7	Contingency Planning	What further steps, including possible research, are recommended?
Step 8	Defensive Actions	

The resulting analytical framework is a systems diagram of the decision-making process. The framework's diagram provides a structure to categorise the steering factors, the internal influential factors, and the external factors influencing in the decision-making process. Applying system diagram methods to analyse the strategic asset management process allows for the characterisation of the decision-making process as a system. The system diagram method allows the development of an analytical framework that outlines the system demarcation by defining a boundary of the system and the elements that are relevant for the analysis. By defining the boundaries of the decision-making process, the factors that are part of the decision-making system where separated from the contextual factors that are part of the external environment. Figure 2.8 illustrates the system diagram that will be used as the analytical framework of the decision-making process.

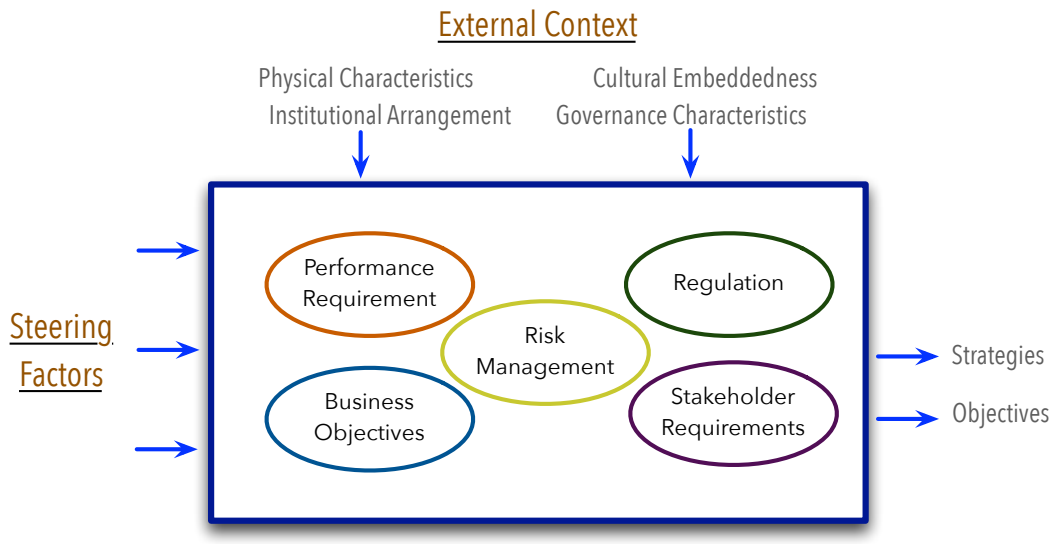


Figure 2.8: System Diagram for Decision-Making Process

It is important to clarify that, from the perspective of an asset management system, the asset management strategies are considered as the framework to determine investment and activities to reach the outputs and/or outcomes. The strategy influences the asset management system at the investment planning level to reach the strategic objectives. In the perspective of the system diagram, strategies and objectives are considered as the output of the strategic asset management process. Steering factors are actions that influence the decision-making process, means or actions conducted to influence the governing system of influential factors. An example would be changes in the criteria for risk management. Outside of the defined system of the decision-making process are the external factors. These factors are the socio-technical elements (Physical Structure, Institutional Arrangements, Cultural Embeddedness, and Governance Characteristics) defined using the socio-technical context framework (Table 2.3). Figure 2.8 shows the socio-technical level influence over the decision-making level.

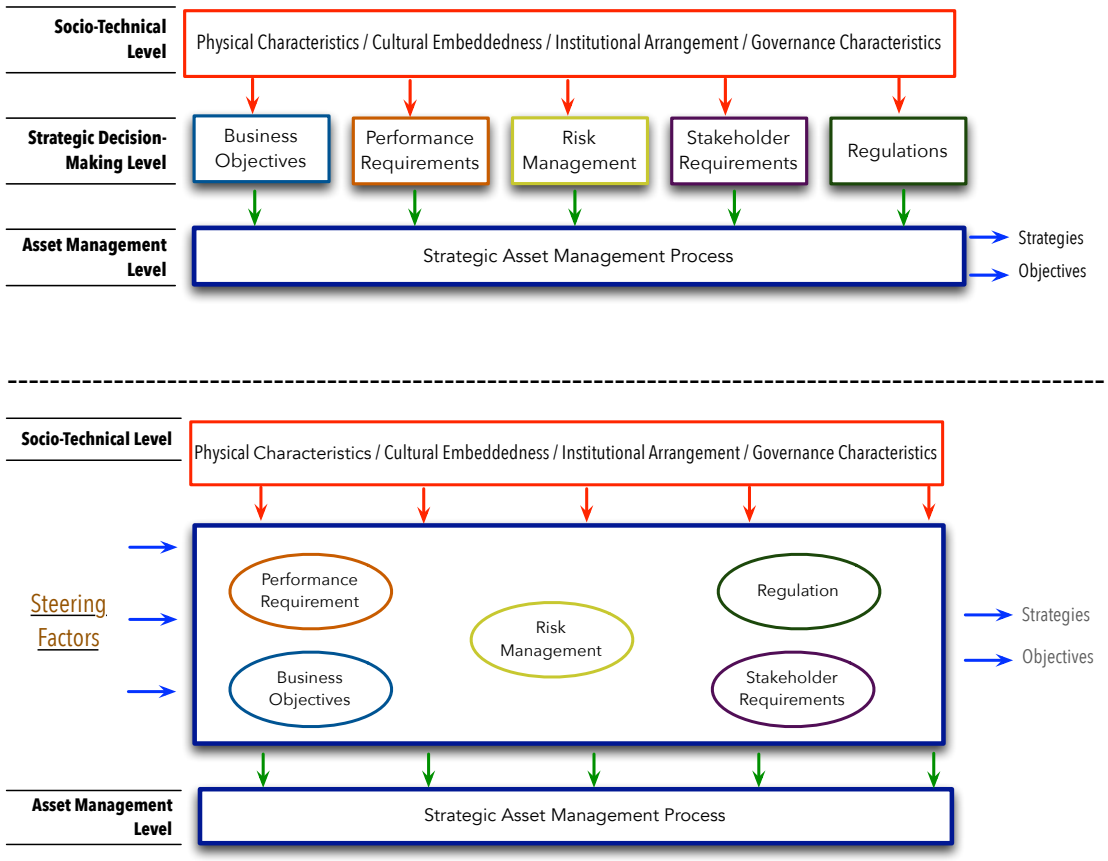


Figure 2.9: External and Internal Influential Factor on the Decision-Making Process of Asset Management

Figure 2.9 provides an illustrative outline of the different layers that were used to evaluate and analyse the system. The combination of the evaluative framework and the analytical framework resulted in the methodological framework of this thesis. The evaluative framework characterised the respective components of the asset management process. The result of applying the framework in the case of Thames Water was the structure of the asset management process and the long-term strategies and objectives. The analytical framework was used to identify the interrelations and influences of the decision-making process on the asset management process. Then, the analytical framework conceptualised the interrelations and influences between the external context and the decision-making level.

2.5 Methodology Framework-Discussion

The objective of this chapter was to answer the following sub-question:

> How can a long-term strategy decision-making process for investment in assets be evaluated and analysed?

A tweak track approach was used to evaluate and analyse the decision-making process for long-term strategies for investment in assets, where the determination of an evaluative framework and analytical framework were needed in order to reach a methodological framework. The evaluative framework is the result of the need to identify the components on an asset management process. The analytical framework resulted as a need to identify the influences and interrelations of these components to develop long-term strategies and objectives. The hypothesis for this methodological framework was that the impact of the external context can be understood more clearly if the different levels of Asset Management are evaluated independently.

To develop these frameworks, the decision-making process and the asset management process were characterised as two separate levels. This helped to identify what was needed from an evaluative framework. The Evaluative Asset Management Framework was based on the PAS-55 standard, which is used in the practise of asset management. Establishing a framework on standardised practices provided two benefits: 1) a systematic structure that enables the evaluation of a complex asset management system; and, 2) an alignment between the practical domain and the theoretical perspective of this research. The objective of the evaluative framework was to define the asset management process, long-term strategies and the influential factors on the asset management process.

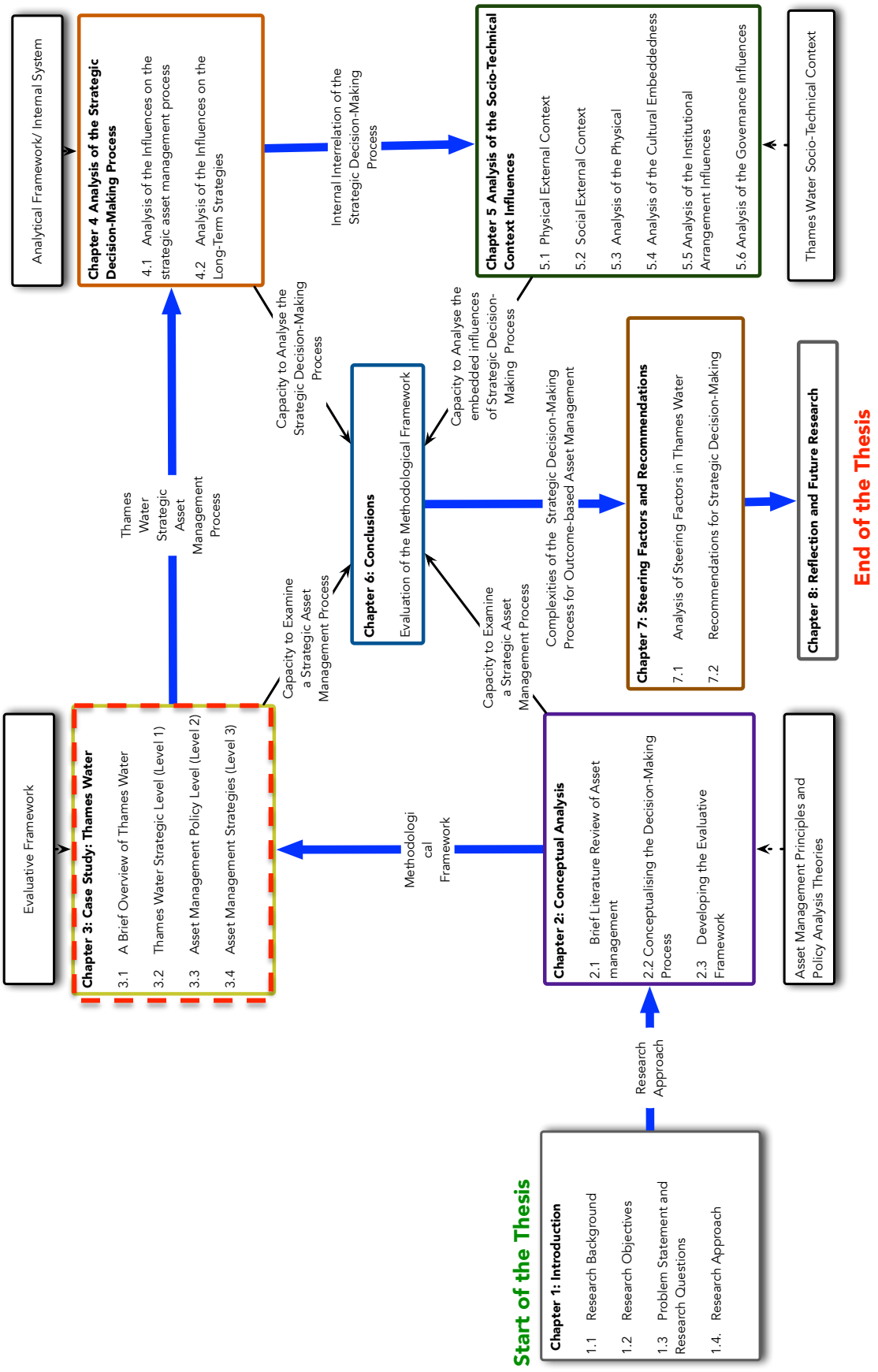
The analytical framework was developed with the purpose of analysing the influences of the decision-making level and the external context on the asset management process. The analytical framework is based on the methodologies that

focus on developing long-term strategies under complex multi-actor problems and uncertain futures. The analytical framework combines the steps of the Adaptive Policymaking and systematic methodologies to develop a System Diagram. Adaptive Policymaking is used as an analytical perspective to identify the threats and opportunities of a system that operates in an external context that is susceptible to changes and uncertainties. The Systems Diagram provides an analytical framework that conceptualises the system boundaries on the decision-making process and the interrelation with the socio-technical context, strategies and objectives and steering factors.

Chapter 3

Applying the Evaluative Framework

Case Study- Thames Water's Asset Management Process


Start of the Thesis
Chapter 1: Introduction
1.1 Research Background
1.2 Research Objectives
1.3 Problem Statement and Research Questions
1.4. Research Approach
Research Approach
Chapter 2: Conceptual Analysis
2.1 Brief Literature Review of Asset management
2.2 Conceptualising the Decision-Making Process
2.3 Developing the Evaluative Framework
Asset Management Principles and Policy Analysis Theories
Methodological Framework
Chapter 3: Case Study: Thames Water
3.1 A Brief Overview of Thames Water
3.2 Thames Water Strategic Level (Level 1)
3.3 Asset Management Policy Level (Level 2)
3.4 Asset Management Strategies (Level 3)
Evaluative Framework
Capacity to Examine a Strategic Asset Management Process
Capacity to Examine a Strategic Asset Management Process
Chapter 6: Conclusions
Evaluation of the Methodological Framework
Complexities of the Strategic Decision-Making Process for Outcome-based Asset Management
Chapter 7: Steering Factors and Recommendations
7.1 Analysis of Steering Factors in Thames Water
7.2 Recommendations for Strategic Decision-Making
Chapter 8: Reflection and Future Research
End of the Thesis
Thames Water Strategic Asset Management Process
Capacity to Analyse the Strategic Decision-Making Process
Capacity to Analyse the embedded influences of Strategic Decision-Making Process
Internal Interrelation of the Strategic Decision-Making Process
Chapter 4 Analysis of the Strategic Decision-Making Process
4.1 Analysis of the Influences on the strategic asset management process
4.2 Analysis of the Influences on the Long-Term Strategies
Chapter 5 Analysis of the Socio-Technical Context Influences
5.1 Physical External Context
5.2 Social External Context
5.3 Analysis of the Physical
5.4 Analysis of the Cultural Embeddedness
5.5 Analysis of the Institutional Arrangement Influences
5.6 Analysis of the Governance Influences
Thames Water Socio-Technical Context
Analytical Framework/ Internal System

3 Case Study: Thames Water

This chapter describes the thesis case study. The strategic asset management structure is examined following the evaluative asset management framework with the chapter objective to answer the following research sub-question:

> What are the asset management long-term strategies and objectives of Thames Water in terms of investment on water supply physical assets?

First, a brief overview of the company will provide a sense of its environment (Sec. 3.1). The strategic asset management components are examined in sections 3.2 to 3.4 following the structure of the Evaluative Framework. First, the high-level components and relevant stakeholder requirements are presented (Sec. 3.2). Level 2 of the framework represents the Asset Management Policy at the strategic level (Sec. 3.3). Lastly, Level 3 is the level where the process to develop long-term strategies occurs (Sec. 3.4). At this level the different components of the process are discussed along with the identification of the long-term strategies and objectives. The chapter concludes by answering the sub-research question and re-examining the input-output-outcome model (Sec. 3.5). Figure below illustrates the evaluative framework established in Chapter 2 adapted to illustrate the sections of this chapter:

LEVEL 1 (SEC. 3.2)	LEVEL 2 (SEC. 3.3)	LEVEL 3 (SEC. 3.4)
Organisational Strategic Level	Asset Management Policy	Strategy and Objective
Company vision, mission and business policy (Sec. 3.2.1)	Policy Strategic Objective – Defining the Strategic Goals for Assets (Sec. 3.3.1)	Strategic Goals- Intent of the Service long-term strategies (Sec. 3.4.1)
Stakeholder requirements- Analysis of the main Stakeholders (Sec. 3.2.2)	Prioritising of Investment (Sec. 3.3.2)	Methods of Identification and Decision-making (Sec. 3.4.2)
Thames Water Strategic Objectives (Sec. 3.2.3)	Governance over the Asset Management Policy (Sec. 3.3.3)	Description of the Criteria and Tools for Optimisation (Sec. 3.4.3)

Thames Water's Long-term Strategies (Sec. 3.2.4)		Service Long-Term Strategies and Objectives (Sec. 3.4.4)

3.1 A Brief Overview of Thames Water

Thames Water is a private company which has been owned by Kemble Water Limited since 2006. Kemble Water Limited is managed by Macquarie Capital Funds (Europe) Limited. The shareholder consortium is comprised of Macquarie's European Infrastructure Funds and other non-Macquarie investors largely made up of pension funds and other institutional investors from Europe, Canada and Australia.

Thames Water is the asset owner of the entire water value chain and possesses the license of water services and sewerage in a regional monopoly environment. Figure 3.1 illustrates how the water value chain is structured in Thames Water. The company serves over 13.6 million customers in London and the Thames Valley, supplying on average 2,600 million litres of drinking water each day via 95 water treatment works and 31,400 kilometres of water mains (Thames Water, 2009). The wastewater business disposes and treats approximately 2,800 million litres of sewage every day via 68,200 kilometres of sewers and 349 sewage treatment works (Thames Water, 2013b). This makes the company the largest water and sewerage company in the UK. Their area of research in the water value chain is the water drinking supply within the wholesale section of the business. The sub-systems are Water Resources, Water Treatment and Water Distribution.

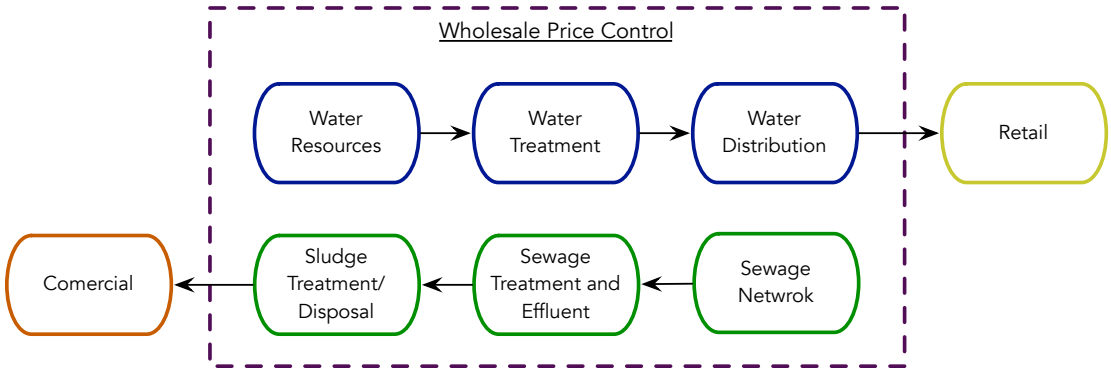


Figure 3.1: Water Value Chain structured based on Thames Water

3.2 Thames Water Strategic Level (Level 1)

This subsection describes the strategic objective level of Thames Water. The section provides a summary of the company mission and policy (Sec. 3.2.1), stakeholder requirements (Sec. 3.2.2), objectives (Sec. 3.2.3) and long-term strategies (Sec. 3.4.4) for Thames Water.

3.2.1 Company vision, mission and business policy

After the new shareholders acquired the company, the company vision and mission was changed. The current Thames Water vision is "If customers had a choice, they would choose Thames Water" (Thames Water, 2009). The mission makes reference to the monopolistic position of Thames Water in the region. The mission statement "provide(s) the best-in-class water and sewerage service that is profitable, sustainable and acts in the long-term interests of both our customers and the wider community" which provides the overall objective of the company on their intent of operation (Thames Water, 2009).

The main policy change after the 2006 acquisition was to lay down an organisational strategy to focus on delivering the objectives and commitments, by focusing on the core operations and customer base of the appointed water and sewerage business (Thames Water, 2009).

3.2.2 Stakeholder requirements- Analysis of the main Stakeholders

Thames Water is exposed to a number of different stakeholders that range from regulators, customers and private and public organisations. The main stakeholders are the regulators and the customers. The regulator requirements are based on regulations established by them and by legislative requirements and their strategic intentions. Customers' requirements are determined based on qualitative and quantitative research conducted by Thames Water, their complaint calls and consultations from the regulatory reports that the company needs to develop every five years.

The main requirements from the customers and regulators are related to affordability, water quality and water reliability. In addition, Thames Water conducts "willingness to pay" studies of their customers in order to understand their priorities in regard to particular issues such as climate change and enhancement of the infrastructure system.

There are three central regulators for the drinking water section. The responsibility for economic and financial regulation is assigned to the Water Services Regulatory Authority (Ofwat), the Drinking Water Inspectorate (DWI) which became responsible for overseeing the quality and safety of drinking water, and the responsibilities of the environmental and river basin function were transferred to the Environmental Agency (EA). The regulators regulate the operational plan of Thames Water with a frequency period of 5-years.

At the beginning of each regulatory period, key performance indicators (KPIs) are assigned. These KPIs are categorised into four themes: customer experience, reliability and availability, environmental impact and financial. The table below provides a summary of the stakeholder requirements and the regulations for the water supply side. A more detailed stakeholder analysis is provided in Appendix 10.5.

Table 3.1: Summary of stakeholder requirements and regulations

Stakeholder and	Requirements

Regulations	
Customers	Affordability, leakage reduction, re-use of water and metering over alternatives related to security of supply, consideration sustainability
Water Services Regulatory Authority (Ofwat)	Involvement of customer views into the development of the plans and decision-making processes, reduce the Capex bias in relation to investment, foment innovation in the sector and separate wholesale controls
Drinking Water Inspectorate (DWI)	Drinking water compliance, demonstrate investment to provide resilience and maintain a sustainable level of investment on quality programmes and on asset maintenance to ensure safe drinking water
Environmental Agency (EA)	WFD, take a long-term view (25yrs) taking into account the impact of climate change, take better account of the value of water by reflecting its scarcity, consider all the options related to securing the supply of water, reduce demand through lower leakage and water demand management and ensure

	customers views are taken into account in plans
Customer Experience	Service incentive mechanism (score based on complaints of the customer), water supply interruptions (hours per total properties)
Reliability and Availability	Serviceability of water treatment (such as water quality) and water distribution, leakage (ml/day), Security of Supply Index (Index score based on water available to use against demand)
Environmental Impact	Greenhouse gas (GHG) emissions, pollution incidents (water)
Financial	Post-tax return on capital, credit rating, gearing, interest cover

3.2.3 Thames Water Strategic Objectives

The company board and the executive level define the strategic objectives of the company, and are reviewed at each review period. The company's strategic objectives for the last review period are planned to be amended in the upcoming 2014 review period. The actual strategic objectives were developed with the aim of meeting the requirements of the stakeholders, regulators and shareholders (Thames Water, 2009). The objectives cover areas of risk, involvement with the customers, environmental

impact and efficiency of the system (Table 3.2).

Table 3.2: Strategic Objectives for the 2009 price review period.

Strategic Objectives	Description
Secure service levels	The objective focuses on assessing risks from their operation. Risks are focused on the reliability of the system to provide the service required by customers and regulators and maintain a positive supply-demand balance to couple with forecasted growth in demand for services over the longer term.
Be responsive	The objective focuses on reflecting customers' priorities on the investment decisions. For example: "intend to reduce sewer flooding, address localised issues affecting the appearance of tap water, and improve customers' experience when dealing with billing or operational matters" (Thames Water, 2009, p. 12).
Act sustainably	Actions related to this objective include considering climate change effects, demand of water and carbon emissions in the investment decisions. There is an emphasis on improving the performance of the wastewater operation.
Ensure value for money	Objective focus on increasing operational and capital efficiencies, including moving to a new operating model and an efficient approach to financing the business. Main actions are related to innovation, in particular a more real-time operational system, more elaborated decision-making tools for investment, operation optimization.

For the next price review period, the objectives established by the executive level are defined using an outcome-based approach established by Ofwat ([1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]). Thames Water has defined outcomes at different levels of the business, e.g. outcomes at the executive level, financial level, asset level, etc. Outcomes at the high level have become the business objectives for the next price review period and are expressed in a customer focus way per the definition of

outcome provided by Ofwat (Ofwat, 2011b)

In the table below, there is a summary of the company objectives for the next price review period. These outcomes will be the basis of the development of the plan for the regulatory period and long-term strategies (Thames Water, 2013b). Outcomes proposed from Ofwat for PR 2014 are described next to Thames Water outcomes based on the possible interrelation (Table 3.3).

Table 3.3: Comparison between Thames Water and Ofwat Outcomes (Source draft Thames Water 2013, p. 3)

Thames Water Outcomes per draft Five-Year Plan	Possible relation to Ofwat Outcomes
Provide a safe and reliable water and sewerage service that complies with all necessary standards and is available when our customers require it	Mitigating Risk
Demonstrate to customers and stakeholders that they can trust us, that we are easy to do business with and that we care	Revealing Information
Provide the level of service our customers require, in the most economic and efficient manner, to ensure their bills are no more than necessary	Securing Value for Money
Limit the impact on the environment to achieve a socially responsible and sustainable business for future generations	Using Resources Better
Offer customers choices as to what services they use, how and when – such as how to get in touch, how we bill them and how they pay	Focus on Delivery

Thames Water's strategic objectives are defined from Thames Water strategic stakeholder perspective ([9], [10], [7], [8], [5], [6]). The measurable objectives will be evaluated and an adjustment period based on the business and stakeholders' priorities would be expected. The company is still working on defining their outcomes at the

lower levels. To provide an idea, these are preliminary operational outcomes: Customer Experience, Affordability, Service Today and Tomorrow, Meet New Statutory Requirements, Manage Business Resilience, Develop Sustainable Environments and Communities, Financial Stability, Engaging Stakeholders, Innovating and Continuously Improving.

3.2.4 Thames Water's Long-term Strategies

Thames Water's long-term strategies are reviewed at each regulatory period. The company's long-term strategies are based on the long-term priorities. They are the objectives of the company over a 25-yr timeframe defined in consultation with the customers and other stakeholders (Thames Water, 2012c). These long-term priorities are the outcome-based objectives described above; that they underpinned by measurable objectives (or now outcome-based outputs) and defined for the different areas of the business. Long-term priorities (what they want to achieve), outcomes (how they would be measured) and strategies (how to deliver the outcomes) create the strategic framework for the different organizational policies and strategies. The long-term strategies for the company are included in Table 3.4.

Table 3.4: Thames Water Strategies (Source: Thames Water, 2012)

- Minimise the amount of water that is taken from the environment
- Be efficient in the use of water
- Be a good neighbour and promote water value
- Real-time control and monitoring to target investment to reduce customer service failure
- Source control
- Working in partnership to manage drainage holistically
- Maintain Sewage Treatment Works compliance in a sustainable manner whilst reducing costs
- Maximise energy recovery from sludge

3.3 Asset Management Policy Level (Level 2)

The asset management policy at Thames Water provides definitions and guidelines of

how asset management should work and how other policies, such as Risk Management ([10], [9]), should be taken into consideration. The policy level is described based on the Asset Management Policy Level. The asset management policy level can be described within three main areas: the policy strategic objective (Sec. 3.3.1); prioritisation of investment (Sec. 3.3.2), and governance over the process of the asset management system (Sec. 3.3.3). The policy strategic objectives refer to the relationship between the asset management level to the organisation strategic plan, involvement with stakeholders and relation to other organisations. The prioritisation of investment refers to the framework to control the strategic asset management. The investment areas are grouped by assets that are defined by the asset management executive level on where investments would be focused during each regulatory period. The governance of the asset relates to the risk management framework utilised for the asset management planning.

3.3.1 Policy Strategic Objective – Defining the Strategic Goals for Assets

At the asset management strategy level, there is a fusion between the asset management policy and the asset management strategies ([10]). To decouple the asset management policies from the asset management strategies, Thames Water developed the strategic policy objectives. The strategic asset planning section defines these strategic policy objectives.

The strategic policy objectives for asset management define internal guidelines to deliver the outcomes and business priorities from the asset base perspective ([10], [9], [6]). In other words, the policies integrate the company strategies and long-term priorities on what needs to be done, and how ([10], [9], [8], [5]). The policies for the water sector are described below:

Table 3.5: Asset Policy Strategic Objectives (Source: Thames Water, 2012)

- Promote metering and investigate re-use opportunities
- Reduce process water losses
- Raise awareness through advertising and billing
- Develop technology and methods to support fact based decision making
- Work proactively with customers and stakeholders to maximise capacity of existing assets

For the 2014 review period, the outcome-based objectives of the company are broken down and come into asset management outcome-based objectives. Preliminary outcomes are affordable bills, stewardship and a reduction of carbon print. These outcomes will be translated into measurable objectives and policies.

3.3.2 Prioritising of Investment

Investments on the assets are proposed during each price review period and are divided into 50 investment areas, which are determined by the executive and the asset management level. The asset management level suggests the different areas of investment and the executive level determines the final areas of investment during the regulatory period ([9], [3], [10]).

These investment areas are comprised of asset groups or activities that are defined from the company objectives and strategies, and reflect the customer and business priorities. Normally, the areas are divided 50/50 between water and wastewater businesses. In the next section, how investment areas are part of the asset management process will be discussed (Sec. 3.4.2).

The Water Distribution sub-sector has been the main area of focus for Thames Water and the regulators. This sub-sector is where customers are directly affected, and where customers have directly expressed an interest on repairing leakages ([1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]). Investment areas that are relevant for the long-term strategies within the water supply business are summarised in the table 3.6.

Table 3.6: List of preliminary investment areas for 2014 Price Review Period (Source: Thames Water, 2012)

Water Value Chain	Investment Areas
Water Distribution Service	Trunk Mains
	Distribution Mains
	Storage Reservoirs
	Tunnels and Aqueducts
	Network Pumping Stations
	Water Infrastructure Other
	Revenue Meters (planned and reactive replacement)
Water Reservoir Service	Resource Development
	Low Flow and Drought Management
	Water Efficiency and Leakage
Water Treatment Service	Large London Process Plants (LLPPs)
	Other Surface Water Treatment Works
	Ground Water Treatment Works
	Drinking Water Quality
	Raw Water Pumping Stations

3.3.3 Governance over the Asset Management Policy

The asset management process is a risk-based process that evolved from the Capital Maintenance Planning Common Framework (CMPCF or Common Framework) and Asset Management Planning Assessment Process (AMPAP). The common framework is a guideline that was put forward by Ofwat during the 2009 review period of the water industry to create a risk-based approach for the decision-making process on assets (Defra, 2011). The guidelines specify how the company should: 1) translate their data into the risk; 2) assess their risk; 3) develop interventions; and, 4) prioritize actions over that risk. The Common Framework approach is the base for the company risk-based strategic decision process and asset planning. More details on the Common Framework are included in 10.7.

Since the 2009 price review period, Ofwat conducted an Asset Management Assessment (AMA). The criteria for this assessment were: Stakeholder Engagement; Leadership, Policy and Strategy; Management; Processes; Systems, Data, Analysis and Reporting; and, Balance (Ofwat,

2008). On the past review period Ofwat challenged Thames Water's reliance on expert judgement, asset data issues and their lack of integration and use of asset planning tools (Linscott, 2012). In response, Thames Water launched the Data Improvement and Decision Support Tools Programme. The objective was to improve data quality in key areas and implement tools that improve investment cases to the regulator in time for the 2014 review period ([1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]).

The programme focused on four main areas: Data Cleanse, Strategic Data, Decision Support Tools and Whole Life and Unit Costing. Data Cleanse and Strategic Data are concentrated on improving data management and data requirements defined for the price review 2014. Decision Support Tools and Whole Life and Unit Costing programmes are focused on developing models and tools to develop integrating decisions. The programme has launched 15 asset class investment-planning tools to prioritise against AMA. In addition, there has been a focus to improve cost data availability for the WLC assessment (Linscott, 2012). A list of these tools is provided in Appendix 10.7.

Another action was documenting procedures with the objective to provide a more transparent asset management process since this was highlighted during the AMA. The mapping procedures focus on demonstrating how outcomes-based objectives are translated down to the activities at the asset level. The process maps connect the investment decisions taking into account the corporate and business level and how those investments transpire back to the lower level and activities. The process map at Thames Water is called the gateway process, where decisions for investments are challenges at each gateway process. Thames Water can then be in a position to justify investments to regulators, customers and other stakeholders ([6], [9]).

3.4 Asset Management Strategies (Level 3)

At this level the strategies are defined and the objectives for the assets are identified.

The intent of the asset management strategies is to translate the business objectives in terms of what is needed in the water supply side ([10]). A strategy (such as asset strategy, service strategy, long-term strategy) is defined based on the regulator requirements, historical knowledge and as asset-operating plan. The strategy provides the guidelines or framework to identify which asset requires to be renewed, and in what time frame ([3]). Strategies are divided into service and asset strategies. The service strategies are Thames Water's long-term strategies for their assets and the scope of this research. According to the strategic group manager, efforts have been focused on implementing a decision-making process with the goal to develop long-term strategies that are based on providing a service, and are not asset centric ([10]). Service strategies are the framework for the actions and objectives needed under a 25-yr timeframe, with targets divided in 5-yr segments.

Following the evaluative framework, this section discusses the strategic goals (Sec. 3.4.1), methods for identification and decision-making (Sec. 3.4.2) and criteria for optimisation (Sec. 3.4.3). The section finishes with the list of the service strategies and objectives for the next review period (Sec. 3.4.4).

3.4.1 Strategic Goals- Intent of the Service long-term strategies

Strategic Goals are defined as the ends towards which effort and action are directed at the asset level. The strategic goals are defined in Thames Water as Policy Objectives and they aim to provide internal guidelines on what and how to deliver the long-term priorities and outcomes. The strategic goals are divided into sub-systems of the water value chain: Water Resources, Water Treatment and Water Distribution. Five strategic themes define the aims of the policy objectives (strategic goals).

3.4.1.1 Water Resources Policy Objectives

There are 12 strategic goals defined for the long-term strategies on water resources (Table 3.7). Most of these strategic goals are focused on reducing the demand of the water infrastructure system by reducing leakages and losses, and influencing the customer consumption behaviour with the use of metering.

Table 3.7: Water Resources Strategic Themes and Strategic Goals (Source: Thames Water, 2012)

Themes	Water Resources Strategic Themes
Take Less	Maximize the use of existing assets and reducing the levels of demand to limit the amount of water taken from the environment
Lose Less	Reduce the amount of water lost through treatment and distribution, and having a resilient quantity and quality of supply through the safe operation of sites, and reduce site losses
Increase Capability	Increase water resource management technical knowledge and hardware / software support
Understand More	Work towards a real-time controlled and monitored system that enables a greater understanding of performance leading to targeted investment to improve resilience and deliver improved customer service
Be a Good Neighbour	Improve engagement and promote the value of water to reduce demand for water

Strategic Goals (Policy Objective)	
Water Resources	• Optional and compulsory metering to reduce customer demand, provide information on leakage, wastage and high usage (Take Less, Lose Less, Understand More) • Indirect Planned Potable Re-use (IPPR) through targeted schemes at large sewage treatment works in London (Take Less) • Artificial aquifer recharge to ensure that resource use is flexible and maximises existing licences where appropriate (Take Less) • Inter and intra company bulk transfers to maximise existing licences internally and to make best use of resources regionally (Take Less) • Programme of demand management and customer education (Take Less) • Increase available water resources in the London zone through supply side loss reductions (Lose Less, Understand More) • Targeted mains replacement to further reduce levels of leakage in the network (Take Less) • Increase internal technical capability on water resources and hydrology (Increase Capability) • Increase capability of water resource planning tools that are linked with day to day operation and include cost of operation (Increase Capability) • Focus on analysis of meter data and continue to develop water resource tools (Understand More) • Promote the value of water to aid demand reduction (Be a Good Neighbour) • Work with stakeholders to find holistic solutions (Be a Good Neighbour)

3.4.1.2 Water Treatment Policy Objectives

There are eight strategic goals for the water treatment section aiming to improve the asset capability of new technologies and asset management tools, techniques and practices (Table 3.8).

Table 3.8: Water Treatment Strategic Themes and Policy Objectives (Source: Thames Water, 2012)

Themes	Water Treatment Strategic Theme
Take Less	Maximise the use of the existing assets and efficiently reduce the amount of water taken from the environment
Lose Less	Build resilient quantity and quality systems of supply through the safe operation of sites, reduce site losses
Increase Capability	Increase technical knowledge on system operations
Understand More	Work towards a real-time controlled and monitored system that enables investment targeting to reduce customer service failure
Be a Good Neighbour	Improving engagement and promoting the value of water to reduce demand for water
Strategic Goals (Policy Objective)	
Water Treatment	• Maximise use of existing assets through the refurbishment of the asset base to optimum design capability (Take Less) • Improve efficiency through reduction in process losses and improvements to component efficiency (Take Less) • Reduce environmental impact through reduction in carbon footprint and improvements to effluent discharges to receiving watercourses (Take Less) • Resilient and quality supply to customers through safe operation of sites, provision of standby assets, improved storage provision and flexibility in linkages to other network zones and identification (Lose Less) • Increase internal technical process engineering knowledge to improve system resilience (Increase Capability) • Develop overall system resilience understanding (Increase Capability)

	• Improve asset performance and extend asset life-spans through increased levels of automation and control achieved through improved metering and linkages to SCADA (Understand More) • Promote the value of water to aid demand reduction (Be Good Neighbour)

3.4.1.3 Water Distribution Policy Objectives

There are nine strategic goals for the water distribution section aiming to improvements similar to the treatment work. The main difference between their strategic goals is the focus on the optimisation of activities to improve the performance of the distribution system (Table 3.9).

Table 3.9: Water Distribution Strategic Themes and Policy Objectives (Source: Thames Water, 2012)

Themes	Water Distribution Strategic Theme
Take Less	Promotion of demand management to reduce the demand on the system
Lose Less	Continue to reduce losses from the system
Increase Capability	Increase technical knowledge on system operation
Understand More	Work towards a real time controlled and monitored system that enables target investment to reduce customer service failure and extend the life of existing assets
Be a Good Neighbour	Engage and promote the value of water to reduce demand for water

Strategic Goals (Policy Objective)	
Water Distribution	• Reduce the cost of trunk and distribution mains replacement (Take Less, Lose Less) • Innovate ideas in the use of no-dig techniques (Take Less, Lose Less) • Improve network performance through system control (Understand More) • Improve accuracy of leakage targeting through the use of technology (Understand More, Lose Less) • Improve the understanding of usage/demand/leakage through metering roll-out (Understand More) • Continue to gather quality data to improve the understanding of the asset and impact to the customer (Understand More) • Maintain / improve network condition in the short / medium term through targeted mains replacement (Lose Less) • Increase technical knowledge on system operation (Increase Capability) • Improve engagement and promoting the value of water to reduce demand for water, and to extend the life of the asset base (Be Good Neighbour)

3.4.2 Methods of Identification and Decision-making

In this subsection, the methods involved for risk identification and decision-making are described.

3.4.2.1 Identification of the Risk Position

Thames Water has utilised a framework that describes the main areas where risks are identified. This process in the past review period has been conducted based on expert judgement. One of the areas where improvements have been done to reduce expert judgement is on the risk identification. Thames Water has focused on implementing models that are more capable of identifying risks and improved investment decisions by having a system-based approach ([1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]). Some of these are deterioration models (asset base), resilience models (system base) and Asset Investment Management (AIM). As a result, Thames Water has highlighted the fact that where they thought they had a risk, they in fact did not. However, where

they have a risk, they have been able to start quantifying the risk and act where they really need to do something or where they do not ([10]). The risk identification framework is described in Table 3.10. Risks considered in the decision-making process are labelled as *need*.

Table 3.10: Risk Identification Framework

Drivers	Description
Capital Maintenance needs	Identified against a threshold defined by risk to service performance.
Quality needs	Identified by stakeholders (Environment Agency, Drinking Water Inspectorate, DEFRA).
Supply demand needs	Identified by modelling future population increases against current assets to identify areas where levels of service will deteriorate with growth projections.
Enhancement needs	Identified on the basis of customers' priorities for service improvements.

After a risk is promoted to a need, then it passes to the identification of the Risk Position with Asset Planning System (APS). APS is a corporate database with a web-based frontend that was introduced to the company in 2007 to replace the existing Operations Risk Register. For the required asset, it holds all the risks, needs, solutions, costs and impacts with full links and an audit trail (Thames Water, 2009). These elements are held for each Output Performance Measure (OPM), and a review of the investment requirements for over 25 years. APS establishes pre and post risk positions (based on sub-lines, asset types, dates, project references etc.) that are used to determine the cost-benefit of the need/solution. The result is the benefit level of the need/solution that feeds the Investment Management System (IMS), which is capable of reporting by geographic areas, assets, and risk type to help produce long term Asset Plans.

3.4.2.2 Risk Framework - Output Performance Measure (OPM)

OPMs are a number of risk frameworks linked to the service performances (such as security of supply, interruption of supply). OPM aligns services to elements such as customers, the environment, and business and asset stewardship drivers. Each framework provides a risk position based on the characterisation of the risk and the impact to these elements. The characterisation of the risk is done on the basis of the frequency of failure and the probability of failure leading to the impact. The impact on the customer and business is determined on the basis of the severity of impact and quantity of impact (Figure 3.2).

(frequency of failure) * (probability of failure leading to impact)

*

(severity of impact) * (quantity of impact)

Figure 3.2: Overall Equation for the OPM

The determination of the inputs for these variables is based on Decision Support Tools, expert judgement or the system database. Each OPM has a different level of impact and different ways to measure these levels. For example, there is an OPM for Security of Supply and one for Interruption to Supply. Interruption of Supply computes the impact of the customer at different rages of hours/ days. In the case of Security of Supply, the OPM quantifies the impact in terms of the water capacity to supply a particular zone or area.

3.4.2.3 Cost-benefit Analysis

The cost-benefit analysis is conducted for each of the needs/solutions to identify their beneficial level. First, the risk is defined in terms of money. The beneficial level is the difference between pre-solution risk and post-solution risk. The general framework for the element to monetise the risk is provided in Table 3.11.

Table 3.11: General Framework for Cost-benefit Analysis Application (Source: Thames, 2011)

Costs Block	Benefits Block
Capex (£) Incremental Opex (£/yr.)	Costs avoided (repairing asset failure) (£)
Embodied Carbon (tonnes)	Costs avoided (service failure) (£) - Fines, Clean up costs, Legal costs
Operational Carbon Impact (tonnes)	Willingness to Pay (£)
Project Traffic Disruption Environmental and Social Cost (£)	Avoided Environmental and Social Costs (£)

3.4.3 Description of the Criteria and Tools for Optimisation

The following subsections describe the approach and tools that Thames Water uses for the optimisation of the long-term strategies.

3.4.3.1 Investment Areas- Optimisation-Frame

Investment areas provide Thames Water with the ability to optimise the programmes on the basis of asset groups having common risks with different impacts. Solutions will be related to a particular failure. Normally these failures represent different areas within a benefit. For example, sludge is a problem to Thames Water as a company, but it does not really have an impact on the customer. On the other hand, odour is an impact to the customer, and does not have a direct impact on the business ([3]). They affect the same asset; so needs/solutions related to the same asset are combined by an investment asset. In this way, it is possible to look into all pipes and leakages or look into all water treatment works where there are pollutants and odour issues. Optimization is not capable in advancing to optimize the whole programme together. After optimization, all the investment area is passed onto another team that balances the entire programme.

3.4.3.2 Investment Management System (IMS)

Need/solution selections are based on the benefit level and it is optimised using the IMS. IMS is an optimisation tool which uses costs benefit analysis as the basis for solution selection and is included in an optimised programme. IMS optimisation is fundamentally based on selecting solutions that generate the maximum net benefits/reward based on the parameters entered into the programme. The optimisation is performed against the whole life cost and the whole life benefit of each of the solutions in the system. For the 2014 Price Review, a new parameter included in the optimisation was the customer bills; what the customer was going to pay for the investment ([3]).

The programmes are assessed based on five criteria (Financial, Customers, Sustainability, Delivery and Flexibility) (Table 3.12). IMS looks into monetised and non-monetised effects of the plan in a structured way (Thames Water, 2013a).

Table 3.12: Criteria to Optimise Solutions

Criteria	Description	
Financial	Total NPV	Environmental and Social (E&S) and Carbon NPV
Customers	Alignment with customer preferences	The bill impact for AMP6
Sustainability	Government	Strategic Environmental Assessment (SEA)
Delivery	Deliverability	Flexibility
Resilience	Sensitivity	Regional perspective

The Financial requirement is evaluated under three parameters. These are Total NPV, Environmental and Social (E&S) and Carbon NPV. The NPV is described for all the schemes in a programme. These include the financial costs, Opex and Capex and the monetised environmental and social impacts (including carbon emissions).

The Customer requirement is focused on efficiently delivering the outcomes that the customers hope for (Thames Water, 2013a). There are two parameters: the bill impact for AMP6 and the alignment with customer preferences. The bill impact simply refers to the relative impact of the programme to the current bill costs. The alignment with customers is based on research where customers have expressed a preference in terms of investment options.

The Deliver requirement measures the relative deliverability of the plan. The optimisation will produce a plan with the least cost but will not take into account the non-monetised risk of delivering that programme. The two parameters are: deliverability and flexibility. Deliverability takes into account aspects of how the programme will be delivered, the business synergies and risks. Flexibility takes into account aspects of the flexibility of the programme and, whether the programme contains elements that can be readily modified.

The Resilience requirement is based on an assessment to understand the degree of how each option could be affected by future uncertainties and deliver the expected benefit. The two parameters are: sensitivity and regional perspective. Sensitivity measures the effect to changes, such as cost on power and chemicals, ability to deal with population change and network integration, and water quality.

This assessment can be conducted using strategic or optimisation scenarios. Within these criteria, optimisation applies to those that are relevant for the optimisation of that particular programme. The main decisions relate to whether the programme is optimised against willingness to pay or cost of failure. Willingness to pay is the level that is identified by which the customer will pay for a particular investment. The willingness to pay is determined by conducting surveys and producing a statistical determination of the average willingness to pay per household. Cost of Failure is the money saved by eliminating a certain risk.

The scenarios objectives and results are dependant on the subsection of the water system. A general description of the objectives and limitations is provided below

based on Thames Water analysis.

Table 3.13: Investments Scenario for the Optimisation Process (Source: Thames Water, 2012)

Investment Scenario	Description
Short-term minimum spend approach	• Objective of maintaining the existing levels of serviceability with the minimum amount of capital and operational expenditures. • Scenario is calculated with a bottom-up assessment of the *needs*, and a limited focus on developing capability and data • Results of the assessment led them to not meeting the strategic goals and would lead to more expenses in future planning periods.
Long-term maintenance spends approach	• Objective of maintaining the existing levels of serviceability with minimum spend, but moving the focus to the asset lifecycle management and minimum whole life cost of the asset-based. • Assessment of the *needs* is based on a bottom-up approach considering the future asset replacement, efficient asset acquired to operate at minimum whole-life cost, deterioration profile of assets with significant risk to customer. • Focus on investment profile, a focus on data, capability and in system control. • Results led to long-term supply reliability but did not respond to long-term uncertainty

Resilience approach	• Objective to increase the resilience of the asset system against uncertain external factors such as climate change and population growth. • Framing solutions that will enhance the flexibility of the system, and adapt to internal and external impacts, the long-term goals will be achieved. • Identification of *needs* is based on resilience modelling, which is fed by their knowledge on the asset availability and deterioration. • Focus on data, capability and system control and strategic links to increase flexibility. • Results meet the majority of the strategic goals, and customers' requirements for a safe and reliable supply. However, high capital expenditure would be needed.
Sustainability approach	• Objective is a sustainable water infrastructure system through a planned reduction in the use of energy and carbon emissions. • Focus on solutions that will promote the use of efficient plants and reduce energy/materials and consumable usage, data, and capability and system control. • Result addresses the majority of the strategic goals. • High levels of investment which may not be needed in the future if demand growth does not materialise. It would also result in a heavy Capex, risk avoidance approach to managing the service.

3.4.4 The Service Long-Term Strategies and Objectives

The service long-term strategies and objectives are examined in this subsection. The long-term strategies and objectives are organised based on the segments Water Resources, Water Treatment and Water Distribution) of the water supply.

3.4.4.1 Water Resources Strategies and Objectives

Strategies from the water resource segment separate effort between demand and supply (Table 3.14). Strategies from the water resource segment interconnected with the development of the Water Resource Management Plan and the approach

conducted during the plan (See Appendix 10.2.4). As it is proposed in the plan, the strategies separate effort between demand and supply. In the demand side, the strategies focussed into reducing the demand in a short to medium term. On the supply side, strategies are focused on creating new resources such as indirect reuse (considering cost effectiveness and operational viability). The investment approach is around a minimum whole life cost that is focussed on leakage reduction, water efficiency and metering, where it reduce the amount of water abstracted. However, in a long-term investment in a large resource storage will be necessary. This decision will be determined based on the progress of better understanding form the system. The objectives to deliver the strategies are divided based on the review period. On the demand side, the objectives focus on reducing the demand over the review period 2014-2019.

Table 3.14: Long-term Strategies and Investment -Water Resources

Strategies	Objectives
Key Elements of the Strategy	**Key Actions Underpinning the Strategy**
Focusing primarily on demand reduction through metering and continued leakage activity	Implementation of compulsory metering programme within 2014 Review Period to deliver 80% of leakage repairs by 2025 (Take Less and Understand More).
In the short-term, selected implementation of IPPR schemes along with minor ground water development schemes	Develop new tariffs by 2020 to reflect the changing value of water and the change in the value as scarcity increases during drought conditions (Be a Good Neighbour)
In the long-term, continue to focus on demand reduction but develop a regional South East solution to increase available resources through either transfers, re-use or additional storage	Reduce leakage by [50Ml/d] through a combination of pressure management, metering and some mains replacement (in targeted areas) (Lose Less)
Focusing on data and control to better understand the performance of the assets and improve the targeting of the investment needed	Further reduce leakage by specific numbers defined with customers (Lose Less)

Focusing on improving the management of water resources through technology and developing class-leading water resource analysis capability to meet the future demands on the system operation	Reduce overall system losses through quantification and additional foreseen metering benefits such as Capex avoidance, understanding of wastage and usage levels (Lose Less)
	Focusing resources on data and control – placing operational intelligent control as central to the long-term operation of the business and moving to real-time control information by 2025 (Understand More)
	Extending current water resources modelling tools to include cost and link to network and production tools to understand overall system resilience (Increase Capability)

3.4.4.2 Water Treatment Strategies and Objectives

The Water Treatment Strategies main objectives are focused on improving the performance of the system. Objectives entail establishing a plan to deliver the strategies in an escalated way to reach resilience of the system. The Water Treatment Strategy is characterised by identifying the objectives that Thames Water wants to reach but using a flexible approach. The strategy would balance between maintaining the system in the condition and learn from the system to gradually move to a more resilience and sustainable system. The approach is to mitigate the consequences of overinvesting or underinvests due to the uncertainties of the future (Table 3.15).

Table 3.15: Long-term Strategies and Investment -Water Treatment

Strategies	Objectives
Key Elements of the Strategy	**Implementation Actions Underpinning the Strategy**
No less than short-term minimum spend on all assets	Fixing 'must do' items such as short life assets

Resilience where risk is untenable	Developing a programme of work to improve the resilience in 2014 Period at large treatment works (Take Less and Lose Less)
Gradually bring all works up to their original design capacity over a 10-15 year period - the timing of which depends on demand growth	Restoring sites with immediate capability issues (Lose Less)
Increased focus on data and internal capability to continue to allow better decision making in the future	Rolling-out a programme of power resilience to sites over 2019 Period (Take Less and Lose Less)
	Rolling-out a programme of technical capability improvement over AMP 6-7 (Increase Capability)
	Focusing resources on data and control - placing operational intelligent control as central to the long-term operation of the business (Understand More)

3.4.4.3 Water Distribution Strategies and Objectives

Strategies and objectives for the water distribution follow a similar approach as Water Treatment Strategies. The focus on the short-term is to reduce the deterioration of the system and move into a more resilience system in the next 10-15 yr. Reduction in deterioration is based on a whole-life cost network management. Decisions on investment are aligned with strategies from the Water Resources and will be supported by the current and innovations on investment targeting programs. The flexibility of options is limited due to the pressure to reduce leakage. Thames Water has identify the need to increase the value of repairing leakage by considering a more integrate approach (Table 3.16).

Table 3.16: Long-term Strategies and Investment -Water Distribution

Strategies	Objectives
Key Elements of the Strategy	Implementation Actions Underpinning the Strategy

Move to a resilient network approach over a 10-15 year period	Focus on reducing the cost of trunk and distribution mains replacement (Take Less and Lose Less)
A programme that focuses on whole-life cost network management to ensure that the network does not deteriorate in the 2014 Period.	Maintaining network condition in the short term through targeted mains replacement with increased levels of replacement in the longer term (Lose Less)
The use of innovation in investment targeting and solution delivery (approach works in synergy with Water Resource approaches, which includes some leakage reduction in the 2014 Period)	Improving accuracy of leakage targeting through the use of technology (Lose Less and Understand More)
	Improving understanding of usage/demand/leakage through roll out of metering (Understand More)
	Improving network performance through system control (Understand More and Increase Capability)
	Continuing to gather quality data (performance, pipe samples, customer complaints, costs) to improve understanding of the asset and impact on the customer (Understand More)
	Develop zonal hydraulic models and decision support tools and develop long term trunk mains strategy (Lose Less, Understand More and Increase Capability)
	Innovating in the use of no-dig techniques for trunk and distribution mains (Good Neighbour)

3.5 Case Study Discussion- Synthesis of the Chapter

What are the asset management long-term strategies and objectives of Thames Water for investment on water supply physical assets?

The asset management long-term strategies and objectives for Thames Water are a combination of short-, medium- and long-term strategies and objectives to maintain the service of the water supply infrastructure. The system borders as defined by Thames Water divide the strategies based on the water value chain: water reservoir, water treatment and water distribution. Within each sub-system, strategic goals are defined based on the characteristics and challenges of each sub-system and the company organisational strategic goals. These strategic goals are focused on reaching five thematic strategic goals: take less, lose less, increase capability, understand more

and be a good neighbour.

The Asset Management Evaluative Framework was used to examine the internal structure of Thames Water that led to the development of the long-term strategies and objectives. On the Thames Water Strategic Level the company's strategic objectives and stakeholder requirements were identified. The company defined a set of abstract long-term priorities based on customer value and overall outcomes defined by Ofwat. These long-term priorities are underpinned by outcome-based objectives and long-term strategies focused on the wholesale business. The company's outcome-based objectives have been defined every five-years as part of the regulatory price review. Up to the 2014 review period, these objectives have been changed for internal (change of owners) and external reasons (new regulations).

Stakeholder requirements are based on the stakeholder analysis. These stakeholders are primary regulators and other organizations (private and public) that work as an interface between government interests, societal needs and Thames Water activities. The main influential stakeholders are the EA, DWI, Ofwat and customers. Ofwat was identified as the mediator between the interests of the stakeholders and Thames Water and was also responsible for determining the regulatory requirements. These regulations were established with key performance indicators. The main stakeholders, their interests and regulations are then described from this analysis.

On the asset management policy level, the asset strategic goals for the water supply assets, which are named in Asset Policy Strategic Objectives, were identified. These asset strategic objectives are defined from the asset point of view, the company goals and strategies. Asset strategic goals are the end that Thames Water want to achieve with their asset base. The prioritisation of investment and the risk framework of the company are determined at this level. Investment areas of the assets are determined by the executive level based on their objectives and final determination of the price of water. Therefore, they are established every five-years during the regulatory price review process. Ofwat defined the risk management framework for all the water companies: Common Framework. The framework is the base for the risk management process to identify risk

and determine investment on physical assets.

Besides the strategic goals, the long-term strategies and the objectives, on the final level of the evaluation framework, the components of the asset management process are characterised. The main components are the identification of the risk position, output performance measure, cost-benefit analysis and optimisation. The risk position is determined based on four categories that will identify a need of investment based on the actual or future performance of the assets. OPM is the framework that translates that need into a quantified risk based on the impact on performance and service to customers. The cost-benefit analysis provides the framework to monetise the risks based on the benefit of reducing or eliminating the risk. Optimisation is dynamic and based on the objectives of the long-term priorities, and with criteria relating to the business, environment, customers and performance.

To conclude, the Asset Management Evaluative framework reached the objective of understanding the internal process of asset management at Thames Water. Based on the description of this evaluative process, the five influential factors have been indirectly identified (Performance Requirements, Business Objectives, Stakeholder Requirements, Risk Management and Regulations) as part of the asset-management process. Using the evaluative framework, high-level interrelations can be defined in relation to the organisational context (internal), strategic asset management process and the external context (Stakeholder Requirements and Regulations) (Figure 3.3).

Figure 3.3 illustrates the interrelation of the Asset Management Process with Thames Water. Using the input-output-outcome model, green lines represent the influential factors affecting the asset management process. The asset management process is risk-based with a customer centric focus while also considering the business objectives, regulations and customers as criterion of success. Golden lines represent the elements influencing the operation of the infrastructure. Influence is defined by the objectives, resources, activities and outputs. The interrelations and the influences of these elements are reviewed in the next chapter.

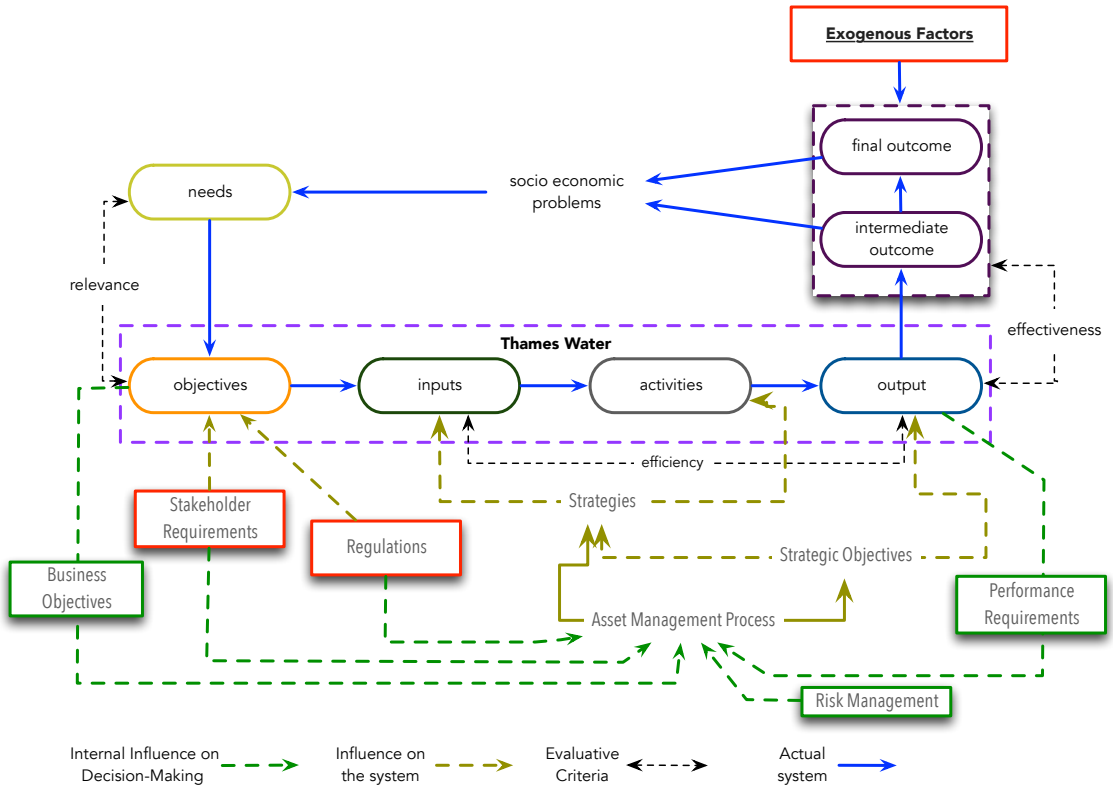
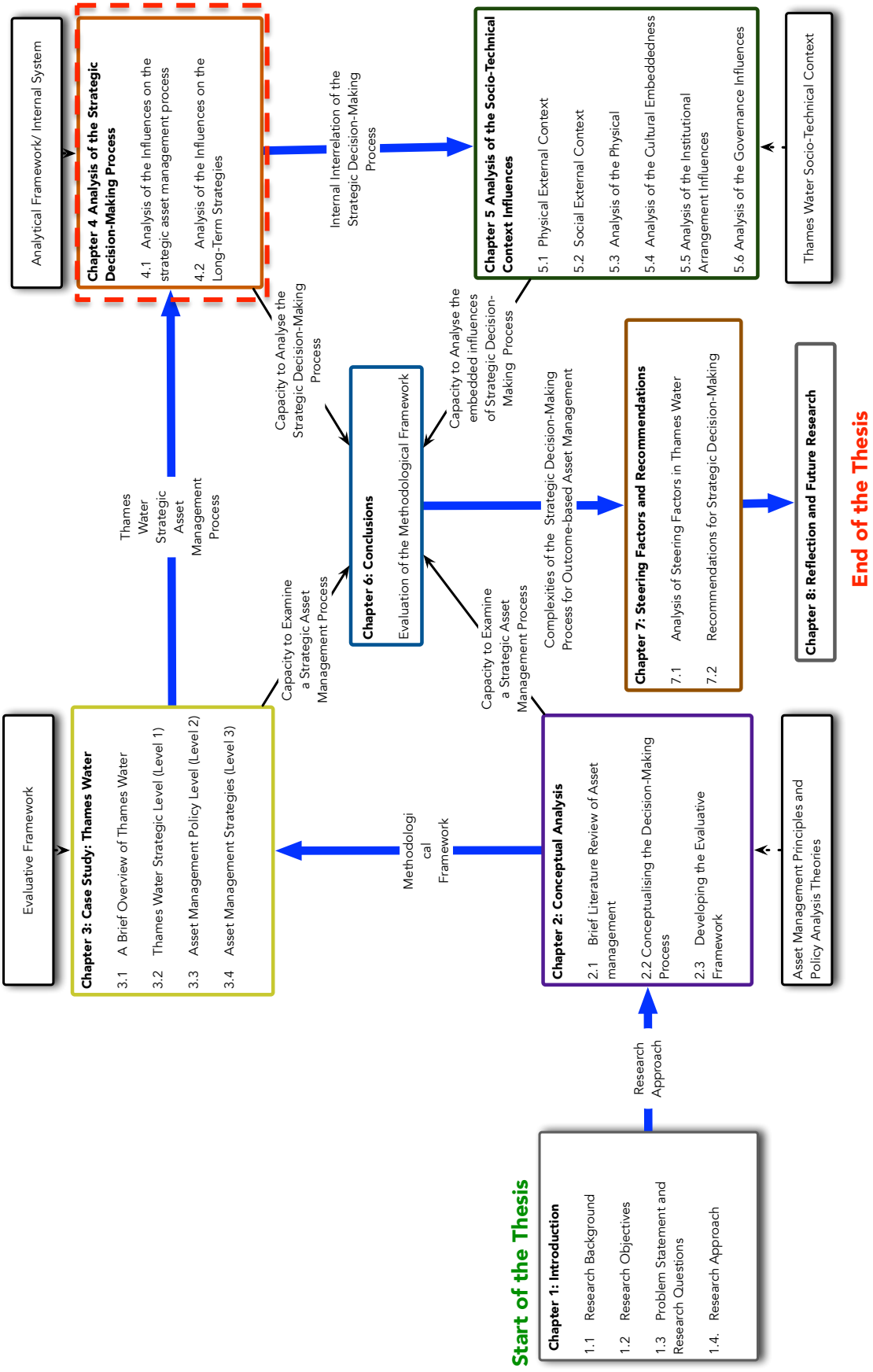


Figure 3.3:Input-Output-Outcome Model with Influential Factors

Chapter 4

Applying the Analytical Framework on the Internal Context

Analysis of the Strategic Decision-Making Process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4 Analysis of the Strategic Decision-Making Process

In this chapter the decision-making process is analysed based on the conceptualisation of the strategic asset management process at Thames Water. The objective of this chapter is to analyse the strategic asset management process using the analytical framework to identify the interrelation and influences of the decision-making process. The analysis will lead to answer the following two sub-questions:

> What is the asset management process of a company that applies a risk-based outcome approach?
>
> What are the influences on the decision-making process on accomplishing aligned outcome-based long-term strategies?

The interrelations and influences are defined based on the influential factors which characterised the decision-making process. The analysis conducted in this chapter embraces the assumption taken in this thesis that the influential factors are independently affecting the strategic asset management process. The analysis of the decision-making process contains two main steps. First the strategic asset management process is described and analysed on the basis of the influential factors. The influential factors are used as sub-frameworks to describe the decisions of the asset managers in different segments of the process (Sec. 4.1). Second, the decision-making process determines the long-term strategies and objectives and are analysed measuring the effects of the influential factors (Sec. 4.2).

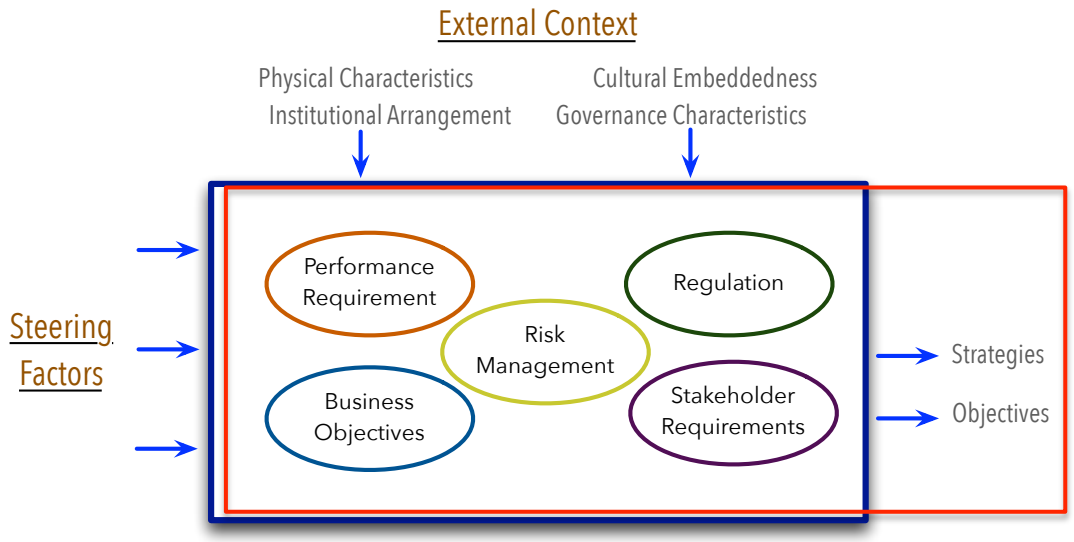


Figure 4.1: System Diagram-Analytical Framework for the Asset Management Process and Influential Factors

Figure 4.1 shows the section of the analytical framework that is used in this chapter. The red square illustrates the internal section, the decision-making system and the influence on the strategies and objectives.

4.1 Analysis of the Influences on the strategic asset management process

The decision-making process of Thames Water is analysed in this section by applying the influential factors over the strategic asset management process established at Thames Water. The strategic asset management process used for investment decisions is described and illustrated (Sec. 4.1.1). Then, each of the influential factors is identified; and where and how they act in the process is described (Sec. 4.1.2- 4.1.6).

4.1.1 Describing the strategic asset management process

The strategic asset management process refers to the procedure to develop strategic actions in Thames Water. The overall procedure applies to the business-as-usual decisions, Price Review Period and long-term strategies. The process for the asset management is comprised of 5 steps:

1) Past and current performance assessment

2) Predicted future performance

3) Risk analysis and need scoring

4) Solution development

5) Programme development

The detail of the process is slightly different when the focus is to develop 5-yr strategies vs. long-term strategies. Five 5-year strategies are asset centric and they are developed for each Price Review Period. Since the long-term strategies are developed for a 25-yr period, more iterative actions from the decision makers are incorporated and are based upon different criteria for evaluation ([10], [5], [8]). The asset management process for the development of long-term strategies is discussed below and it is a conceptual view of the established structure and approach that Thames Water is conducting for the 2014 Price Review and for the development of the 5-yr and 25-yr strategies.

The process starts by identifying risks at the operation level or by the strategy intention. The risk can be conceptualised as the gap between what is wanted with the strategy and the actual expected condition of the system. The risk is evaluated based on a preliminary framework to classify it as low-probability, low-consequence or high-probability, high-consequence. A risk that is classified as high-probability; high-consequence is promoted to a need. Risks that are considered low-probability, low-consequence are managed at the operational level and will not be considered for capital delivery. Risks identified as part of the development of a strategy are considered as need and/or forecasted need.

All the needs are assessed to identify their risk position. The risk position is determined utilizing a web-based programme, Asset Planning System (APS). APS will take that *need* and confront it against the respective Water Risk Framework or Output Performance Measures (OPM). APS will then link the needs to solutions

stored in the system that will mitigate the risks. A cost-benefit analysis is conducted on the needs/solutions to determine the respective benefit level.

The need/solution is then selected for the optimisation level based on its benefit level. Different needs/solutions are grouped on the basis of investment areas for optimisation. The optimization is conducted utilizing a computerised system; the Investment Managing System (IMS), whose output is via several programmes (portfolios of needs/solutions) that are forwarded to the next evaluation procedure.

The programmes are sent to the balancing team which will select the preferred programme. The selection is based on different aspects, such as the present environment with customers and regulators, Capex, Opex, and reward curves. For example, if there is a high level of complaints for low-pressure, that programme will be selected. After the preferred programme is selected, it is sent for delivery and development.

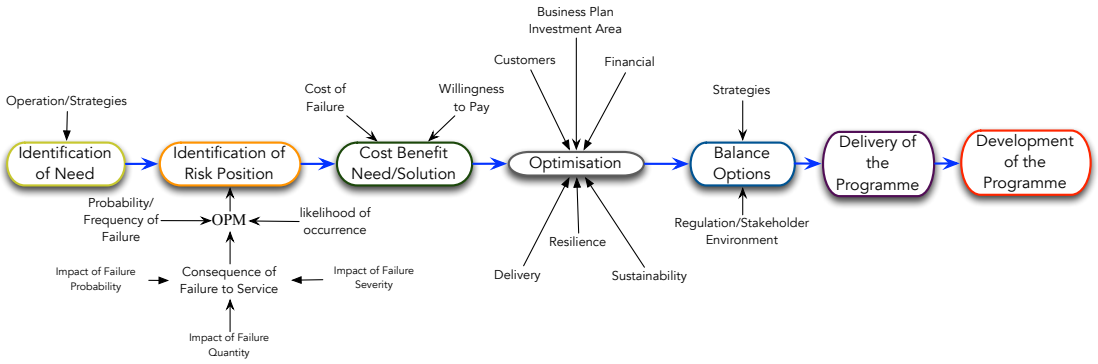


Figure 4.2: Strategic Asset Management Process (AMP)

The figure above represents the section of the asset management process that is relevant to the thesis. The structure is the base used for taking decisions and developing the long-term strategies. Combining the decision support tools and the structure above, the strategic team develops a series of iterations ('what if' scenarios, etc.) that leads to the long-term strategies ([5], [10], [8]). Sections 4.1.2 to 4.1.6 review the influence of the internal elements -Performance Requirements, Risk Management, Stakeholders Requirements, Regulations and Business Objectives - on the asset management process (AMP) of Thames Water. This analysis is based on the

described components of the asset management process in the previous chapter and long-term asset management process described and analysed in Appendix 10.6.

4.1.2 Determining the Influence of the Performance Requirement

The main interrelation between the performance requirements and the asset management process is the identification of a need. The performance of the asset is evaluated at the beginning of the process to develop the long-term strategies. The assets are evaluated to review their historic performance, the current conditions of the assets (integrity of the pipes, treatment works, etc.) and future performance. The interrelation of the performance requirements on the asset management process are identified in the identification of a need, identification of the risk position and cost-benefit need/solution. Figure 4.3 shows the areas of the structure where the performance requirements are considered and that could be influential in the asset management process.

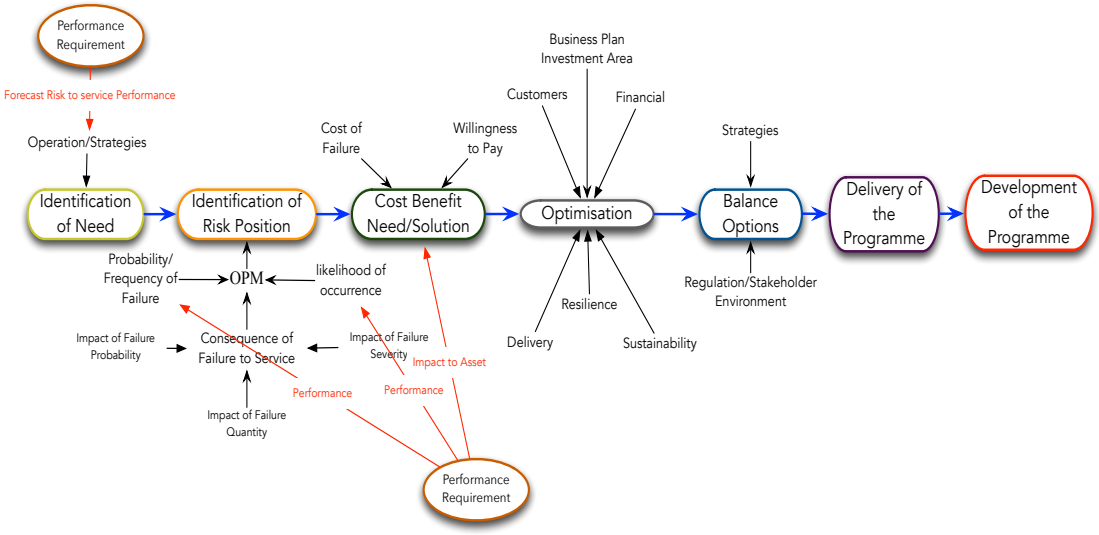


Figure 4.3: Influence of the Performance Requirement on the Asset Management Process

4.1.2.1 Identification of Need- Influence of the Performance Requirements

The need identification is primarily managed depending on the asset type classification. For long-term strategies, the parameter to identify a need depends on the asset system under evaluation: Water Resources, Water Treatment and Water

Distribution. Water Resources provide a larger scale. Water Treatment refers to the assets that are non-infrastructure; assets above grounds as defined by Ofwat (such as treatment works). Infrastructure are undergrounds assets such as water mains. These parameters are used for historical, current and future evaluation.

Needs identified on Water Resources are based on the Security of Supply Index (SOSI) which reflects the company's ability to meet specific levels of service for water supply and is scored for an annual average. This parameter is basically the balance between supply and demand. The performance is modelled under different components (such as Water Available for Use (WAFU), Dry Year Distribution Input (DI), Bulk Import and Export, Target Headroom, Percentage of Surplus) and then it is scored.

The needs identified for Water Treatment and Water Distribution are based on the trend of the serviceability indicator. Serviceability is the capability of a system of assets to deliver a reference level of service to customers and to the environment. Serviceability is a parameter that combines asset performance indicators with service indicator parameters. The intent of the serviceability is to determine performance indicators that provide an indication of the impact on the service. The serviceability parameter looks to the assets as the serviceability to customers, and it is not limited to the parameters needed to maintain the asset (Pearsons, 2010). The limitation of the serviceability parameters is that they need to be monitored over the same period of time. A summary of these parameters is provided in the table 4.2.

Water Distribution, Water Treatment and Water Resources are interconnected by the need to reduce losses in the system. Leakage and water demand are the parameters that interconnect the three systems, and are used to measure the system overall.

Future impact on the asset is based on the impact on water quality, interruption to supply and performance costs (capital expenditures and operational expenditure).

Table 4.1: Service Indicators (Source: Ofwat 2009)

Serviceability Indicators	
Service indicators	Properties with extended supply interruptions, properties receiving low pressure, proportion of treatment works that are out of compliance
Asset performance indicators	Burst water mains, sewer collapse, and meantime between failures, sub-threshold indicators that indicate potential underlying problems but where the works have not failed, examples of events where a threshold value, say half the permissible value, has been crossed

4.1.2.2 OPM and Cost Benefit/Need Solutions

The determination of the frequency of failure and the probability of failure leading to an impact from the OPM framework is based on the history of performance, unplanned failures and investment. This framework is fed with indicators from a model that defines the deterioration of the asset based on models used as examples. Thames Water's models are used to understand the relationship between performance and failure, and the impact to customers and the environment. The cost-benefit of developing a strategy is analysed by comparing the cost of improvement of the system vs. the cost of failure of the system.

4.1.2.3 Manage of Performance Requirements

Using serviceability indicators to define long-term strategies provides a connection to act on the asset from the perspective of the customers. This provides more alignment with the intent of the strategies in relation to the customer and the environment.

The main influence of the performance requirement on the asset management process is the data available. The quality, level, quantity and interpretation of the data affects the results from the asset

management process and the decision made for investment.

Thames Water has identified that adequate data is needed in order to develop adequate long-term strategies. With the complexity of the asset and risk based decision, there is a greater dependency of the asset management process on where to look to identify key findings for developing long-term strategies. Identification of needs in Thames Water is more dependent in models that align performance with service. The outcome-based strategic objectives increase this difficulty. The company is confronting the difficulty of linking the strategic objectives back to actions needed (input) and measurable objectives (outputs). Their main challenge is to identify measurable objectives (outputs) that will deliver the company objectives at an outcome level, while abiding to existing regulations and customer expectations ([1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]).

4.1.3 Determining the Influence of the Risk Management

Thames Water asset management procedure is based on a risk-based framework. Therefore, the influences of Risk Management on the decision-making process for Thames Water are reflected at all its stages. The figure below shows the main areas where Risk Management influences more directly the asset management process.

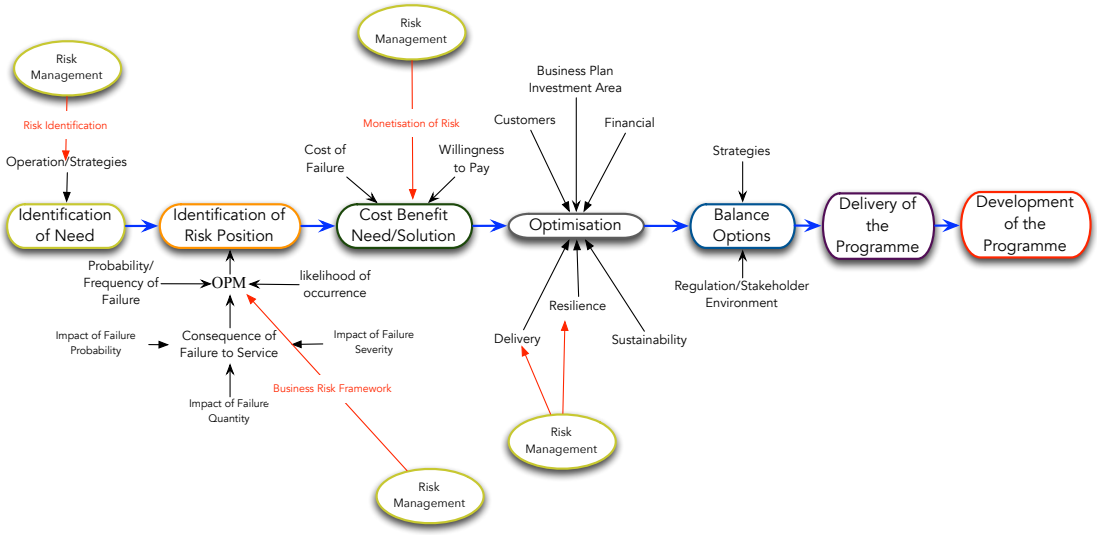


Figure 4.4: Influence of the Risk Management on the Asset Management Process

4.1.3.1 Need Identification - Risk Management

Risk management is used to translate the performance of the asset into risk, where the risk will be further evaluated to develop strategies, which is called a need. The identification of the need is based on the performance, a system bottom-up approach, or top-down approach by requirements of the customers, stakeholders and business.

The strategic team is starting to use resilience as a need identification and level of information to develop strategies for the long-term plan. In the case of the water resources, resilience is not a parameter that is regulated, but an internal criterion to define better investment decisions. Resilience Decision Support Tools (DST) is in the process of being improved for each of the water sub-systems. The benefits identified from the Treatment Works are currently more advanced. Water Treatment works are not linear assets, therefore the effect of an individual's work should not affect the performance of the system. This provides feedback on where to invest to maintain the system for robust, long-term strategies and future challenges. Resilience is only understood from the perspective of the performance of the system and has not been linked to the impact on the service.

Asset Investment Management (AIM) is another DST used for the identification of need. AIM is an infrastructure risk model developed by Thames Water that provides a risk assessment against each single asset (span) at the distribution infrastructure, in the GIS system (Thames Water, 2013a). The model aims to provide an optimum position between risk, cost and benefit and passed to the asset management process. This model combines a number of assets related to water distribution. The model helps to identify where to invest most favourably on the basis on water demand and risk level.

PESTLE (Political, Economic, Social, Technological, Legal and Environmental) methodology is used to create the future scenarios. The five key challenges are: 1) Regulatory and Market Reform; 2) Inflation and Energy Prices; 3) Population Growth and Affordability Trends; 4) Pressure to Innovate, Quality and Environmental Legislation; and, 5) Climate Change. Qualitative and quantitative

impact analyses are conducted. The qualitative impact analysis is performed against the asset base and the customer and stakeholder requirements. The quantitative impact analysis is conducted based on the total cost of operational and capital expenditures during a 25-yr period.

4.1.3.2 OPM and Cost-Benefit- Risk Management

The OPM defines a number of risks that are part of the Business Objectives. This is a method used at Thames Water to manage the risks by clustering them in areas that are critical to regulations, clients and business.

Risk is materialized in pounds (e.g. cost of failure) to improve the decision on investment. This framework is influenced by the level of expert judgement vs. model-based inputs that are based on probability and consequence. Thames Water is moving to model based risk assessment to improve their decisions and consistency on investment by the quantification of risk.

4.1.3.3 Optimisation-Risk Management

The delivery of the strategies is influenced by how Thames Water manages uncertainties. These risks are evaluated in order to understand uncertainty and the level of influence of Thames Water to further decide between a robust and a flexible approach. Two examples on how uncertainty is managed are: 1) consideration of investing on medium scale projects to prepare for future events and reduce over spending or underperformance ([10], [5]; Thames Water, 2012); and, 2) understanding the role of innovation within water networks, e.g. smart networks, language that starts to be used during this price review period - as a key enabler to manage the future pressures from climate change, environment and population growth ([8], [10]; Thames Water, 2012).

4.1.4 Determining the Influence of the Regulations

Regulations are the main constraint on the decision-making process. Their impact in the asset management process is identified on the identification of need, identification

of risk position, cost-benefit and balance option. The steps where the regulations act as constraints are illustrated in the next figure.

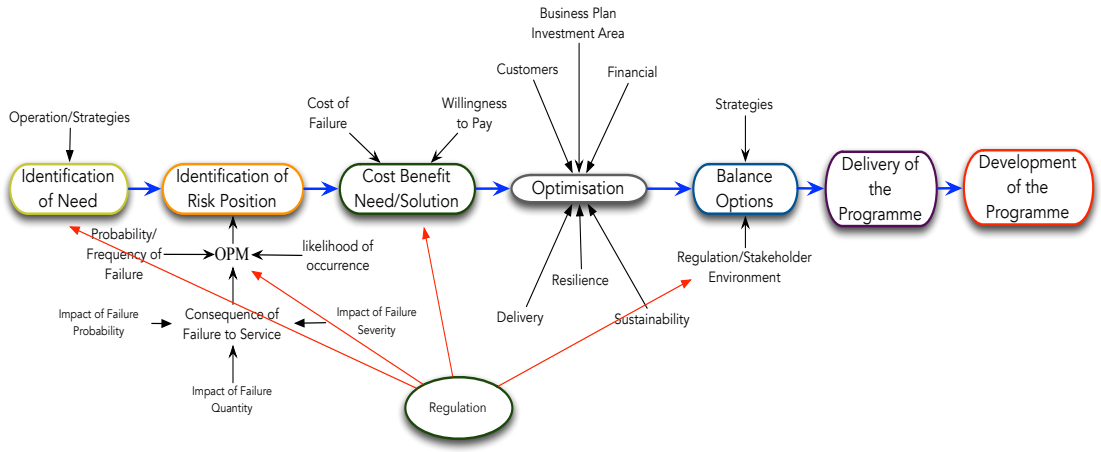


Figure 4.5: Influence of the Regulations on the Asset Management Process

The regulations are first considered in the decision-making process at the need identification process. These needs are named quality and supply demand. These are needs established by regulators and related to the key performance indicators. Ofwat establishes these indicators every five years. Changes in these regulations will change the needs identified (e.g. reduction on the maximum limits of lead in the drinking water).

The business risk framework related to regulations constrains the needs to be integrated in the 5-yr delivery section of the strategies that are directly related to a regulation. An example is the change in compliance related to lead and metaldehyde levels.

The regulations constrain the process of optimisation. Manoeuvre in the decision is limited to the cost-benefit analysis. The expectations of the regulations are then evaluated in the delivery of the 5-yr section of the long-term strategies. The regulatory environment is one of the criterions used to balance the strategies. Then, the delivery of the strategies is adjusted to the expected regulation changes.

Regulations provide direct constraints on the asset management process. Thames Water manages needs or impacts to a regulatory requirement as a must-do action. These regulations provide an alignment with the company strategies, for example, strategies related to leakages.

4.1.5 Stakeholders Requirements- Influence on the AMP

Thames Water integrates the stakeholder requirements on all the steps of the asset management process. The figure that follows illustrates their influences on the system.

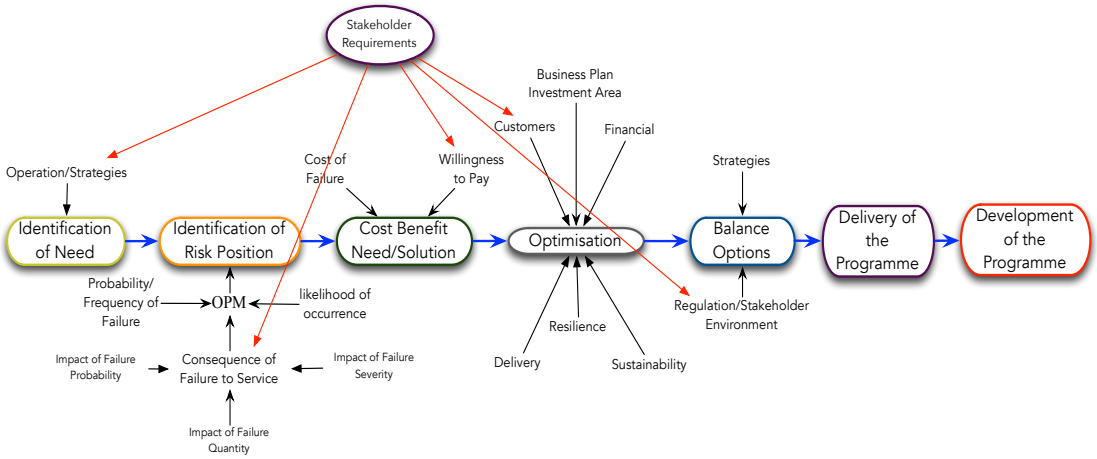


Figure 4.6: Influence of the Stakeholder Requirements on the Asset Management Process

4.1.5.1 Identification of Need

Customer interest to improve the system is used as one of the criterion to identify a need. Examples are: re-use of water and repairs of leakage over the economic efficient point. Qualitative and quantitative research is conducted on the customers to identify these needs. These research pieces on the customers lead to information that is also used in the following step of asset management. The use of impact on water quality, water reliability and water affordability as criteria for long-term planning was identified by this research. Figure 4.7 shows an example of the result of willingness to pay research in relation to supply-demand balance.

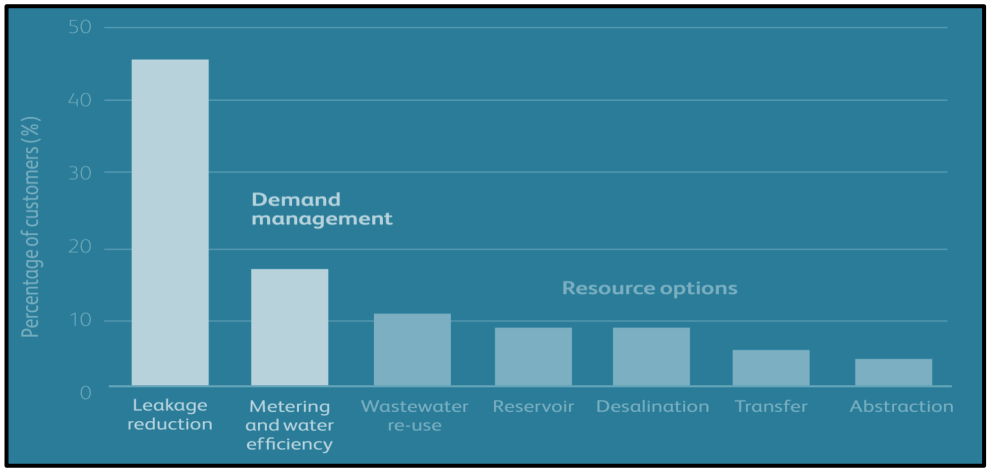


Figure 4.7: Customer Preference (willingness to pay) in relation to Supply-Demand Balance (Source: Thames Water, 2013b)

4.1.5.2 Identification of Risk Position and Cost Benefit

The OPM risk framework considers the occurrence and frequency of failure on assets, but integrates the consequences of failure to the service indicators.

On the cost-benefit analysis, the information of the customer willingness to pay is used to determine the monetary benefit on the decision of the strategies. The willingness to pay is determined during customer research and is the primary consideration on the cost-benefit framework. Outside of the regulations, decisions to implement a strategy are strongly reliant on the willingness of the customers to pay.

4.1.5.3 Optimisation and Balance Option

The impact of the solution on the customer bill is considered in the optimisation process. Environments of customers are considered in the delivery of the strategy. Therefore, the portfolio of a long-term strategy is focused on delivering the benefit to the customer in the short-term. The criteria to define the investment portfolio include customer satisfaction and affordability.

4.1.5.4 Stakeholder Requirement in the overall Asset Management Process

Ofwat influences the process by providing a structure to which the process can be developed. The risk management process was built on the requirements established by Ofwat. Ofwat defined, for all water

companies in the UK, the Common Framework as the base for the risk-based asset management process. In addition, Ofwat provides an evaluation to the system and comments on how decisions are made and how should they be improved.

The influence of the stakeholder requirements on the asset management process is mainly affected by the integration of the customers in the decision rules of the asset management process. Thames Water's decision-making process considers the customers as the primary stakeholder or beneficiary that will be affected by the asset management process. The decision-making process manages the customer as stakeholders that will be impacted by the decisions and as an influence on the decision-making process by considering their demands on the water system. The impacts on the customer are defined by the effect on serviceability. The customers are considered in the decision rules by taking their demands from the system into the parameters of willingness to pay and customer complaints.

4.1.6 Business Objectives- Influence on the AMP

The final influential factor to be considered, in reviewing the impact on the asset management process, is the business objectives. In the development of long-term strategies, the business objectives influence the process in different segments. The influence is based on needs, cost-benefit, and optimisation and balance options. Figure 4.8 shows these interrelations.

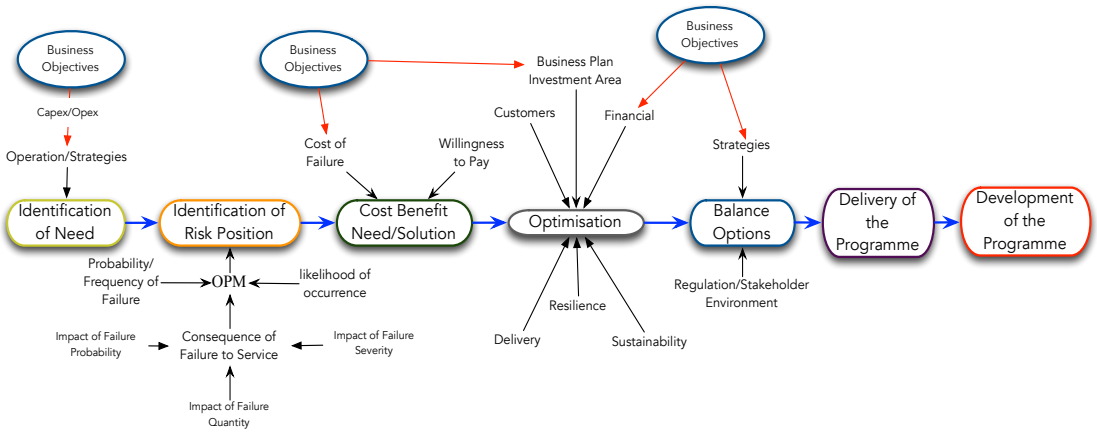


Figure 4.8: Impact of the Business Objectives on the Decision-Making Structure

4.1.6.1 Identification of the Need

There are two ways that the business objectives influence the asset management process at the need identification step. First, the investment area frames the asset to focus on the need identification. Second, history of capital and operating expenditures sets the limit of the need that will be identified. Examples are the capital maintenance investments that aim to reduce the operational cost and increase efficiency of the system.

4.1.6.2 Cost Benefit

Business Objectives are considered in the cost of failure. The level of influence is based on the level of risk that the business is willing to take by not solving a need. This framework is in process and to be defined more in detail. An example is, if a preventive investment or maintenance should be done to an asset or if the asset should be allowed to fail.

In addition, investment scenarios are mapped back to the long-term priorities based on outcomes determined by the company.

4.1.6.3 Optimisation and Balance of Programme

The influence of the business objectives in the asset management process is defined in two ways: the influence of the investment areas, and the strategic framework as criteria for the long-term strategies. The investment area is used to optimise assets under the same sub-system. Conducting this approach, needs, that represents a benefit both for the customer and the business are combined

The defined long-term priorities and outcome-based objectives are defined as the business objectives. Determination of the long-term strategic goals for the assets is conducted based on an analysis of long-term issues facing the water industry, on internal asset based knowledge and on views from customer and stakeholder research (Thames Water, 2012). The strategic goals are defined as strategic themes and policy objectives, which are mapped to the long-term priorities (outcome-based long-term objectives) and outcome-based

objectives. Since the strategic goals are defined based on outcome-based objectives, they are expected to be refined in the future as more understanding from customer engagement is obtained (Thames Water, 2012). A strategic framework is developed based on the long-term priorities, outcome-based objectives and policy goals (Figure 4.9).

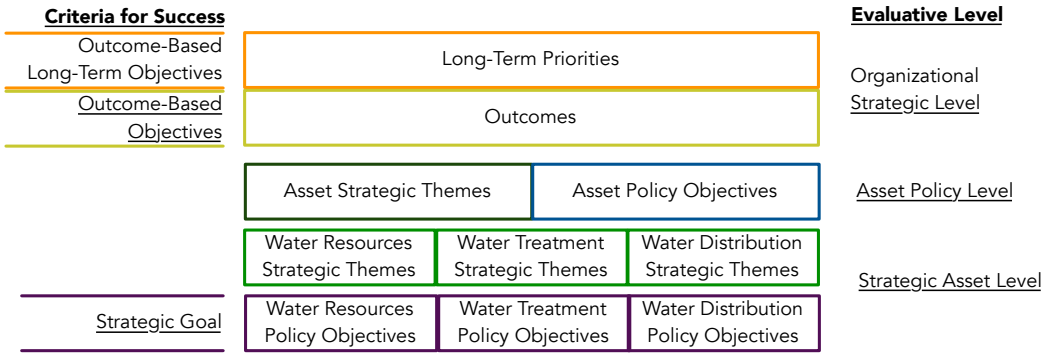


Figure 4.9: Long-term Strategic Framework (Source: Based on Thames Water, 2012; Thames Water, 2013b)

The strategic framework presented in figure 4.9 above represents the criteria of analysis for the long-term strategies. Thames Water defines the lower levels with the aim to underpin the upper levels (Thames Water, 2012). On the left hand, the criteria are named based on the terminology used in this thesis. On the right hand, the levels are related to the Evaluative Framework to provide an understanding of their alignment with the information provided in the chapter above.

4.2 Analysis of the Influences on the Long-Term Strategies

In this section the decision-making process is analysed by reviewing the influence on the long-term strategies and strategic objectives. The analysis is conducted by estimating the impact of each of the internal elements defined in the decision-making process.

A quantitative analysis was conducted on each of the strategies to identify the primary influences. This analysis is based on the on the analysis conducted on the decision-making process in Section 4.1. The analysis was conducted by rating each of the elements from 1 to 3. Level 3 reflects a direct influence from the reference, where Level 2 would be a consequence of the strategy and Level 1 an indirect consequence.

Directly influential strategies from the Performance Requirements (Level 3) are strategies that addressed a need from the assets that rose bottom-up, such as leakage, capability or sufficient water demand. Level 2 are strategies where performance would be affected due to a need under business, regulation or stakeholders. Level 1 is an indirect influence on the performance requirement.

Directly influential strategies related to Risk Management (Level 3) are strategies that are developed to improve the asset management process (or decision-making process) itself or to address uncertainty. Level 2 are strategies that will improve the process as a consequence, and Level 1 indirectly influences the system.

Directly influential strategies relate to Stakeholders (Level 3) and are strategies that are the result of stakeholders' requirements; mostly from a customer perspective. Another direct influence may occur through Ofwat's direct requirements on the decision-making process, such as the improvement of data management. Level 2 are strategies that will address a requirement of the stakeholder as a consequence, and Level 1 is an indirect influence on the stakeholder requirements.

Directly influential strategies related to Business Objectives cover more areas,

but follow the same approach: Level 3 represents a direct requirement from the business objectives. Level 2 are strategies that will address business objectives as a consequence. Level 1 has indirect influences on the business objectives.

An example of this analysis with the following strategic objective:

Focusing data and control resources - placing operational intelligent control was central to the long-term operation of the business

The need for these strategic objectives is related to maintaining the continuity of the business and increasing the knowledge to improve the risk management process and to improve investment decisions. This means a value of 3 for the risk management and business objective. Better investment decisions will improve performance (Level 2), which then results in meeting the requirements of regulators and stakeholders (Level 1).

4.2.1 Influential Factors- Water Resources Strategies

Water Supply-Demand is the main objective of the strategies related to the water supply. Not meeting the regulation on the security of supply will lead to penalties from the regulators. The water companies are required to generate a 25-yr plan to establish how they will balance the water-supply demand. The long-term forecast for resource availability (supply) and water use (demand) was used as a future parameter to determine the overall impact between the different subsections.

Table 4.2: Analysis of the Influential Factors on the Water Resources Strategies and Objectives

Strategies and Objectives	Score Card of Influence					Explanation
	RM	PR	BO	SR	RG	
Focusing primarily on demand reduction through metering and continued leakage activity	1	2	3	3	3	This strategy is primarily influenced by the stakeholder requirements. There are direct requirements from Ofwat and consumer preference to the use of metering and leakage reduction. Customers are willing to pay extra for the solutions derived from this strategy. Optimisation will be expected to be conducted against the willingness to pay of the customers. Leakage is also a result of the performance of the system that is related to the integrity of assets.
Implementation of compulsory metering programme within AMP6 to deliver leakage reduction by 2025 (Take Less and Understand More)	2	1	3	2	2	This strategy is an alternative that was pushed by Thames Water and recently approved. Previously there was an optional metering programme. At the same time the strategy provides more knowledge of the demand patter that Thames Water can use to improve risk management, then identify leakage better and understand the dynamics of demand usage. This option is focused on the demand management that is the main interest of the customer.

Reduce leakage by [50Ml/d] through a combination of pressure management, metering and some mains replacement (in targeted areas) (Lose Less)	2	3	3	3	3	This strategy is primarily influenced by stakeholder requirements. There are direct requirements from Ofwat and consumer preference to the use of metering and leakage reduction. Optimisation will be expected to be conducted against the willingness of consumers to pay. Leakage is also a result of the performance of the system that is related to the integrity of assets. In addition, there is a risk management factor of balance to understand the risk better and conduct better investment decisions.
Further reduce leakage by specific numbers (Lose Less)	1	3	1	3	3	Reduction of leakage is primarily influenced by stakeholder requirements.
In the short-term, selected implementation of IPPR schemes along with minor ground water development schemes	1	3	3	3	3	The preferred options by the stakeholders and regulators are not sufficient to meet with requirements. This option is the preferred option by the customer from the supply options. This strategy is the preferred option by Thames Water since is reduces expenditures in Capex, and meets with the financial stability. There is a regulation requirement to meet the requirement of supply-demand in the short period.
In the long-term, continue to focus on demand reduction but develop a regional South East solution to increase available resources through either transfers, re-use or additional storage	1	3	3	2	3	Thames Water preference is in the development of a portfolio of options to be more cost-effective and improve the capability of the system. The strategy will influence stakeholders and regulation.

Focusing on data and control to better understand the performance of the assets and improve the targeting of the investment needed	3	2	2	3	1	The direct influences of this strategy is due to the risk management process established in the company to understand the system and improve decisions for investment and improve the efficiency on the asset performance. There is an influence from the stakeholders by Ofwat recommendations to improve the decision-making by moving from expert judgment to more accountable decisions.
Focusing on improving the management of water resources through technology and developing class-leading water resource analysis capability to meet the future demands on the system operation	2	3	2	3	3	The direct influence of this strategy is to improve the performance of the water resources by generating better understanding of the system. Better understanding of the system will provide better decisions for investment and improve the efficiency on the asset performance.
Reduce overall system losses through quantification and additional foreseen metering benefits such as Capex avoidance, understanding of wastage and usage levels (Lose Less)	3	3	3	2	1	The direct influence of this strategy is to understand the risk, performance and investment decisions. Better understanding of the system will provide better decisions for investment and improve the efficiency on asset performance. Reduction of the overall losses is influenced by an integrated approach of considering the system asset performance. Capex avoidance is driven by Ofwat interest to reduce companies Capex bias.

Focusing resources on data and control – placing operational intelligent control as central to long-term operation of the business and moving to real-time control information by 2025 (Understand More)	1	3	3	2	1	The direct influence of this strategy is to focus on better performance of the assets and reach the business objectives. Better understanding of the system will provide better decisions for investment and improve the efficiency on the asset performance. There is an influence from the stakeholders by Ofwat recommendations to improve the decision-making by moving from expert judgment to more accountable decisions.
Extending current water resources modelling tools to include cost and link to network and production tools to understand overall system resilience (Increase Capability)	3	1	2	3	1	The direct influence of this strategy is to understand the performance of asset management by using resilience as an indicator of the need for investment. Then, through the understanding of the risk allocation, investment decisions can be improved. Indirectly, Ofwat implements the risk management and there are recommendations to improve the data management from the last AMA.
Total	20	27	28	29	24	
Percentage	61%	82%	85%	88%	73%	

Stakeholder requirements are the main influences on the majority of these strategies. Most of these strategies are directly developed to reduce leakage on the system, which is the customers' preference to improve the deficit of supply-demand. The influences from the business objectives are reflected on strategies in the long-term planning perspectives and their preference on the development of metering strategies. Performance Requirements are the result of the deficit of supply-demand and the leakage on the system. Regulation has a larger impact than risk management. This can be the result of Thames Water not having an integrated system for water resources

and the limited flexibility of the regulations related to the deficit of supply-demand. This is also the result of the specific regulations on the level of leakages and the prescriptive guidelines from the Water Resource Management Plan (WRMP).

4.2.2 Influential Factors- Water Treatment Strategies

Performance Requirements and risk identification for Water Treatment are related to reliability and serviceability. Serviceability is regulated by Ofwat parameters and drinking quality standards. Reliability of the system is not a parameter directly regulated by the regulator, but it is a parameter used by Thames Water asset strategic team to ensure the continuity of the business in existing conditions and the future. With this context and the process described in the previous section, the effects of the internal influences are evaluated below in the following table.

Table 4.3: Analysis of the Influential Factors on the Water Treatment Strategies and Objectives

Strategies and Objectives	Score Card of Influence					Explanation
	RM	PR	BO	SR	RG	
Doing no less than short-term minimum spend on all assets	2	3	3	1	1	The intent of this strategy is to reduce the cost associated to the assets by preventing further deterioration of the assets. Direct influences of this strategy are by Business Objectives and Performance requirements. Less influence is from the Risk Management system that optimises solutions with capital and does not consider operation optimisation. Less influence is from regulators and stakeholders where affordability and investment can be justified with this approach.

Fixing 'must do' items such as short life assets	2	3	3	1	1	The intent of this strategy is to reduce the cost associated to the assets by preventing further deterioration of the assets. Direct influences of this strategy are by Business Objectives and Performance requirements. Less influence is from the Risk Management system that optimises solutions with capital and does not consider operation optimisation. Less influence is from regulators and stakeholders where affordability and investment can be justified with this approach.
Resilience where risk is untenable	3	1	2	1	2	The direct influence of this strategy is from the long-term approach form asset management policy to make investment decisions based on the resilience of the system. In addition, it is a flexible approach to manage uncertainties and be able to justify the investment and balance business and stakeholder risk. Based on the analysis, resilience will increase the overall achievement of the strategic objectives from the organization (and then regulators and stakeholders).
Developing a programme of work to improve the resilience in AMP6 at large treatment works (Take Less and Lose Less)	3	1	2	1	2	The direct influence of this strategy is from the long-term approach form the asset management policy to make investment decisions based on the resilience of the system. In addition, it a flexible approach to manage uncertainties and be able to justify investment and balance business and stakeholder risk. Based on the analysis, resilience will increase the overall achievement of the strategic objectives from the organization (and then regulators and stakeholders).
Restoring sites with immediate capability issues (Lose Less)	1	3	3	2	3	Without adequate capability, the asset will not be able to deliver the serviceability and regulated requirements. This strategy is directly influenced by the performance of the asset, regulations, stakeholders and business objectives.

Gradually bringing all works up to their original design capacity over a 10-15 year period - the timing of which depends on demand growth	3	3	2	1	1	The direct influence of this approach is to ensure the system will be capable to meet the demand growth, Performance Requirements and Stakeholder. They are gradually influenced by the Risk Management approach to be more flexible to manage uncertainties and effects from other external factors and other strategies such as demand management strategies on the other sub-systems. This is an indirect influence from Ofwat to conduct integrated decisions.
Rolling-out a programme of power resilience to sites over AMP7 (Take Less and Lose Less)	3	2	1	1	2	The direct influence of this strategy is from the long-term approach form the asset management policy to make investment decisions based on the resilience of the system. It a flexible approach to manage uncertainties and be able to justify the investment. Based on the analysis, resilience will increase the overall achievement of the strategic objectives from the organization (and then regulators and stakeholders).
Increased focus on data and internal capability to continue to allow better decision-making in the future	3	2	3	1	2	The direct influences of this strategy is due to the risk management process established in the company to understand the system and improve decisions for investment and the efficiency on the asset performance. There is an influence from the stakeholders by Ofwat recommendations to improve the decision-making by moving from expert judgment to more accountable decisions.
Rolling-out a programme of technical capability improvement over AMP 6-7 (Increase Capability)	1	3	3	1	2	Without adequate capability, the asset will not be able to deliver the serviceability of the system. Risk Management influence less by the process to identify immediate capability issues and reach the desire resilience. Thames water deterioration models influence the resilience of the site.

Focusing resources on data and control - placing operational intelligent control as central to the long-term operation of the business (Understand More)	3	2	3	1	1	The direct influence of this strategy is to focus on the better performance of the assets and reach the business objectives. Better understanding of the system will provide better decisions for investment and improve the efficiency of asset performance. There is an influence from the stakeholders by Ofwat recommendations to improve the decision-making by moving from expert judgment to more accountable decisions.
Total	24	22	25	12	17	
Percentage	80%	73%	83%	40%	57%	

The influences on the treatment work show a balance between the Risk Management and Business Objectives. Strategies are focused to meet the business investment decisions, to invest in the improvement of large treatment works and reduce the impact of operational costs due to the expected increase in resources. To improve certainty on the investment decisions, the focus of the asset management strategy team is to invest based on the resilience of the system and improves the understanding of the system to be more effective. A more comprehensive understanding of the system resilience is desired by Thames Water to improve their decisions on where to invest and to reach the long-term priorities, operative outcomes and policy objectives ([5], [10], [6]). Risk Management also influences the delivery of the strategies to meet the business objectives and regulations.

Regulations have a greater influence than stakeholders since the serviceability parameters established by the regulator were established to protect the customer instead of the parameters established by customers' opinion ([10], [5], [8]).

4.2.3 Influential Factors - Water Distribution Strategies

The future scenarios are based on the impact of water interruption. Water Distribution is interconnected with the Water Resource Management Plan and the functions of the

assets that directly impact the customers. From the regulation perspective, parameters are established by Ofwat, and not by water legislation.

Water Distribution Strategies are based on serviceability for infrastructure (unplanned interruption, burst piping, pressure, and customer contacts). Regulations have established thresholds related to the number of complaints and on the duration of interruption. Regulations also evaluate the actions on the system, by reviewing the level of leakage reduced. Resilience of the system is not regulated.

Table 4.4: Analysis of the Influential Factors on the Water Distribution Strategies and Objectives

Strategies and Objectives	Score Card of Influence					Explanation
	RM	PR	BO	SR	RG	
Move to a resilient network approach over a 10-15 year period	3	1	2	3	2	The direct influence of this strategy is from the long-term approach form the asset management policy to make investment decisions based on the resilience of the system. In addition, it is a flexible approach to manage uncertainties and is able to justify the investment and balance business and stakeholder risk. Based on the analysis, resilience will increase the overall achievement of the strategic objectives from the organization (and then regulators and stakeholders).
A programme that focuses on whole-life cost network management to ensure that the network does not deteriorate in AMP6	2	3	1	2	2	The direct influence of this strategy is to improve the asset conditions. The focus is to be more effective in the improvements conducted and reduce the amount of unwanted interruptions to supply. Unwanted interruptions have a direct impact to the customers and are the main reason for complaints in relation to assets. Indirect influences are Ofwat cost evaluation related to Totex.

The use of innovation in investment targeting and solution delivery (approach works in synergy with that of Water Resource, which includes some leakage reduction in AMP6)	3	2	2	3	2	The asset management process directly influences this strategy. Better investment tools will reach better efficiency on investment and will help Thames Water to justify the investment decisions. Indirectly, Ofwat observes to improve the integration on decision-making tools.
Focus on reducing the cost of trunk and distribution mains replacement (Take Less and Lose Less)	1	2	3	3	2	The main influence is the Business Objectives and stakeholder requirement to be more affordable. The strategy is an asset problem that will cause high impact to stakeholders and the poor conditions of some of these assets that require replacing.
Maintaining network conditions in the short term through targeted mains replacement with increased levels of replacement in the longer term (Lose Less)	3	3	2	2	2	The direct influence this strategy is to improve the asset conditions by maintaining low Capex and Opex. Unwanted interruptions have a direct impact to the customers and are the main reason for complaints of customers is in relation to the assets. There is an influence of risk management by targeting investment to benefit the other sub-systems.
Improving accuracy of leakage targeting through the use of technology (Lose Less and Understand More)	3	3	2	3	3	The direct influence of this strategy is due to the risk management process established in the company and to meet with the business objectives. Better understanding of the risk placed on the system will provide better decisions for investment and improve the efficiency on the asset performance. There is an influence from the stakeholders by the recommendation that was offered by an external evaluator requested by Ofwat.

Improving understanding of usage/demand/leakage through roll out of metering (Understand More)	2	2	3	2	2	Customers, Regulators and Thames Water are pushing the use of metering as an option to manage demand. Thames Water is pushing for smart metering to improve the understanding of the system and customer behaviour.
Improving network performance through system control (Understand More and Increase Capability)	2	3	3	2	1	The direct influence of this strategy is due to the risk management process established in the company and to meet with the business objectives. Better understanding of the system will provide better decisions for investment and improve the efficiency of the asset performance. There is an influence from the stakeholders by Ofwat recommendations to improve the decision-making by moving from expert judgment to more accountable decisions.
Continuing to gather quality data (performance, pipe samples, customer complaints, costs) to improve understanding of the asset and impact on the customer (Understand More)	2	2	2	3	1	The direct influence of this strategy is due to the risk management process established in the company and to meet with the business objectives. There is an influence from the stakeholders by Ofwat recommendations to improve the decision-making by moving from expert judgment to more accountable decisions. Better understanding of the system will provide better decisions for investment and improve the efficiency on the asset performance.

Develop zonal hydraulic models and decision support tools and develop long term trunk mains strategy (Lose Less and Understand More and Increase Capability)	2	2	3	3	2	The direct influence of this strategy is to improve the performance of the system to develop better strategies that meet the asset perspective the business objectives.
Innovating in the use of no-dig techniques for trunk and distribution mains (Good Neighbour)	1	3	2	3	2	This strategy is based on the consultant requested by Ofwat to improve the actions of Thames Water on the replacement of mains and reduction of leaks.
Total	24	26	25	29	21	
Percentage	72%	79%	76%	88%	64%	

The stakeholders' requirements have the greatest influence on the strategies. The Water Distribution system has a direct impact on the customers. The direct impact on the customers is reflected on the 30% of customer calls complaining about the water distribution (Thames Water, 2012c). These calls affect one of Ofwat's KPIs. Thames Water is increasing the resilience of the system and improving the decision-making process to be more efficient on the improvement of the system. Influences between Risk Management, Performance Requirement and Business Objectives are difficult to determine and may be the consequence of a more balanced approach of the strategies. There are no direct strategies focusing on leakage, which is a result of the synergy with Water Resources Strategies.

4.2.4 Outcome-based Asset Management Process

Based on the analysis conducted on the asset management process, the influential factors were identified at different segments of the asset management process. The analysis reviewed indicates that the asset management process is influenced by different factors that appeal to an outcome-based asset management process. This characteristic is identified first in the risk identification stage as it was identify in section 4.1. Using Heather et al.'s service-performance model (2007) can be illustrates the interrelation of the influential factors in the risk identification process (Figure 4.10). The model characterised the decision-making frame to identify *needs* as part of the long-term strategic asset management process.

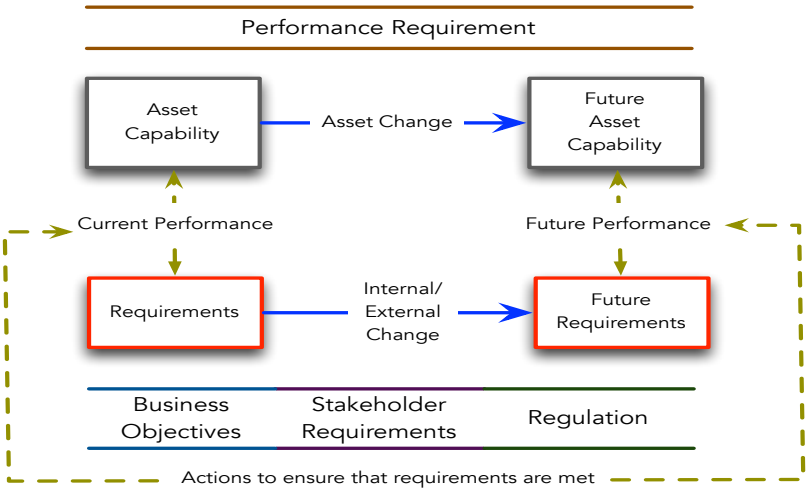


Figure 4.10: Service-Performance Model (Source: Heather et al., 2007)

The core risk-management framework defined different areas to engage the beneficiaries' values on the decision rules; the Common Framework established by Ofwat for all UK water companies. This framework was based on standardised asset management guidelines such as PAS-55 and United Kingdom Water Industry Research (UKWIR). According to Pearson (2009), the main difference between them is that PAS-55 is asset centric, where the Common Framework is customer centric. The parameters that underpin the delivery outcome-based objectives are serviceability, willingness to pay, key

performance indicators and criteria from the strategic framework. From a long-term perspective, Thames Water identified that the resilience of the system needs to be used as a parameter on the asset management process.

With these parameters as part of the decision-making process, it is expected that the resulting long-term strategies and objectives are developed to help achieve the outcome-based objectives of Thames Water. The result from the analysis on the strategies and strategic objectives shows a balance of influences by the internal elements on the strategic decision-making process. The long-term strategic objectives were outlined in order to achieve long-term outcome-based objectives by considering external influences. This reflects the relevance of the optimisation stage to an outcome-based asset management process. It can be concluded that the strategies and strategic objectives are outcome-based focused.

4.3 Asset Management Process - Discussion

What is the asset management process of a company that applies a risk-based outcome approach?

The 5-elements proposed as the internal influential elements on the system diagram were identified through the evaluation of the strategic asset management process for long-term strategies. In the case of Thames Water, the structure is the product of the Common Framework established by Ofwat on all UK water companies. This framework was based on standardised asset management guidelines such as PAS-55 and United Kingdom Water Industry Research (UKWIR). Therefore a structure that incorporates those elements was expected, if the influences of Ofwat were strong on the asset management procedure of Thames Water.

Considering the customer, environment and shareholders as the beneficiaries of Thames Water Infrastructure, the risk framework considers the impact on the three, now, and in the future. The structure allows for considering the impact on the

customer and their requirements on the cost-benefit analysis and optimisation. The core risk-management framework then defined different areas to engage the beneficiaries' values on the decision rules. This implies, along with the influential factors (Performance Requirements, Risk Management, Regulations, Stakeholders Requirements and Business Objectives), that the characteristics of the asset management process are of a risk-based outcome approach.

The performance requirements influence is primarily at the identification of the need. Need identification is based on parameters that correlate with the indicators of performances of the assets and with service indicators. The combination of these indicators provides a trend that allows for the identification of needs in the future. The serviceability provides high-level information to make decisions for the future; however, performance indicators of the asset, that is data dependent, underpin the parameters. In addition, the serviceability would not be the only measurable parameter to meet all the outcome-based objectives. An outcome-based approach makes it difficult to identify what the parameters at the asset level that are linked to outcome-based objectives really are. This identifies a need within the asset management system itself to improve the data quality, level, quantity and interpretation.

The risk-management influential factor connects all the other influential elements. The outcome-based structure is not only a customer centric risk framework, but includes the impact of the environment and investors in decision rules. The link between performances and failure provides the base for Thames Water to identify relevant needs to confront future challenges and increase the possibilities of achieving output and outcomes-based objectives. Resilience is currently the indicator that Thames Water is considering to improve their asset management process. Thames Water identified that resilience would provide them with the level of data that enables them to make high-level decisions for long-term planning ([5], [10], [6]). To improve the resilience on the system, Thames Water has identified the need to understand the effect of the system resilience and how it is linked to customer relevance.

Thames Water manages the influence of stakeholder requirements by considering customer requests that drive decisions within the asset management process. Impact on the customers and their demands on the service are established as decision rules. The decision-making process manages the customers as stakeholders that will be impacted by the decisions and have an influence on the decision-making process by considering their demands on the water system. The impact on the customer is defined by the effect on the serviceability. The customers are considered in the decision rules by incorporating their demands for the system into the parameters of willingness to pay and former customer complaints.

The strategic framework contains the criteria for the outcome-based structure. This strategic framework is the most direct influence of the business objectives. The business objectives represent the executive level (asset owner) interpretation of the outcomes that should be reached with the asset management process. The strategic framework is mapped from the really high level long-term priorities down to the asset long-term strategic goals. Therefore, it is the high-level framework for the asset management process and defines whether the asset management process is an outcome-based approach. This highlights the dependency of the long-term strategies to the business objectives. Changes in the business objectives would then influence the delivery of the long-term strategies.

What are the influences on the decision-making process on accomplishing aligned outcome-based long-term strategies?

Aligned long-term strategies are linked to the asset strategic goals with the business objectives by sustaining the long-term value of the stakeholders from the infrastructure asset (Too, 2012). From the analysis on the long-term strategies, a focus to develop aligned long-term strategies was observed. The decision-making process was analysed along with the impact of the influential factors on the asset-management process. The assumption was that, understanding the influence of these elements on the long-term strategies and objectives would provide information on how the decision-making process at

Thames Water manages the influential factors and in turn validate the alignment of the strategies and objectives.

It was observed, that the delivery of the strategic objectives was influenced by the knowledge from the assets, business objectives, regulators and stakeholders to influence the asset management process. Within the portfolio of the Thames Water long-term strategies, there were established short-term, medium-term and long-term strategies that were path dependant in reaching strategic goals in the 25-yr timeframe.

Short-term strategies are focused on reaching specific goals such as leakage, security supply index and other water standards and customer requirements. Strategic objectives that are focused on a long-term perspective are more influenced by the risk-management process and business objectives than by regulations or stakeholder requirements. Strategies were not only focused on the asset management performance, but also in improving the asset management and decision-making process. Therefore, minimum investment is done to reach long-term objectives until there is knowledge capability in the asset management process. By doing this, Thames Water is capable to justify capital investments needs based on the customer priorities and cost-benefit. This is reflected by the strategies related to resilience.

Resilience investments are typically expensive, and it is difficult to justify who is responsible to pay for them if there is no direct influence on the customers based on the decision rules of the asset management process. As a result, Thames Water has focused on understanding the resilience of the system to improve investments that will lead them in reaching long-term objectives.

The influences between the different elements change depending on the sub-sector under study. The majority of the strategies developed for the Water Resources segment are part of the Water Response Management Plan. These strategies result in very specific strategies to manage leakage. The Water Resource Plan is a document that provides very specific guidelines on how to develop programmes to address the risk of water scarcity. These are the results of strictly prescribed guidelines to develop the strategies related to water resources and the influences from the customers to

make leakage one of the priorities for the water companies. Under these constraints, Thames Water is developing supplementary strategies such as metering to develop targeted investment that will improve the performance of the overall drinking water supply.

The Water Treatment work is more influenced by the risk management system and business objectives. A possible explanation is that output is based on regulations and the operation does not have a direct interface with the customer. Therefore the decision-making process is not only aligned within the requirements of business objectives, regulators and stakeholders, but considers external physical factors that affect reaching outcomes in the future. The main factors that influence the decision-making process are leakage, climate change, population growth and water availability.

The strategic team (asset managers) are responsible for developing long-term strategies that align the asset strategic goals with the business objectives by sustaining the long-term value to stakeholders of the infrastructure asset (Jones, 2000; Humphrey, 2003) which can be identified in this analysis. The asset management process underpins this link with the integration of the Common Framework and Optimisation within the strategic framework. This implies that the decision-making process links the knowledge from the assets, business objectives, regulators and stakeholders to influence the asset management process (Sklar, 2004; Too 2010). This presents the main challenge of missing the alignment of the long-term strategies during each price-review period. The main influence of the decision-making process in Thames Water is the delivery of the strategies - balance between short-term and long-term strategies and between a robust and a flexible approach - and to identify the crucial knowledge gaps and opportunities on the asset management process.

This chapter concludes with the input-output-outcome model based on the analysis conducted on the strategic decision-making process. The high-level perspective of the internal context is illustrated for the asset management process to develop long-term strategies in Thames Water. The diagram reflects the interconnection of the process and illustration of an outcome-based approach (Figure 4.11).

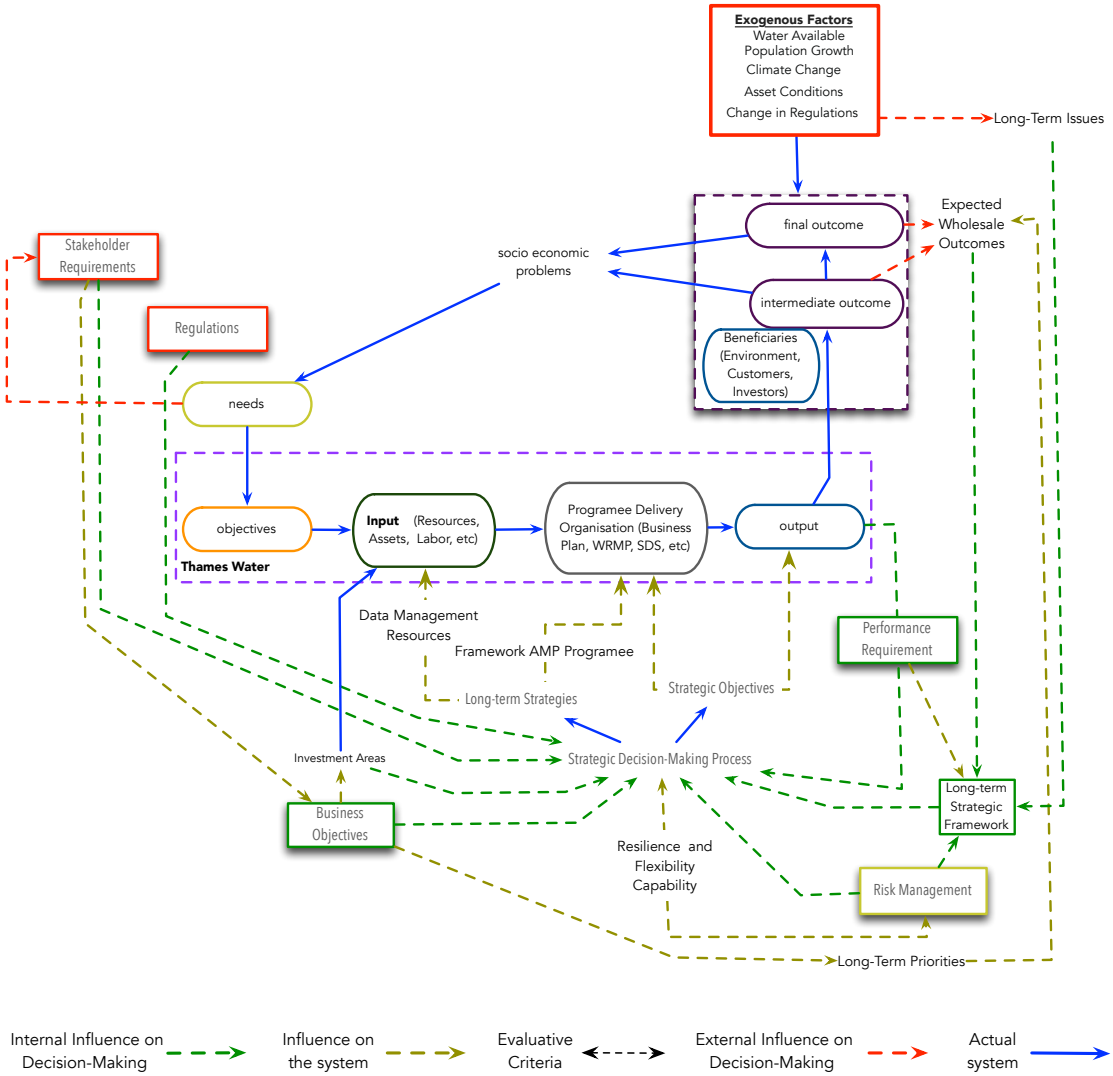
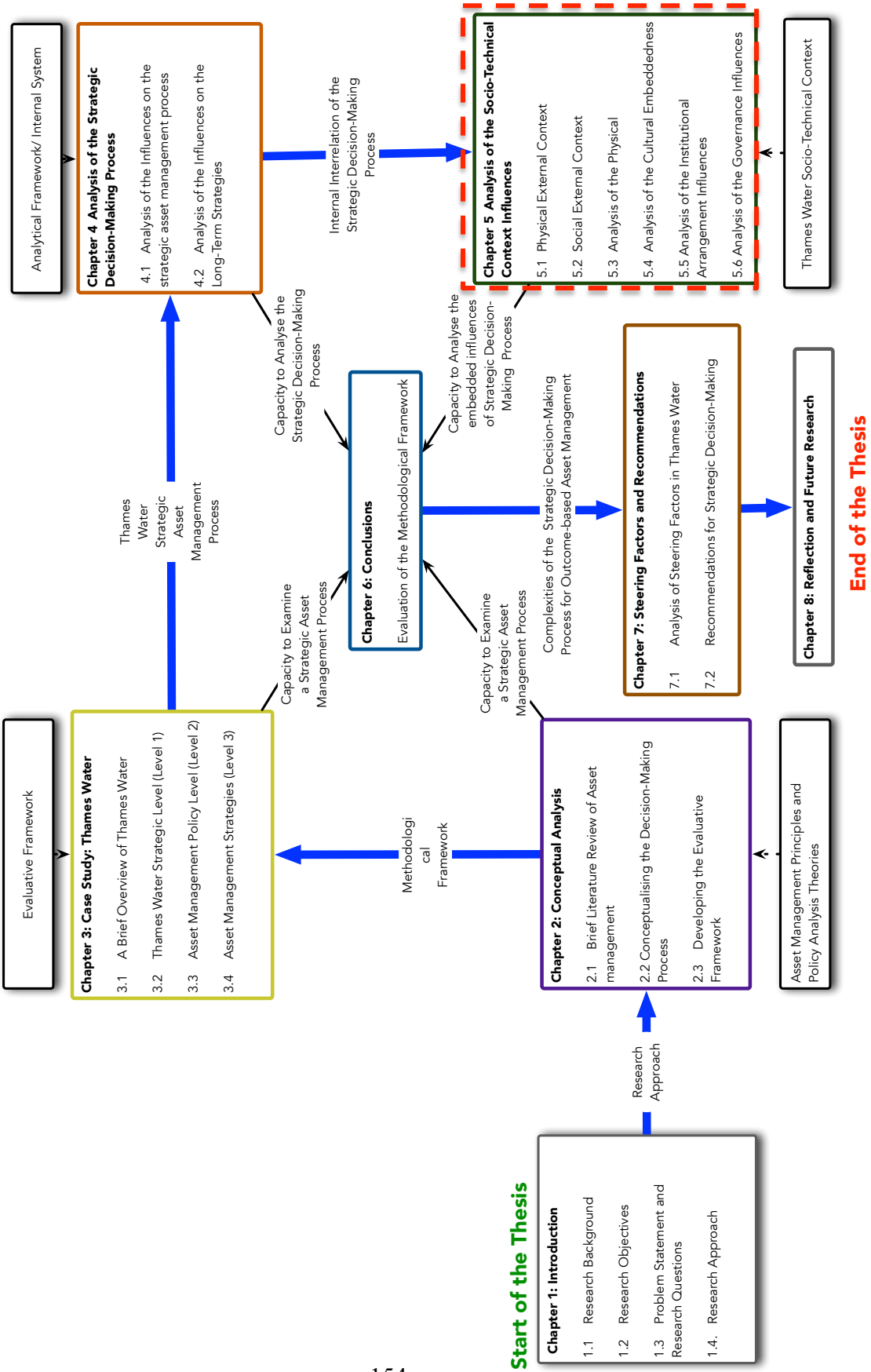


Figure 4.11:Input-Output-Outcome Model- Internal Context of the Asset Management Process

Chapter 5

Applying the Analytical Framework on the External Context

Analysis of the Socio-Technical Context Influences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End of the Thesis

5 Analysis of the Socio-Technical Context Influences

The decision-making process is analysed in this chapter by defining the interrelation and influences of the external context on the decision-making system. The socio-technical context that is considered influential for the decision-making process of Thames Water will be described and studied with the objective to answer the following two sub-research questions:

> What are the interrelations between the decision-making process and the socio-technical context?
>
> What are the influences of the external context on the outcome-based asset management decisions in Thames Water's Strategies and Asset Management Policies?

The analysis of the external influences of the strategic decision-making process starts with an overall description of the socio-technical context of Thames Water (Sec. 5.1 to 5.2). The review is divided into two main sections that describe the Physical External Context (Technical Subsystem) and Social External Context (Social Subsystem) that are relevant for asset management. The physical external context describes the main characteristics and challenges for the water sector, specifically in London. The social external context provides an overview of institutional arrangements and the main regulations.

Revisiting the system diagram proposed, the external context is characterised based on the elements of Physical Characteristics (Sec. 5.3), Cultural Embeddedness (Sec. 5.4), Institutional Arrangement (Sec. 5.5) and Governance Characteristics (Sec. 5.6) which will be evaluated and analysed to describe the influences on the decision-

making process to develop long-term strategies. This is a descriptive analysis considering the socio-technical elements defined using the Bauer and Herder extended model. The chapter will conclude by answering the sub-questions and defining the input-output-outcome model that interconnect the decision-making process with the internal and external context (Sec. 5.7).

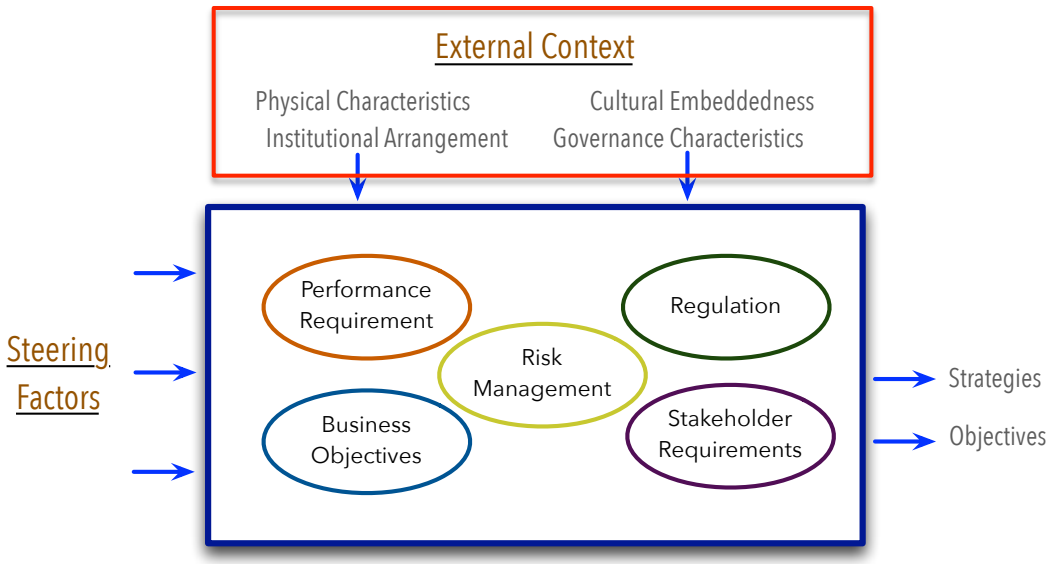
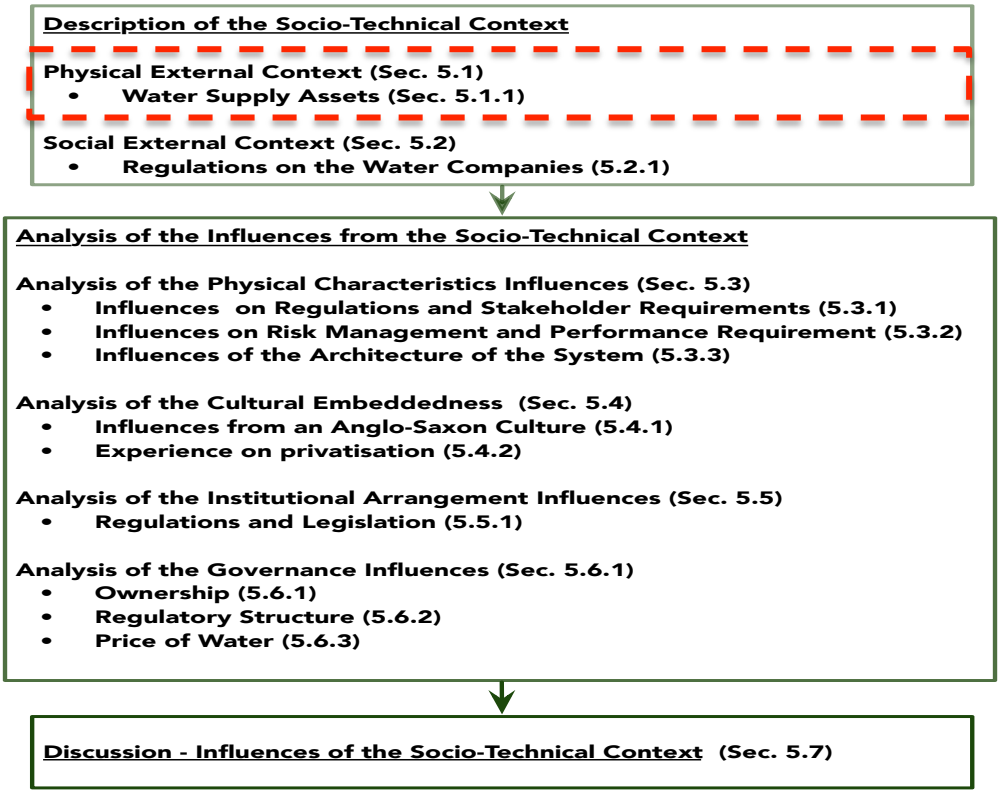


Figure 5.1: System Diagram-Analytical Framework for the External Context

The red square in Figure 5.1 shows the segment of the analytical framework that is applied in this chapter. From a system diagram perspective, this segment represents the contextual factors that influence the internal factors that are a part of the system (strategic decision-making system) but cannot be controlled by the strategic team. The study conducted in this chapter characterises the embedded factors that are a part of the decision-making process and which make it a unique process for Thames Water.

5.1 Describing the Physical External Context



The major challenges faced by Thames Water are ensuring security of supply, managing environmental impacts and meeting affordability targets (Rawlinson, 2012). These main challenges are primarily related to the available water supply and maintaining the service standards in the future.

Thames Water operates in the Southeast area of the UK and is designated as a water stressed area by the EA. The main drivers are availability of water resources due to the (geo) hydrological characteristics and levels of rainfall, combined with population growth. Much of the population growth forecasted is in localised areas, where water resources and the capacity of the environment to absorb new development are constrained (Thames Water, 2009). In addition, climate change is expected to produce higher temperatures, drier summers and wet winters across much of the UK. Reductions in water availability are expected as a consequence of climate change, increasing the pressure on the ability of water companies to provide a reliable

supply of water to customers (Arnell, 2004; Charlton et al., 2009).

The operating area of Thames Water is primarily divided in two water resource zones, the Thames Valley area and the London area. The Resource Zone is the fundamental planning unit within a water company, which resources can be managed as a coherent unit (Thames Water, 2007). Water resources in the Thames Valley are divided to 70% groundwater and 30% surface water. The London area's water resources are 70% surface water and 30% ground water.

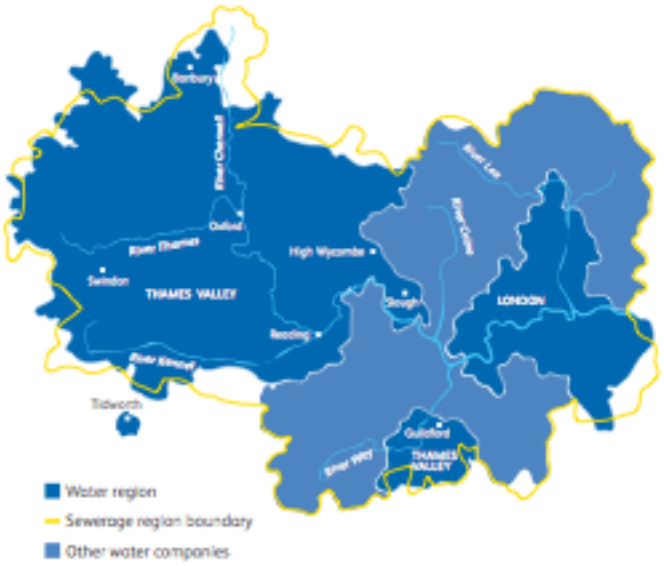


Figure 5.2: Map of Thames Water operational area in London and the Thames Valley (Source: Thames Water, 2007)

The rainfall levels in both water resource zones are relatively low. The amount ranges from 1000mm per year to as low as 500mm per year (WRMP, 2009). Beside the low levels of water supply available, London is one of the most densely populated areas of the UK serving approximately 13.5 million customers. Climate Change is identified by Thames Water as the key driver to impact the water supply systems, especially by affecting the reliability of raw water sources and the reliability of the supply infrastructure. The table 5.1 summarizes some of the potential impacts of climate change on the water resource zone were Thames Water operates.

Table 5.1: Potential Impact of Climate Change on Thames Water Supply System (Source from Arnell et al., 2006, Thames Water, 2013a)

Reliability of raw water sources	Changes on the frequency of low flows and recharge, increasing the frequency of floods which may increase the frequency of highly turbid flows and threatening abstraction points with saline intrusion
Reliability of the supply infrastructure	Altering reservoir safety
Ability to treat raw water to potable standards	Changes on the frequency of inundation of treatment works and by changing the quality of the abstracted water
Demand for water	Limit the inability to distribute treated water quickly enough to customers at periods of peak demand

5.1.1 Water Supply Assets

Thames Water is considered the owner of the water supply and wastewater physical assets. These assets are divided by infrastructure and water non-infrastructure (following the same terminology as Ofwat). Most of the assets owned by Thames Water are old and limit their strategic intent to achieve the service standard in the future. The company operates the oldest network in the UK (Thames Water, 2013c). The age of the distribution system creates a more vulnerable system to bursts and leakages. A summary of key statistics for each of the assets is provided below.

Table 5.2: Summary of Key Statistics for Thames Waters' Infrastructure (Thames Water, 2012)

Water Value of Chain	Key Statistics
Water Resources	• 70% of total Thames Water Distribution Input is from surface water sources • 30% of total Thames Water Distribution Input is from ground water sources • London has an 80% to 20% surface water / ground water division • Thames Valley has a 30% to 70% surface water / ground water division • Current total demand is approximately 2579 Ml/d • Current total Water Available For Use (WAFU) is 2817 Ml/d • Current headroom is 78 Ml/d
Water Treatment	• 108 - total number of Surface and Ground Water Treatment Works (WTW) • 47 - WTWs in London, of which 6 are Large London Process Plants • 4 of 6 Large London Process Plants have Slow Sand Filters • 95% of London demand serviced from Large London Process Plants • Approximately 2100Ml/d supplied every day to 9 million customers • Value of assets - £2,769m
Water Distribution	• 31,000km of network, with 2,800km of mains 18" (450mm) and above • 67% cast iron mains pre-1960s • Oldest operational main, from the 1800s (Oxford Street) • Leakage continuously reducing over the last 5 years • Bursts reducing and water quality among best in industry (99.98%) • Average age of the water mains is approximately 70 years • 9 million customers served every day • Network links to over 3 million properties

The historical approach for investment in UK Water companies was conducted on the basis of aged-based and condition based. Though, in most of the case, the assets were replaced as they deteriorated and investment funds were limited to those directly affecting the service (Heather et al., 2006). These approaches led to an accumulation of investment needs and further deterioration of the assets (Balance, 2006).

With a risk-based approach expenditures during the last four years show a consistence higher expenditure on capital investment versus operating costs. Large fraction of these investments is attributed to improve the capability and improve the poor conditions of the asset based (Bridgeman et al., 2011). Thames Water has been consistent on their expenses trend during the 2009 prices review period. The

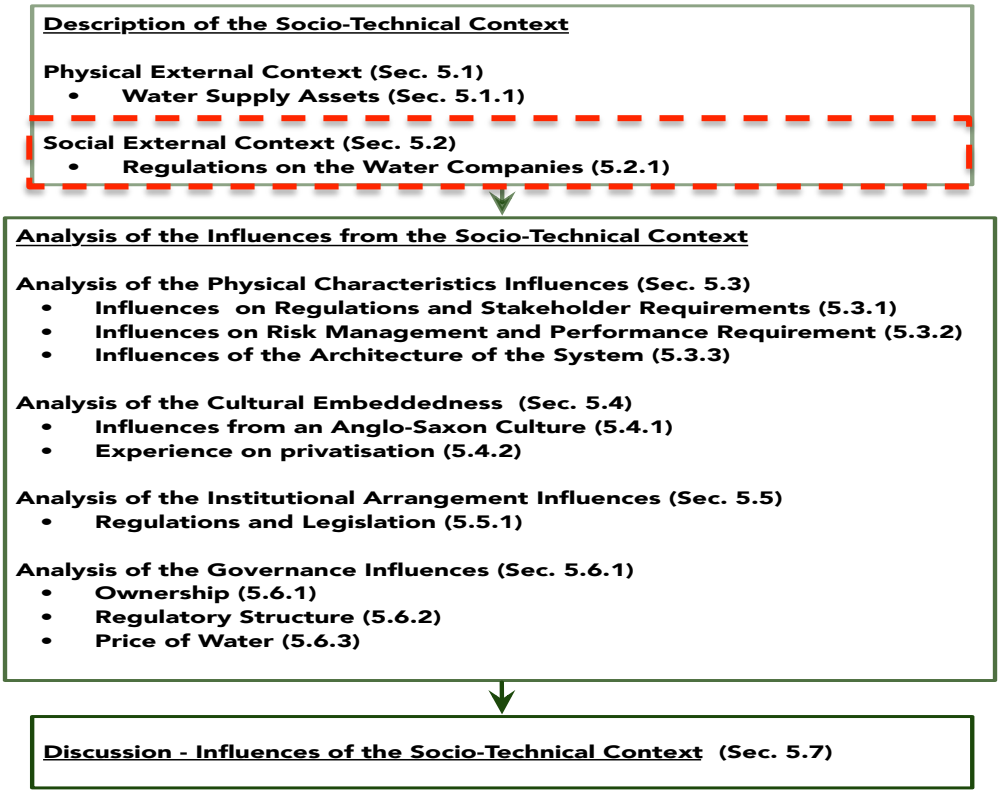
consistent trend started since the privatisation of the water companies (Ofwat, 2013). This investment has been funded through increased borrowing as well as customer bills (Balance, 2006).

As part of the operating expenditures, the increase during the past few years is due to increased power costs, increased contractor rates, and the impact of extreme weather, drought and flood (Thames Water, 2013). The table below shows a summary of the expenses during current price review.

Table 5.3: Summary of Financial Data for the 2009 Price Review Period

	2012/13	2011/12	2010/11	2009/2010
Turnover	£1,759m	£1,671m	£1,600m	£1,593m
Operating Expenditure	£770m	£666m	£627m	£605m
Net Capital Investment	£963m	£1,056m	£1,003	£763m
Profit before tax	£128m	£169m	£598m	£690m

5.2 Describing the Social External Context



The government of the UK privatised the water companies under the Water Act 1989 with the objective to increase capital and revenue in order to achieve the requirements from the European legislation (Defra, 2006). The privatisation followed the trend of other utilities such as telecommunications, electricity and gas. The result was 21 regional monopolies (10 water and sewer companies), vertically integrated water companies, which provided a 'source to tap' service: obtaining water from source through abstraction, treating it to an appropriate standard, and providing it to customers' taps via company-owned infrastructure (White Paper, 2012).

The Water Act of 1991 consolidated different water related legislation, setting the powers and duties of a system of regulators that would be responsible to enforce the Water Act and subsequent legislation. The main regulator for the water sector is the Department for Environment, Food and Rural Affairs (Defra), whose main responsibilities are to define the laws and policies related to water and the environment. Responsibility for

economic and financial regulation was vested in the Water Services Regulatory Authority (Ofwat), the Drinking Water Inspectorate (DWI) who became responsible for overseeing the quality and safety of drinking water, and the responsibilities of the environmental and river basin function were transferred to the Environmental Agency (EA).

Regulatory arrangements emerged from the privatization of public sector monopolies. The regulatory structure aimed to promote efficiency on reaching the statutory requirements and preventing exploiting monopoly positions of water companies (William et al., 2003). The systems of regulators were established as independent regulators from the government departments and a central administrative control. As independent regulators, the powers of the regulators with respect to water companies were broadly legislatively determined which left room for decision making, particularly with regard to the content of the relationship between the regulator and firm (Arnell, 2011, Charlton et al., 2010; William et al., 2003).

In addition to the regulation structures established with the privatisation of the water companies, regulations from the Water Framework Directive (WFD) started to push a more active participation from the Environmental Agency in the regulation of the water companies. Water Framework Directive is a requirement established by the European Union (EU) to all member states of the EU and all candidate countries. This legal framework focused the water companies to start integrating actions to protect and restore the freshwater resources across UK for this and future generations by encouraging a sustainable use (Refer to Appendix 10.8).

5.2.1 Regulations on the Water Companies

Water Companies operate under a long-term licence granted by the Secretary of State. Companies are required to report their performance to Ofwat on an annual basis (see subsection below). The annual report provides Ofwat with a progress account from the water companies towards stated key performance indicators determined by Ofwat, which includes the competition, environmental and drinking water quality objectives. These parameters represent the requirements from legislations, EA and DWI. Then,

the key performance indicators are updated every five year and ranges of different activities and services, such as bills, service levels, quality compliance, leakage, operational costs, capital expenditure, relative efficiency, network activity and financial performance as described in Chapter 3 (see also See Appendix 10.2). The aim of the established comparative competition is to enable and stimulate efficiency and service improvements to the benefit of customers (Aikman and Doherty, 2006; Bridgeman, 2011).

Along with the licence there are financing arrangements driven by an incentive-based system of price cap regulation. Regulators set a price limit every 5 years in what it is called the Price Review process. Price limits are established on the basis of the formula RPI $\pm$ K, where RPI is the retail price index and K is the amount by which water companies can increase or decrease the prices charged to customers over a period of time (Thames Water, 2009). This regulated price mechanism sets an upper limit on price increases, which enables an efficient company to generate a revenue stream that is sufficient to allow the financing of its functions (Bakker 2003). Ofwat aims, with the price mechanism, to encourage companies to operate more efficiently and sustainably (Ofwat, 2009). Details of the regulations and legislations in the water industry are provided in Appendix 10.8

5.2.1.1 Statutory And Regulatory Reports fro the Water Companies

Water Companies are required to produce regulatory documents every five years. These documents' main objective to report where the money collected from customers will be invested over the following 5-yr period. With this information, Ofwat determines the price limit that the company can charge to the customers over that period of time (Price Review Period) and the next one is in 2014. During this process, companies outline the investment proposal for the next 5-yr regulatory period. Ofwat gave its decision in a 'final determination' (FD), which sets billing limits for the five-year period. The regulatory period as result of the Price Review is called the Asset Management Plan (AMP). The companies are currently finishing AMP 5, and AMP 6 will run from 2015-2020.

The Business Plan (BP) is the main report that covers all these investments, which are separated into different sections. Regulators request the companies to provide detailed information of the process requesting a particular report for these sections of the BP. These sections are covered with the Water Resources Management Plan (WRMP), Long-term Strategies, Asset Management Plan (AMP) and Annual Return. The figure below illustrates the timeframe for each of the regulatory reports.

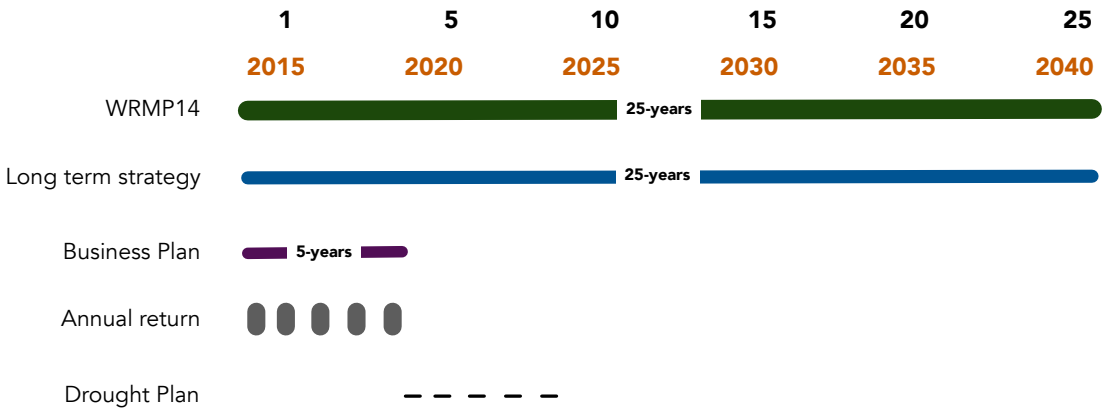


Figure 5.3: Relationship between the outputs prepared by Thames Water (Source WRMP, 2009)

As it can be appreciated from Figure 5.3 the timeframe between the different regulatory reports are different and not necessarily complementary. Ofwat determines the final approval of the activities proposed in the plans during the review of the Business Plan. Approval is subject to priorities determined by Ofwat on the evaluation and perception of the price of water that customers will be able to pay (Anell, 2011). The plans provide specific requirements such as scenarios for climate change, the lowest cost plan that should be implemented, asset management decision-making guidelines and they require consultation with customers and main stakeholders. More details of the structure of the plan are presented in Appendix 10.2.

5.2.1.2 Changes in Regulation for Price Review 2014

Ofwat has proposed a reformed price control approach that will be implemented in the

2014 period. The new framework is expected to provide an incentive for water companies to evolve the way they operate in order to confront future challenges with the water industry. Two main changes are reviewed in this subsection that are relevant for the asset management decision-making process.

5.2.1.3 Outcome Based Regulation

Ofwat regulates the water companies based on the input-output-outcome model, which is used by the UK public sector for the evaluation of the activities and the evaluation of their programme (HM Treasure, 2000). During the past price review periods, the key reporting requirements (outputs) required by the water companies were determined by Ofwat. For the 2014 price review period, Ofwat will be using outcomes for the price determination, instead of the output approach conducted in the past, and reducing the prescriptive approach also used in the past (Ofwat, 2011c).

The outcomes definition of evaluation is aligned with the definition of outcomes used on this research. They are defined as "higher-level objectives that company actions, activities and achievements are intended to help deliver. They represent what customers and society really value." (Ofwat, 2011b, p. 9). The outcome based approach aims to achieve two main objectives. First, a less prescriptive approach would provide more flexibility for water companies to innovate and couple with future challenges, such as the deficit on water supply, climate change, and so on. The established outcomes are generally continuous, long-term requirements that do not necessarily fit into one price control period. Therefore, the outcomes that customers receive immediately may differ from those they gain later, and differ again from their ultimate outcomes. Second, improve the effectiveness in understanding and what customers and society need and value and achieve it (Ofwat, 2012b).

Water Companies will be responsible to determine, up to some level, their KPI (outputs) for the next price review period based on the outcomes that they define. Ofwat will evaluate the performance of the water companies on the basis of outputs that are in compliance with legal requirements and outputs that the company

determines to deliver the outcomes that they define. The impact of Ofwat is illustrated in this compound version of the input-output-outcome model. In the model, activities are changed by the programme of the company that are approved by Ofwat based on the regulatory documents.

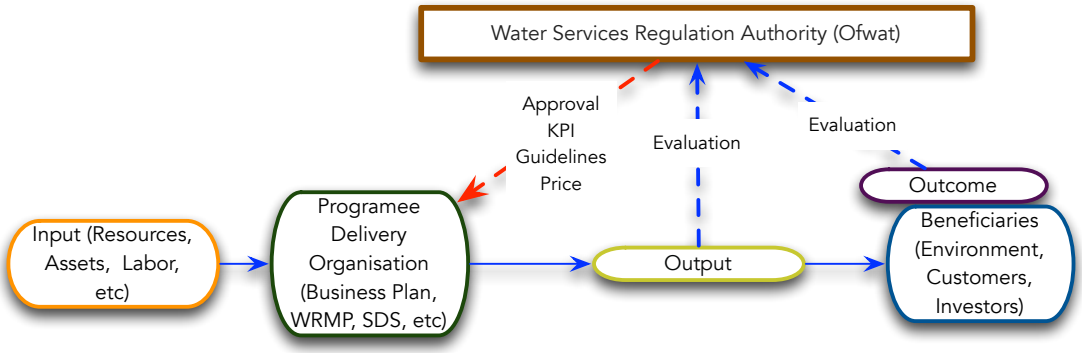


Figure 5.4: Input-Output-Outcome Model Adapted for Ofwat (Source: Excitant, 2012)

Ofwat activities are decentralised by passing some of the responsibilities to the water companies and the Customer Challenge Group. The Customer Challenge Group is an independent group assembled by Thames Water and established as a requirement from Ofwat to oversee the interest of the customers in terms of Thames Water's objectives and decision-making. Water Companies will have the responsibility to propose outcomes and outcome delivery incentives. Challenges to the proposal will be conducted by the Customer Challenge Group by reviewing the quality of the companies' customer engagement and the extent to which the companies' proposed outcomes and delivery incentives reflect customers' views (Ofwat, 2012). Ofwat will then make a final assessment of the companies' proposals. In addition to these company-specific outcomes and incentives, Ofwat will determine some minimum performance levels that will apply to all companies. More detail information is provided in Appendix 10.

5.2.1.4 Describe of the Price Control

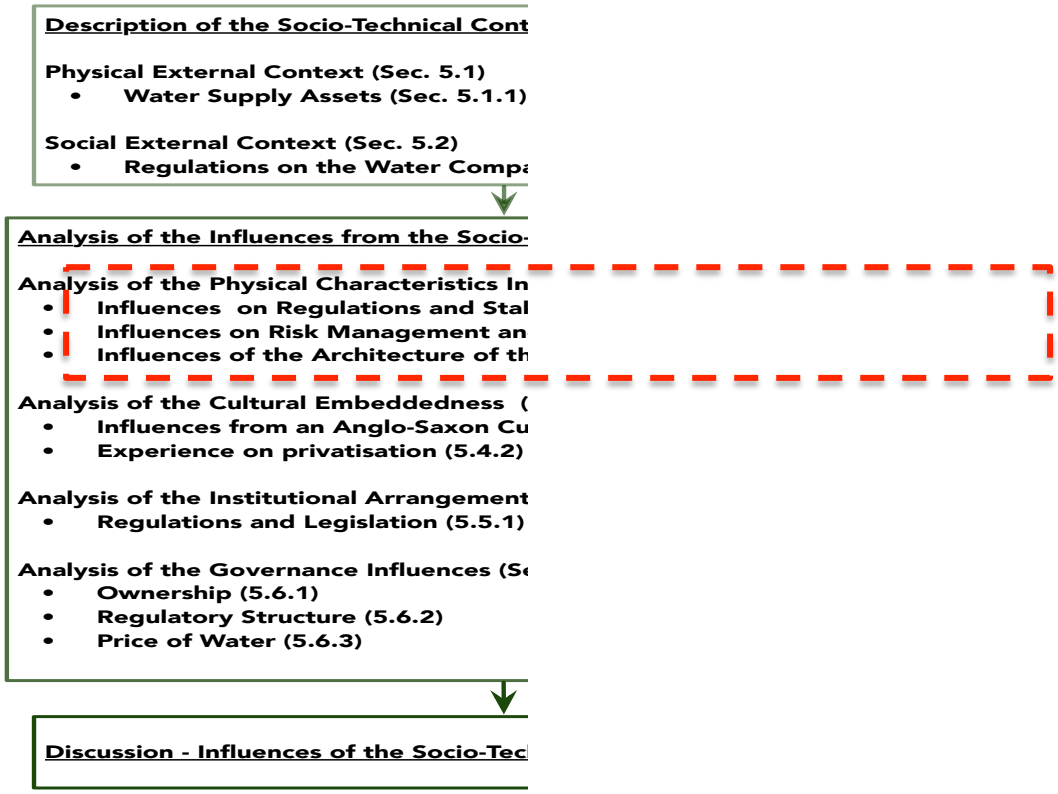
Ofwat intends to separate the retail and wholesale control. Within the wholesale, two

binding wholesale controls will be established, one for water and one for wastewater, using the traditional RPI ± K approach. However, the way the K factor is calculated will change.

For the wholesale water, the revenue of companies will be controlled utilizing a total revenue approach and a revenue yield approach. This approach will incorporate annual adjustment mechanisms for variable parameters such as operation costs, expected demand and metering.

The cost assessment for the proposed business plans will change to a total expenditure approach (Totex). Based on the interviews conducted for this thesis, there is still no clear proposal from the Ofwat approach. However, the company has started to look into possible areas that will change their asset management structure.

5.3 Analysis of the Physical Characteristics Influences



The physical characteristics will be discussed based on the related elements: climate, (geo) hydrological system and water availability. Thames Water environmental area provides constraints to the decisions taken during the development of long-term strategies. The limited availability of water resources as a consequence of extreme variances on rainfall affects the water available to supply the system. These occur in combination with an increasing population that results in higher levels of water demand. The effects of both have created reactions from the regulators and the company due to the possible risk of water scarcity. As result, a more dynamic-decision making process is part of the long-term strategy.

5.3.1 Analysis of the influences of the Physical Characteristics on Regulations and Stakeholder Requirements

The water availability on which Thames Water operates is highly influenced by the regulators and stakeholder requirements. The government recognises the increasing risk of water scarcity in large areas of the UK. In response, the Water Act of 2003 established the statutory requirements that companies must: 1) maintain a level of security of supply; 2) produce and maintain, with public consultation, the Water Resources Management Plans (WRMP); and, 3) include climate change effects. Indeed, "All water undertakers in the England and Wales have a statutory duty under sections 37A to D of the Water Industry Act 1991, to prepare and maintain long-term WRMPs" (Thames Water, 2009). In addition, Water Companies should consider the requirements of the Water Framework Directive that limits the water abstraction limits.

The requirements of the plan have made Thames Water focus on understanding the effects of climate change on their water resources. On the last price review period, the investments proposed by the water companies (including Thames Water), where based on scenarios of climate change determined under the guidelines of the WRMP. Due to the uncertainty of climate change, Ofwat assumed a position that limits water companies to invest on the basis of scenarios of climate change, arguing that there is not enough evidence available for companies to justify investment (Ofwat, 2009). What

underpins this decision is that current funding structures in the UK passes on investment related to adjustments for climate change into Thames Water clients and not to society (Arnell, 2011).

As result, it can be perceived, from the Water Resources strategies, that Thames Water investments have been based on customer preferences. The strategies for the next price review period are focused on strategic goals related to demand management. Long-term investment strategies focus on developing better tools; models that will better argue for investment related to climate change.

5.3.2 Analysis of the influences of the Physical Characteristics on Risk Management and Performance Requirement

There are direct influences caused by climate change on risk-management elements. The uncertainties of climate change makes Thames Water develop long-term strategies that follow a real-option approach ([10]) instead of approaching by robust decisions. Indirect influences are the changes in weather fluctuations on the performance of the system. An example is temperature fluctuations that increase the number of burst pipes during winter periods. As a result, Thames Water is considering storages that can buffer the impact on the system and smart meters in their water mains.

The limitations of water resources and the uncertainties of climate change may be pushing Thames Water to develop strategies for the next generation of water infrastructure. Water stressed countries, such as Australia and Singapore, are trendsetters for the next generation water infrastructures. Brown et al., (2008) present a framework that describes how cumulative socio-political drivers affect the service delivery functions of water companies (Figure 5.5). The research is based on different water companies in Australia. Long-term strategies for Thames Water are starting to follow that same pattern. The future expectations of limits on natural resources have made the company look at different options. These strategies are moving to what Brown et al., (2008) describe as the Water Cycle City. The activities that underpin the strategies in the 5-yr timeframe are focused on promoting demand management

(metering) and water re-use schemes. Under the uncertainties created by climate changes, strategies for the long-term will need to have a smart infrastructure that is adaptable to change.

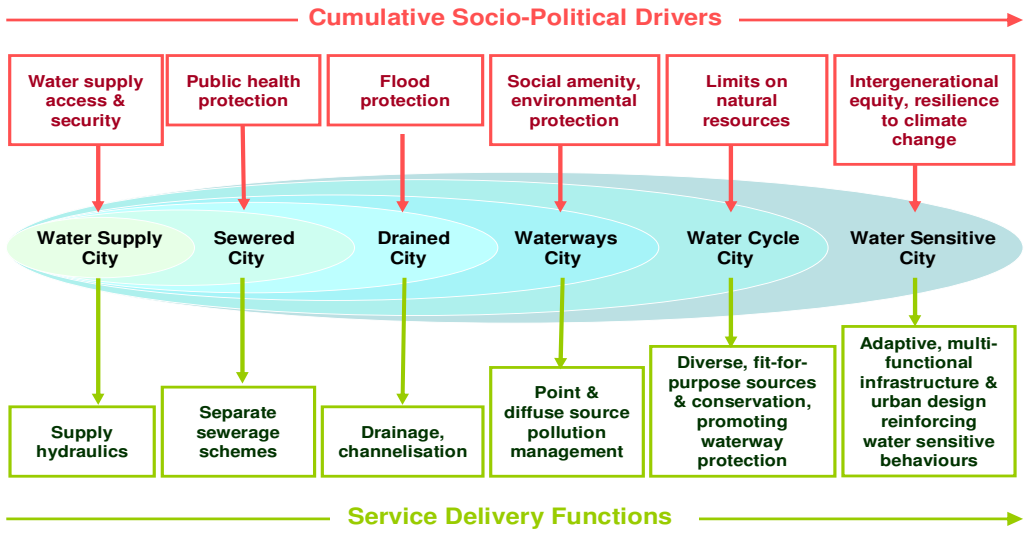


Figure 5.5: Urban Water Management Transitions Framework (Sources Brown et al., (2008, p. 5))

5.3.3 Analysis of Influences of the Architecture of the System Structure on the Decision-making Process

Strategic decisions are conducted following the water value chain. The impact of the architecture in the development of the strategies is reflected in the approach of risk management. The strategies in the long-term are focused on moving into a more resilient system, to develop strategies to gain more knowledge of the system, and to develop strategies that are more integrated between the different subsystems of the water value chain.

However the conditions of the assets are driving the majority of the strategies that influence the performance requirements. Old infrastructures and decisions on the material used for the water mains. The push of water to invest it can be observed with efforts to improve the leakage position in Thames Water and with the specific long-term strategies to address this issue. Thames Water have reduced its leaks by almost a 26% over the last 5-years (Thames Water, 2012). Since the mid-1990's leaks have reduce in 35% between all the water

companies. However, if all the pipes could be fixed it would save enough water to supply 22.4 million people every day (Bridgeman, 2010).

Attribution of leakage percentage of Thames Water (25.7 per cent leak rate) is mainly attributed to the age of the system and complexity to mange the leakage. These complexities have result in Thames Water to have the higher number of leakage targets (Figure 5.6). In London alone, more than 50% of water mains are over 100 years old, and 30% are over 150 years old. Bridgeman (2010) established that in order to meet its 2010 leakage target of 690 ML/day, Thames Water must replace an additional 360 km of mains at a cost of £150 million, which 6% of its total capital expenses in 2012. This needed amount invested in leakage is double what Vitens spent in their infrastructure in total in 2012, £58 million (Vitens, 2012).

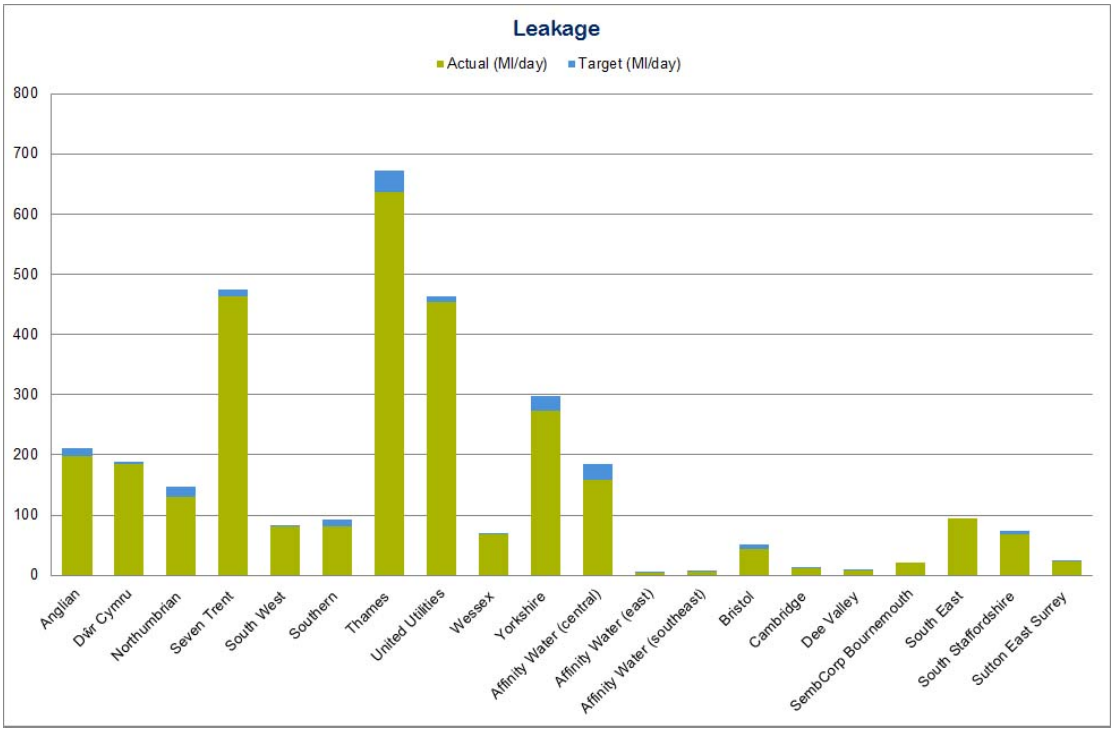


Figure 5.6: Level of target leakage established by Ofwat and the actual performance of the water companies (Source: Ofwat, 2012c)

The complexity of the size of infrastructure is comparable to the one in Vitens. Vitens infrastructure (less than 6 per cent leak rate) is estimated to be 48,000-kilometre of mains compared to the 31,000 km of mains that Thames Water owns. Therefore, attribute of the existing leakage is mainly due to previous decision related

to investment approach that act in a more reactive approach that in a preventive approach. Between 1996 to 2001 Thames Water have not expenses assigned to upgrade of the mains. After 2006, the level of expenses in mains upgrade was equal to expenses similar to the expenses to repair and correct leakage. This ratio of investing in upgrading the mains have increase to more than 50% and have kept the level of leakage controlled (Thames Water, 2010 June Return).

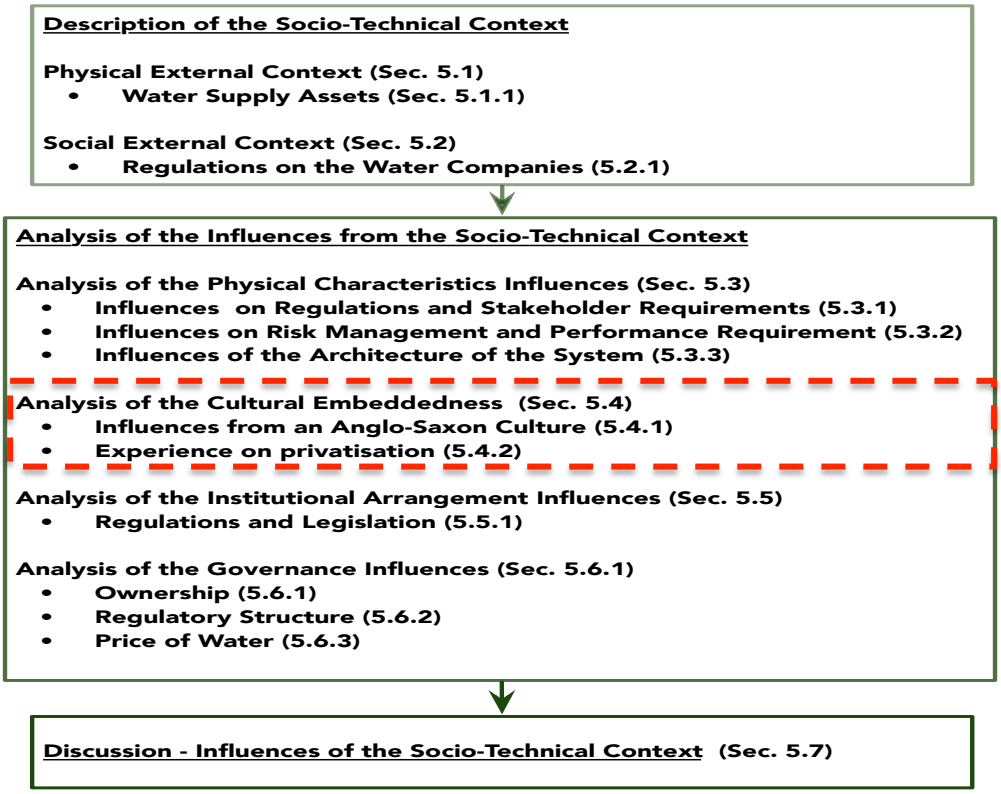
As a result of the sustainability, perceived wastage and high cost issues, leakage management enjoys a high profile in the UK media and among the general public. In addition, the susceptibility of the system increases a concern of the uncertainty of the impact of climate change in the system and the ability to maintain the security of supply. Consequently, effective and economical leakage management remains a key focus and challenge for all water companies (Bridgeman, 2010). The large level of leakages on the system is driving the performance of the system and customers' requirements to replace the mains. As a result of the condition of the system, leakage is one regulatory parameter from Ofwat and the company has established a specific position at the executive level and at the strategic planning section with the objective to address leakage.

London operating area is primarily supplied by 5 water treatment works. The works operate in a network infrastructure that provides resilience if one of them fails. In addition, these treatment works were a high-capital investment, but there are simple technologies that reduce the impact from future price increases from power and chemical costs. As a result, investment decisions have focused on increasing the resilience of the assets and not in investing in large-scale water works. The architecture influence can be perceived in strategies related to increasing resilience and knowledge of the treatment works.

The predetermined conditions of the system are pushing strategies related to increasing the performance of the system. In the case of water distribution, the capability of the system is affected by the condition of the system and not by the design. Assets such as the water mains are reaching their maximum life of operation and this is pushing the specific focus

on replacement of these assets as it was observed on the strategies where performance and customer requirements had a greater impact on the strategies. In the case of water treatment, the approaches of the strategies were such that the performance requirements had a high level of impact compare to the stakeholder requirement. These strategies focus is to increase the capacity of the system and improve the decision-making process to maintain the technical design of the system.

5.4 Analysis of the Cultural Embeddedness Influences



The effect of the cultural embeddedness is analysed in two main areas. Characteristics of the Anglo-Saxon culture (Sec. 5.4.1) are detailed in relation to the stakeholder, authority relationship and affinity to society. The second area is related to the embeddedness of privatisation (Sec. 5.4.2). The level of analysis in this section is a high level and is based on the experience specific to the case.

5.4.1 Reflection on the Influences from an Anglo-Saxon Culture

As discussed in the previous chapter, there is a direct and indirect influence of the stakeholders in the process of decision-making. Customer and regulatory requirements affect the development of company values, mission and objectives. In addition, the customers are part of the process, and strategies developed are focused to meet with the willingness of the customers to pay.

From the asset management perspective, the asset owner can be also viewed as another stakeholder in the development of asset management strategies. Different publications and scientific papers have identified these characteristics, intentionally or not, by referring to the higher level in the decision making process as asset managers. Thames Water follows this approach- the executive level strategic objectives are considered in the decision-making process with the same approach they consider as customers in the decision-making process. The consideration of the stakeholder is also a standardised approach that occurs in the majority of cultures; however the influence of the stakeholders varies between country and cultures.

According to Steers et al., (2011), the nature and power of a stakeholder group is influenced by the predominant culture on where a company conducts its business. This nature and power can be characterised with a model that distinguishes between a centralized and a distributed stakeholder (Steers et al., 2011). Companies in Anglo-Saxon countries such as the UK are confronted with stakeholder groups where power and influence is fairly centralized. These influences are typically reflected in missions and goals that include profit, customer satisfaction and the avoidance or legal or ethical challenges. On the other hand, the distributed stakeholder model in Rhine cultures such as Germany and The Netherlands consider a major influence from investors, customers and governments and still have a major influence over the mission and strategies by the employees and general public. The influences from distributed stakeholders reflect profit, customers satisfaction, ethical and legal behaviour, social responsibility and sustainable growth and development.

This culture effect can be identified in the case of Thames Water where

shareholders (and the executive level), customers and regulators are present in the asset management decision-making process while employees and the public are not. Thames Water's behaviour is primarily driven to avoid the challenges of the regulators, even when there is no specific regulation requiring a specific action. Strategies developed in the asset management process were developed with the intent to ensure that the performance of the assets, now and in the future, satisfies the customers, regulators and business requirements. Strategies are developed to maintain the existing system to be capable of meeting the actual requirements, rather than considering the vision of the next generation of infrastructure ([10]).

The participants in the interviews indicated that water companies in the UK are using expert judgement to make decisions related to investments. In the case of asset management that behaviour is primarily influencing the risk quantification. Anglo-Saxon countries are characterised by rationalisation in taking a central management decisions on where to invest in order to generate benefits in a short-term perspective (Steers et al., 2011; Hoftede, 2010). Shareholders and regulators focus on the results of the risk-based analysis as a tool to make decisions based on investment outputs obtained from these decisions (Aikman et al.., 2006). As a result, a structure from regulators and business objectives emerges that does not consider the total benefits over a longer period of time instead, one that provides benefits in the present situation (Steers et al., 2011).

5.4.2 Reflection on the Influences from the Experience on privatisation

After the radical changes involved in the privatisation on the public utilities, a structure and perspective on the way public utilities should operate in UK has since developed. With privatisation, utility goods have been perceived as commodity goods instead of public goods leading to: commercial activities, price-cap regulations and stimulating profit-maximising behaviour (Kunneke, 2008). Outcomes established by the central government have been reached more effectively since being exposed to higher levels of competition (Water White Paper, 2012). The experiences from the institutional structures developed in

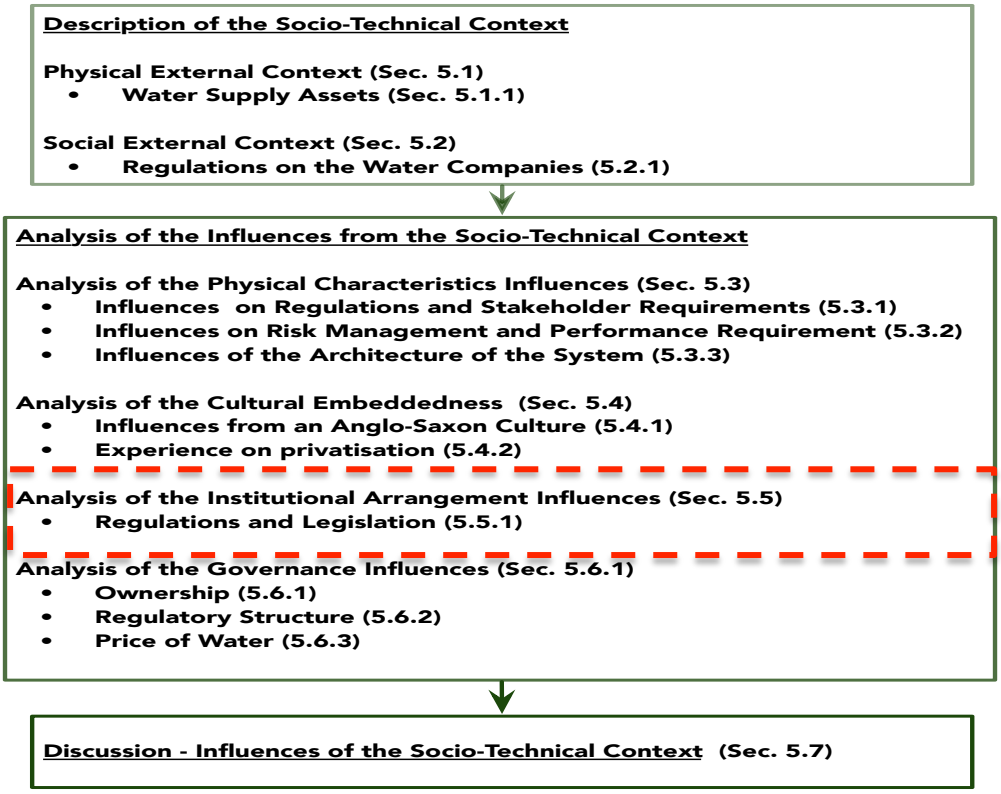
the UK public utilities have been a large influence to the utilities and structures that followed.

An example of the reflection of completion in the public authorities can be contemplated by comparing the vision and mission from Thames Water with Vitens. Thames Water vision and mission statement are ""If customers had a choice, they would choose Thames Water" and "Provide(s) the best-in-class water and sewerage service that is profitable, sustainable and acts in the long-term interests of both our customers and the wider community" (Thames Water, 2013). In the other hand, Vitens vision "focus on client-driven initiatives within the water chain" and "provide the highest quality drinking water at the lowest price" (Vitens, 2012). Two contrast words can be appreciated from Thames Water statements, choice and profitable. The use of these concepts in their vision and mission statement could reflect of the competition and profitability as drivers at the level of water companies. However, it is important to highlight the direct integration of clients/customers in both visions and value the relationship with them.

William et al., (2003) argues that efficiency reached by privatization is not necessarily due to increased competition, but by the evolving relationship between the firms and the economic regulators. The confidence obtained by regulators and competition has led to the development of a focus by central government to continue looking into expanding the competition between public utilities in order to be efficient in reaching the future challenges (Water White Paper, 2012).

The experience of the gas sector and the company Water Scotland, is leading the reform in water industries. The Water White Paper (2012) proposes an increase in the levels of competition in the retail side and the upstream section of the sector in order to encourage efficiency. The exact effects on the development of long-term strategies for the water supply are not completely understood. Integrated long-term strategies between the different sub-systems will be expected to be affected, and may not be effective in reaching the long-term outcomes without adequate modifications.

5.5 Analysis of the Institutional Arrangement Influences



5.5.1 Regulations and Legislation

The government policy is delivered in the UK through Acts of Parliament, associated secondary legislation and through guidance to regulators since privatization (Defra, 2008). Privatisation has led to regional monopolies and vertical integrated water companies with limited access to competition. To ensure the interests of customers and the environment, privatisation led to further restructuring by separating the roles of regulation and provision of water and sewerage services. The result established institutional arrangements for the water companies and a complex context for the water companies and the regulators (Defra et al., 2008; Parker et al., 2011; Byatt, 2013).

Water companies are heavily regulated and directly affected by the strategies of high-level government. The government has established statutory requirements on water supply companies including: level of competition, regulator structure, water quality standards and water security of supply standards (as discussed in the previous section), to reach their goals to achieve a financial stable infrastructure, environmental improvements and increase the value of water in society (Arnell, 2011; Byatt, 2013).

The 2003 Water Act implicitly provides regulated legislation to the water supply section. These values are related to the quality of water, security of supply and impact to the environment. These values create technical standards for the performance of the asset, and they are the main reason for the influences of the regulation requirements on the asset long-term strategies, especially on the management of the water reservoir and water treatment works. The operation of the business is influenced by legislation to manage competition in the industry. Using the input-output-outcome model (Figure 5.7), the high level perspective of Defra regulatory structure (central government on the water companies) is established.

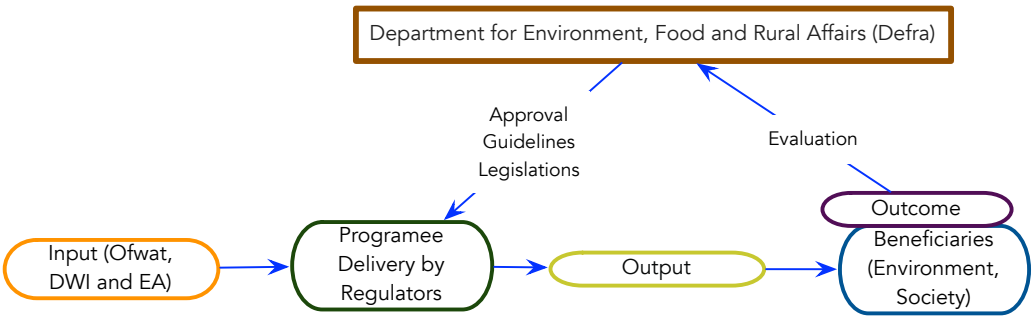


Figure 5.7: Input-Output-Outcome Model for Defra evaluation on Water Companies

Enforcement of these pieces legislation is the responsibility of the regulators; water companies are required to obey with the determinations of these regulators. Ofwat, EA and DWI are independent bodies situated outside of the government. The independent regulators system creates a regulatory structure with powers that are broad which have left space for the regulators to determine the content of their relationship with the water companies (Vogel, 1986; Wilks, 1997). As result, the regulators tend to be the primary stakeholders for the water company.

Regulators are able to develop policies and regulatory frameworks to establish their own strategies that aim to be for the benefit of society from their regulatory perspective (Anell, 2011; Charlton et al., 2011). The regulations of their established regulatory framework are output based, which are the key performance indicators established at each price review period, Ofwat is the mediator between EA, DWI, Defra, Water Companies and Customers. From the performance requirement point of view, there are: 1) the requirements of regulations established directly by the government looking for the benefit of society; and, 2) performance requirements established from the perspective of the regulators to benefit a particular beneficiary. Therefore, asset water strategies are influenced by the regulations established by the Water Act as regulations and regulatory interests that established the stakeholders' requirements.

This creates a decentralised structure of instruments by the central government and opens the space for more frequent changes in regulations for the water companies. At the same time, the influence of the regulation requirements is not only focused from a perspective of water standards, but also includes; value of water, impact to the environment and a healthy investment environment. Thames Water regulations cover more than water standards, as it is the case in many other countries. Asset based strategies are then impacted or constrained by environmental impact and societal needs. This facilitates the relevance of the objectives from Thames Water and indirectly makes them operate within an outcome-based approach (Figure 5.8).

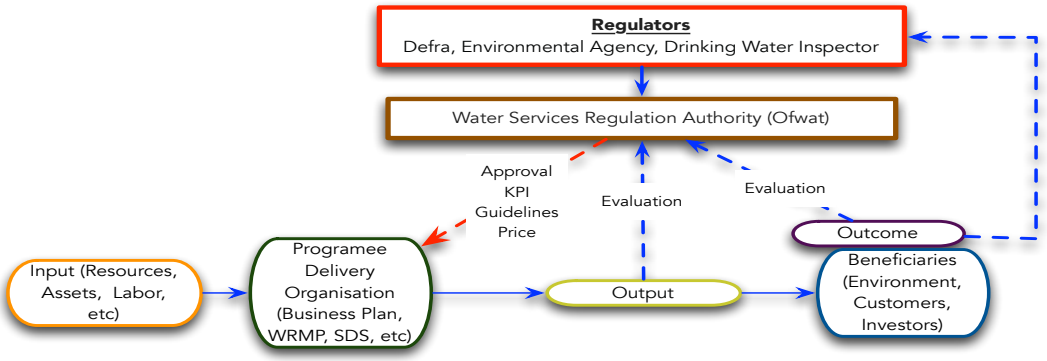
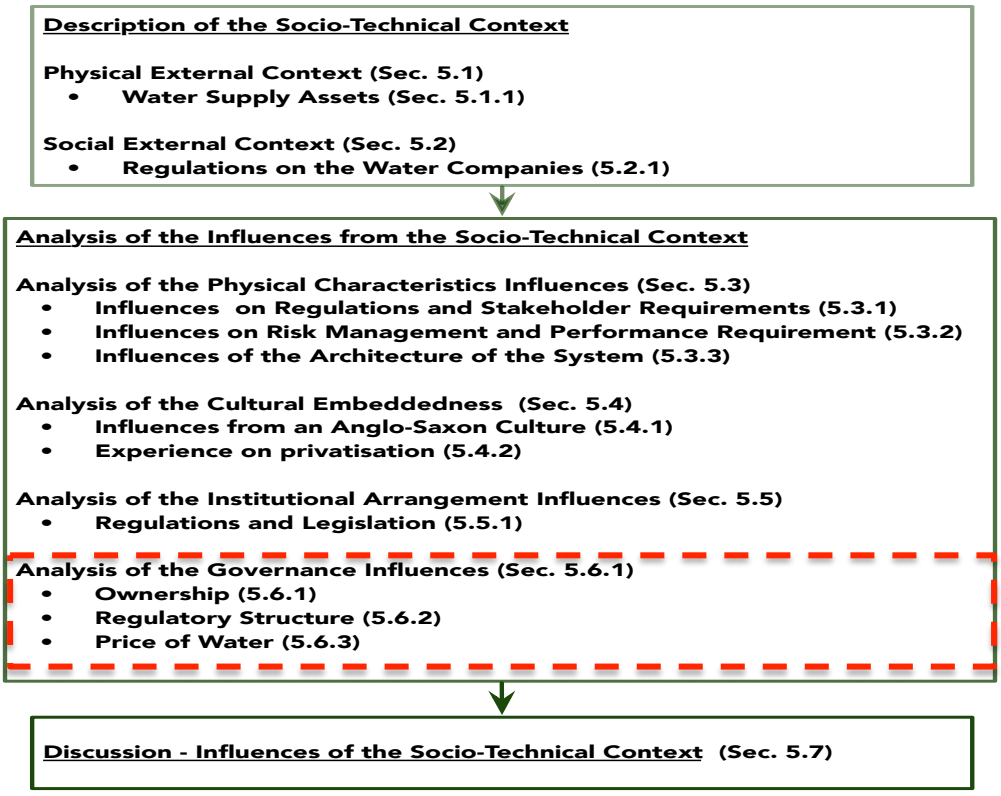


Figure 5.8: Regulators Structure using Input-Output-Outcome Model

The figure above illustrates a summary of the institutional arrangements in relation to Thames Water. The intent is to illustrate how Thames Water was indirectly operating under an outcome-based approach, but with a short-term focus.

5.6 Analysis of the Governance Influences



The influence of the governance layer is more dynamic, which makes it more difficult to characterise. Three main areas are discussed: ownership, regulator interaction and the price of water. Ownership will review the impact of a shareholder-focused company on the development of long-term strategies (Sec. 5.6.1). Regulator interactions and price of water is analysed by reviewing the impact on determined elements of the decision-making process (Sec. 5.6.2).

In addition, the determination of the system borders for the company due to the influence of regulators reviewed. Although the effect of price determination on the supply-demand balance is clear, the effect of the physical context on the supply-demand balance will be reviewed (Sec. 5.6.3).

5.6.1 Analysis of the Ownership Influences

The impact on the water companies' ownership is occurs by the change between owners and not by an expansion of territory. High impacts by merging companies or changing from private to public are not expected due to UK legislation. The main change occurs in terms of owners, where in the case of Thames Water, different groups of shareholders change the structure and strategic objectives of the company. However, the structure was changed to be more aligned with the requirements of the regulators and to dedicate departments to manage regulations and stakeholders. A characteristic described previously.

In the case of the objectives, there was more alignment with Ofwat expectations. As a private company, of shareholders, the governance of the water company is oriented towards shareholder objectives, which are focused in maximising returns in a short period of time within the context of the company. Due to the high regulations and pressure from customers, the influences of privatisation are diminished, and focused internally to obtain the maximum revenue within the context of operation. Therefore, they focus on efficiency and capitalise from the incentives established by the regulators.

This creates a challenge to the realisation of the strategies that require a long-term perspective. Thames Water is developing long-term strategies that are path dependent following a real-option approach, such as increasing resilience. If the executive does not move along with these approaches, the investment priorities will move to a different area in the next price review period ([1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]).

Since the privatisation of the water companies from 1990 and 2012 the water

industry will have invested around £100 billion in England and Wales – around double the rate of investment from when it was in public ownership (WIUK, 2012). After the 1990's price review period the companies have maintain the level of capital investment. At the moment, companies are judged to need a return on their assets of around 5%, meaning that for every £100 that their investors put in, they should expect to get approximately £105 back. This is aligned with Thames Water 5.9%. According to Ofwat (2012), companies may be focus in the growth investment as a metric that symbolises company growth. This growth must be finance and the extent to which a company and its investors may focus on this metric could influence a preference for capital investment.

When is compared the expenses in with operating expenditure, during the 2009 Thames Water have showed the trend to invest in capital investment. In the 2011/12, the expenses on the net capital where £1,056m versus £666m in operation costs with a ratio of C/O of 1.59. To compare to Vitens, their £106.2 million net capital expenses versus £311.9 million in operating costs, for a ratio of C/O of 0.34. Both companies have followed the same trend during the past 10 years. In case of Thames Water, a similar ratio was kept similar to Vitens before privatization.

Based on this data, it can be observed an influence of privatisation to increase revenue by investment and increasing efficiency in the operational cost. These contrast to Vitens as a public company operational cost are higher than Thames Water.

5.6.2 Analysis of the Regulatory Structure Influences

As it was discussed in the above section, Thames Water is required to obey the regulators established under the Water Act. The regulators have increased the complexity of the decision-making process for the development of strategies. Thames Water decision-making process to develop strategies needs the funding from Ofwat, the support for customers and approval from regulatory bodies. As a result of the impact of the regulatory structure, the different elements of the decisions of the

regulators directly influence the decision-making process.

The influences of Ofwat are about the price review structure established every 5-years to regulate the companies and make sure that they are capable of financing their functions and protecting the customers' interests. The Business Plan has been the standardised instrument that Ofwat uses to understand how water companies are investing the money from customers to provide return to investors, make improvements that customers want, balance supply and demand, maintain existing pipes and treatment works, meet drinking water standards and meet environmental obligations (Ofwat, 2011b). As a result, the process has created an interactive relationship between regulators and the firm. The results are formal and informal relationships that directly influence the structure of the decision-making process of long-term strategies. Below, these influences, based on the internal elements of Risk Management, Business Objectives and Stakeholder Requirements, are reviewed.

5.6.2.1 Influence of the Regulatory Structure on the Risk-Management

In the previous chapter the influence of the decision-making process on the development of the strategies for Thames Water was presented. As it was mentioned, the risk based decision-making process is based on the Common Framework established by Ofwat. The process is the connection between the performance requirements, the business objectives, customers and regulatory requirements. The influence of Ofwat is established in the identification of risk, the requirement of the customers on the business risk framework and the optimisation of the strategies based on the customers' perspective. As a result, the customers are considered in the identification of needs and as part of the decision-making process. This has pushed Thames Water to demonstrate their alignment between the business objectives down to the activities of the assets with the development of process mapping and development of integrated decision-making support tools. Therefore, the developed strategies on the basis of this framework would be expected to be aligned between the levels of asset management and the requirements of the stakeholders.

The key element to long-term investment in a risk-based outcome approach

for asset management is the concept of serviceability as an indicator to make decisions. Serviceability is the capability of a system of assets to deliver a reference level of service to customers and to the environment, now and into the future (Parsons, 2006). The indicator is a function of the capability of an asset or a group of assets and the means by which those assets are managed. Therefore, it provides two benefits to make decisions in an outcome-based approach: 1) combining the output from the asset with the outcome (benefit) to the customer; and, 2) providing a level of data high enough to make high-level decisions, such as long-term investment.

At the same time, Ofwat asset management assessment is forcing the company to be more accurate in evaluating risk management. Outcomes and strategies related to asset management are motivated to invest more accurately and be able to justify the decisions related to investments now and for future challenges. The investment decisions are pushing Thames Water to be more accurate and to understand the risks better, and move from expert judgment to a model based approach.

5.6.2.2 Influence of the Regulatory Structure on the Business Objective

The impact on the business objective it is appreciated on the changes that are part of the strategic asset management process as result of the outcome-based approach established by the regulators. Thames Water has started to develop a number of outcomes that were defined based on the value to the customer and regulators. The outcomes are determined from the value to the customer from the perspective of Thames Water and the Customer Challenge Group.

Outcomes were determined for the water industry based on customer and societal needs for the UK. These outcomes were measured based on performance indicators established by Ofwat. Since outcomes are at a higher level they are valued differently depending on the expectations of the customers and society (Ofwat, 2011b). Ofwat is then shifting their responsibility to water companies in order to better reflect the society value at a regional level. As a result, Thames Water is shifting from developing strategies that are based on task-oriented guidelines to developing their own performance and key performance indicators. Here, Thames

Water is spending more effort on engaging with stakeholders and defining the alignment of these high-level outcomes to asset strategies. If the alignment is not reached, asset management long-term strategies many be reaching to different business objectives than those intended by the company. As a result, there is a more complicated decision-making process.

The company is investing time and effort in aligning the outcomes to measurable parameters. The outcomes are impacted by external factors and will not necessarily be delivered. This will provide less certainty to the companies on whether they are effective or not in delivering the correct outputs (Ofwat, 2011b). These will result in an iterative process to adjust outputs and outcomes.

5.6.2.3 Influence of the Regulatory Structure on the Stakeholder Requirements

The regulatory structure forces companies to consider the interests of main stakeholders on the evaluation and determination of the strategies. Customers in particular are part of the decision-making process, as discussed in the previous chapter, both indirectly and directly. In addition, regulatory parameters established by Ofwat are intended to represent the interests of the government, regulators and customers.

The strategies related to the supply-demand balance are an example of the influences that stakeholders have on the decisions taken by the company. Solutions relating to managing the demand of water are the solutions preferred by customer and regulators. Solutions, such as repairing leakages, are expected to be conducted further from the economic value of repair. Reducing leakages will not necessarily reduce the risk of water scarcity since it is reliant in other factors, such as water demand controlled by metering, that are affected by uncertainty factors such as customer behaviour. As a result, Thames Water, without the influence of the customer, would have invested in a more robust solution such as constructing a large reservoir (Arnell, 2011).

5.6.2.4 Influences of the Regulatory Structure on the Performance Requirements

The established risk-based approach is leading Thames Water to focus on developing parameters that measure the right outcome, and developing models that provide better understanding and accuracy of the investment decisions. The company has embedded an understanding of the importance of data in order to make decisions that will result in the efficient delivery of key performance indicators, as they have been doing so since the implementation of the risk-based framework (Figure 5.9). The knowledge developed of the asset will provide Thames Water with a better understanding of their asset performance and strategies to define to prepare for the challenges now and in the future.

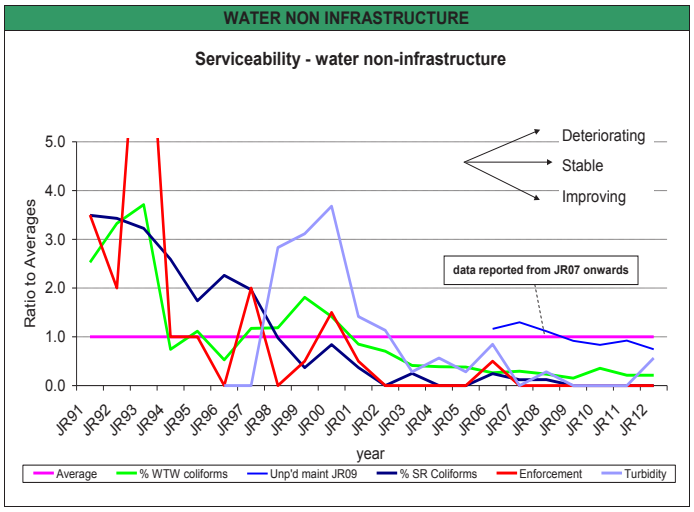


Figure 5.9: Operational Performance - Serviceability Measures history on Thames Water (Source: Strategies, 2012)

5.6.2.5 Influence of the Regulatory Structure on the Regulations

Regulations influence the decision-making process as the primary decision rule. That influence is the direct link between the regulators and the asset management process. Strategies are then built around these regulations in order to increase the benefit.

Regulations also represent other beneficiaries from the outcomes beside the customers, which in the case of Thames Water, is the environment. Therefore, they help with the alignment between other needs from society that are not covered by the business objectives or customers. For Thames Water, regulations are established every 5-year period. The influence of new regulations could change the approach of the long-term strategies.

5.6.2.6 Influence of the Regulatory Structure on the System Borders

The long-term strategies for the assets based in Thames Water are divided into the business units, wastewater and drinking water, and within the different sub-systems of the value chain. In order to determine long-term strategies, the system borders were grouped based on the performance requirements determined by Ofwat. During the price review period and annual review, companies are requested to report the justification to capital investment based on the non-infrastructure and infrastructure assets. With the expected unbundling of the water system, the long-term strategies were developed using the individual sub-systems, water resources, and water treatment and water distribution. Summarizing, the system border determination of Thames Water in relation to long-term strategies is directly influenced by Ofwat standardisation to regulate the water companies. This has created embeddedness in the decision-making process which could be interesting to evaluate after the new regulatory changes and the implementation of re-use water.

5.6.3 Analysis of the Price of Water Influences

The price limit set every 5 years has developed a structured approach by Thames Water to determine investment decisions that follows this structure. The determination and incentive mechanisms of the price of water have created a weight in the decision-making process of Thames Water. Price limits are established on the basis of the formula RPI $\pm$ K, where RPI is the retail price index, and K is the amount by which water companies can increase or decrease the prices charged to customers over a period of time (Thames Water, 2009). This regulated price mechanism sets an upper limit on price increases, which enables an efficient company to generate a

revenue stream that is sufficient to allow the financing of its functions (Bakker 2003). Ofwat aims, with the price mechanism, to encourage companies to operate more efficiently and sustainably.

5.6.3.1 Influence of Price of Water on the Business Requirements

After the regulator determines the price of water, the price limit will determine the projected revenues of the company. Based on the projected revenue, Thames Water will determine the areas of investment and the distribution of the money to these areas. The funds available for the investment areas will determine the priorities of the investment that will be conducted during this 5-year period. Priorities of investment are based on the cost-benefit of available solutions. As a result, the resources available to deliver the strategies will be limited to determined prices. Therefore, the price constrains the available resources, on the input, that will be available to deliver long-term strategies and affect long-term strategies that may not increase a benefit such as resilience.

5.6.3.2 Influence of Price of Water on the Stakeholders Requirements

The price mechanism establishes the amount that a customer will pay for a service and will lead the customer to determine requirements such as affordability. Affordability will be affected by investments in the present to reach objectives of the future. Due to the influence of the customers and interest in an affordable water price, the customer and Ofwat interests focus on the present benefits. As a result, they will be less supportive of long-term strategies that will bring a benefit for future generations.

5.6.3.3 Influence of Price of Water on the Regulations

Price will be the base to determine regulations that will drive an increase in efficiency of the system and also affordability. Therefore, regulations are susceptive to change over a five-year period in order to deliver regulations that will increase the affordability of the system. For the next, or the following review period, the regulators have established mechanisms to increase competition and achieve lower

cost on the customer bills. Examples are the fragmentation of the value of chain and the introduction of Totex as mechanisms to determine the price cap.

Ofwat considers that there is a Capex bias on the water companies due to the regulatory structure of the price. Thames Water considers the introduction of the Totex system which will have an effect on the process of optimisation for the strategies. Long-term strategies reviewed in the previous chapter are still focusing on short-term period strategies against total cost based investment strategies.

5.6.3.4 Influence of Price of Water on the Risk Management

The price mechanism requires water companies to develop a plan that can be justified to ensure the requirements of the assets, supply-demand, water standards and enhancement of the system. To justify the investment needed under the price cap mechanism, the company will have to demonstrate that the investment will be able to reduce the impact of risk to the performance and cost. The total risk will then be limited to a cost-benefit by conducting the investment.

To develop long-term strategies that will be effective (outputs that achieve long-term outcomes), Thames Water has to consider the impact of the external environment and future challenges. Therefore, the strategies will need to be robust or flexible to adapt to these challenges. Robust strategies mean higher investment, or a reduction of risk at a higher cost. Since these are risks for the future, the cost-benefit to develop these strategies may not be justified in the present. As a result, Thames Water has been forced to develop flexible strategies that better balance between risk, cost and performance of the system. This provides a better approach to manage uncertainties of the future.

On the other hand, the mechanisms to implement the flexible approach (such as real-option, adaptive policy) are based on the determination of path dependent solutions. In order for a strategy to be effective in reaching the outcomes of the future, these short-term investments need to be implemented. In response, Thames Water is investing to better understand the impact of resilience to the benefit of the customer

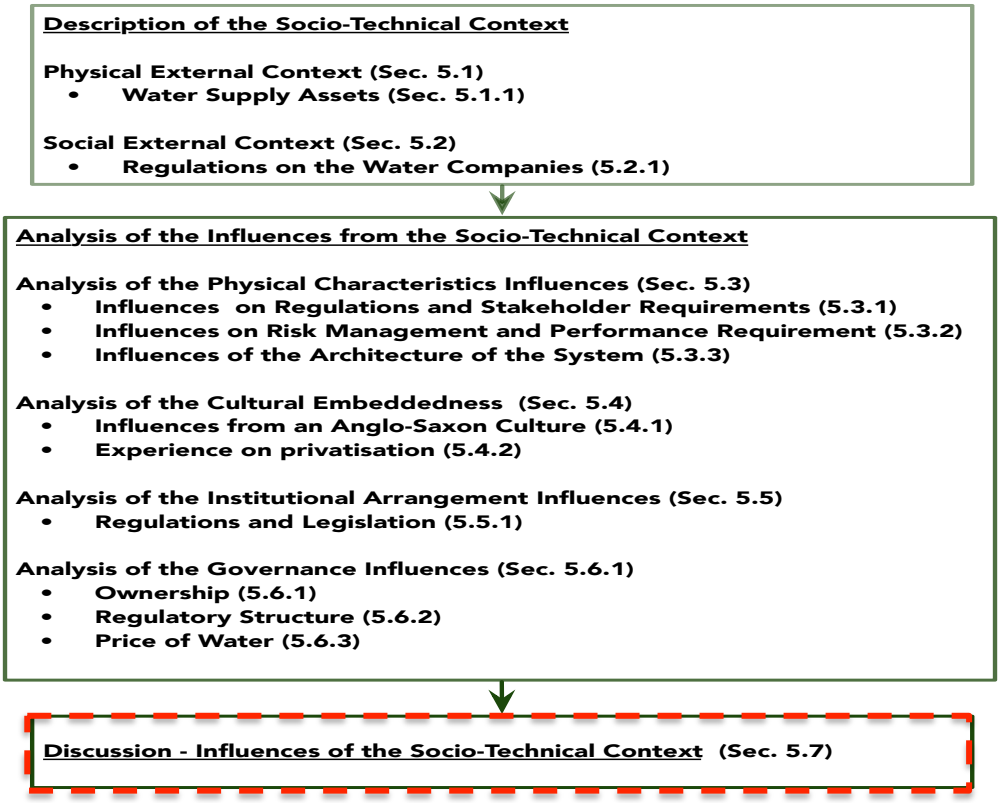
service and why the level of risk is unacceptable.

5.6.3.5 Influence of Price of Water on the Performance Requirement

Conducting investment decisions in Thames Water is based on decisions that are focused on the benefits of capital investment and the impact on the cost of operation. The long-term decision does not focus on conducting investment decisions that consider optimisation of the operation and capital investment. Decisions where operation costs will increase the efficiency of the asset in the short-term and long-term are more likely to not be considered. These decisions may include actions that are preventive instead of reactive.

As a result, the optimisation of the investments has been focused on the short-term benefit of the assets and not from the long-term perspective. In other words, the decision making process has been taking decisions that are efficient by reducing cost and/or increasing the benefits in the present, and not by extending the life-cycle of the asset. Due to the uncertainty of the future, the asset may not be there to perform their tasks in delivering the long-term strategies.

5.7 Influences of the Socio-Technical Context- Discussion



Two sub-research questions were intended to be answered with the analysis conducted in this chapter. The description of the socio-technical context of Thames Water provides an outline of the main interrelations between the decision-making process and the socio-technical context.

What are the interrelations between the decision-making process and the socio-technical context?

The interrelations can be separated between the social context and technical context. From the social context an interrelation between the institutional arrangement and the development of the long-term strategies was identified. The funding for future investments on the water companies is determined by the regulators and based on the regulatory reports required for the water companies. These regulatory reports

represent the activities that Thames Water conduct to reach the outputs and outcomes. Final approval of the resources to develop these activities is directly related to the price determined on the water. In addition, the plans are developed under specific guidelines which include the risk framework. These guidelines are an interconnection between customers, regulations, environment and UK policies. The key performance indicators provided by Ofwat are based on the outcomes that the regulators are expected on the society. These performance indicators are the measurable parameters that represent the interests from the other regulatory agencies, including the legislation. As a result, this created an interrelation between the decision-making process with regulators and the beneficiaries of Thames Water outputs.

The interrelation of the technical context and the decision-making process is driven by the focus on the long-term strategies. The physical-external context describes the operating environment context of the water companies and the assets characteristics. Climate change influences the management of uncertainty to consider a flexible approach in reaching the strategic goals and better understand the system to be more reactive to changes. The availability of water is interrelated with strategic objectives and performance requirements of the system. There is also an interrelation with the conditions of the assets that are interrelated with the long-term strategies focused on repairing leaks. The condition has driven leakage to be a parameter to operationalize the strategies.

What are the influences of the external context on the outcome based asset management decisions at Thames Water's Strategies and Asset Management Policies?

The influences of the external context on the outcome based asset management decisions where reviewed describing the socio-technical context of Thames Water. The influence will be reviewed below on the basis of alignment, efficiency and effectiveness. The cultural embeddedness analysis reflects two main factors that are relevant to long-term strategies. In terms of alignment, orientation of the strategies is

focussed on particular goals and stakeholders. Since the system is strongly regulated, given the compliance characteristics of Anglo-Saxon countries, an alignment between the different levels of the company to meet with regulation and stakeholder requirements is expected. Efficiency of the system is results-driven on managerial techniques with a strong focus on risk-based techniques to aid investment decisions. The perception that it is not looking for the next generation of infrastructure may affect Thames Water to reach effectiveness in the long-term.

Privatisation in the UK was considered as an effect on the strategies on the decisions and strategies developed by Thames Water. The "privatisation culture" is driven by the increase of efficiency on the utilities and profit maximisation. Perceiving a water service as a commodity good led to strict investment on the infrastructure based on funding and on the need to increase competition. Increasing competition in the future could influence maintaining the alignment between the water companies and integrated strategies such as the strategies related to the security of supply. It was review the trend in capital investment since the privatisation of the water companies. In the case of Thames Water higher capital investment double the trend before the time that the company was public. These trends in investment were compared to Vitens expenses where the trend goes in opposite ratio having higher cost in operation.

Physical Characteristics guide the strategic objectives and strong interactions from the social and technical structure. The impact from previous decisions in investment and maintenance are reflection of the leakage problems that Thames Water is currently confronted. As result, large capital investment has to be conducted to improve the current system. This increase in investment is noticed as the same time the investment start after privatisation. However, results are not comparable to leakages from Vitens which investment ratio is by far less than Thames Water. Therefore, this reflects the impact of previous investment and philosophies as in the current decisions in the strategic asset management process.

Physical Characteristics from the social perspective, it has driven to establish regulations to force water companies

to plan over a long-term perspective and engage with the customers when selecting the preferred plan. This engagement between the multi-sector and regulators will reflect more alignment within the strategies in reaching the desired outcomes by requesting specific plans such as the WRMP. However, there is misalignment on the timeframe of the outcome-based objectives, which would make it difficult to invest in high-capital investment that will increase the resilience to confront future challenges. In response, Thames Water's focus has been on the dynamic and flexible nature of the optimisation stage of their strategic asset management process.

The institutional arrangement, as result of privatisation, created a complex structure of regulations. The result is a dynamic system of interactions with the regulator continuously interacting with the water company and with the flexibility to allow for strategies and modifications in relation to society needs. The strong regulations, at almost all of the stages of the process, have led to a structured system of operation for Thames Water that should be the primary reason for them focusing on alignment. In addition, the diversity of the regulations has led Thames Water to operate on an outcome-based structure by specifically defining the beneficiaries of the outcomes and the needs that should be met, and being driven focused on outputs that will be of more relevance to society needs.

The main characteristics of the governance layer are the focus on short-term perspectives due to the ownership and the price review period. Both balance between each other, therefore this has driven Thames Water to focus on meeting the outputs established by Ofwat. On the other hand, there is a short vision of the impact of the outcome in the future. Since benefits in the present are the main drive for alignment, strategies that do not reflect a benefit in the present could be implemented to later reach the desired effectiveness. The main challenge is the determination of what the amount of money will be that the present customers will have to pay for the benefits of the future.

The level of interaction between multi-sectors has the cognitive effect of making decisions of what is relevant to society and exchanging challenges between the water companies due to the

presence of Ofwat as a common denominator. To summarise, the actual socio-technical structure is embedded with challenges in the present and the future. These challenges are limiting the chances of establishing long-term strategies to meet long-term outcome based objectives. At the same time, there is a strong interrelation between multi-sector structures that could facilitate the decision-making process approach on the water company.

In the previous chapter, outcome-based decision-making process and structure, and their influence in reaching outcome-based long-term strategies, were characterised. In this chapter, the socio-technical context was reviewed with the intent of characterising its impact on the decision-making process. Based on the Thames Water decision-making process, the socio-technical context has produced a way of thinking in their decision-making process that reflects their structure for decision-making and processes. In other words, the socio-technical context has embedded in their way of thinking in regard to long-term strategies.

The final version of the input-output-outcome model shows the interrelations summarised on the social context affecting the business objectives and processes to establish the strategies and the technical context interrelations in developing the strategic goals and strategic intentions. Figure 5.10 is the complete illustration of the main interrelations and influence discussed by the analysis of the strategic decision-making process.

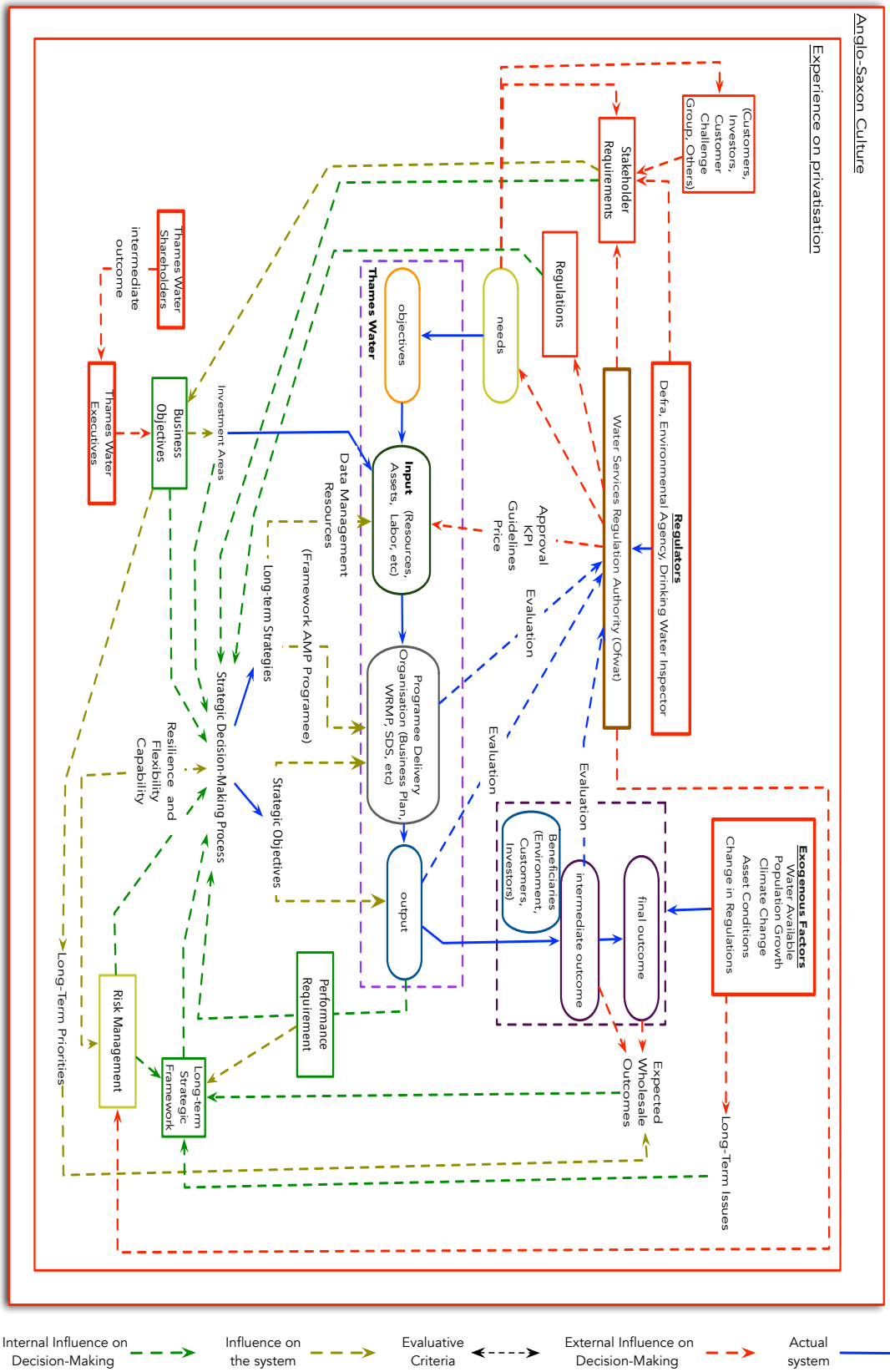
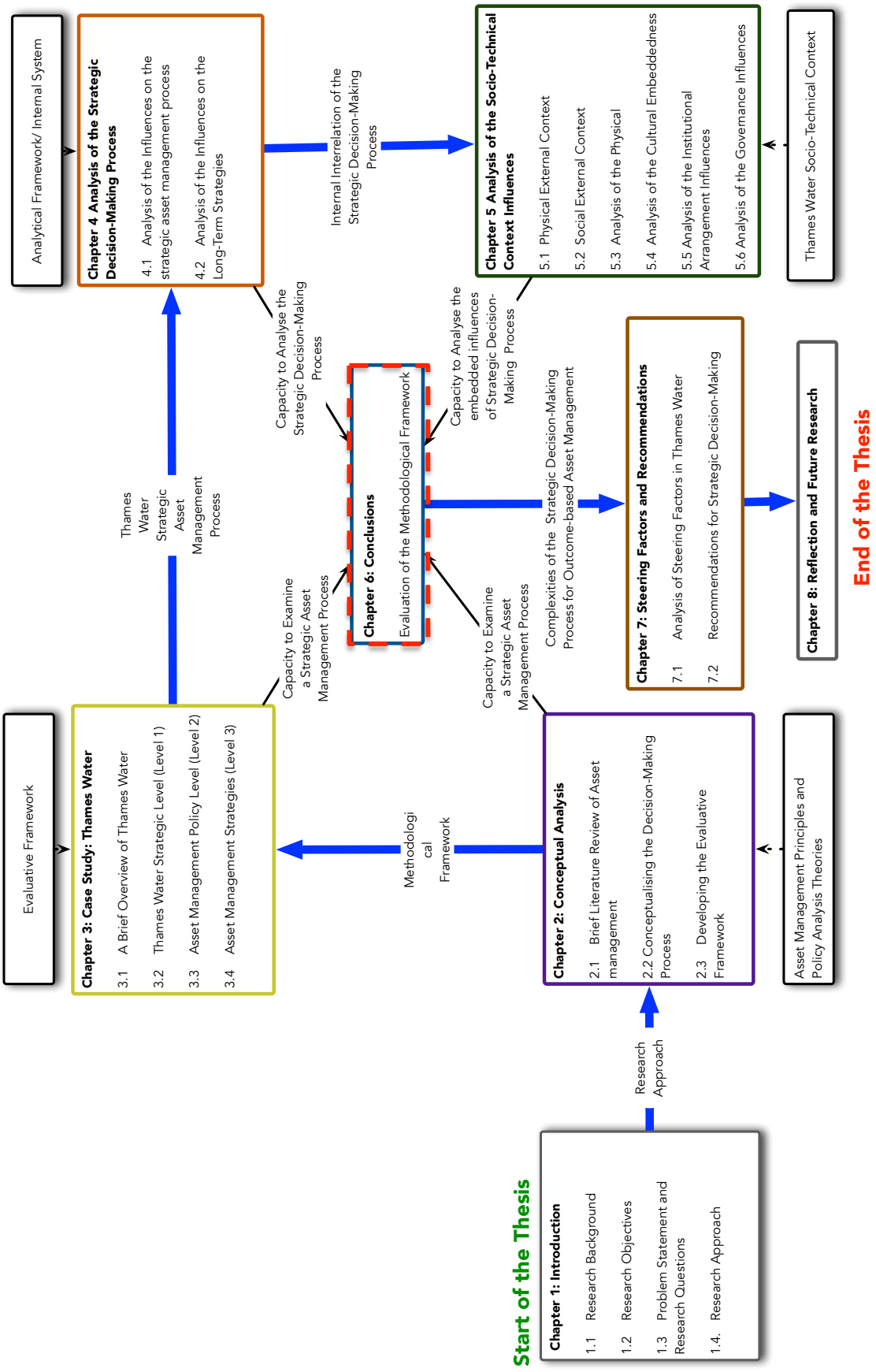


Figure 5.10 Input-Output-Outcome Model of the Interrelations at Thames Water

Chapter 6

Conclusions

Revisiting the Research Questions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6 Conclusions

The main objective of this chapter is to present the conclusions of the research by answering the main research question.

> What methodological framework could be used to analyse the long-term strategy decision-making process for investments in water infrastructure assets within companies and in relation to the socio-technical contexts?

The complexity of analysing the asset management process and defining the interrelation with the socio-technical context led to a number of sub-research questions. The sub-questions can be divided in two main areas: the conceptualisation of the methodological framework, and the empirical study of the decision-making process. The presentation of a summary of the findings and conclusions is conducted per these sub-research questions and their respective concluding remarks mentioned through the different sections of the research. This chapter closes by answering the main research question and providing an evaluation of the methodological framework.

6.1 Conclusion of the sub-research questions

Chapter 2	How can a long-term strategy decision-making process for investment in assets be examined and analysed?

The first sub-research question was based on establishing the methodology to study the decision-making process of asset management for drinking water companies. In Chapter 2, the internal complexity of the system and the multiple interactions between the levels of the business objectives and the different timeframes was reviewed. Due

to its complex nature, it was necessary to develop a methodological framework that could characterise the asset management process and its interrelation with the external context. The characterisation of the long-term strategic decision-making process was defined by three layers: 1) the asset-management process layer; 2) an intermediate layer for the strategic decision-making process that influences the asset management process; and, 3) a superior layer for the external context that influences the decision-making process. In this characterisation the decision-making process was defined as a governing system composed of interconnected elements which produce actions to influence the asset management process.

The components of the asset management layer and the decision making layer were defined using the Asset Management Evaluative Framework that was based on current asset management practices and PAS-55 standards. Founding the evaluative framework on PAS-55 provided an alignment between the practical domain and the theoretical perspective of this research. Five thematic factors were defined as the influential factors of the decision-making process. These influential factors are - Risk Management, Business Objectives, Performance Requirements, Stakeholder Requirement and Regulations – and were used as indicators on how the asset management process is affected by internal decisions and external factors.

The evaluative framework was constrained to determine influences between the decision-making process and the external context. Three methodologies for analysis of problem in complex situations - Adaptive Policymaking, Dynamic Adaptive Policy Pathways and Soft System Science - were considered as analytical frameworks that focus on developing strategies under uncertain futures by determining their robustness or flexibility. The System Diagram method for the analysis of the decision-making process was considered as more suitable for the intent to analyse linking mechanisms and influences. System Diagram analytical framework portrays the strategic decision-making process for long-term strategies as the system of interest, and makes a heuristic conceptualisation between the relationships of the steering factors, internal context of the asset management process, socio-technical characteristics as contextual factors,

and long-term strategies and objectives.

To answer the sub-research question, a long-term strategic decision-making process for investment in assets was examined and analysed by developing a methodological framework that met two criteria: 1) characterise the asset management process and the decision-making process as two different levels; and, 2) identify the influential factors within the decision-making layer and its influences on the asset management process, which in this research was done with a combination of an evaluative framework and an analytical framework.

Chapter 3	What are the asset management long-term strategies and objective of Thames Water for investment on water supply physical assets?

The purpose of this research question was to gather the data that was used for the analysis of the decision-making process. The main data collected were the long-term strategies and objectives, and the components of the asset management process relevant in the development of long-term strategies and objectives. The data of the strategies, objectives and components were categorised by applying the Asset Management Evaluative Framework developed in Chapter 2. The evaluative framework was primarily filled with the analysis obtained from interviews and public documents of Thames Water. The analysis methods included thematic coding analysis and stakeholder analysis.

A set of asset system long-term strategies and objectives were seized as part of the evaluation process. These strategies and objectives on Thames Water are a combination of short-term, medium-term and long-term strategies and objectives to maintain the service of the water supply infrastructure. The system borders defined by Thames Water divide the strategies based on the water value chain: water reservoir, water treatment and water distribution;, and the definition of the system and asset level is based on the service and performance of the assets. Within each sub-system, strategic goals are defined based on the characteristics and challenges of each sub-system and on the company organisation strategic goals. The strategies are a strong focus for improving the capability of the system to confront future challenges and

uncertainties. Their main areas of focus can be determined as: 1) reducing the losses of the drinking water infrastructure; 2) managing the demand of water; and, 3) increasing the understanding of the water supply system.

The use of the Asset Management Evaluative Framework with the objective of understanding the components of the asset management process at Thames Water was reached. Based on the description of this evaluative process, it identified the five influential factors (Performance Requirements, Business Objectives, Stakeholder Requirements, Risk Management and Regulations) as part of the asset management process. This led to the observation that, not only the organisational strategies are focused on the interests of the main stakeholders, but that the asset management process is a risk-based process with a customer centric focus while considering the business objectives, regulations and customers as criteria for success. This approach contributes to an alignment of the company with the relevance given to the stakeholders, both at the organisational level, and at the asset management level.

The next set of research questions were designed to analyse the strategic decision-making process used to develop these strategies. To answer these research questions the developed System Diagram was applied as an analytical framework. The objective of using this analytical framework was to understand and define the internal influences from elements of the organisation (such as business objectives, asset capacity, resources, internal policies, etc.) and the embedded elements (sus as culture, institutional arrangements, asset conditions, etc.) that influence the strategic decision-making process.

Chapter 4	What is the asset management process of a company that applies a risk-based outcome approach? What are the influences on the decision-making process on accomplishing aligned outcome-based long-term strategies?

In Chapter 4, these two sub-questions were intended to review the capacity of the analytical framework to analyse the strategic decision-making process in Thames Water. To answer the first of these two sub-questions, the structure of the strategic

asset management process was analysed to understand if the process applied is an outcome-based approach. The analysis was based on determining the influence of the 5 elements proposed as the internal influential elements on the asset management process for long-term strategies. These influential factors were identified primarily because Thames Water asset management process is a product of the Common Framework established by Ofwat on all UK water companies. This framework is based on standardised asset management guidelines such as PAS-55 and the United Kingdom Water Industry Research (UKWIR). Information used is based on the results from the evaluative framework and explorative open interviews conducted at Thames Waters in relation to the asset management process. Methods used for the analysis are based on thematic coding and soft methodologies such as causal diagrams and goal tree analysis. The latter methods were used for the identification of connections and mechanisms of the influential factors with the process and components of asset management. For this analysis, the influential factors were considered as an individual "lens" or sub-framework to describe the strategic decision-making process.

The analyses indicated that an asset management process of a company that applies a risk-based approach relies on their risk framework. The Common Framework considers the impact on the customer and the environment, which are the main beneficiaries as determined by Thames Water and the regulators. In addition it considers, not only the impact on the beneficiaries, but incorporates the customer values of the service as part of the decision rules of the process. In combination with the outcome-based objectives, Thames Water presents an asset management process with an outcome-based approach. The risk framework is not the only relevant factor on the risk-based outcome approach. The risk identification (need) and the criteria for optimisation are relevant to the defined outcome-based strategies. This arouses the limitation of defining abstract high-level goals (such as outcome-based objectives) that translate into the performance indicators that identifies a risk at the asset level to meet the outcomes in the short and long-term. In the case of optimisation, the criteria should be based on the objective of the company and translated into a strategic

framework for evaluation.

The strategic decision-making process frames the asset management process to develop aligned long-term strategies with the clear intent of maintaining the service of the water supply. Then the strategic decision-making process in Thames Waters is characterised by the company as a separate procedure from the 5-yr planning process conducted during each price review period. The procedure considers different criteria, scenarios and approaches. This is observed at Thames Water where the long-term strategies are defined as long-term service strategies, and not asset strategies.

The asset management process with outcome-based characteristics will not necessarily result in developing aligned long-term strategies. The decision-making process was identified as dominant in the process on governing the five influential factors. The analysis was conducted by reviewing the influence of these factors over the strategies and objectives. The result of the analysis was that the decision-making process linked the knowledge from the assets, business objectives, regulators and stakeholders to influence the strategic asset management process. With this knowledge, Thames Water delivered strategies by balancing between short-term and long-term and deciding between a robust and a flexible approach to specific needs in order to reach the stakeholders' requirements and manage the uncertainties. In addition, strategies were focused on improving the asset management process itself and improving the identification of needs such as limit knowledge of the assets, identification of critical assets, and future uncertainties. Finally, Thames Water decision-making process influences the accomplishment of aligned long-term strategies which is predominantly influenced by the delivery of the strategy, the identification of the crucial knowledge gaps and opportunities on the asset management process.

Chapter 5	What are the interrelations between the decision-making process and the socio-technical context? What are the influences of the external context on the outcome based asset management decisions at Thames Water's Strategies and Asset Management Policies?

The institutional arrangement in the UK shows that they have a large influence on establishing interrelations between the socio-technical context and the decision-making process. Ofwat is in charge of designing the involvement with customers and integrating the requirements of the other regulators. The mechanisms used, such as the regulatory report, risk management guidelines and engagement with customers, are responsible for making the long-term strategies in line with the needs of society. Regulators have determined that the outcomes for the water industry are to be based on customer and societal needs for the UK and have pushed the asset management process to be an outcome-based approach. This shows that there is a strong interrelation between the socio-technical context and the decision-making process.

The interrelation between the decision-making process and the socio-technical context opens the possibility for additional influences on the process. The influences were reviewed comparing the socio-technical context (Cultural Embeddedness, Physical Characteristics, Institutional Arrangement and Governance Characteristics).

The cultural embeddedness description reflects two main elements that are relevant to the decisions of Thames Water. First, companies of an Anglo-Saxon culture tend to be customer focused, with a short-term vision and compliant with regulators. This reflects on the functionality of the system of the Water Companies based on the structure designed by the regulators; this can be the source of the coherence of the system. The second is the privatisation culture for the infrastructure, which was not considered before the research. This embeddedness in the culture can be discussed in different ways, but the main remark is that utility goods have been perceived as commodity goods instead of public goods, leading to commercial

activities, price-cap regulations and the stimulation of profit-maximising. These aspects are reflected on the companies and the regulators; benefit is considered as the main driver to make decisions.

Physical characteristics influence the strong interactions with the social and technical structure. Previous decisions on the capital maintenance led to an unreliable and aging water infrastructure. Leakage and supply-demand deficits are problems that are the result of those physical characteristics. Thames Water's decisions over these issues are not conducted in isolation from the regulators and customers. There is a strong involvement of them in the decision-making process and in the selection of solutions. This reflects a strong engagement between the multi-sector and the regulations and will reflect on more alignment within the strategies in reaching the desired outcomes. Within this context, and the uncertainties of climate change, Thames Water has started to focus in improving their asset management process by being more flexible and by its decision-making process being supported by more real-time data.

In addition to creating a strong interrelation between Thames Water's decision-making process and the socio-technical context, the diversity of the regulations has led Thames Water to operate on an outcome-based structure by specifically defining their beneficiaries of the outcomes, the needs that should be met, and by being focused on outputs that will be of more relevance to societal needs.

The relevant element of the governance characteristics is the focus on the short-term by both the regulators and the executive level. Benefits in the present are the main drive for alignment between the asset management process and the socio-technical context. Actions that are needed in order to reach a benefit in the future are difficult to implement if the customer, regulators and executives do not perceive the benefit.

The extent of interaction between regulators, stakeholders and water companies could be perceived as an increase in the level of complexity in the decision-making related to asset management. However, the level of interactions

between the multi-sectors helps reduce the cognitive effect of making decisions about what is relevant to society and confronting the common challenges. This beneficial interaction can be attributed to the presence of Ofwat as a mediator between the relevant stakeholders. Although the challenges faced could be affecting the chances for efficiency and effectiveness, the strong interrelation within the multi-sector structures could act as facilitators in the decision-making process for the water companies.

This alignment to reach efficiency (internal changes of objectives) and effectiveness (external changes of requirements) may be affected in relation to long-term strategies. The customer, the executive level and Ofwat focus on achieving benefits over a 5-yr timeframe based on the established price review period. With changes in focus for any of them, there is a danger of the long-term strategies not delivering the objectives and not reaching the desired long-term outcomes. This makes a high interdependency of Thames Water to focus in the risk identification, risk framework and delivery of the strategies to reach alignment of the decision-making process.

By answering these sub-research questions, the developed methodological framework was able to provide relevant knowledge to Vitens' feasibility research to implement an outcome-based approach in terms of: 1) the decision-making process to develop long-term strategies and strategic objectives: 2) the alignment within in the levels of the asset management process: and, 3) integration of society needs, institutional arrangements, environment and the business functions in the decision-making process.

6.2 Conclusion of the main research question

What methodological framework could be used to study the long-term strategy decision-making process for investments in water infrastructure assets within companies and in relation to the socio-technical contexts?

It can be concluded that selecting a suitable methodological framework to study the strategic asset management process is dependent on the context and nature of the problems, the content and objectives of the organisation, and the decision-making process and stakeholder involvement. In this thesis it was shown that the strategic decision-making process of asset management can be studied by applying an integrated and systematic methodological framework. The proposed methodological frameworks combine asset management principles and policy analysis methodologies. With the developed methodological framework, three articulated complexities to study the decision-making process were managed: 1) the contentious concept of the asset management process where it varies within industries, strategic asset management maturity and institutional arrangements; 2) the functions of the assets in WCS are complex and norms governing are hard to define and quantify; and, 3) the difficulty to characterise the interrelation between the internal and external context that constitute the decision-making process.

The contentious complexity was managed with the development of the evaluative framework. Asset management was possible to be conceptualized by using a framework that is based on asset management standards and able to cope with established asset management principles. The framework structures the strategic asset management process by defining the level where the strategic asset management process occurs. The framework also highlights the importance in characterising the strategic asset management process in three main segments: risk identification, risk framework and optimisation. This asset management framework provides the advantage of examining the content of different strategic asset management processes. The limitation of the framework is the determination of the process aspects: how are

they connected and how they behave.

Applying system diagram methods to analyse the strategic asset management process allows for the characterisation of the decision-making process as a system. The system diagram method allows the development of an analytical framework that outlines the system demarcation by defining a boundary of the system and the elements that are relevant for the analysis. By defining the boundaries of the decision-making process, the factors that are part of the decision-making system where separated from the contextual factors that are part of the external environment.

The defined internal system comprises of factors and mechanisms that can be influenced by the decision-maker/asset manager. These factors and mechanisms are clustered into five influential factors. By characterising the decision-making process with these five influential factors, the complexity of defining the governing norms in the decision-making process is reduced. However, the full characterisation of the process was not achieved as intended due to the embedded complex system that each of the five clustered factors represent. This limits the analysis to: 1) assume no interrelation amongst the influential factors; and, 2) defining the influences on the long-term strategies using a high-level qualitative analysis.

The contextual factors were defined as factors that influence the development of the system to develop long-term strategies and objectives, but cannot be influenced by the decision-maker. These contextual factors were clustered under four external influential factors that characterised the environment where the decision-making process occurs. This differentiation between system factors and contextual factors help with the characterisation of the interrelation between the internal context of Thames Water and external context where the water infrastructure runs. The characterisation shows that the decision-making process that governs the strategic asset management process integrates factors that are part of the internal and external context. At the same time, the decision-making process is influenced by contextual factors that are a part of the internal context and the external context. This characterisation was illustrated with the integration of the input-output-outcome model. The limitation was to

characterise path dependence contextual factors at the high-level, such as the privatisation ideology.

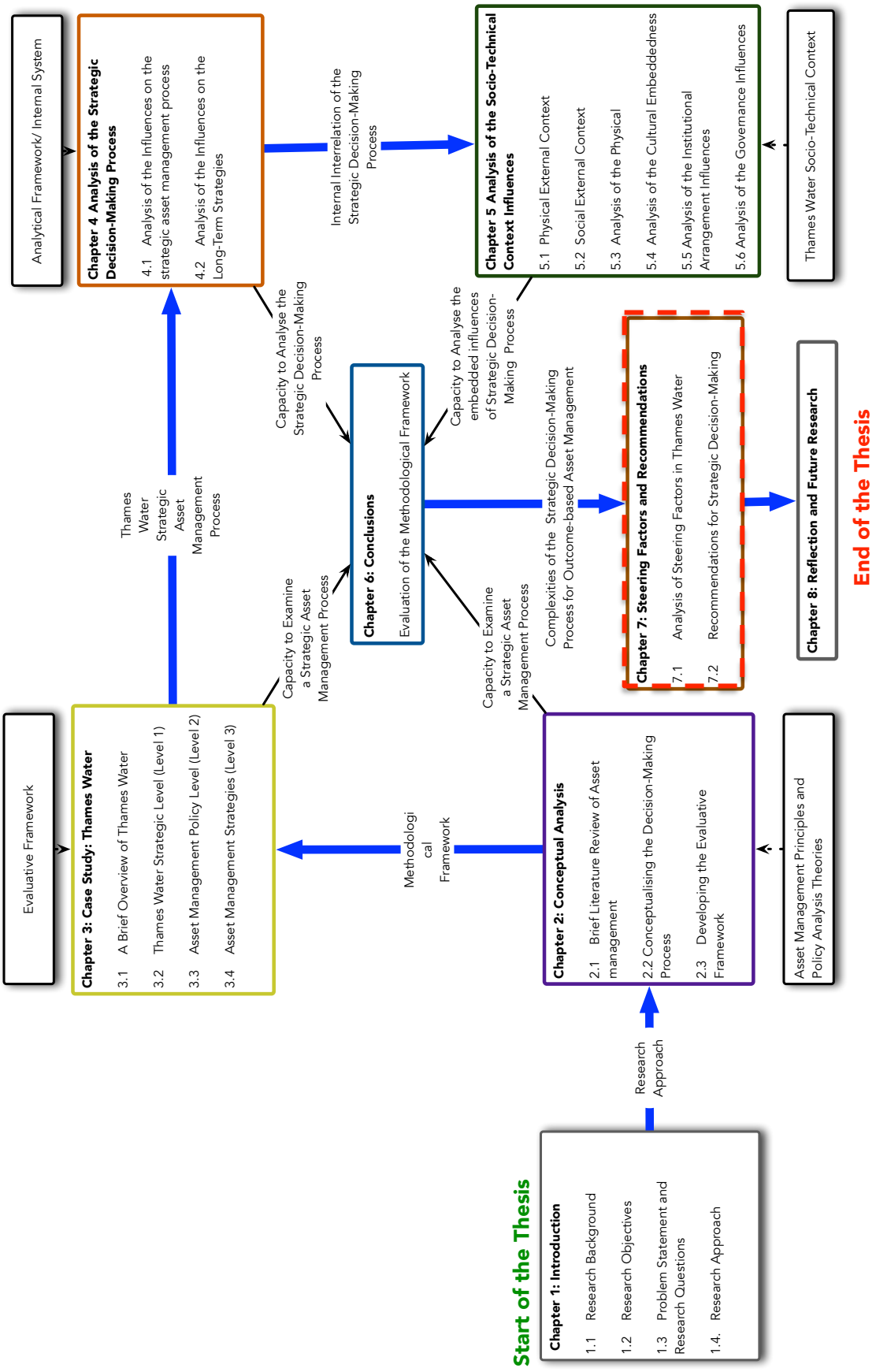
The main limitation of the analytical framework was characterising the interrelation for the timeframes for the long-term strategies. The analytical framework provided a snapshot of the existing structure and mechanisms by characterising the policy scenarios (long-term strategies) and contextual scenario (external environment). However, it ran short of characterising the alignment and perception of both between the asset managers, regulators and executives. One of the main reasons for this is the broad influential factors used to frame the decision-making process and the limitation to differences between short-term and long-term influences. An illustration of this alignment was reached when applying the version of the input-output-outcome model developed by Pollitt and Bouckaert (2004), where short-term outcomes are different from long-term outcomes.

This study adds to the scientific knowledge gap by combining theoretical insights from both the asset management principles and policy analysis. With this approach I was able to explore and analyse long-term strategic decision-making for asset management process as a research domain. By building upon existing asset management and socio-technical perspectives, and by developing the methodological framework, this study adds to the scientific field. Especially the characterisation of the interaction between these two worlds (asset management and socio-technical theories), as illustrated in the Examination and Analysis stage. This provides a useful insight for analysis of long-term strategic decision-making.

Chapter 7

Applying the Analytical Framework on the Steering Factors

Identification, Analysis and Recommendations on the Decision-Making System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7 Steering Factors and Recommendations

In this chapter the steering factors on the strategic decision-making process are identified with the intent to provide general recommendations to Vitens. The definition of the steering factors are based on the actions of the strategic team in Thames Water that mitigate or manage the complexities identified in the long-term strategic decision-making process. In Sec. 7.1, the steering factors are described based on complexities/ challenges identified in the previous chapters. Then, recommendations in regards to the strategic decision-making process for an outcome-based approach are defined based on the analysis of the steering factors and the challenges (Sec. 7.2).

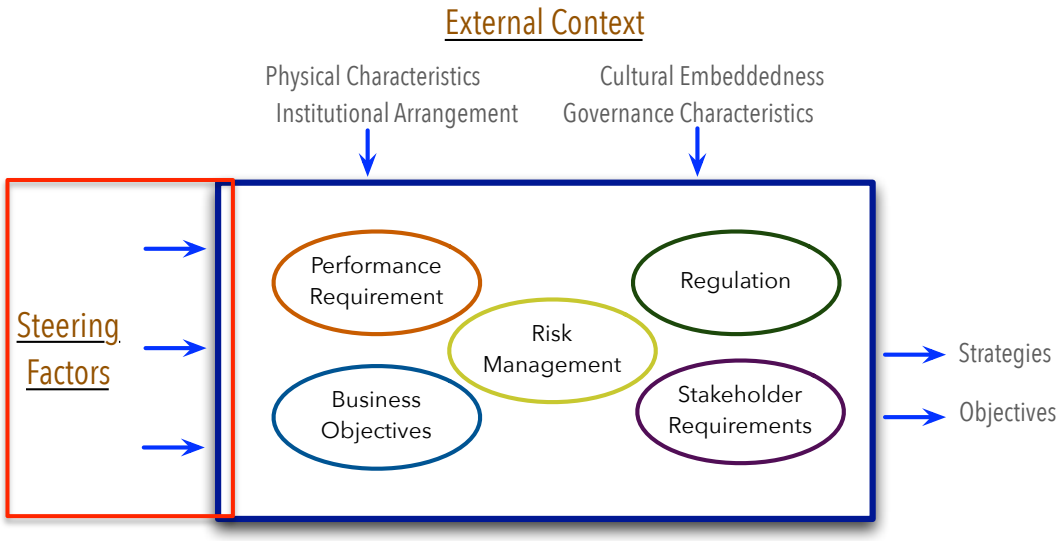


Figure 7.1: System Diagram-Analytical Framework for the Steering Factors

7.1 Analysis of Steering Factors in Thames Water

The literature reviewed and the analysis conducted in this research has provided the identification of several complexities within a strategic asset management approach that is based on outcomes targets. The complexities used in this analysis are limited to difficulties in reaching alignments among Thames Water strategic goals, customers and regulators requirements, infrastructure objectives, assessment of the infrastructure situation, thresholds and the delimitation of assets.

These complexities are summarised below:

These complexities are summarised below:

1. Uncertainties created by Climate Change, Water Demand and Infrastructure Capability
2. Ranges of context specific factors that influence criticality.
3. High-level objectives that are difficult to operationalize at the service and asset level (e.g. outcomes are difficult to measure trough a single metric that meaningfully reflects the extent to which it is being delivered)
4. Alignments between regulators;, customers;, investors and infrastructure objectives;, situations and interventions;, and timeframes
5. Imperfect knowledge of the conditions/capabilities of the assets to identify risk, criticality and impact
6. Management of multiple actors with different interests
7. Trade-offs: a) between cost, performance and risk b) preventive investment versus reactive investment c) flexible versus robust
8. Optimise strategies based on multiple criteria and interests
9. Justify investment decisions in the present for the benefit of future needs

Those complexities can be grouped into three segments of the strategic asset management process. Risk

Identification, Asset Management Framework and Optimisation. Subsections 7.1.1 thru 7.1.5 provide a description of the steering factors identified by Thames Water

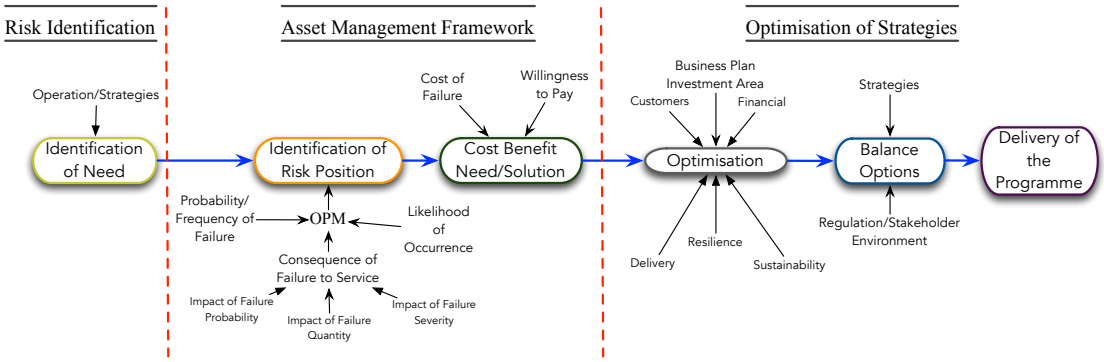


Table 7.1 Summary of Complexities per Segments of the Strategic Decision-Making Process

Complexities on the Strategic Decision-Making Process	Strategic Asset Management Segment
Ranges of context specific factors that influence criticality of the assets for achieving long-term level of service	Risk Identification
Imperfect knowledge of the conditions/capability of the assets to identify risk, criticality and impact	
High-level objectives that are difficult to operationalize at the service and asset level and link to activities	Asset Management Framework
Alignments between regulators;, customers;, investors and infrastructure objectives;, situations and interventions;, and timeframes	
Uncertainties created by climate change, water demand and infrastructure capability	
Management of multiple actors with different interests	
Trade-offs between: cost, performance and risk/ preventive; investment versus reactive investment; flexible versus robust	Optimisation of Strategies
Optimise strategies based on multiple criteria and interests and whole lifecycle of assets	
Justify investment decisions in the present for the benefit of future needs	

7.1.1 Steering Factors in the Risk Identification

7.1.1.1 Serviceability and Reliability as Risk Indicator

Using serviceability and reliability as indicators provides a level of data that is at the same level as the decision-making process, where the performance of the assets can

be evaluated in the present and provide the trends for future changes.

In practice, reaching efficiency from the assets is done by focusing in good engineering practices that take for granted organisational goals, such as providing service (Mardiasmo et. al, 2008). This opens up the possibility that engineering asset management practices are not aligned with the organisational strategic goals. Using serviceability and reliability as a parameter provided Thames Water an indicator from customers' perspective, which is a mutual ground between the organisation's strategic goals and the asset performance level. The development of these indicators is based on trends of performance of the assets and they are a better representation of the expected impact on the long-term level of service and costs, against future requirements and events.

Resilience as an indicator is moving Thames Water to identify risks using a system approach instead of an asset approach. By using a systems approach, asset criticality can be defined easier, since its impact on achieving the business; customer and regulator objectives could be aligned. The next step for Thames Water is to improve their understanding of the impact in the service to justify current investments that do not provide a benefit at the present. The difficulty in defining the system is then reduced since serviceability and resilience are used as factors of consequence by Thames Water, in determining the areas to be taken into consideration in the development of long-term strategies.

7.1.1.2 Cluster Risk Identification

Risk identification was clustered into four main areas that facilitated criticality assessment and risk identification. These were: capital maintenance, quality, supply demand and enhancement. Clustering the asset risk identification provides a focus on where to allocate resources to improve the connectivity with needs of society, business, infrastructure assets and regulators, now and in the future; identifying needs to improve determination to promptly respond to changes. This approach balances between bottom-up and top-down risk identification approaches.

By developing the cluster identification, the gap between current performance and future performance of the infrastructure asset is stated. Performance is then defined on the basis of combining asset capability and the requirements of stakeholders, regulations and business objectives. Then, risk identification aligns better with the impact on the service-performance, or in the case of Thames Water serviceability. Heather et al.'s model (2007) characterises the interrelation between asset capability, requirements and changes at the asset and socio-technical level. Their model is expanded to include serviceability and illustrates the matrix of risk identification that Thames Water is using (Figure 7.2).

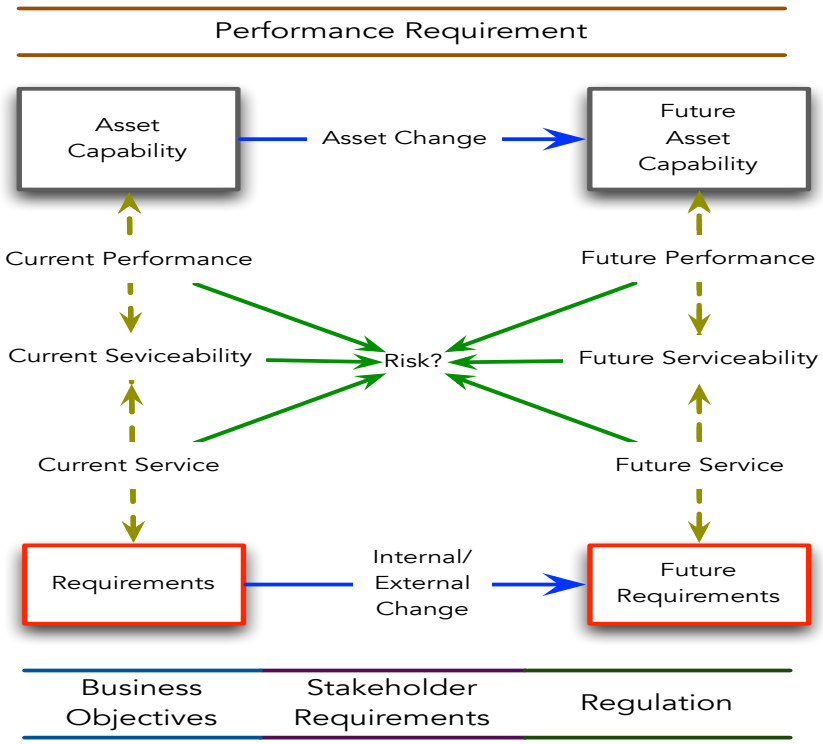


Figure 7.2: Long-term risk identification model / frame of Service and Performance (Based on Heather et al., 2007)

In addition, clustering allows Thames Water to start the strategic asset management process with an integrated approach and a better registration of the correct data. Asset managers are able to integrate asset modelling (such as deterioration modelling, performance and cost forecast) with other scenario modelling (such as sensitivity analysis, water demand, population migration and climate change). At the same time, the approach facilitates demonstrating to regulators,

customers and investor the scale of investment that will be required when future risks come in perspective.

7.1.2 Steering Factors in the Asset Management Framework

7.1.2.1 Development and Synergy of Decision Support Tools

Thames Water is focusing in improving risk characterisation and evaluation to be consistent, repeatable and with a system approach perspective by focusing on developing integrated and forward-looking investment decision support tools. To move into a service and system approach in their decision-making process, Thames Water is starting to integrate their different models, to reach synergy between their functions and different identified risks. By conducting this approach, Thames Water is looking into a more holistic approach for their assets and a better determination of where it needs to invest to characterise and increase the overall value to its beneficiaries.

At the moment, they are combining models related to the water reservoir with the water distribution. Leakage is the primary driver to integrate the models. Since leakage needs to be addressed, they want to understand from which, of all the existing leakage situations, they would get the most benefit for the entire system. A reduction on leakage would reduce the impact on the deficit of the water demand balance and could reduce the efforts of the treatment works.

Resilience Decision Support Tools also provide support on the decisions related to where to invest on the asset to maintain the resilience of the system and not specific to an asset. Resilience is used in Thames Water as a long-term goal and helps with prioritisation of where to invest in the short-term to reach future objectives under different uncertainties. Constructing the framework of the decision support tool on Resilience provides the system with the capacity to absorb disturbances and reorganize while undergoing changes so as to still retain essentially the same functions, structure, identity, and feedbacks (Folke el al, 2005).

7.1.2.2 Outcome Performance Measure Matrix

The main challenges in Thames Water, related to an outcome-based approach, are identified performance indicators that are aligned with the outcomes and the risk matrix. The asset systems, the individual assets, the maintenance, operation and retrofitting of the system of assets should be aiming at the long-term outcomes. Therefore, it is essential to operationalize the outcome level of service into infrastructure system and operational service and performance indicators.

To overcome this challenge, they are developing an Outcome Performance Measure (OPM) Matrix. The intention is: to define the measures that will be linked to the outcomes; to link service performance (e.g. interruption of supply) to asset performance (e.g. Number of bursts), and to activity (e.g. km mains replaced); and to understand how to assess efficiency (good unit cost) and effectiveness (right first time) of the investment ([9]). The intent is to increase the knowledge and confidence of the strategic team that it is doing the right investment decision.

OPMs represent the failures at the service level measures and the purpose behind those measurements. They create a matrix that links the different failures: on the service level, on the system level, on the asset level, to the root cause level. The matrix of measurements provides a clear picture of the assets involved, of what influences those measurements, links to the outcome-based objectives and justifies the outcomes back to the long-term strategies and Thames Water's strategies. Thames Water is trying to demonstrate that if all the right things are measured, it would allow them to pinpoint the measured objectives needed to achieve the outcome. The matrix also provides a structure where they can understand better the relationship between failure and performance. After this relationship is known, better strategies can be developed to recognise where to invest more efficiently, and help them move into a predictive approach instead of a reactive approach.

7.1.3 Steering Factors in the Optimisation of Strategies

7.1.3.1 Adaptable Optimisation Scenario and Tools

The optimisation tools at Thames Water are developed to manage customer perspectives, life-cycle costs and the objectives of the company. The main focus is the use of the strategic framework as criteria for optimisation. This improves internal alignment between the asset management level, the organisation level and the stakeholder requirements. Investment scenarios are then analysed against a multi-criteria structure that provides better sight of trade-offs resulting from the strategies. Then, the delivered strategies consisted of asset strategies (such as improve leakage, metering, asset capability), non-asset solutions (data-control, operation of the business), short-term benefit strategies (environmental impact, profit) and resilience strategies (risk reduction).

7.1.3.2 Flexible Approach in the Delivery of the Strategy (Real Option Approach)

Thames Water manages uncertainty by taking decisions that allow for adapting strategies. The strategies developed are based on a risk-based framework where the likelihood of failure increases with age / time / usage and the projections for the future. Then, decisions to deliver the strategies are based on incomplete knowledge about their impact and on a future that cannot be fully predicted. The flexibility approach increases the strategic decision-making capability to confront uncertainty; by learning with time when new information of the assets and external factors such as climate change and customer behaviour are obtained. The advantage of planning ahead is that the manager has the opportunity to decide when to act, or understand if it would be better to prevent poor performance rather than wait and try to recover from it (Heather et. al 2007).

Thames Water flexibility approach is based on defining strategic objectives and activities that underpin the long-term strategies based on different investments choices. The scenarios balance between 1) meeting the short-term commitment from requirements of risk, cost and performance, and 2) commitment to increase the

knowledge of the conditions of the asset and contextual factors to manage uncertainty. The established strategic objectives provide every five-years monitoring capability and flexibility in the decision-making process. The advantage of flexibility is that the strategic team has the opportunity to keep the options open, decide with anticipation when to act, and/or understand if it would be better to prevent poor performance rather than wait and be reactive.

7.2 Recommendations for Strategic Asset Management

These recommendations were developed based on reducing the complexities created by each of the influential factors (internal and contextual).

7.2.1 Recommendation in the strategic decision-making process

7.2.1.1 Recommendations on the Risk Identification

Recommendation 1- *Apply an integrated long-term risk-identification framework*

A long-term risk identification framework would direct the decision-makers to consider the wider environment in their plans in the risk identification process and at the same time facilitates the identification of criticality of the assets. It would improve the foresight for long-term investment plans, and the outcomes of the asset management framework and optimisation. It may also have the effect of demonstrating the true scale of investment that would be required, and discussions related to acceptable risk.

Based on that framework, preliminary treats to the long-term strategies for the optimisation stage would be identified. Indicators to identify the threats could be aligned in the context resilience with indicators for asset capability (e.g. water treatment capacity, capital and operational costs), performance (e.g. serviceability, profit) and stakeholder requirements (e.g. environmental standards, price). The framework does not provide an answer to the data quality and quantity problem.

However, defining areas where data is lacking by assumptions on uncertainties and threats can help to better identify needed improvements of data management.

Recommendation 2- *Integrated information management*

Too (2010) established integrated information management as a process that should underpin the strategic asset management process. The decision-making process relies in the data that feeds the strategic asset management process to make appropriate, effective and efficient decisions. Developing a data improvement process would increase the knowledge of the conditions of the infrastructure assets in order to make confident and repeatable decisions.

The integrated information management process should be focused on the characteristics of the data and the integration into the asset management system. Characteristics of the data should include quality (is the data reliable?), quantitative (is there all the information needed?), and level of information (is the system level properly defined?). The integration of the data should focus on facilitating the implementation of technological advances, data interpretation, and enable the knowledge transfer between the asset management system, asset data, economical data and customer data.

7.2.1.2 Recommendations on the Asset Management Framework

Recommendation 3- *Develop a monitoring system specific for the long-term strategies*

A monitoring program for the long-term strategies can facilitate managing the uncertainties of long-term planning. The monitoring system is developed on the basis of the identification of critical assumptions, signposts and triggers. Critical assumptions could be related to aspects of climate change; signposts could be variables from asset capability, requirements or service performance; and triggers are the thresholds of these variables that would cause a change in the long-term strategy. Based on the identification of these parameters, actions to improve the strategic asset

management process should be defined. Information on capability of the asset, data needed for decisions on investment, and interrelations between asset performance, cost and risk should be considered as signposts. A monitoring system would allow for appropriate timing to address threats and opportunities to the long-term strategies.

Recommendation 4- *Design a specific procedure to develop service long-term strategies*

A procedure designed specifically for the development of long-term strategies would allow the asset manager to gain insight of fundamental factors that would be influential in a strategic decision-making process for an outcome-based asset management process. Long-term strategies applications require different risks, criteria and investment decisions from short-term strategies, planning activities and operational level. The embeddedness in asset management between concepts such as strategy, policy, planning, asset level and service level could restrain the value in designing a long-term strategy. A specific process would facilitate that the decision-maker identifies the relevant criteria and develops long-term strategies that meet their function as a framework for decisions in lower levels of asset management. By characterising the process of long-term strategies, the decision-maker would be capable of developing strategies emphasising on service and not physical assets.

1. A documented process should be capable of examining both internal and external requirements on the context of service of the assets. The basis of that process should cover at least:
2. Historical, current and future asset performance and service resilience
3. Capital and Opex expenditure analysis
4. Beneficiaries from the outcome-based objectives

5. Short-term, Mid-term and long-term outcomes
6. Organisation and stakeholder service requirements, expectations and level of risk
7. Organisation capacity to respond to future internal and context scenarios (asset base, legislations, customers and environment) to define certain and uncertain vulnerabilities
8. Integrated Investment scenario planning (such as reliability, capital and operational costs, sustainability)

The benefits of segregating the procedure could be higher if the process is conducted on different service levels of the segments of the water value chain (such as Water Treatment Level, Drinking Water Level and WCS level).

A documented procedure for the decision-making process would synthesise the actions of the process, the justifications for the long-term strategies, the alignment on concepts and procedures, and allow for a reviewing process between internal and external stakeholders. This yields three significant benefits; (1) better communication between the different stakeholders, (2) making management decisions transparent to all kinds of stakeholders and (3) rendering decision-makers accountable for their choices. The final achievement of a documented procedure would be a common definition of asset management and strategic asset management handled between all the levels of the company.

Recommendation 5- *Develop an outcome performance measure matrix*

An outcome performance measure matrix would cope with the challenges of operationalizing high-level measures from an outcome-based approach. The matrix would allow for conceptualising the alignment between the different objectives at the organisational, service, and operational level.

As it was described in the previous section, the matrix facilitates decisions related to reactive or preventive interventions. The illustrative representation interconnects performance and risk at the asset, system and service level with

different trigger root causes (such as network design, pressure stress). Based on the matrix, parameters and decisions defined could be evaluated. Examples follow:

Effectiveness from the decision-making perspective: number of events where the investment was done; number of reactive activities; ratio of asset failures to system failures

Efficiency from the process perspective: reduction on failures to service (e.g. average time of interruption); reduction of failures performance (e.g. burst); number of asset failures

Recommendation 6- *Integrate beneficiaries and other stakeholders in the decision rules of the strategic asset management process*

The challenge of balancing the long-term strategies and objectives could be reduced by adopting a framework that integrates the diverse requirements at the different steps of the process. Integrating requirements from the WCS beneficiaries in stages such as risk-characterisation, -estimation and -evaluation could lead to a more integrated and balanced set of strategies as the products of the strategic asset management framework. The approach could start with evaluating the level of integration of requirements from the users, the company and regulations. Steps of that integration that could be considered as a start would be the risk-framework and the cost-benefit analysis.

7.2.1.3 Recommendations on the Asset Management Optimisation

Recommendation 7- *Develop a long-term strategic framework for the optimisation the long-term strategies*

A long-term strategic framework is a line of sight between the organisation priorities and service delivery. The framework allows the decision-maker to map the investment scenarios with the framework components. This increases the decision-maker understanding of the impact on the long-term organisation priorities, outcome-

based objectives and strategic goals. Subsequently, the optimisation stage would be underpinned with an assessment and modelling process of investment scenarios that reflect their ability to achieve the priorities of the strategic asset management process. The resulting approach would enable the decision-maker to deliver long-term strategies with a flexible approach that balances between performance, cost and risk.

Recommendation 8- *Define a structured approach for the delivery of strategies based on the uncertainties of the future.*

Defining an optimisation approach to reach the strategic goals in terms of uncertainties would facilitate the choice of the decision-maker between a robust and a flexible delivery of the strategies. Certain threats (e.g. population growth, deterioration) and vulnerabilities (e.g. lack of information capability, long construction time) should be treated with actions in the present to mitigate certain adverse effects on the long-term strategies. Uncertain threats (e.g. climate change, changing requirements) and vulnerabilities (e.g. lack of knowledge of the dynamics of the infrastructure system; alignment with organisation strategies) should be addressed with actions to spread or reduce the risk of uncertain adverse effects on the strategy. These actions that underpin the long-term strategies could be characterised by the strategic objectives.

The strategic objectives would provide monitoring capability and flexibility in the decision-making process. The advantage of the monitoring capability on the decision-making, as mentioned, is to keep the options open, to decide with anticipation when to act, and/or to understand if the delivery of the strategies should be conducted based on a flexible and/or robust approach.

Recommendation 9- *Stress the decision-making process to develop organisational long-term strategies and integrate other authorities responsible of the WCS.*

The long-term strategic decision-making on the asset management is dependent on the long-term strategic goals and objectives of the organisation. Both provide the

rationale for the trade-offs, evaluation criteria and risk acceptability to develop, conceptualise and deliver the long-term strategies. Not clear and defined objectives allow for asset managers rely on their own knowledge and perception of the expectation of stakeholders and the company and not on what is their long-term value from the infrastructure assets.

Interactions between the internal levels of the company are needed to reduce the cognitive effect of making decisions about what is relevant to society. After the organisation reaches maturity in the process, decisions should be conducted by integrating relevant stakeholders in the process. This approach could be conducted by participatory activities and qualitative and quantitative research.

The elaboration of long-term strategies at the organisation level would imply an alignment of the objectives and timeframes between the organisation and the strategic asset management process. Without a common approach, the two levels would be focusing in different risks and objectives. The organisation would focus on short-term success and would not take into account the subsequent performance and value of the long-term strategies. Then flexible delivery of the decision-making process is confronted with changeable objectives that would diverge the long-term strategies in the service strategic goal.

7.2.1.4 Recommendations Vitens' study of asset management process

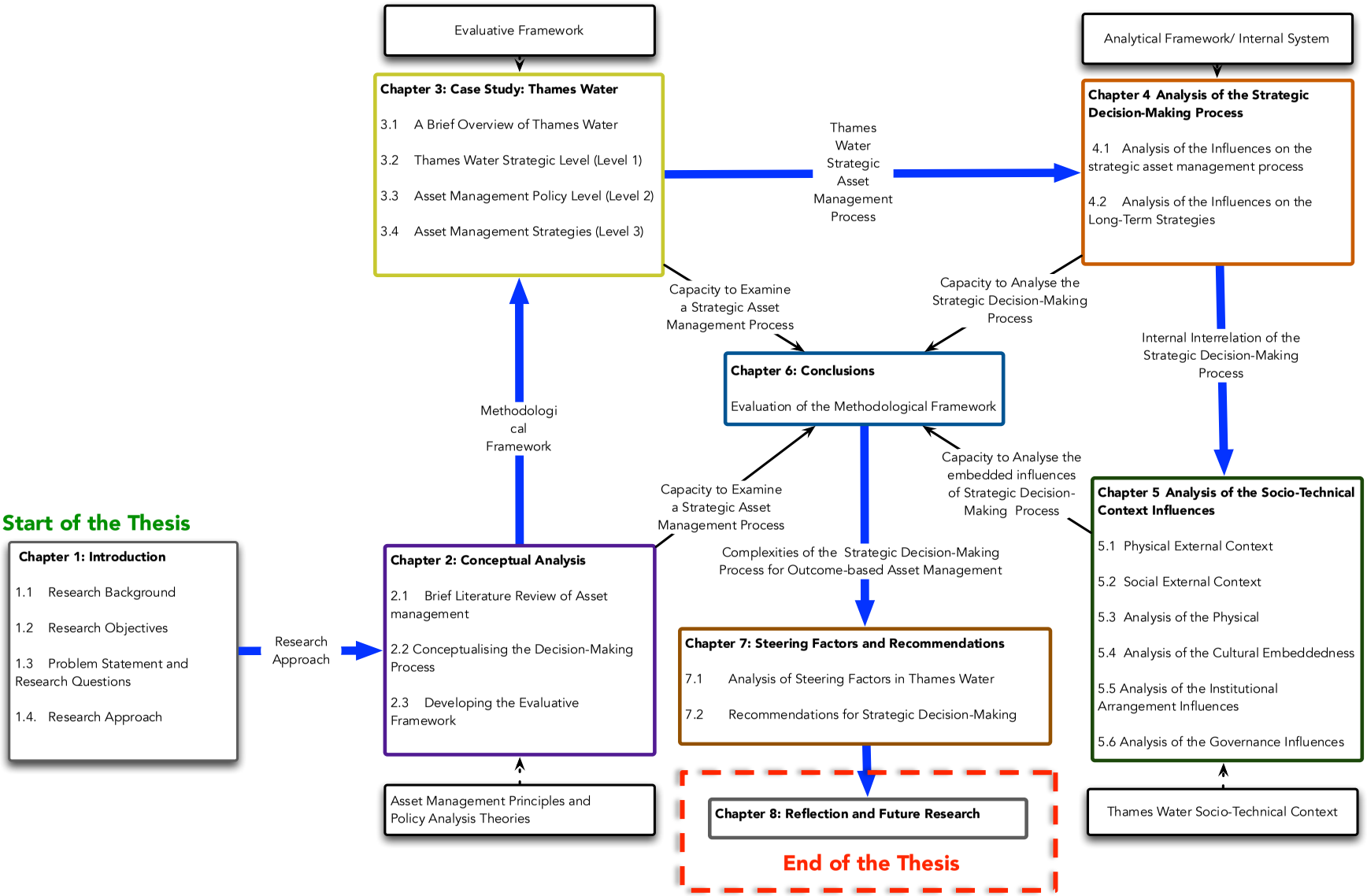
Recommendation 10- *Apply the input-output-outcome model as a comparative framework*

The input-output-outcome model illustrates at an adequate conceptual level of the interrelations of the strategic decision-making process, and the organisation and socio-technical context. Due to its capability to illustrate these complex interrelations, the model can be used as a comparative framework for Vitens future research in other strategic asset management process. The model would work as a consistent base to illustrate water companies under different environments, institutional arrangements and internal organisational structures. The capability of the model to compare asset

management processes is not expected to be limited to WCS, and Vitens can apply it to other public industries. Though, Vitens should be mindful of the limitations that represent the transferability of knowledge obtained under various contexts, including the cultural, the bureaucratic and the political contexts.

Chapter 8

Reflection and Future Research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8 Reflection and Future Research

8.1 Reflection on the process

One of the main contributions of a researcher to the scientific community is to acknowledge the difficulties and limitations encountered in the project by applying the research approach. By describing these limitations, findings may be viewed in a proper context and they can be indicators for future areas of research as well

The approach to applying the policy analysis was changed during the course of the thesis, primary by changes made on the definition of the research domain. The first approach was focused on analysing the entire value chain of the WCS as whole, with the intent of characterising the value to asset management of taking decisions within the WCS approach. Along with this early approach, the intent was to compare the asset management process between the UK and the Netherlands.

After further empirical analysis based on literature and interviews, it was considered that the original approach, the analysis of the asset management process would be too extensive for a master's research project or would result in insufficient (and maybe too superficial) information to contribute to the scientific and knowledge gaps. The research approach was then adjusted from the initial idea due to three main drivers.

First, the characterisation and analysis of the asset management process is challenging. The asset management discipline is no longer about operating the assets and taking decisions on backlog and replacement value. Therefore, it was not suitable to analyse the asset management process for the WCS as one interconnected process.

Second, the new approach brought to the discipline uncertainty-, institutional-, analytical-, integration-, conceptual-, and strategic-challenges making the asset

management process more integrated with multiple variables and feedback mechanisms not only internally but also externally. The level of analysis and methods needed to characterise and compare The Netherlands and UK was also going to be beyond the intent of a master's thesis.

And third, asset management is a new discipline where methodologies or frameworks for to develop and implement the process in the organisations are limited. Lack of methodologies and frameworks makes difficult the separation between empirical description and scientific analysis

These three drivers led us to adjust the research approach and focus on developing a methodological framework that would analyse objectively and comprehensively, with sounded practical and scientific relevance, the asset management process to develop long-term strategies. The research approach was then based on policy analysis methodologies since an opportunity was identified to apply methods and methodologies that manage complexities similar to the complexities currently challenging the asset management discipline.

Then scientific relevance of this thesis resides in the development of a methodological framework that was used to evaluate the decision-making process at the policy and strategy level of asset management in relation to the socio-technical context. With the use of the process, it was highlight the applicability of policy analysis methodologies inside an organisation domain, in particular for the infrastructure industry.

The societal relevance of this thesis, resides in the fact that it demonstrated that it is essential for WCS companies to identify methodologies that will help them increase their knowledge of how to evaluate and improve their investment processes to reach their main goal of increasing societal benefit. The methodological framework developed provides more transparency for the investment choices that are behind the WCS and an approach that considers the effects of exogenous factors. A more transparent and structured asset management system represents good business and governance practices by justifying decisions for expenditures, and also demonstrates the delivery of efficient cost over the long-term. This transparent and structured asset management system should benefit stakeholders, shareholders, customers and the

environment at large.

8.1.1 Reflection on the Methodological Framework

The methodological framework approach was based on using the system diagram method in a different way. After finally defining Vitens' main interest in this research (which combined facts and rationalisations behind the process), it was decided that the asset management process should be studied from the perspective of the decision-making process. This led me to conceptualise the decision-making process as part of the internal system that was analysed, and which evolved further to be conceptualised as the strategic decision-making process in asset management. In practise, the systems diagram is used as a decision-making tool, as part of the decision-making process of policy-analysts and decision-makers. With this approach the strategic decision-making process was established as the system of interest based on the systems diagram method. This different approach shows its capacity to characterise long-term strategic decision-making on asset management for WCS, and the internal and influential factors that act over it.

There were two main limitations with the approach. The first main limitation is that it relied heavily on interpretative methods. Therefore, my level of analysis relies on my analytical capability and on my interpretation of the empirical research conducted. This approach enables deep analysis of the asset management process and takes into account the context of the case, but it is less strong in receptiveness and factual determination. Therefore, the receptiveness of the analysis could be questionable.

I complemented that cognitive limitation by integrating to the research semi-structured interviews to gain more deep factual context. Structured methodologies were used for the analysis with thematic coding of the interviews. The thematic coding included different rounds to characterise the process and elements, and separate round to scrutinise the connections and relations. Both results were then validated; with the participants of Thames Water as part of the validation process. This systematic approach of analysis was intended to make the research approach stronger and more scientific oriented.

The success of a case study is largely dependent on the willingness of the participants to provide information, fully and without bias. Access difficulties with respect to senior management during the stage interview meant that it was only possible to obtain a 'snap shot' understanding of the core strategic asset management processes. To counter the problem of not obtaining full and unbiased information, the views of the participants were corroborated with other information such as published reports and documents.

The second main difficulty encountered was the broad structure of the methodological framework to conceptualise complex sub-systems such as risk management, performance requirements, and stakeholder's requirements. They are comprised of interactions that I did not pre-anticipate, and which can be directly related to the context of WCS in UK. This made it difficult to use the system diagram as first intended; where it would establish the interrelation between these sub-systems. After extensive time trying to build the interrelations, I decided to use the internal influences as a sub-framework that describes their individual influences in the strategic asset management process and the long-term strategies. This approach resulted in the assumption that there was no interaction between each of the elements.

To conceptualise the interrelation between the elements and their influence, I developed a qualitative method that assigned a value of influence to these elements on the long-term strategies and objectives. This approach generated the interrelations between the internal influential factors. Without characterising individually these relations in the system, a similar approach was done to describe the influence of the contextual factors on the system. The limitations faced in clearly characterising the relations brought inside of the complexity of the strategic asset management process points to opportunities for future research that address some of these knowledge gaps.

Difficulties also aroused due to the importance of characterising complex processes and interactions using the adequate level of analysis. In order to have an illustrative diagram of the interrelations, I applied an input-output-outcome model that integrates a high-level of interaction between high concepts such as objectives, outcomes, and external and internal concepts. By doing this, I was able to illustrate the relations of the decision-making process with the internal aspects of Thames

Water and the socio-technical aspects. The model improved my understanding of the interrelation between the decision-making process and the socio-technical context, and led me to identify a relevant use for the analysis of the strategic asset management process. Based on this, this model could be a powerful complement to use in comparing strategic decision-making on asset management among water companies or other industries.

8.2 Reflection on the Results

Thames Water is confronting a challenge aligned with Vitens interests. The socio-technical context may be different and thus creates different influences, but as it was recognised in our discussion at the beginning of the thesis, describing and evaluating the decision-making process of a water company working in a different institutional environment can provide insights of steering factors and strategies that could be relevant to Vitens' decision-making process on asset management. Asset management decision-making is a centric factor to drive WCS to achieve societal and environmental needs. With more challenges on the future, the interrelations and interdependence of the WCS with society, institutions and physical context is getting stronger. It is this complexity, that both Thames Water and Vitens face and both have identified the importance of incorporating the decision-making process as a subject of study.

The application of the framework to Thames Water has shed light on the relevance of the long-term strategic decision-making process on asset management. The developed approaches led me to structure and analyse the strategic decision-making process in an asset intensive infrastructure company. As a result, it illustrated the diverse challenges faced in the management of infrastructure assets to support business operations and societal values. To overcome these challenges, an infrastructure organisation must concentrate on developing their integration of the asset management process in order to be effective and efficient in an increasingly demanding environment by societal needs.

Although the focus of the thesis was on the examination of the strategic decision-making, the approach allows identifying steering factors that can be applied

to manage the complexities attached to the decision-making process. This shows the capabilities of the approach that could be used for asset intensive public companies and governmental agencies that are looking to improve their asset management practices. The improved asset performance would send a powerful signal to senior management of the strategic importance of the asset management function in contributing to the business goals of the organisation.

8.3 Future Research

8.3.1 Future Research on the methodological approach

The interrelation between the decision-making processes and an asset management outcome-based approach has been showed in this research. Demonstrating this interrelation opens an opportunity for further research that focuses in characterising and understanding the importance to act over this interrelation in order to reach the desire goals.

First, future research can be conducted in defining the causal relations that are part of the decision-making process in the strategic asset management process. Defining these causal relations could be part of a systematic empirical testing and value to practicing analysts of the asset management process. In possible future research, attention should be put on complex systems such as risk management, stakeholder requirements and performance requirements. One of the areas that a researcher could consider is the research method to define those relations. Surveys and structured interviews focusing in particular relations could be a proper approach.

Second, a concept that was mentioned by most of the participants, but was out of the scope of this research, was the effect of the culture on the outcomes of asset management. Most of the participants have recognised that asset management is not only a standardise approach to manage the asset, but it is also a way of thinking about the assets. From the experience gained during this research, we learned that alignment between the participants was felt when discussing common topics that cannot be characterised but were part of the embeddedness of the organisation. Examples are sustainability, innovation, and the topic of this thesis, outcome-based approach.

Further research could be considered to evaluate and characterise the interrelation between the asset management process, the decision-making process and the embeddedness of the system.

One of the reasons for the importance of embeddedness is the dependence on small changes and decisions to adapt the asset system into the desired approach (such as sustainable, outcome-based and resilience). It has showed up in recent researches, managing uncertainties of the future and outcomes, that the adaptability of the system is necessary. The embeddedness on the decision-making process should be considered as a factor for adaptability.

8.3.2 Future Research on Water Cycle Systems

The research focused in the drinking water segment. The description of the drinking water segment as part of the WCS was addressed from a very broad perspective in this research. The WCS approach is to integrate multiple-technologies and stakeholders as result of the storm water management/rainwater harvesting, water conservation, water reclamation and reuse, energy management, nutrient recovery, and source separation. The segment of re-using water is a rich segment that should benefit from using this thesis study approach to contribute to the WCS knowledge and integration. The re-use water segment combines a more extended number of objectives and an interrelation of assets with very different functions. n The challenges in connecting technologies, organizations and stakeholders throughout the water industry value chain could directly impact the effectiveness of long-term strategies developed today.

8.4 Closing Comments

Asset management can be considered a discipline of study with its own standardisation, procedures, and rules; and it has started to develop its own theories and principles which are reflected in the number of books, articles and courses that have started taking place. With no previous experience in the field of asset management, the details of my evaluation were limited to the understanding obtained during the research process. However, the evaluative frameworks based on PAS-55

provided a strong structure to communicate and illustrate my intents during the research period at Thames Water. This reflects the movement of infrastructure industries to a more standardise process of asset management. Still, many concepts and objectives are not completely clear within the discipline of asset management so it would be expected that an expert on the field would use this framework more resourcefully.

One of the main challenges of the methodological approach used was the balance between conducting a comprehensive analysis of the process of asset management and at the same time providing sufficient factual knowledge to cope with Vitens' interest. Large amount of factual information can be tangential to delivering a comprehensive analysis and convincing argument. Extensive cover of multiple areas expands the influences created, the stakeholders involved, disciplines, details etc. The result may become a just a capitulation of a summary of different reports and information.

A second difficulty was conducting a research for a problem owner when its research domain is different from the research domain of this thesis. As a result it was difficult to conceptualise a thorough analysis embedded on the policy analysis approach: problem definition, formulating and evaluating alternatives, conceptualisation of the system, policy action and strategic advice.

Taking apart these difficulties, the research process allowed me to explore asset management as a discipline when I was unaware of its development and relevance in critical industries such as WCS. Coming from the industry in the United States, it was interesting to find out that my unawareness is shared with different experts in the industries and in the water sector that were defining asset management as a limited process that focuses in the replacement and maintenance of the assets. I hope that this research contributes to the importance of asset management as a resource to confront the future challenges that await society, principally in relation to the water sector. WCS are essential to society not only for their functioning, but also to human and ecosystem survival, now and in the future.

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Appendix

10 Appendix

10.1 Water Companies in London

The context of the Water Companies in London is reviewed in the chapter. The review is divided in into two main sections that describe the Social External Context and Physical External Context that is relevant for asset management. The social external context provides an overview of institutional arrangement and main regulations. The physical external context describes the main characteristics and challenges for the water sector, specific in London.

10.2 Description of the Social External Context

10.2.1 Water Companies in UK

Water companies are regionalised since 1974. Ten Regional Water Authorities (RWA) were created with the intent to cover the major river basins. The companies were responsible of implementing an integrated management of water and to cover environmental as well as supply issues.

The government of UK privatise the water companies under the Water Act 1989 with the objective to increase capital and revenue to be able to achieve the requirements from European legislation (Defra, 2006). The privatisation follows the trend of other utilities such as telecommunication, electricity and gas. The result was 21 regional monopoly (10 water and sewer companies), vertically integrated, water companies, which provide a 'source to tap' service: obtaining water from source through abstraction, treating it to an appropriate standard, and providing it to customers' taps via company-owned infrastructure (White Paper, 2012).

The Water Act 1991 consolidates different water related legislations, setting the powers and duties of a system of regulators that will be responsible to enforce the Water Act and subsequent legislations. Responsibility for economic and financial regulation was vested in the Water Services Regulatory Authority (Ofwat), the Drinking Water Inspectorate (DWI) became responsible for overseeing the quality and safety of drinking water, and the responsibilities of the environmental and river basin function were transferred to the Environmental Agency (EA).

The regulatory arrangements emerged from the privatisation of public sector monopolies. The regulator structure was aiming to promote efficiency on reaching the statuary requirements and prevent exploiting monopoly position of the water companies (William et. al, 2003). The systems of regulators were established as independent regulators from the government department and administrative control. As independent regulators, the powers of the regulator with respect to water companies were legislatively determined broadly and left room for decision making, particularly about the content of the relationship between regulator and firm (Arnell, 2011, Charlton et. al, 2010; William el al, 2003).

10.2.2 Ownership between and within Water Companies

Merge between companies is regulated under Water Act 1991 with a slight margin from regulation to allow it. The merging is overlook by Ofwat and the Competition Commission (CC). There have been a number of mergers but only involving smaller companies as the ten large companies have stayed separately owned since the reform in 1974.

Within water companies, regulation has not created a significant impact in companies changing ownership, which continues to impact upon the industry (Bailey, 2007). Companies change owners relatively frequently and some are no longer listed on the London Stock Exchange as they have been bought by companies based outside of the United Kingdom. The process is scrutinised and an amended licence is granted.

10.2.3 Regulations on the Water Companies

Water Companies operates under a long-term licence that is granted by the Secretary of State. Companies are required to report their performance to Ofwat on an annual basis (see subsection below). The annual report provides Ofwat with a progress from the water companies towards stated environmental and drinking water quality objectives determined by Ofwat, which are primary based on requirements from legislations, Environmental Agencies and Drinking Water Inspector. Then, Ofwat assess the performance on a comparative basis between the water companies in England. Key Reporting Requirements are updated every five year and ranges of different activities and services, such as bills, service levels, quality compliance, leakage, operational costs, capital expenditure, relative efficiency, network activity and financial performance. The aim of the established comparative competition is to enable rive efficiency and service improvements to the benefit of customers (Aikman and Doherty, 2006; Bridgeman, 2011).

Along with the licence there are financing arrangements driven by an incentive-based system of price cap regulation. Regulator set a price limit every 5 years in what it is called the Price Review process. Price limits are established on the basis of the formula RPI $\pm$ K, where RPI is the retail price index and K is the amount by which water companies can increase or decrease the prices charged to customers over a period of time (Thames Water, 2009). This regulated price mechanism sets an upper limit on price increases, which enables an efficient company to generate a revenue stream that is sufficient to allow the financing of its functions (Bakker 2003). Ofwat aim with the price mechanism to encourage companies to operate more efficient and sustainable.

10.2.4 Statutory And Regulatory Reports

Water Companies are required to produce regulatory documents every five year. These documents have the main objective to report where the money collected from customers will be invested over the next 5-yr period. With this information, Ofwat determines the price limit that the

company can charge to the customers over that period of time. This process is called the Price Review (PR) and the next one is on 2014 that it is called PR14. During this process, companies outline the investment proposal for the next 5-yr regulatory period. Ofwat gave its decision in a 'final determination' (FD), which sets limits for customers' bills for the five-year period. The regulatory period as result of the Price Review is called Asset Management Plan (AMP). The companies are currently finishing AMP 5. AMP 6 will starts from 2015-2020.

The Business Plan (BP) is the main report that covers all these investments, which are separate in different sections. Regulators request the companies to provide more in detail information of the process requesting a particular report for these sections of the BP. These sections are cover with the Water Resources Management Plan (WRMP), Long-term Strategies, Asset Management Plan (AMP), and Annual Return.

The figure below illustrates the timeframe for each of the regulatory report.

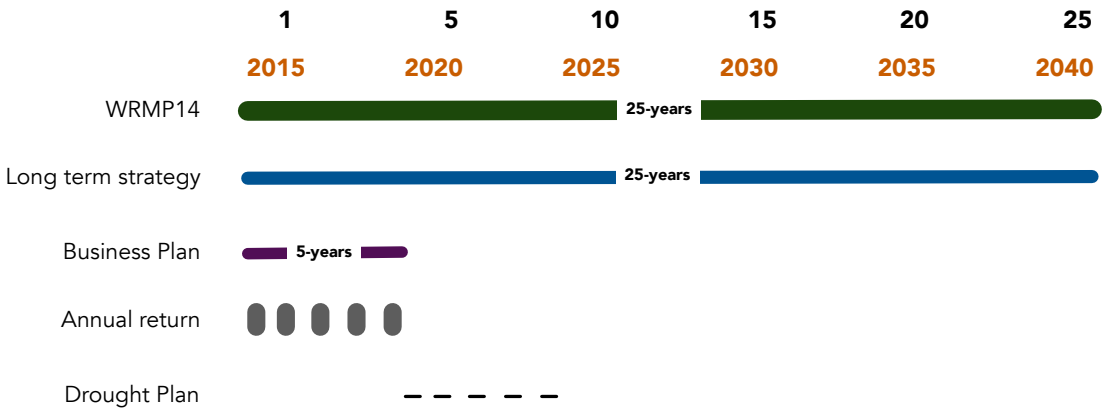

Figure 10.1: Relationship between the outputs prepared by Thames Water (Source WRMP, 2009)

The regulatory plans are assembled following guidelines developed by the regulators. In the case of the WRMP there is a specific document called the WRMP guideline and to develop the BP, there is a combination of guidelines to address the different sections of the report. These are very detailed guidelines, on which, the regulators, Ofwat and Defra, are expected that companies put out their plans together. The plans provides specific requirements such as

scenarios for climate change, the least cost plan should be implemented, asset management decision-making guidelines. The figure below illustrate an overview of the WRMP, which illustrate the guidelines that companies need to follow during the developing of the plan. Most of the subsection is provided guidelines to how should be assessed and reported.

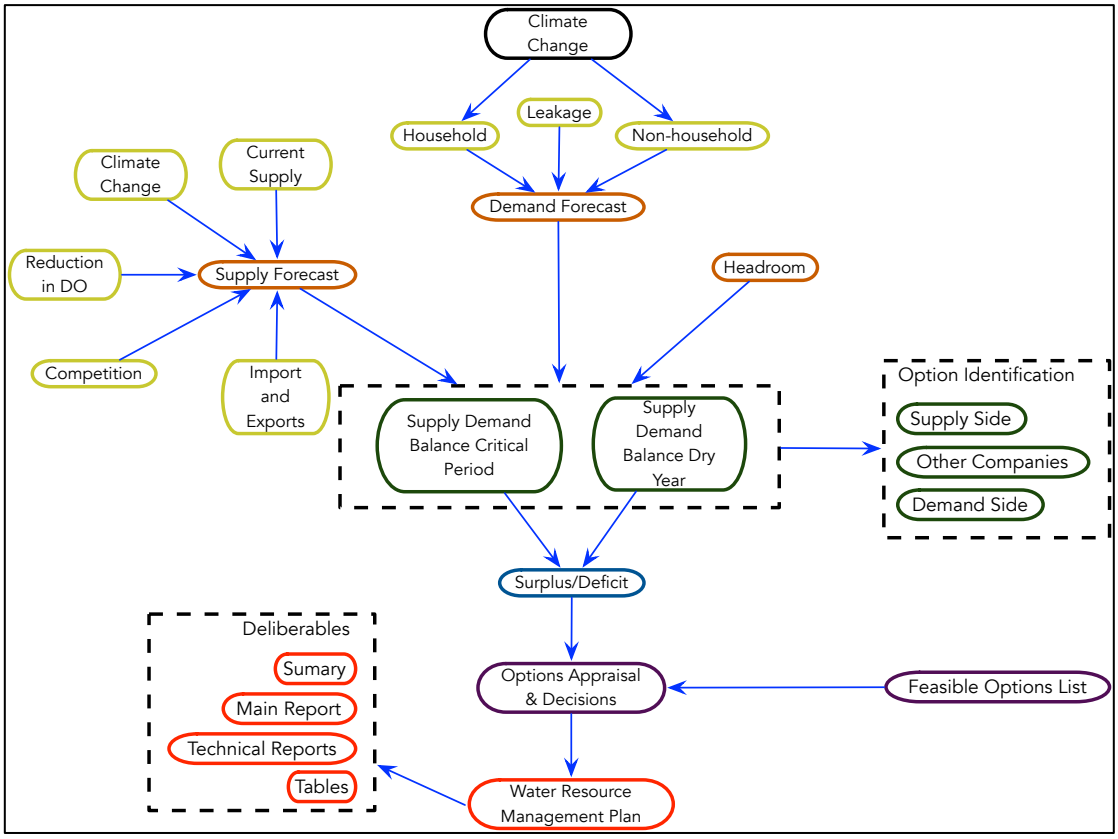

Figure 10.2: Components of a WRMP (Source: EA WRPG, 2007)

In that context, the regulators require that the plans are developed in consultation with the customer and that expectations of the customers are taken into account in the decision-making process. Customers' perspective is primary acquired by conducting external participatory customer research and internal research in the companies' customer service. Another aspect in the development of the plans is that water companies need to ensure that other stakeholders are supporting their actions. Mechanisms are then developed to engage with stakeholders. Engaging with the stakeholder aims to ensure that the stakeholders got a very good understanding of

what are the problems that the company is facing, why the company is suggesting the investment that needs to be undertaken, and why considering this programme the best solution ([7], [2]). Activities include presentation, meetings and workshops. The process is discussed more in detail in the stakeholder section.

After the plans are developed, the plans are published for consultation. During the 12-week consultation period, all the stakeholder, regulators and customer will have the chance to comment on it. Also, there is an active consultation process were companies interrelate with the interesting parties. The process follow by Thames Water is illustrated in the figure below. From the figure it can be perceived the interaction of the customer in the development of the plan.

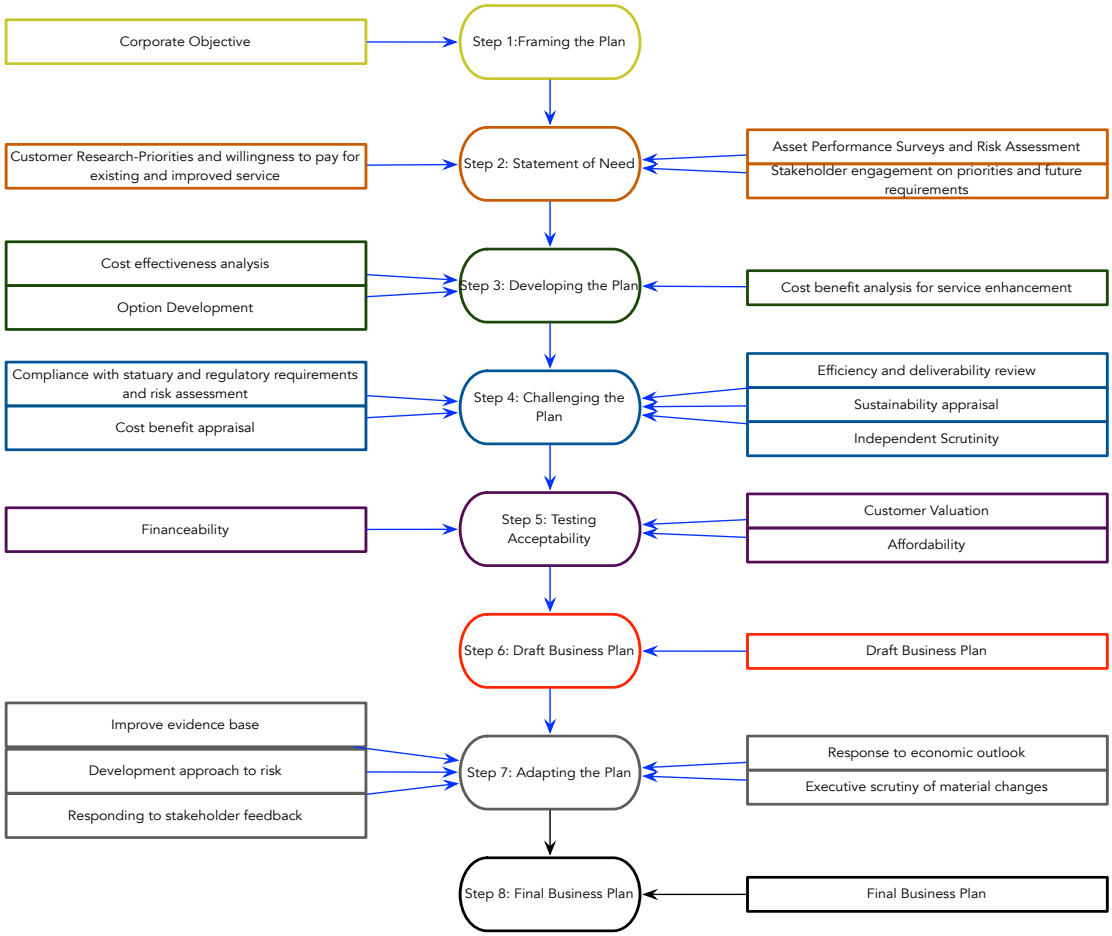

Figure 10.3:Business Plan Process (Source: THAMES WATER, 2009)

Following the consultation period, companies have a further period of 14 weeks

within respond to the comments that they receive and revise their plan. In case the company decide to make changes to the plan, there are required to explain why they are not revising the plan. Then the final draft is published. Figure below provides the timeline between the reviews processes for the WRMP for the next 25-yr and BP for the next 5-yr.

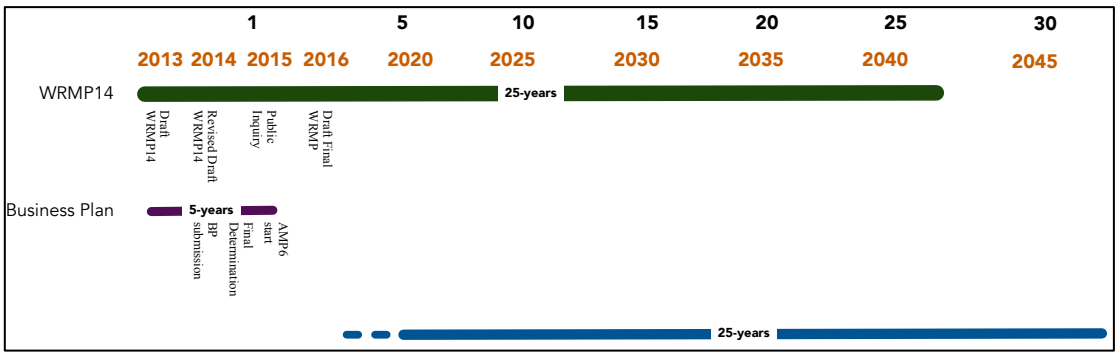

Figure 10.4 Timeline for key statutory and regulatory reports (Source: THAMES WATER, 2013A)

Table 10.1: Summary of the regulatory reports

Business Plans

Ofwat sets price limits for water charges every 5 years through a process known as the Price Review (PR). The next PR is in 2014. Water companies submit Business Plans to Ofwat setting out their funding requirements for the next 5 years as part of this process.

Water Resources Management Plan (WRMP)

Water companies in England are required to produce a WRMP every five years which sets out how a water company intends to maintain the balance between supply and demand for water over a 25-year period. Currently, the company has published for publish consultation a draft plan which covers the 25-year period from 2015 to 2040. The preparation and maintenance of the plan is a legal requirement for water companies in England as established by the Water Act 2003.

Strategic Direction Statements (SDS)

In recognition of the need to consider issues in a longer-term context, Ofwat introduced the requirement for Strategic Direction Statements (SDS) in PR09 which set out a 25-year strategy and enabled the 5-year Business Plans to be framed within this longer-term context. Ofwat do not require companies to produce an updated SDS every five years. Thames Water did publish an updated version of the SDS for PR14 as part of their draft Business Plan. The plan includes strategies that are a result of internal research (performance, cost, etc.) and external research (customers and stakeholders consultations). The draft of the document is published in Thames Water Website for customers and stakeholders' comments on it.

Annual Return

This covers all business activities and provides regulatory bodies and the public with an up-to-date picture of the company's performance and progress against regulatory targets. The Annual Return provides information for the base year i.e. the year from which WRMPs forecast forward. For this plan the base year is 2011/12.

Drought Plans

The Drought Plan is an operational-level plan, which sets out the short-term steps that will take in the event of a drought. It is updated on a 3 yearly cycle. There is an expectation that the cycle should be extended to five years to align future updates with that of the WRMP.

10.2.4.1 Common Framework

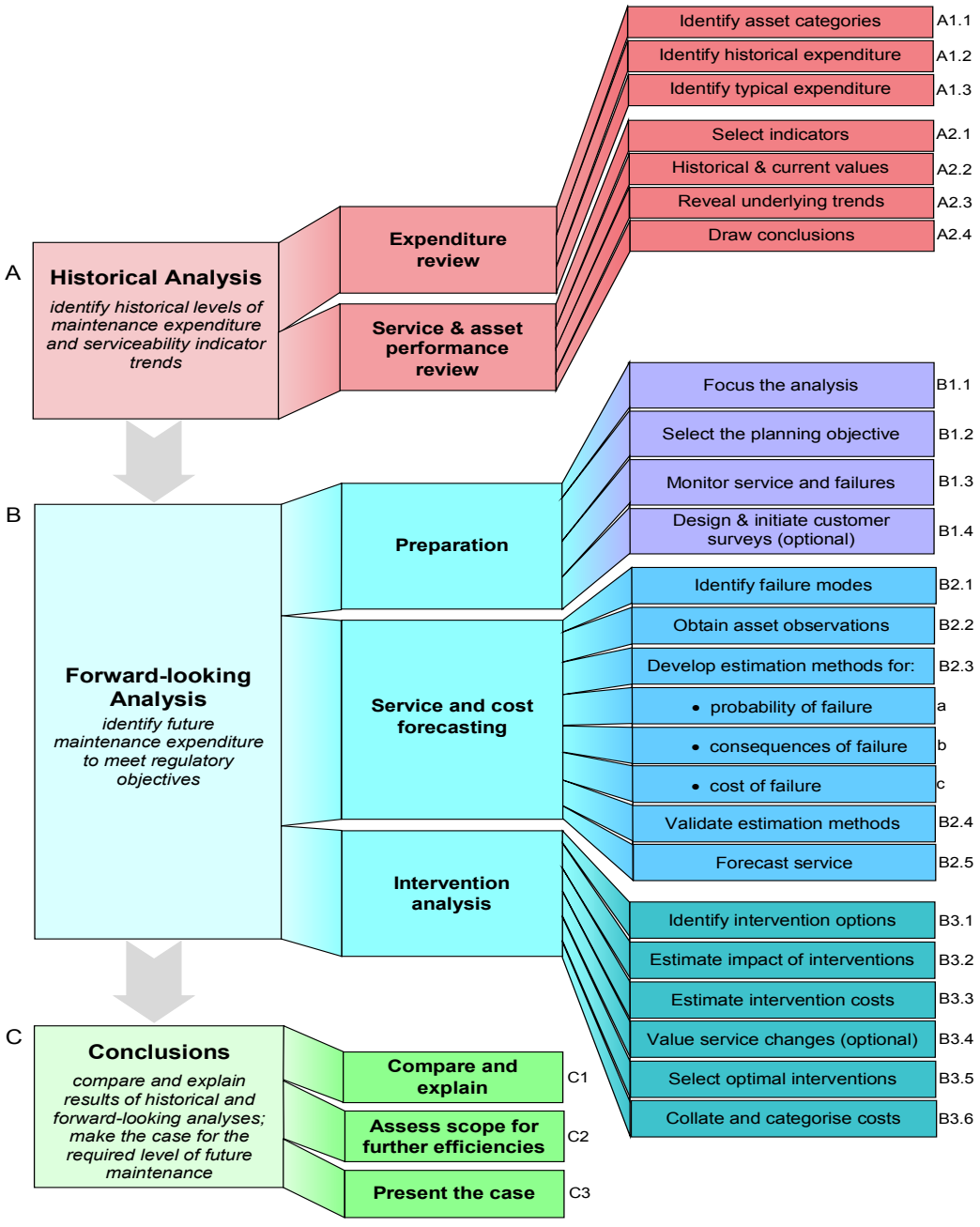

Fig 1: The Common Framework Process

Figure 10.5: Common Framework Process (Source: Pearson, 2006)

10.2.5 Changes in Regulation for Price Review 2014

Ofwat has proposed a reformed price control approach that will be implemented in the 2014 period. The new framework would be expected to provide an incentive for water companies to evolve in the way they operate in order to confront the future challenges with the water industry. Two main changes are review in this subsection that will be relevant for the asset management decision-making process discussed in the following chapters.

10.2.5.1 Outcome Based Regulation

Ofwat regulates the water companies based on the input-output-outcome model, which is used by UK public sector for the evaluation of the activities and the evaluation of their program (HM Treasure, 2000). During the past price review periods, the key reporting requirements (outputs) required to the water companies were determined by Ofwat. For the 2014 price review period, Ofwat will be using outcomes for the price determination instead of the output approach conducted in the past and reduce the prescriptive approach used in the past (Ofwat, 2011c). The outcome based approach aims to achieve two main objectives. First, a less prescriptive approach would provide more flexibility for water companies to innovate and couple with the future challenges, such as the deficit on water supply, climate change, etc. Second, improve the effectiveness in captures and achieving what customers and society need and value (Ofwat, 2012b).

Figure 10.6: Simplified version of the input output process

First, lets define inputs, output and outcomes on the perspective of Ofwat. Outcomes are defined as "higher-level objectives that company actions, activities and achievements are intended to help deliver. They represent what customers and society really value." (Ofwat, 2011b, page 9). The outcomes are generally continuous, long-term requirements that do not necessary fit into one price control period. Therefore, the outcomes that customers receive

immediately may differ from those they gain later, and differ again from their ultimate outcomes.

Outcomes are difficult to measure trough a single metric that meaningfully reflects the extent to which it is being delivered. An example used by Ofwat is that sustainability will reflect not only the quality of the water environment but also the sustainability of the solutions used to deliver it, such as the carbon footprint of new asset schemes.

Outputs are goods and service delivery by the water company. These are observable and measurable activities; actions or achievements that the company needs to deliver in order to achieve the outcomes. Ofwat (2011) classifies the output as high level that relates to a specific achievement (e.g. maintaining or restoring the serviceability of assets, which relates to the outcomes of providing a reliable and safe service and legal compliance), and to a low level that relates to a specific activity (e.g. programme of replacing lead pipes).

Inputs are the resources that the company have to deliver its activities or a particular output. These could be specific resources (such as goods, services, energy, labour or capital), or they could be enablers (such as the skills base).

Table 10.2: Summary of main facts on Input, Output and Outcome (Source : Ofwat 2011)

Measure	What it is	Examples
Outcomes	Higher-level objectives than company actions, activities and achievements are intended to help deliver. Things that customers and society value. Delivered through outputs.	Reliability/availability/safety of supply. Customer satisfaction. Environmental sustainability. Fair, transparent and acceptable bills. Compliance with legislative requirements. Reducing carbon emissions.

Outputs	Observable and measurable activities, actions and achievements needed to deliver outcomes. May be high level or lower level. Should help to achieve outcomes.	Reductions in sewer flooding. Maintaining/restoring serviceability. Pesticide removal. Meter installation. New billing system. Compliance with discharge consents. Reducing service interruptions.
Inputs	Resources an organisation needs to deliver outputs. Includes money, people and products.	Money spent on reducing sewer flooding (Opex/Capex). Number of people employed on operating a water/sewage treatment works. Length of new pipe needed to comply with drinking water standards.

On PR-09, water companies were responsible to develop under certain requirements the programme that defines their investment to reach the outputs established by Ofwat. The Business Plan was the document used by Ofwat to determine for the next five year the outputs that the water company will achieve. The output established by Ofwat, were the key performance indicators that were based on Ofwat understanding of how the beneficiaries will reach their value, and were grouped in four areas customer experience, reliability and availability, environmental impact and financial. Example of the key performance indicator for the 2009 price review is provided in Appendix.

Water Companies will be responsible to determine until some level the outputs for the next price review period based on their outcomes. Ofwat will evaluate the performance of the water companies on the basis of outputs that are compliance with legal requirements and outputs that the company determines to delivery the outcomes that they define. Therefore, companies will need to argue the outcome defined and the output they will used to reach these outcomes and how they will be achieved.

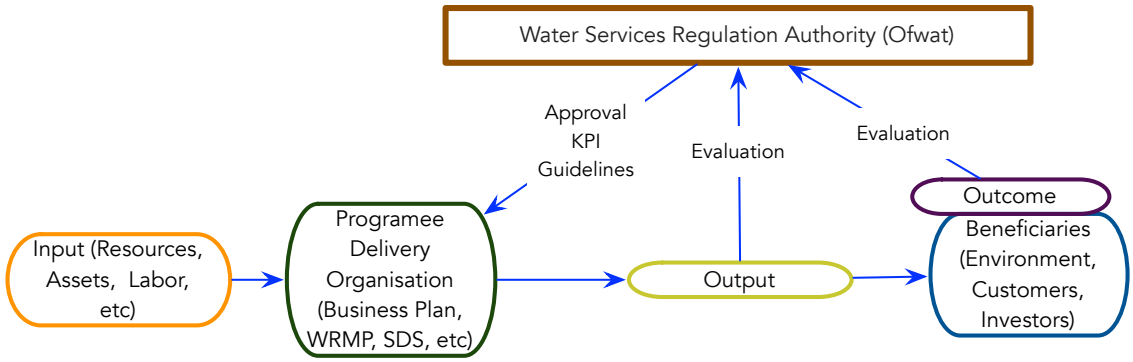

Figure 10.7: Input-Output-Outcome Model Adapted for Ofwat (Source: Excitant, 2012)

Ofwat activities are decentralised by passing some of the responsibilities to the water companies and Customer Challenge Group. Water Companies will have the responsibility to propose outcomes and outcome delivery incentives. Challenge to the proposal will be conducted by the Customer Challenge Groups by reviewing the quality of the companies' customer engagement and the extent to which the companies' proposed outcomes and delivery incentives reflect customers' views (Ofwat, 2013). Ofwat will then make a final assessment of the companies' proposals. In addition to these company-specific outcomes and incentives, Ofwat will determine some minimum performance levels that will apply to all companies.

With this approach, Ofwat is changing their approach from water companies that are based on outcome-based instead of an output-based.

Simplify Example on Output Approach versus Outcome Approach

When a water companies submit their Business Plan with a proposed amount of 100m in investment, Ofwat will scrutinise very ensure that investment is justified and will ad a value to the customers. Ofwat will scrutinised and basically will say that it will not cost that much, it will be 80 m instead. Therefore, the company is allowed to increase what they charge on their customer so they can fund that 80m. When the investment is approved, the company needs to be confident that it will deliver what the are going to deliver, and meet a set the number of outputs that are expecting from them to be delivered. If the company does not achieve the outputs, they will penalise you. So, that has been the approach previously.

What Ofwat said now is that they are going to have a hand-off approach. So Ofwat will set high-level standards and how they are delivered is the water company decision. Depends on the program selected, the companies will be penalised or rewarded on the basis of the performance. So, Ofwat is not into the detail on the same extent that were, but some of the performance criteria are still there. Meaning that there are articulate standard that water companies have to deliver. For instance, Ofwat will set, because is quite controversial, leakage targets. How do reduced is up to the company, but within that context Ofwat Is expecting to have a reduction of 100-Mega litter per day. So is not quite flexible as appear to, because there is something, that it seen so significant, so important that Ofwat still put criteria around that. So for instance the outcome will expect the water companies to provide water to the customer with in this levels, certain levels of service. Within that those water need to meet these quality requirements, leakage have to be reduce to that much. So Ofwat still control that.

10.2.5.2 Price Control

Ofwat will separate the retail and wholesale control. Within the wholesale, two binding wholesale controls will be established, one for water and one for wastewater, using the traditional RPI $\pm$ K approach. However, the way the K factor is calculated will change.

For the wholesale water, the revenue of companies will be controlled utilising a total revenue approach and a revenue yield approach. This approach will incorporate annual adjustment mechanisms for variables parameters such as operation costs, expected demand and metering.

The cost assessment for the proposed business plans will change to a total expenditure approach (Totex). Based on the interviews conducted for this thesis, there is still not a clear proposal from Ofwat approach. However, the company have started to look into possible

areas that will change their asset management structure.

10.3 Water Companies in London- Discussion

The institutional arrangement of the water companies established specific set of legislations with the main intent of preventing monopolistic advantages of the water companies. The main legislations were focused on competition, water standards, impact to environment and the regulators structure to deliver these legislations. Three main regulators where established which each one will be responsible to deliver each of these regulations and independently identified additional strategies that will require to establish the legislation. Ofwat ends as the mediator between the government legislations, other regulators requirements, customers' benefits and companies' performance.

Statutory and Regulatory Reports are the instruments that Ofwat used to monitor the programme proposed by the water companies. These documents are developed to provide guidelines to the water companies to address different areas of interest by the government (such as security of supply), by the individual regulators (such quality parameters of water), by European regulations (such environmental impact), and by customers (such as affordability of water). Key Performance Indicators (KPI) are determined by Ofwat to monitor the water company performance in annual basis and compare with the other companies. Then water companies will have to develop internal management targets, aligned with the regulatory guidelines, to meet with the KPI's. Then, Ofwat funded the water companies programme by determine the maximum price that they will charge to customer based the resources needed and justification of these investment.

The incentives of the water companies to generate income are by improving efficiency on the operation and reduce operational cost (spend less that the income received as part of the price of water). The expected change for the next review period will focus regulation of the industry in outcomes and incentives based on the total cost. The outcome approach will led

water companies to determine the level of regulation and will allow them to determine additional KPI's that they consider will achieve the outcomes of their customers. Companies will be responsible to determine their outcomes based on their customers and feedback from the Customer Challenge group. As result, Ofwat will be adding more flexibility on the water companies to determine their investment decisions and they will be evaluating the output and outcomes of the company. Totex are intended to shifting the water companies in focusing on the initial costs and focus on the best whole life cost performance.

The physical external context pressures the ability of Thames Water to reach their outcomes. Thames Waters will then need to consider investment decision that will deliver outputs that will achieve their intended outcomes. External factors that are outside of their control include available natural resources of water, climate change, population growth and inherent asset's condition. The operational area where Thames Water operates is a risk of water scarcity due to the limited natural water resources and ascending growth in population. The future impacts of climate change are expected to increase this stress and affect the operation of the other assets. At the same time, the integrity of their assets it is affecting their actual performance to deliver the require service by regulators and customers.

10.3.1 Organisational Structure

Within Thames Water, there are two main groups, Thames Water Finance and Thames Water Utilities. Thames Water Utilities is responsible of the decisions and manage the operations of the company. The Thames Water Utilities Board comprises of 15 directors, 13 of whom are non-executive, together with two executive directors - the Chief Executive Officer (CEO) and Chief Financial Officer (CFO). The Board is responsible to set the goals and objective that the Executive level needs to meet in annual basis and long-term. Long-term objectives for the executives have a time frame of 5-years (Investor Annual Report, 2012)

The executive level is responsible of the managing the company. The executive team includes the Chief

Executive Officer (CEO) and Chief Financial Officer (CFO) and nine directors. These nine directors are Customer Service Director (management background), External Affairs and Sustainability Director (Science Background), Commercial Director (industry experience and technical background), Human Resources Director (experience on area), Operations Director (strong managerial background), Strategy and Regulation Director (Experience on regulation as senior), Managing Director for the Thames Tideway Tunnel (industry experience), Capital Delivery Director (Project Management), and Asset Management Director (Technical Background and Industry Experience). There is a balance on the managerial background.

After the new shareholder acquired Thames Water, the strategy of the owners was re-organise the business in order to develop the Business Plan 09 (THAMES WATER, 09) ,which is the regulatory report developed by water companies as part of their price review process. The restructure and actions provided specific tasks to certain areas of the business that address different component of the BP and other regulatory plans. The following diagram provides an idea of the existing structure in terms on governance for the BP, WRMP and long-term strategies.

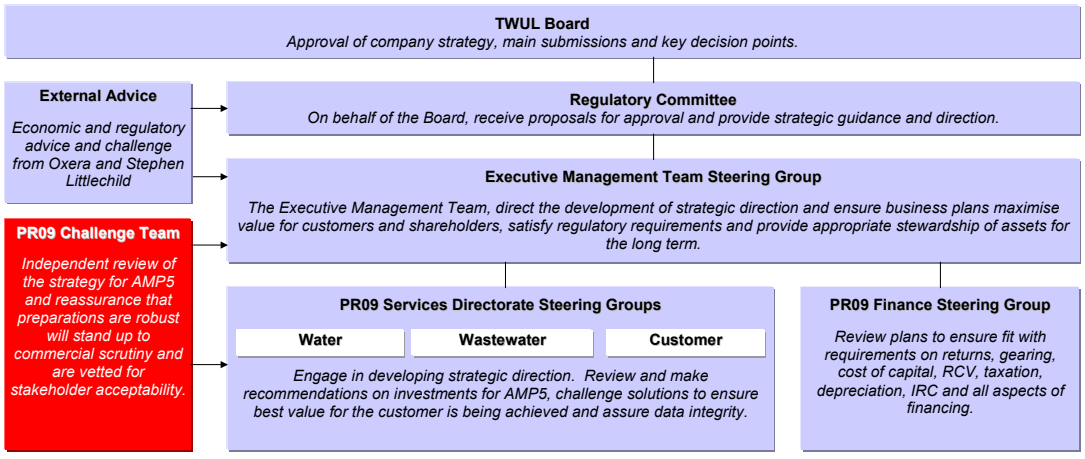

Figure 10.8: Governance Structure of the Business Plan (Source THAMES WATER, 2009)

The interviews were conducted primary on the service directorate steering group for the water business, and other direct areas such maintenance strategies, optimisation and strategy and regulation. Within this group, there is the Strategic

Water Planning that is responsible for the development of strategies for the business plan and long-term plan related to the assets. The group that covers the entire process to develop Asset Management Strategies, Objectives and Planning. The group is divided in Asset Strategies, Network Deterioration, Water Treatment Work, Asset Planning and Water Modelling.

10.4 Appendix Vitens

The Water Supply Act is the institutional and legal framework governing water in the Netherlands. The intent of the framework is to guarantees access to water, ensures that the management of water systems is transparent, and allows citizens to participate in decision-making (Dutch Water Sector, 2013). Ownership of the production of water in the Netherlands is public by law. Contract Services such as client service and repairs can be conducted by the private sector.

The Formal Institutional arrangement where Vitens is part can be separated in three different levels: national, regional and local. At the national level, the Ministry of Infrastructure and Environment is responsible for the sector with no independent regulatory agency. The regional levels are the provinces that comprise of 10 drinking water companies and 27 water boards. The provinces are responsible of surface water with regard to transport, bathing and other water quality, wastewater treatment and managing groundwater levels. The local level comprise of the municipalities that are responsible of the sewerage: system collection and transport of raw sewage and safeguarding urban water.

As a water pubic company, Vitens company's goals are the increase of the efficiency of water systems to provide the highest quality drinking water at the lowest price in other to reduce the social costs. The company own the operation of the production of groundwater to drinking water, water distribution and technical services to consumers and businesses in different provinces and municipalities. In the WCS where Vitens operate, the municipalities own the sewer system and the water boards own the sewer treatment plants. The

drivers for performance are based on benchmarking between the other 9 companies.

10.5 Appendix Stakeholders Analysis

Thames Water engagement with stakeholders is part of Ofwat evaluation. The main reason is to ensure that the customer's interest is taken as a priority and there is a balance between companies' financial health and statutory requirements ([7], [8], [10]). A process is established by Thames Water to engage stakeholders in the development of their strategies at the organisational and asset policy level. The yield of the process should be an understanding of the priorities and willingness to pay for the proposed service levels. Thames Water describes the process in four stages: pre-consultation for the draft of the long-term strategies, consultation on the long-term strategies draft, pre-consultation for the BP draft and consultation on the BP draft. The figure below provides the main activities under these stages that include surveys, workshops, meeting, etc.

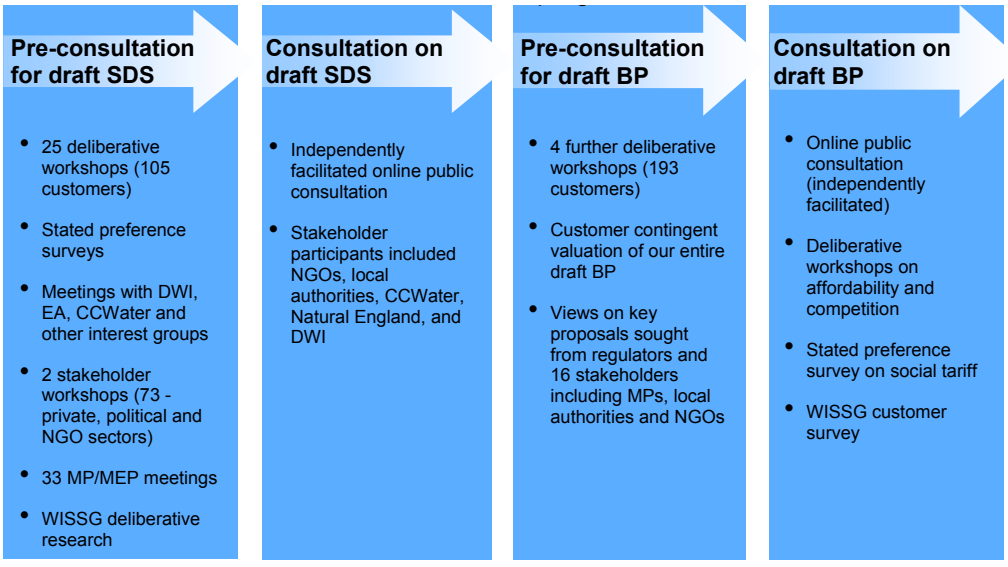

Figure 10.9: Consultation Process of the Stakeholders (Source THAMES WATER 2009)

In the case of Thames Water, the main stakeholders are the Customer, Regulators, local authorities, NGOs and other groups. This structure and procedure to develop the regulatory plans makes the company to balance with their internal requirements and the stakeholder requirements. In addition, within the stakeholders, primary the regulators, there is a backstage process where they coordinate the policy and regulations to confront the water companies (Refer to figure 10.10). A summary of the main stakeholders is described below based on the function and interest of the main stakeholders from the strategy perspective.

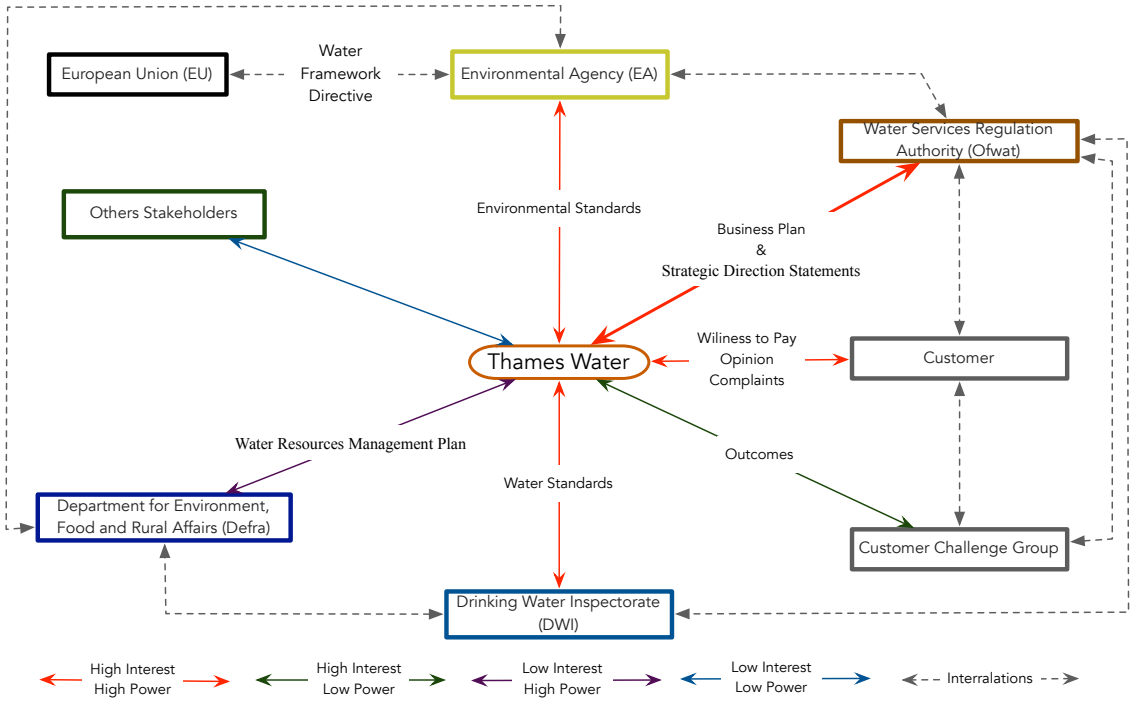

Figure 10.10: Stakeholders Requirements, Power vs. Interest, Interrelations

10.5.1.1 Customers

Customers range from domestic to business customer (households and non-households). Their main interest is to have a safe and reliable supply of water by keeping bills affordable. Thames Water conducted researches to understand their perception on the company and willingness to pay studies to ask them what they want

Thames Water to do, which is a how directly the customer expectation is manage ([8]). The main findings are: the company should reduce leakage (willing to pay a premium for the improvements), take the environment in consideration, dislike supply interruptions, and prefer metering and effluent reuse options over abstraction, desalination and water transfer.

Customer's opinion on the water companies is regulated by the Service Incentive Mechanism (SIM) score. The Service Incentive Mechanism (SIM) is designed to improve the level of service that water companies provide, and is based on the number of complaints and unwanted contacts a company receives, and consumer experience survey.

10.5.1.2 Challenge Group

Challenge Group is an independent group assembled by Thames Water and established as a requirement from Ofwat. Members of the group include representatives from the Consumer Council for Water, the Environment Agency, the Drinking Water Inspectorate, Natural England, Greater London Authority, the Federation of Small Businesses, and Age UK. The main interest is to balance customer's views and the investment needed to be socially, economically and environmentally sustainable (THAMES WATER, 2009).

The Challenge Group influences are delivered through a report that conducts directly to the company and to Ofwat. The group is evolving to be the primary body to represent the customers and be more participative in the process of decision-making for the companies.

10.5.1.3 Ofwat

Ofwat is economic regulator and the main functions are to sets price limits and monitors compliance with licence conditions and standards of service. Their aim is 1) to ensure the proper provision of water and sewerage services and that companies are funded adequately (including earning a reasonable return on their capital) to achieve this, 2) to protect customers' interests

with respect to charges, 3) to promote economy and efficiency and to facilitate competition.

Based on a research conducted by Thames Water, Ofwat is focusing on increasing involvement of customers views into the development of the plans and decision-making process, 2) reduce the Capex bias to provide more flexibility of companies to consider the best option 3) foment innovation in the sector and 4) separate wholesale controls and adoption of accounting separation.

10.5.1.4 Department for Environment, Food and Rural Affairs (Defra)

Defra has overall responsibility for all aspects of water law and policy in England, including water supply, water resources management and the regulatory systems for the water environment, drinking water and water industry. Specific actions include standard setting drafting of legislation, creating special permits (e.g. drought orders). In other words, is the government agency that sets the overall policy framework in England and Wales.

Based on Thames Water assessment, Defra interest is that water companies embrace affordability as the core of the decision-making process and reduce the environmental effects. To reach this, Defra understand that competition between the companies should be increased and more flexibility should be allowed. Therefore, future policies that have been evaluated are focused on removing barriers to competition and introduce more flexible upstream and abstraction licenses regimes.

10.5.1.5 Drinking Water Inspectorate (DWI)

The drinking water quality regulator. They check that the water companies in England and Wales supply water that is safe to drink and meets the standards set in the Water Quality Regulations. Specific actions include checking the tests that water companies carry out on drinking water and inspect individual companies.

Based on Thames Water's research, their desire from the company are to 1) achieve 100% drinking water compliance, 2) demonstrate where and when investment

is needed to provide resilience and 3) maintain a sustainable level of investment on quality programmes and on asset maintenance to ensure safe drinking water to consumers.

10.5.1.6 Environment Agency (EA)

EA is the environmental regulator of the water and sewerage sector. They are the principal adviser to the government on the environment, and the leading public body protecting and improving the environment of England and Wales. Their objectives of their main actions are to reduce flood risk, promote sustainable development and secure environmental and social benefits. In addition, EA is the competent authority for implementing the Water Framework Directive. Work in partnership with a range of other organisations to reduce flood risk, promote sustainable development and secure environmental and social benefits.

Based on Thames Water's research, their desire from the company actions are to 1) to take a long-term view (25yr +) taking into account the impact of climate change, 2) to take better account of the value of water by reflecting its scarcity, 3) consider all the option related to secure the supply of water, 4) reduce demand through lower leakage and water demand management and 5) ensure customers views are taken into account in plans.

10.5.1.7 Other less active stakeholders

Natural England

The main role of Natural England is to advise the government on the natural environment. They provide practical advice, grounded in science, on how best to safeguard England's natural wealth for the benefit of everyone. Their purpose is to protect and improve England's natural environment and encourage people to enjoy and get involved in their surroundings.

Consumer Council for Water (CCW)

They represent consumers within the water and sewerage sectors. They also investigate consumer complaints that have not been satisfactorily resolved by the water companies.

Competition Commission (CC)

Their role is to make sure that there is healthy competition between companies in the UK for the benefit of companies, customers and the economy. In the water and sewerage sector they investigate proposed company mergers, and are also the body of appeal for some disputes between Ofwat and the water companies.

Mayor of London

The main interest of the Mayor London is to secure the water in the future by investing in a robust infrastructure that supports economic growth. According to Thames Water research, Mayor London desire to develop an integrate strategy that involve more investment on the water management and sewerage infrastructure system, support and encourage Londoners to take practical actions to save water, save energy and save money off their utility bills and enhanced London's green spaces.

Mayor of London is a critical stakeholder from the perspective of reducing leakage that is one of the main focuses from Thames Water. Reducing leakage involve coordination between the different local authorities to do public work and intervene in the day-to-day activities of the city.

WWF NGOs

The World Wide Fund for Nature (WWF) is one of the main NGOs that interact with Thames Water. Their main interest is to reduce the stress created from the water abstraction on the natural resources. Based on Thames Water Research, their would like that the company works in alternative to alleviate low flows in rivers and improve water efficiency work.

10.6 Appendix Decision-Making Process

Long-Term Strategies are developed in Thames Water following a structured process termed the Service Strategic Development Process, which is supported by the structure described above. The process is comprised of two main areas. First, is the *needs* identification for the long-term strategies based on key findings from internal and external research. The second phase is the optimisation of these strategies, which are based on the investment scenarios against the strategic framework. The strategic framework is comprised of the long-term priorities, the measurable outcomes and the strategic goals. The outcome of the process is the Service Strategic Investment, which is the portfolio of the long-term strategies and objectives. (Figure 10.11)

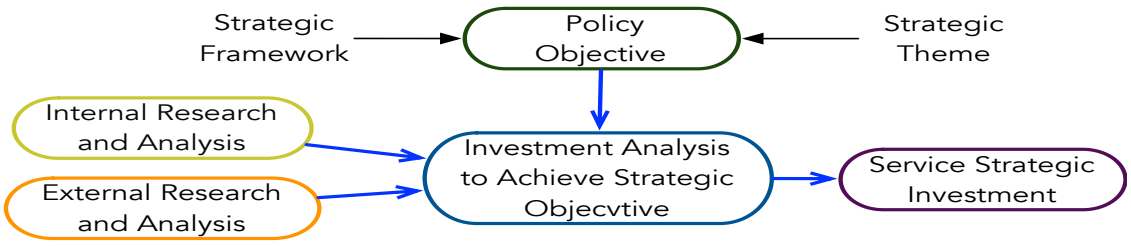

Figure 10.11:Long-term Strategy Process (Source Thames Water, 2012)

The Service Strategic Development Process is conducted for each component of the Water Value Chain- Resource, Treatment and Distribution. Below the decision-making process for the development of the long-term strategies will be described.

10.6.1 Internal Research and Analysis

The internal research and analysis process is focused on identifying *needs* related to investment history and the performance of the system. The investment history is determined by reviewing the capital and operational expenses on the particular system of assets. Performance evaluation is based on serviceability, water standards and

water demand balance. Future performances are based on the impact of the supply-demand balance on each of the sub-systems. The supply demand balance is an approach used by water companies in the UK to manage the risk of water scarcity. The long-term forecast for resource availability (supply) and water use (demand) is used as a future parameter to determine the overall impact between the different subsections.

10.6.1.1 Historical Review

The internal research analysis focuses on: an historical review, the current position and future internal drivers. The review analyses historic expenditures and the security of the supply index of the Water Resources.

Findings reveal that investment for the Treatment plant has spent more in capital expenditure than operational cost. Since Capex are the main driver to price determination, the company will need to justify the expenditures and need, in relation to long-term strategies. Opex costs are primary driven by external factors such as energy and chemicals.

In relation to water distribution, Thames Water spent almost double in the distribution system compared to its competitor (Thames Water, 2012). The main driver was the repair of the system caused by unplanned interruptions. These unplanned interruptions were driven by leaks of the system. This increased the costs of operation due to the labour and the increase of capital maintenance to replace the mains.

The security of supply index (SOSI) reflects the company ability to meet its specific levels of service for water supply and it is scored for annual average. The SOSI has been maintained due to the investment on the desalination plant, but it would be expected to fail due to projected deterioration of different key treatment plants and water distribution systems (Thames Water, 2012).

Table 10.3: Summary of Main Findings for the Historical Review and Analysis (Source: Thames Water, 2012)

Water Value Chain	Factors Considered	Main Findings
Water Resources	Security of Supply Index (SOSI) reflects the company ability to meet its specific levels of service for water supply and it is scored for annual average. Supply / Demand Position Capital Expenditure	SOSI position has been achieved with the assistance of the Thames Gateway Desalination plant and through a reduction in demand. Supply/Demand balance in London is marginally positive. £1.5bn capital expenditure has been invested in water growth since privatisation
Water Treatment	Total Expenditure Capex and Opex Operational / Capital Expenditure Split Capital Expenditure Operational Expenditure	50% of operational expenditure is externally driven, therefore there is a need to reduce spend on power, service charges and materials. Capital expenditure has increased by 47% since AMP3 with concentration of spend on failing assets. Investment has a Capex bias and/or a low Opex. Thames Water considers addressing this to keep pace with regulatory drivers.
Water Distributio n	Total Expenditure Capex and Opex Operational / Capital Expenditure Split Expenditure vs. Performance Leakage Expenditure Capital Expenditure Operational Expenditure	For every kilometre of main, Thames Water spent around £33.0k in total expenditure in AMP4, which represents an uplift of approximately 20% on AMP3. This is more than double the expenditure per km, of the nearest competitor. For every pound sterling of investment in the Water Distribution asset base, approximately 60% will be operational expenditure and 40% capital expenditure. However, this split does vary. The historic instability of mains replacement spends is of concern. The high cost of operation is driven by two systematic issues – high work volumes and high operational costs including wages, insurance, street works etc. level of Capital investment asset base have been high and have contributed to the reduction in the level of leakage

10.6.1.2 Current Asset Performance

The current performance position analyses the ability of the asset base to deliver the serviceability measures (operational performance), replacement rate and water standards. The water resources were analysed to understand the SOSI performance for the existing year. The SOSI reflects Thames Water ability to meet its specific

levels of service for water supply and it is scored for annual average. The performance is modelled under different components (such as Water Available For Use (WAFU), Dry Year Distribution Input (DI), Bulk Import and Export, Target Headroom, % of Surplus) and then it is scored. From these research and analysis, Thames Water concluded that the current security of supply performance in London is marginal and identified the necessity to improve their understanding of the resilience between the sons.

Water Treatment assessment shows a lineal relationship between the improvement in the serviceability and the capital expenditures. Due to the increase on capital expenditure, Thames Water may be challenged by the regulators and would have to provide evidence to demonstrate that all proposed future investment is based on actual performance and condition data (Thames Water, 2012). Besides the serviceability, a Mass Balance / Resilience model is used to understand the resilience of the water treatment assets. The model provided an understanding of the risk from the performance perspective of the system. However, the model is limited to postulating the level of resilience of the asset base in terms of the customer (Thames Water, 2012). Thames Water identified that resilience would provide them levels of data that would enable them to make investment decisions for long-term planning ([5}, [10], [6]).

Key findings for the distribution system are about the performance failures driven by busts. The performance failures are twice compared to competitors, and drive high numbers of customers' calls (Thames Water, 2012). As result of the high number of calls, the Service Incentive Mechanism (SIM), a score based on complaints of the customer, has been impacted. The analysis is conducted by serviceability measures and the average age of the mains. The performance failures have influenced the operational cost and efficiency of the invested capital maintenance. Increases on inefficient capital investments means that the unplanned failures are not reduced, and also increases the operational cost due to labour. The other driver to the increase in system failure is the conditions of the mains whose average age is around 70-yr.

Table 10.4: Summary of Main Findings for the Current Condition and Analysis (Source: Thames Water, 2012)

Water Value Chain	Factors	Main Findings
Water Resources	Supply/Demand Performance	Maintaining Security of Supply The current security of supply performance, particularly in London is marginal. Deterioration in the total Water Available For Use (WAFU) Resilience There is only a small surplus in the largest water resource zone of London. Within each zone the sub level of resilience varies with some specifics areas having low resilience levels.
Water Treatment	Operational Performance - Serviceability Measures Comparison of Supply / Demand Factors Mass Balance / Resilience models Drinking Water Quality Raw Water Pumping Stations	Resilience of all Water Treatment Works: Identifying the level of resilience of supply to the customer offered by the WTW asset base in their existing condition, Identifying where best to invest capital maintenance funding to improve business resilience and customer service. Maintaining Drinking Water Quality Ensuring that the Drinking Water Safety Plan process is fully embedded into the business planning process. Ensuring that there are plans in place to address the main causes of compliance failure, such as lead and metaldehyde. Understanding Raw Water Pumping Stations Identifying the level of resilience of supply to the customer offered by the asset base in their existing condition. Increasing the flexibility in the event of low river flows Further understanding the Abstraction Incentive Mechanism and how it can be maximise
Water Distribution	Operational Performance Serviceability Measures Average age of mains Impact failure has on service and Health and Safety (trunks)	Performance of the Network Water Network performance indicates a stable to improving trend, More than twice the performance failures driving the high number of customer calls and therefore impacting the Service Incentive Mechanism (SIM). Replacement Process and Metering Mains replacement rate has matched material deterioration for distribution (approx. 0.5% p.a). However, the rate has varied consistently and has not improved asset age. Replacement rate of Trunk Mains is not acceptable (~0.1%), and is a serious cause for concern. 500,000 of the existing customer meters are operating beyond their working life, and are in need of replacement.

10.6.1.3

10.6.1.4 Future Internal Drivers

Future evaluation assesses the supply-demand balance. Findings show that a growing deficit is projected during the 25-yr period. As result, Thames Water is expecting more pressure from customers and regulators on leakage reduction and constrains on treatment and resources with the existing conditions of the asset base.

10.6.2 External Research and Analysis

External research is an assessment on the customers and stakeholders' requirements and the impact of external future drivers. The customers and stakeholders' requirements are used to define the parameters that are relevant to measure the assets performance. The general customer research covers qualitative and quantitative analyses on perceptions and views from the customers. The research includes the willingness to pay studies that ask customers what they want Thames Water to do ([8], [7], [9]). Their views are considered on the service analysis, modelling, and scenario planning and then in the investment proposal (Thames Water, 2012). In addition, an investigation is conducted to understand the customer contact profile (e.g. what drives customers' complaints). Results from the research shows that customers want a safe/reliable system, to reduce the stress in the water resources and maintain bills affordable (Thames Water, 2012).

The assessment conducted on the main stakeholders, regulator and local authorities indicated as there main interests: affordability, compliance of water standards and sustainability. More in detail, interests and expectation are described in the stakeholder analysis. Based on this analysis Thames Water categorises the stakeholder requirements into three categories, Affordable Service, Reliable Service and Quality Service. The impact of the external future drivers is quantified based on these categories.

Thames Water identified five future external challenges using the PESTLE (Political, Economic, Social, Technological, Legal and Environmental) methodology. The five key challenges are: 1) Regulatory and Market Reform 2)Inflation and Energy

Prices, 3)Population Growth and Affordability Trends, 4)Pressure to Innovate, Quality and Environmental Legislation, and 5)Climate Change. Qualitative and Quantitative impact analysis are conducted. The qualitative impact analysis is performed against the asset base and the customers and stakeholder's requirements. The quantitative impact is conducted based on the total cost of Opex and Capex during the 25-yr period.

An ability to respond to analysis is conducted for the 5 challenges, where they are ranked based on an uncertainty vs. influence chart. Uncertainty by way of population growth and climate change implies for Thames Water that flexible strategies for the investment of assets are needed ([10], [5}, [8]; Thames Water, 2012). Two main ideas have result from this flexibility approach. First, the consideration of investing on medium scale projects to prepare for future events and reduce over spending or underperformance ([10], [5], Thames Water, 2012). Second, understanding the role of innovation within water networks (smart networks) as a key enabler to manage the future pressures from climate change, environment and population growth ([8], [10], Strategic, 2012).

As part of the evaluation, two changes on regulation are taken into consideration, Abstraction Reform, and Regulatory and Market Reform. Both were issued under UK White Paper (2011). Abstraction Reform will affect Thames Water abstraction licensing for the future and could reduce the existing availability of water supply. Regulatory and Market Reform will drive to unbundle the value chain. As a result, Thames Water will have to understand the cost of water at each location in its operational area in order to set appropriate prices for retailers and new water resources entrants ([7], [10], Thames Water, 2012).

Table 10.5: Summary of the main findings of the external future drivers (Source: Thames Water, 2012)

Water Value Chain	Factors	Main Findings

Water Resources	Future External Key Challenges Qualitative Impacts on Water Treatment Asset Base Qualitative Impacts on Customer / Stakeholder Requirements Quantitative Impacts Ability to Respond	Market reform, inflation, population growth, and climate change will have an impact in the company ability to continue to provides the reference levels of service to its customers Population and climate change have both high uncertainty and limited ability to influence Environmental programme and market reform have uncertainty but more ability to influence The government recognises the increasing risk of water scarcity and the need to reform the existing abstraction licensing regime. Thames Water will review the predetermined policy options; understand their feasibility and the operational, financial and risk implication to the business The proposed wholesale / retail market reform will dictate that a unit cost of water must be established for sale to the retail company, and need surety that this rate can be consistently met, even given the cost variation across the treatment asset base.
Water Treatment		External Factors such as market reform, inflation, population growth, and climate change will have a medium to high impact on water treatment. Population and climate change have both high uncertainty and limited ability to influence which suggest that a flexible strategy is needed. Environmental programme and market reform have uncertainty but more ability to influence.
Water Distribution		External Factors such as market reform, inflation, population growth, and climate change will have a medium to high impact on water distribution and capability to supply the require demand. There will be an increase stress on both costs and resources due to future potential externalities and focus on managing power Population and climate change have both high uncertainty and limited ability to influence which suggests that a flexible strategy is needed. Environmental programme and market reform have uncertainty but more ability to influence.

10.6.3 Strategic Themes and Policy Objectives

Determination of the long-term strategic goals for the assets is conducted based on an analysis of long-term issues facing the water industry, internal knowledge asset based and views from customers and stakeholders research (Thames Water, 2012). The strategic goals are defined as strategic themes and policy objectives, which are mapped to the long-term priorities (outcome-based long-term objectives) and outcome-based objectives. Since the strategic goals are defined based on outcome-based objectives, there are expected to be refined in the future as more understanding from the customer's engagement is obtained (Thames Water, 2012). A strategic framework is developed based on the long-term priorities, outcome-based objectives

and policy goals.

Thames Water defines the lower levels with the aim to underpin the upper levels (Thames Water, 2012). On the left hand the criteria are named based on the terminology used in this thesis. On the right hand, the levels are related to the Evaluative Framework, to provide an understanding of their alignment with the information provided at the chapter above.

10.6.4 Strategic Investment Choices General

Strategic investment choices are evaluated against the strategic framework illustrated in the above subsection. The delivery of the strategies is based on investment scenarios. These scenarios are short-term minimum spend approach, long-term maintenance spend approach, resilience approach and sustainability approach. The scenarios objectives and results are dependant on the subsection of the water system. A general description of the objectives and limitations is provided below based on Thames Water analysis.

The short-term minimum spend approach has the objective of maintaining the existing levels of serviceability with the minimum amount of capital and operational expenditures. The scenario is calculated with a bottom-up assessment of the *needs*, and a limited focus on developing capability and data. The result of the assessment led them to not meeting the strategic goals and would lead to more expenses in future planning periods (Strategy, 2012).

The long-term maintenance spends approach follows a similar approach to the minimum spends, but moving the focus to the asset lifecycle management and minimum whole life cost of the asset-based. As the short-term scenario, the assessment of the *needs* is based on a bottom-up approach. The difference is that the scenario considers the future asset replacement, efficient asset acquired to operate at minimum whole-life cost, deterioration profile of assets with significant risk to customer. There is a focus on investment profile, a focus on data, capability and in system control. The results led to long-term supply reliability but did not respond to

long-term uncertainty (Strategy, 2012).

The resilience approach has the objective to increase the resilience of the asset system against uncertain external factors such as climate change and population growth. Thames Water intent is that by framing solutions that will enhance the flexibility of the system, and adapt to internal and external impacts, the long-term goals will be achieved. The identification of *needs* is based on resilience modelling, which is fed by their knowledge on the asset availability and deterioration. The strategy is underpinned with high focus on data, capability and system control and strategic links to increase flexibility. Forecasted performances meet the majority of the strategic goals, and customers' requirements for a safe and reliable supply. However, high capital expenditure would be needed.

Last scenario is the sustainability approach. Its objective is a sustainable water infrastructure system through a planned reduction in the use of energy and carbon emissions. The scenario includes a number of solutions that will promote the use of efficient plants and reduce energy/materials and consumable usage. This strategy approach will be also underpinned by high focus on data, capability and system control. The scenario will also address the majority of the strategic goals. However, it would lead to high levels of investment which may not be needed in the future if demand growth does not materialise. It would also result in a heavy Capex, risk avoidance approach to managing the service.

10.6.5 Strategic Investment Choices

A final programme of the strategies is defined based on the results of the stages described until now. The overall long-term strategy for each of the water sub-systems is a number of strategies that will be underpinned by the strategic objectives. The objectives are defined per price review period and most of them are path dependent. Below is a summary of the story behind the final strategies for each subsystem based on the draft Water Service Analysis (2012).

10.6.5.1 Water Resources Strategies

Strategies from the water resource segment interconnected with the development of the regulatory document Water Resource Management Plan. As it is proposed in the plan, the strategies separate effort between demand and supply. In the demand side, the strategies focussed into reducing the demand in a short to medium term. On the supply side, strategies are focused on creating new resources such as indirect reuse (considering cost effectiveness and operational viability). The investment approach is around a minimum whole life cost that is focussed on leakage reduction, water efficiency and metering, where it reduces the amount of water abstracted. However, a long-term investment in large resource storage will be necessary. This decision will be determined based on the progress of a better understanding of the system.

Strategic investment choices are evaluated against the long-term priorities, outcomes and policy objectives described in the subsection above. Different investment scenarios were assessed and model using a combination of investment tools. The scenarios for each segment are provided in summarised in the below table.

Table 10.6: Summary of the main findings of the Scenario Analysis- Water Resources (Source: Thames Water, 2012)

Water Value Chain	Factors	Main Findings
Water Resources	Short-Term Minimum Spend Approach	• The objective of this scenario is to ensure that the forecast supply /demand deficit would be addressed with the minimum amount of Capex and Opex spend in AMP6. • This has been calculated through a management decision support package that selects the optimum range of solutions from the strategic objectives with least cost to the business in AMP6. Limited focus on capability and data. • The Short-Term Minimum Spend Approach scenario would be heavily weighted toward IPPR, with minor ground water development schemes, some mains replacement and optional, but crucially, no compulsory metering. This scenario would lead to increased cost in subsequent investment periods, greater risk and would not enable the additional benefits from compulsory metering to be derived.

	Minimum Whole-Life Cost	• The objective of this scenario is to ensure that the forecast supply / demand will be addressed with minimum whole programme cost • This has been calculated through a management decision support package that selects the optimum range of solutions from the strategic objectives with least whole programme cost. Additional focus on capability and data to develop intelligent operational control over a 5-10 year period. • The Long-Term Maintenance Approach scenario would lead to a selection of solutions that are equally balanced with some IPPR, minor ground water development schemes, some mains replacement, optant and compulsory metering. This scenario would align with all the strategic objectives and enable the additional operational, customer and asset management benefits from compulsory metering to be derived.
	Resilience (Universal Metering)	• Objective of this scenario is to ensure that the forecast supply /demand deficit would be derived from the introduction of compulsory metering. • This has been calculated through a management decision support package. This selects the optimum range of solutions from the strategic objectives, that provide minimum whole programme cost and additional business benefits from the introduction of compulsory metering. • The Universal Metering scenario would lead to a selection of solutions that are more costly than the Long Term Maintenance scenario, but less costly than the Sustainability scenario. The programme would include some IPPR, minor ground water development schemes, some mains replacement and extensive compulsory metering. This scenario would align with all the strategic objectives and enable the additional operational, customer and asset management benefits from compulsory metering to be derived. The benefits accrued from this scenario include reduced demand, Capex avoidance, leakage targeting, understanding of actual wastage and high usage levels and improved accuracy of bills; resulting in fewer customer calls and improved customer satisfaction.

10.6.5.2 Water Treatment Strategies

The Water Treatment Strategy intent is to reach Thames Water short and long term objectives by implementing a flexible approach. The strategy has as the main focus to improve the capability of the system by increasing gradually the resilience. The strategy would balance between maintaining the system in the required condition and learn from the system to gradually move to a more resilience and sustainable system. The approach is to mitigate the consequences of overinvesting or underinvesting due to the uncertainties of the future.

Table 10.7: Summary of the main findings of the Scenario Analysis- Water Treatment (Source: Thames Water, 2012)

Water Value Chain	Factors	Main Findings
Water Treatment	Short-Term Minimum Spend Approach	• Objective is to ensure that supply/demand and the water quality service remains at the existing levels of resilience • Calculated through a "bottom-up" assessment of needs water non-infrastructure asset base for capital maintenance. Limited focus on developing capability and data • Will not address the strategic objectives. This scenario may appeal in the short term, but would lead to more expense in future planning periods (beyond 2020)
	Long-Term Maintenance Spend Approach	• Achieve the objectives in the minimum spend but to move towards a position of asset lifecycle management with asset investment, maintenance, deterioration, repair and replacement with minimum whole life cost. • Calculated based on the above scenario and considering the future asset replacement, efficient asset acquired to operate at minimum whole-life cost, deterioration profile of assets with significant risk to customer supplies and water quality to smoothen investment profile, focus on data, capability and system control • Provide greatest focus on maintaining long-term supply reliability and but little proactive management of long-term uncertainty
	Resilience Approach	• Objective is to increase company resilience to external factors algal blooms, climate change, flooding, population growth and internal factors such as outage. • Focus on solutions that enhance the flexibility of the system to respond to internal and external impacts. Solutions are developed using the mass balance / resilience modelling, coupled with an understanding of asset availability and deterioration. High focus on data, on data, capability and system control and strategic links to increase flexibility • The scenario will address the majority of the strategic objectives, and customers requirements for a safe and reliable supply
	Sustainability Approach	• Objective is to be sustainable future water treatment through a planned reduction in the use of energy and carbon emissions • Include a number of solutions that will promote the use of efficient plant and reduce energy/materials and consumable usage. High focus on data, capability and system control. • The scenario will also address the majority of the strategic policy objectives. However, it would lead to high levels of investment which may not be needed in the future if demand growth does not materialise. It would also result in a heavy Capex, risk avoidance approach to managing the service.

10.6.5.3 Water Distribution Strategies

Strategies for the water distribution follow a similar approach as Water Treatment Strategies. The focus on the short-term is to reduce the deterioration of the system and move into a more resilience system in the next 10-15 yr. Reduction in deterioration is based on a whole-life cost network management. Decisions on investment are aligned with strategies from the Water Resources and will be supported by the current and

innovations on investment targeting programs. The flexibility of options is limited due to the pressure to reduce leakage. Thames Water has identify the need to increase the value of repairing leakage by considering a more integrate approach.

Table 10.8: Summary of the main findings of the Scenario Analysis- Water Distribution (Source: Thames Water, 2012)

Water Value Chain	Factors	Main Findings
Water Distribution	Short-Term Minimum Spend Approach	• The objective of this scenario is to maintain service with the minimum amount of Capex and Opex spend in AMP6, but not to maintain deterioration of the asset. • This has been calculated with the assistance of a decision support package, the Asset Investment Manager (AIM). This selects the optimum range of solutions from the strategic policy objectives with least cost to the business in AMP6. • The short-term minimum spend approach scenario would include limited mains replacement but would result in deterioration of the network and in turn could limit long-term service performance. Leakage would be controlled through active leakage control and pressure management. This scenario would see a decreased level of capital investment but an increased level of operational expenditure. There would be a requirement for a greater level of capital investment in AMP7 to catch up with the deterioration of the asset not managed in AMP6. Overall this scenario does not align with the customer preference to reduce leakage.
	Long-Term Maintenance Spend Approach	• The objective of this scenario is to ensure service and maintain deterioration levels with the minimum whole programme cost. • This has been calculated with the assistance of a decision support tool, the Asset Investment Manager (AIM). This selects the optimum range of solutions from the strategic objectives with least whole programme cost. • The long-term maintenance approach scenario would maintain unwanted call volumes and other service impacts (interruptions to supply, low pressure etc.) and target investment through a focus on data management and in turn reduce long-term cost of service. Levels of monitoring would be increased to protect high consequence sites from failure of larger diameter assets. Metering would be used per DMA and against key buildings prior to mains rehabilitation being undertaken (as per MRPIR recommendations). This would lead to improved operational responses and investment targeting. • Innovation and data collection are key activities, improving the ability to target investment in AMP6 and in the future (strategic hydraulic models, material analysis tools, deterioration rate analysis etc.), and in-turn reduces long-term cost of service provision. This scenario would manage leakage through mains replacement and pressure management but would not improve the position. On its own this scenario does not align with the customer preference for leakage reduction.

	Resilience Approach	• Objective of this scenario is to ensure service and maintain deterioration levels but with additional targeted investment to improve performance and resilience. • This has been calculated with the assistance of a decision support tool, the Asset Investment Manager (AIM). This selects the optimum range of solutions from the strategic objectives that provide business resilience with minimum whole programme cost. • The resilience approach scenario would lead to further targeted investment to reduce levels of leakage, unwanted call volumes and interruptions to supply. This scenario would align to the long-term priorities, outcomes and strategic themes. However, in the short-term, insufficient data on the detailed location of all demand and leakage would lead to higher costs to the customer.
	Sustainability Approach	• The objective of this scenario is to ensure service and maintain deterioration levels but with additional targeted investment to improve the long-term sustainability of the service area, through service enhancement. • This has been calculated through a management decision support package, the Asset Investment Manager (AIM). This selects the optimum range of solutions from the strategic objectives that provide minimum whole programme cost and additional business benefits from the implementation of sustainable options. • The sustainability approach scenario would lead to additional targeted investment to further reduce levels of leakage and energy usage and promote innovative 'no-dig' mains replacement techniques. This scenario would deliver most of the long-term priorities but would deliver higher bills and, as with the resilience approach above, could lead to higher short-term costs than would otherwise occur. This is due to the insufficient information available precise demand and leakage on a street by street basis

10.6.6 Decision Support Tools

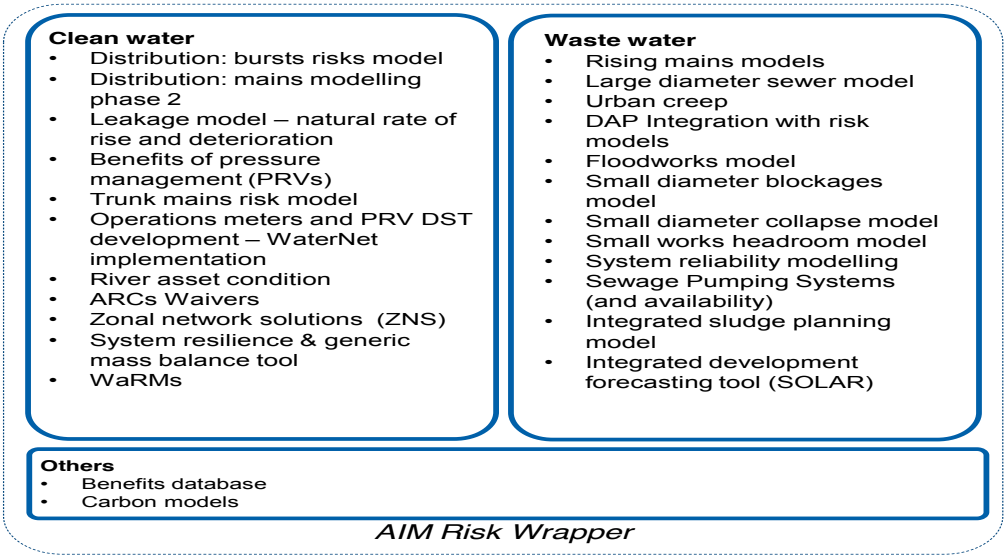

Figure 10.12 Lists of Decision Support Tools (Source: Linscott, 2012)

10.7 Appendix - Interview Questions

Below shows a list of the various interview respondents used for the analysis in this research. Also, participant is employer.

Table 10.9: List of Interviews conducted on April 2013

Ref Num.	Name	Position	Organisation
1	Mr Rob Casey	Modelling Manager Water	Thames Water
2	Dr Mark Engelhardt	Science Director	SEAMS
3	Dr. Helen Evans	Optimisation Manager	Thames Water
4	Dr. Michael Jones	Groundwater Resources Manager	Thames Water
5	Mr Simon Jones	Asset Strategy Manager (WTW)	Thames Water
6	Mr. David Joynson	Asset Management Planning	Thames Water
7	Dr. Chris Lambert	Regulations and Strategies	Thames Water
8	Mr Anthony Owen	Network Infrastructure	Thames Water
9	Ms. Clair Parmenter	Asset Management Consultant	Thames Water
10	Mr. Rob Scarrott	Strategic Water Planning Manager	Thames Water
11	Mr. David A White	O&M Strategy and Standards manager	Thames Water

In the section, questions designed to collect the empirical data necessary from documents, report and interviews. Target participant will be asked with specific questions, so not all questions are intended to be asked at each interview.

10.7.1 What is the structure of the decision system for asset management in Thames Water at the Strategy and Policy level?

Level	Questions
Company Objectives	Who are considered to be the asset owner?
	What are the objectives related to drinking water and wastewater? How are they separate?
	How, the shareholders, regulators or other parties influence these objectives?
	How is the company takes in consideration the objectives of the stakeholders? What mechanisms are in placed to take their opinion and how it is incorporate in the objectives?
	Is there are method to weights between the objectives?

	What are struggles and constrains to implement Thames' strategies in the Asset Management Policy? Is there a review procedure to evaluate the alignment between the strategy and policy level?
Asset Management Policy	What is the asset management process for Thames Water? Bring Diagram
	How much capital is assigned for innovation? How many PhD, RandD, etc.? Is there documentation of the structure and/or policy?
	Are innovation and technical conditions considered in the decision process?
	How does Thames Water set the criteria for the Risk Manager Framework? How much is dictated by the regulator, company strategy, shareholders, experts, etc.?
	What are the main overall intentions/principles and framework for control of asset management?
	How important is the Financial and Safety aspect in the Asset Management Policy? How is the relevance established or quantified?
	How are the internal and external stakeholders and shareholders opinions used in the evaluation process of the policy? How is measured, and how is translated?
	Does Thames Water distinguish between asset systems and asset as object? How are the asset systems defined? Is the interrelation between the water sub-systems (e.g. waste water) consider in the development of strategies and objectives?
Strategy	Can I review business cases on new water resources, water reuse, and desalination plant?
	What is the process to establish the criteria for optimisation and the asset management objectives? What are the methods for optimisation and decision-making? What are the main factors considered in these methods?
	Is the decision making process focused on solving current bottleneck issues like system stabilisation? Does the decision-making process contemplate the next generation of infrastructure? What is the vision on this? How is this vision incorporated in today's decision-making process?
	What are the main factors considered when establishing criteria and priorities? Are established criteria or priorities changed over time? How often do this kind of changes occur?
	Does Thames compare (evaluate) the strategies based on the steering factors?
Objective (Outcomes)	What is the information that is gathered for the performance indicators, information process related to asset management? How Thames Water decides which information is gathered?
	What are factors considered to establish the target values for the objectives?
	Does Thames compare (evaluate) the objectives based on the steering factors?

10.7.2 What are the relevant elements of the Physical Characteristics that influence on the Thames Water's Strategies and Asset Management Policies?

Element	Questions

Physical Geology	Is there guidance on the application of modelling tools (software or other) on providing decision support to end-users of model results and long-term strategies?
	Is the water resource management scheme (groundwater vs. surface water) based on internal needs or is driven by regulators?
	What elements are important for the system definition of the Physical Geology, Hydrology System and Water Availability (e.g. biophysical aspects, system boundaries, economic and social components, temporal and spatial scales)?
Hydrology system	Is the hydrology system integrated in the development of long-term strategies?
Water availability	How is the water availability considered as a factor in the decision making process?
Climate	Is the effect of climate change considered on investment decisions? What are the considerations to consider the climate change scenarios in investment decisions?
	Is there a process/methodology to manage the uncertainties from Climate Change in the development of long-term strategies? Are other uncertainties beside climate change considered in the context of the models?

10.7.3 What are the relevant elements of the Cultural Embeddedness that influence on the Thames Water's Strategies and Asset Management Policies?

Element	Questions
Relation to Authority	How can be described the interaction between the main regulators with the company? Are the regulators considered part of the decision making-process for asset management? Are there specific guidelines?
Managerial Background	Do experts in the water sector or manger with managerial background mainly support the decision-making process?
	What's exactly risk based AM (on strategic, tactics and operational level; how does the alignment look like?) and what are the typical Anglo Saxon elements in it? Is Risk based from Anglo Saxon culture?

10.7.4 What are the relevant elements of the Institutional Arrangement that influence on the Thames Water's Strategies and Asset Management Policies?

Element	Questions
Property Right	Are there concessions to extract water? Are the licenses temporary or permanent? Licenses to operate and extract? What kind of licenses?

Ownership	Who is the owner of Thames Water? What is the behaviour of the owner? Want to earn money in a long term with less risk or short term with higher risk way? Investment decisions are based on the earning scope, long-term vs. short-term?
Regulations and Legislation	What are the specific regulations that Thames Water needs to consider for the asset management on drinking water?
	How are the expected changes in legislation will be considering in the long-term planning? Is there a general approach to accommodate these changes?

10.7.5 What are the relevant elements of the Governance Characteristics that influence on the Thames Water's Strategies and Asset Management Policies?

Element	Questions
Price of Water	Does Thames Water have an influence in the price determination? How is the price affect the decision for investment in the long term between Capital Investment and Operating Costs?
	How the shareholders consider the price of water to determine objectives and decisions?

10.8 Appendix Legal Framework

10.8.1

The Water Framework Directive is a requirement established by the European Union to all member states of the EU and all candidate countries. It provides a legal framework to protect and restore the freshwater resources across Europe for this and future generations by encouraging a sustainable use.

The objectives, defined as environmental objectives, focus on preventing the deterioration of the status, achieve a "good water status" by 2015 on all the EU's water bodies, and reduce pollution from priority substance (Art. 4). WFD categorises the water bodies as surface water, groundwater and protected areas. In the case of the surface water and protected areas the good water status is achieved when both its ecological status and its chemical status are at least good (Art.2). The chemical status is an expression of the water quality standards based on concentration of pollutants identified as priority substances (Art. 2). An ecological status is defined as an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters, which basis is the reference condition of the biological

elements (Art. 2, Annex V). The reference conditions are the natural or near-natural conditions of the specific type of water body.

Implementation of the WFD is underpinned by a system of river basin management planning. Member States have to follow specific deadlines of actions with emphasis on: 1) specification of the environmental objectives, 2) assessment of the current situation and the prediction of the future situation if no additional measures are taken, 3) development and implementation of a programme of measures to achieve the environmental objectives (Mostert et al, 2009). In UK these activities are conducted by the EA. Main activities with the deadlines are provided in the below table.

Table 10.10: Milestones of the WFD with Respective Sections

2000	Directive entered into force	Art. 25
2003	Transposition in national legislation	Art. 23
	Identification of River Basin Districts and Authorities	Art. 3
2004	Characterisation of river basin: pressures, impacts and economic analysis	Art. 5
2006	Establishment of monitoring network	Art. 8
	Start public consultation (at the latest)	Art. 14
2008	Present draft river basin management plan	Art. 13
2009	Finalise river basin management plan including programme of measures	Art. 13 & 11
2010	Introduce pricing policies	Art. 9
2012	Make operational programmes of measures	Art. 11
2015	Meet environmental objectives	Art. 4
	First management cycle ends	
	Second river basin management plan & first flood risk management plan.	
2021	Second management cycle ends	Art. 4 & 13
2027	Third management cycle ends, final deadline for meeting objectives	Art. 4 & 13

10.8.2 UK Legal Framework

After privatisation, four Acts of Parliament codified all past legislation still in force. The four Acts were (Source Development of Water Industries in Whale):

9. The Water Industry Act 1991 set out the powers and duties of the Water and Sewerage Companies, thus replacing those set out in the Water Act 1989, and defined the powers of the Director General of Water Services.

10. The Water Resources Act 1991 set out the functions of the National Rivers Authority and introduced water quality classifications and objectives for the first time;
11. The Statutory Water Companies Act 1991 applied specifically to the former statutory water companies;
12. The Land Drainage Act 1991 transferred the functions of previous internal drainage powers of local authorities to the NRA.

In addition, subsequent Acts have modified this framework. These include:

- The Competition and Service (Utilities) Act 1992. This increased Ofwat's powers to determine disputes and increased the limited opportunities for competition in the industry.
- The Environment Act 1995. This led to restructuring of environmental regulation and placed a duty on the companies to promote the efficient use of water by customers. It consolidated the functions of the National Rivers Authority, Her Majesty's Inspectorate of Pollution, the Waste Regulation Authorities and certain elements of the Department of the Environment to a new body, the Environment Agency.
- The Competition Act 1998. This prohibits any agreements between businesses that prevent, restrict or distort competition. It also prohibits any abuse of a dominant market position. The Director General of Water Services shares investigative powers in the water industry with the Office of Fair Trading under the Act.
- The Water Industry Act 1999, made several important amendments to the Water Industry Act 1991, including removal of an undertaker's right to disconnect domestic customers for non-payment of bills, a limit on the circumstances in which companies can compulsorily meter customers, and gave the Director the task of approving companies' charging schemes. It also secured that companies could continue to charge customers on the basis of rateable value.
- The Water Act 2003, which amended the framework for abstraction licensing, revisions to the corporate structure of economic regulation and extended the scope for competition in the industry to large users.
- The Enterprise Act 2002, which has provisions relating to the merger regime.

10.8.3 General duties of water undertakers

The general duties of the water undertakers, as defined in section 37 of the Water Industry Act 1991:

- to develop and maintain an efficient and economical system of water supply within the undertaker's area;
- to provide supplies of water to premises in the undertaker's area and make such supplies available to persons who demand them; and
- to maintain, improve and extend the water undertaker's water mains and other pipes.

These duties are enforceable by the Secretary of State or, with her consent, the Director General of Water Services.

10.8.4 Specific duties and powers of water undertakers

1. The Water Industry Act 1991 also places specific duties on and gives powers to the water undertakers, including:
2. A duty to connect premises to the network where a supply for domestic purposes is requested (Sec. 45-49 of the Act). Undertakers may recover

expenses for the connection from the person requesting it.

3. Once connected there is a duty to supply water that is sufficient for domestic purposes and maintain the connection between the water main and the service pipe which supplies the customer (Sec. 52 to 54). Section 218(1) of the Act defines domestic purposes as "drinking, washing, cooking, central heating and sanitary purposes".
4. A water undertaker is required to provide services for various other purposes, including for fire fighting and public purposes. An undertaker must also provide supplies for non-domestic services unless the provision of services would put at risk the abilities of the undertaker to meet its existing or future obligations, or unreasonable expenditure would be incurred in meeting those obligations (Sec. 55-59).
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6. Sections 60-63 gave undertakers the power to disconnect properties from supply in the event of (i) action required to carry out necessary works,
7. (ii) non-payment of bills or (iii) where the customer no longer requires a supply. The undertaker's ability to disconnect household customers for non-payment of bills was removed by the Water Industry Act 1999.
8. Section 65 requires undertakers to provide water at a sufficient pressure to supply customers' premises.
9. Section 68 requires undertakers to supply water that is wholesome at the point of supply. Standards for wholesomeness and steps to preserve water quality are determined by the Secretary of State through regulations made under sections 67 and 69. The Secretary of State may appoint inspectors to act on her behalf (see section 5.4.5) in monitoring and regulating the quality of water. Local authorities also have a duty to keep themselves informed about the quality of water in their areas.
10. Water undertakers enforce the regulations regarding water fittings made in section 74 of the Act.