2 Context and literature

2.1 Introduction

This chapter introduces the concept of water demand management and describes the institutions involved and the origin of the scenarios they use for their forecast. The argument presented is that water demand management is necessary in many developed countries but the dynamics of water demand are not yet well understood.

Many important decisions have been taken in order to adjust the policies and capacities of the water supply industry to both the changing needs of the consumers and the environment. Due to the fact that some of these decisions will involve projects that would take a long time to be implemented, they must rely on a sound analysis of what the situation will be. But predicting the evolution of demand is not obvious. Predicting consumer behaviour in general has been the focus point of marketing and policy research. The present research endeavours to assess the forecast via scenarios in the particular case of water demand.

The interactions amongst agents, the institutional environment, and the diffusion of innovative appliances are the driving components of water demand. They will be specifically addressed later, but have an immediate impact upon the form of this work. The analysis required to deal with this subject is consequently multi-disciplinary, as it involves knowledge of environment sciences, marketing, and sociology. This makes the issue interesting, but also less likely to be adequately addressed through only one of these multiple aspects. A presentation of how the literature can treat this kind of issue is provided below.

The first section presents the details of the various definitions and underlying consequences of management. It is followed by a description of the particular side of management that is involved in this work and a brief list of the various approaches that can be used. An introduction of the different actors in the question follows, providing further information on the particular institution which is the Environment Agency.

2.2 Water management

This section presents the different views of water management, and the definition that will be used follows, explaining why some water management methods or issues are not developed in this work (such as water supply management, pricing policies, and water quality).

2.2.1 Definitions of management

To define management is quite difficult. The Webster dictionary defines it as:

1. the act or art of managing: the conducting or supervising of something (as a business)
2. judicious use of means to accomplish an end
3. the collective body of those who manage or direct an enterprise

Management is a vague concept to apprehend. It requires the accurate definition of the end, and the knowledge of available means. The means will be discussed further, focusing here on the “ends”.

Essentially, this is where the differences in the literature appear. The definition loses here some objectivity, as defining the “ends” of management requires taking into account economic theories or philosophical concepts. Amongst these concepts are sustainability and social welfare. The introduction of these two concepts, as well as the balance between the two poses problems because of the challenges in measuring such outcomes. Taking into account social components can drive the problem into an ideological debate. In the present case, management in a context such as natural resources is mostly understood as a reduction of the ratio of costs to benefits for the society. From then on, the different measures of costs and benefits for a society could lead to other possibly similar debates of definition, measurement and representation. As one can see, the careful definition of management is not easy.

There are several common uses of “management” in this context and that is why trying to give a global definition of it is probably ambitious. These uses mainly refer to the way water is provided.

In developing countries, water management refers to methods of allocation or repartition. The aim is basically to provide enough water to everyone. It is a huge task, and any progress is marginal on a global scale, but very significant at the scale of the user.

In developed countries, water management refers more to these complicated definitions, including welfare and social components in the reflection, rather than the single issue of providing water to those whom are deprived of it. What matters then is how water is used, its supply, repartition, and waste. When a critical level of available water is reached, a fear of depletion arises. That is when the management starts involving sustainability and when reducing the demand matters most. In the following work, it is considered that water management is equivalent to water conservation, since there are already ways of distributing it, and “water conservation is any beneficial reduction in water use or in water losses” (Baumann, Boland et al. (1998)).

In the following section the two possibilities of water management are presented, and the opportunity is seized to describe a simple presentation of the meaning of management throughout this work.

2.2.2 Managing Water demand or managing water supply

The reasons for focusing on a particular side of water management need to be expressed.

Firstly, the original issue is the impact of climate change in some European countries, and specifically in a region of the UK (Downing, Moss et al. (2000)). The consumers have the central role in the questioning. Looking at their behaviour and its changes in the event of climate change, the possibility of changes that could have some impact on the demand is not

considered, and the demand is unconstrained[1], apart from specific occasions and actions taken by the institutional body. This allows a focus on the demand itself. It is mainly validated by historical events.

Also, without the climate change issue in mind, one could realise that water supply management is generally driven by the necessity of improving the supply of water. It is then either an improvement on quality, or quantity, or both (Twort, Law et al. (1985)). It is assumed in this research that the quality requirements for water from the appropriate institutions are met. This is driven by the fact that although a failure in meeting these requirements would impact on consumers, it is up to institutional bodies to solve this problem. Hence, water supply is widely treated in the literature on developing countries and sustainable development. Again, it is not the case here, even though sustainability is clearly becoming a concern for everyone.

The needs for water on a worldwide scale are growing. And the last decades showed increased concerns over natural resources scarcity. The examples are numerous, from the Malthusian approach and the simple ratio population / natural resources, to the Club of Rome and its equivalents, adding the different options of production and pollution.

The only common part amongst these is that water is seen as an economic good. But one must distinguish between the necessity of water and public water supply. Different uses have different elasticity, hence the tendencies to use water-pricing policies to influence the level of water demand[2] as shown further.

2.2.3 The context of water demand management

The current literature in water demand management in England and Wales is frequently the result of research undertaken by the institutions involved in the field, mostly the water companies and the regulators. See Butler and Memon (2005), the Environment Agency's report on variable flush

[1] In other words, it is considered that the demand for water is the actual consumption of water.
[2] As some water uses have an elasticity with respect to price greater than one, *e.g.* for lawn and garden areas, an appropriate pricing policy could reduce the expenditure.

retrofitting (Environment Agency (2005)), OFWAT's report on “security of supply, leakage and the efficient use of water” (OFWAT (2005)), WRc’s Sustainability of Water Efficiency Measures project (WRc Plc (2005)).

Regulators expect the companies to have sufficient knowledge to make sound assumptions in their forecasts, but they also need this knowledge to be in a position to assess the current situation and the other stakeholders’ positions and actions. Companies need to increase their knowledge. That is why for example they try and quantify the effects of simple measures over water demand, and how they might evolve over time.

One of the main challenges with demand management is that it is a soft approach. A hard approach would consist in building structures such as dams or reservoirs. This would help with securing the water supply, and can be relied upon as it reacts to various constraints or situations in a predictable way that engineers can describe. The soft approach, based on changing behaviours and enabling water efficiency by promoting different appliances, is more sensitive to everyday variations and there is little certainty about how it might change over time. For that reason, water companies and regulators undertake research projects, trying to understand future trends in water demand.

For example, a promotion campaign for cistern displacement devices, or a trial of retrofitting variable flush mechanisms to existing toilets might be reasonably affordable to a water company, but the uptake of the method, while the campaign is ongoing and after, will vary. How much water tools like these would save on average, and for how long, is the subject of many projects over the past few years, and every actor in the field recognises the need for more investigation.

Butler and Memon (2005) provide an exhaustive view of the current demand management knowledge and challenges. The Environment Agency (Environment Agency (2004)) assesses water companies resources plans, particularly the main aspect of their duties, the security of their water supply.

This has to take into account the evolution of water demand following the companies' actions. The model developed in this work relates to that forecast.

Other techniques have been used for representing natural resources management:

For example, Howitt, Reynaud et al. (2002) have applied a set of calibrated stochastic models to North California water supplies. However, their research does not differentiate between decision makers and customers, although they seem to obtain significant conclusions on the importance of some components of the model rather than others (namely intertemporal substitution preferences rather than risk aversion or the discount factor).

On a larger scale the SORTIE model by Landcare Research (2002) developed to investigate forest dynamics is based on probabilities. It attempts to quantify the natural processes of forest recruitment, growth, and mortality, adding into this the effects of herbivory by exotic pests.

In addition to approaches such as probabilities or system dynamics, agent based models seem reasonably suitable to tackle the different aspects involved.

Natural resources and environmental issues in general have been the subject of multiple research using modelling techniques based on Multi Agent Systems. Bousquet, Lifran et al. (2001) present an overview of the different uses of game theory and agent-based modelling in management of natural resources. Barreteau, Bousquet et al. (2001) suggests that agent based modelling together with role playing games can provide a way to explain the contents of the model, validate it, and communicate around it. Another example of such a mix is in Etienne (2003), where vegetation dynamics and agent's behaviour have been implemented to assess negotiation process in sylvopastoral management planning.

The sole use of Multi Agent Systems is also present, for example in Etienne, Le Page et al. (2003), where the authors describe how MABS can be

integrated into a step by step approach to build land management scenarios. Another example of land management can be found in Polhill, Gotts et al. (2001), where the authors compare agents' strategies and their results on land selection.

Scenarios as such are not the only option to try and represent uncertainties. There are other methods available.

The use of scenarios, as pioneered by Shell, is growing. They are best used when they are devised while remaining aware of the reason for their creation, keeping in mind their goal assists in ensuring the robustness of the approach (Schwartz (1997)).

As expressed in Fahey and Randall (1997), the most important steps in scenario planning are:

- Decide on the key question to be answered by the analysis
- Set the time and scope of the analysis
- Identify major stakeholders / objects involved
- Find key uncertainties
- Define the scenarios and identify extremes
- Write out the scenarios
- Assess the scenarios, developing appropriate methods if required.

Other possible approaches for dealing with uncertainties include contingency planning and sensitivity analysis. While the former tends to focus on a single (often major) issue or uncertainty, the latter tends to assess how a model reacts to changes in the variables or parameters.

Sensitivity analysis frequently involves a large amount of work, trying to cover many combinations of values, but the usefulness comes mainly when expected changes remain simple. When the importance (and possible

number) of variables increase, sensitivity analysis becomes more difficult, and less meaningful. In more complex environments or models, a scenario will, from a set of assumptions, provide a result from major changes in the dynamics of the model.

2.2.4 The pricing aspect

This research will not focus on the financial point of view. This part presents the main ideas and explains why they are not considered. The financial side of water management is theoretically the easiest to change, and also a very efficient one, as the different international experiences show.

A point to be made is that the definition of water management adopted is (purposely) not appropriate for social or economics debate. Despite the existence of successful examples of financial policies, it is not a substitute for demand management, since they differ not only in their application, but also in their meaning. The second one is that economically, the results depend very much on the specificities of the water uses, and probably even more on the characteristics of the households themselves (Rees, Williams et al. (1993)).

Financial pressure can be easily (at least in many countries other than the UK) applied onto households. As an economic good, water demands will react to water prices. They rely on monetary incentives and disincentives to relay accurate information to the households about the value of water, to promote better water use practice (OECD (1999), Pezzey and Mill (1998)).

The basic economic theory argues that the more expensive a product gets the less the demand. This implies several assumptions on the underlying characteristics of that good.

First the concept of elasticity must be introduced. It refers to the extent to which the demand will vary according to variations of some other economic indicator. There are different variables generally linked with the demand of a product: its price, and the available income. They respectively qualify the substitution effect and the income effect. The former is for most goods positive, since as their price rises, other equivalent products can replace

them. The latter is also generally positive, although there are several distinct situations then. Either it is less than 1 and the proportion of the income used to buy this product is diminishing, or it is more than 1 and the demand proportionally increases with the income. The last possibility is a steady demand with respect to the income.

This concept of elasticity is very important, since different uses of water will not have the same elasticity. For example it is easier to reduce the water use for gardening purposes than it is to reduce the water for hygiene purposes.

Second, using that concept, it must be expressed that the good is an ordinary good. There are specific ones that can see their demand vary in different ways with respect to the variations of its price, depending generally on the income.

Also, the appropriate values of elasticity must be known for every use, in order to find the specific pricing policy that will give the expected results. It is hence necessary to know the household income[3], and the part devoted to some specific water use. This difficult task would need knowledge of the characteristics of the relevant area that could well be out of reach from the current classifications like ACORN.

Finally, in the UK the water prices for domestic use cannot be changed easily. There is a regulator for the water companies, since they need to have the OFWAT authorise them to have their prices changed. One must keep in mind the fact that the economics of the “market for water”, due to the nature of the good, that is common, fragile and necessary, cannot be taken independently of other matters. For example, they depend on the political regime, and the choices made by the government. It is extremely difficult to debate about strictly economical matters, since these have extensions (causes and consequences) into other fields. They are therefore limited not

[3] If the households are not rich enough, water might become a Giffen good, *i.e.* a good showing an increase in demand as its own price rises, and this kind of policy would become useless, and inequitable.

only by their feasibility, but also by the acceptance of the ideas or theories they rely on.

Consequently, the focus on pricing issues for water demand is not only relying on other assumptions about the good involved, it also requires assumptions, appropriate research and estimation of the elasticity of that good. In addition, the representation of the various levels of demand relative to the price would be themselves relying upon economic theory and a most likely debatable statistical analysis. Therefore, it is not going to be one of the aspects involved in this work. Although the income levels can play an important role in the demand for water, they will be represented later by the adjustment of parameters in the different cases.

2.3 Demand side management

In developed countries, a lot of effort is now turned towards the management of water. The concern is that the water demand has been increasing, while the available quantity of water is limited. As water supply must meet that demand it is the whole water system that is endangered. This research is aiming at the demand for water not as a way to help reducing actual demand as such, but more generally in order to improve our understanding, and then being able to use that understanding to better adapt the policies to the demand, or find the appropriate policy for a specific aim, and use that understanding to debate possible future situations in various cases of climate change (Hulme and Jenkins (1998)).

In many cases, the increasing interest in demand side management is due to its relative low cost and flexibility (Barnett, Morse et al. (1963)). This section presents the main differences between demand and supply management, as well as giving examples of the former in the literature.

2.3.1 Characteristics of demand management and supply management

Water demand management and water supply management have the same target (as a product). But they are different approaches and as such have different means and ways to influence it. It is important to note that they

are not competing against each other, but are complementary to each other, both in terms of supply meeting the demand, and in terms of adapting the structures for the evolution of the system.

Because they are on opposite sides of the market, their components (quality and quantity), structure (*e.g.* the timescale they deal with), situations (active or reactive) and tools differ.

In the current study, the quality of water provided is not a priority. It is assumed as meeting the minimal requirements from the regulators, but no more, since water quality is not really influencing the demand. Apart from the exceptional case where the water would not be drinkable and hence the appropriate demand would be null, there is no real influence of the quality upon the demand itself. Also, there is no competition amongst water companies in terms of market shares. One company will not become the provider of a specific household just because they provide better water. For water supply, the quality of water is quite an important factor. Being analysed from the company's side, it has a direct impact upon the deliverable quantities. In that sense, water demand management does not have to deal with water quality issues, while water supply has to.

Being in a developed country, the quantity of water that is used is set by the demand, rather than by the supply (apart from rare occasions). It would be logical to start acting on what sets the demand instead of reacting to a phenomenon. Moreover, the relevant structures involved are on different scales, both financially and in terms of time. For example, generalising metering for households is a prerequisite for many demand management policies, as well as a tool to better forecast the supply for the water companies themselves. Where a demand side policy would use metering and pricing, being flexible, a supply side policy would build or remove additional dams and reservoirs, being permanent.

Since there is a sequence in the system, from demand to supply, succeeding in understanding and eventually influencing demand is being

active. The water companies are trying to forecast the demand in order not to remain reactive, being able to plan for their own development.

For short-term management, the financial angle is certainly the most effective on households, although it has its limits. Raising the price of water helped reduce the demand in most cases. It is not the most appreciated or the most equitable approach and there are surely alternatives. Actions and influences must be evaluated in order to influence them in due time.

In the medium term, demand management would educate, raise the importance of knowledge and responsibility.

It is actually in the long term that the knowledge brought by demand management can have the most impact. Because it leads to questioning the behaviour of households, and tries to find influences, patterns, and explanation, it reduces the uncertainty the water companies face when devising future important investments.

The current knowledge in water demand management is relatively centred upon the different pricing policies available and their impacts.

2.3.2 Partial approaches

The water demand management literature in UK in particular, and in Europe in general is quite sparse. In the existing literature, two different approaches are used to deal with water demand management: a qualitative one (used in surveys or interviews), and a quantitative one mainly based on econometric studies.

2.3.2.1 Qualitative approaches

Qualitative research relies on the collection of qualitative data via techniques such as interviews, notes, or observations. These methods often produce very descriptive data, intending to describe a phenomenon in textual or spoken form.

Recent research projects (for example Water cycle in New Developments[4], or preliminary work from Lancaster University) are investigating the reasons for which people use water. Going further than how the water was used, their aim is to improve the understanding of why it was used in such a way, and is therefore addressing the issue of the perception of water by its users. In this interpretive process, the researchers use interviews with customers from a specific water company to obtain the information required.

Carefully selected customers are contacted by their water company to ask if they would be ready to discuss water use. When they accept, they are later contacted by an interviewer to agree a meeting date at their house. During the meeting, the interviewer will questions to guide the conversation, while taking notes / recording it, in order to capture and synthesise the perception and the underlying reasons for using water. This often leads to assessing what do people think is the purpose of a bath (which is often seen as a way to relax), of a shower (similarly, a fast way to get clean), sometimes even what does clean / dirty mean, or when are clothes “clean” or “dirty”.

The data accumulated is valuable and informative, but comparisons between different households are rarely possible, as they have different beliefs that cannot be measured (literally) against one another.

The qualitative approach is mainly dealt with in surveys. It is trying to link water consumption ex-post to qualitative characteristics, like the socio-cultural patterns, or income levels, but also the influence of the area, such as the urban / rural characteristics.

One can distinguish two different steps in surveys. While the first one is trying to understand the consumption structure and patterns, the second is more focused on trying to devise and evaluate policies related to water demand. In the late 80s, several studies were undertaken in the UK, for many of which the issue of metering was central. In order to evaluate its potential effects upon consumption, this consumption had to be analysed and its

[4] Cf. http://www.wand.uk.net/

drivers understood. The SODCON is a comprehensive survey launched in 1994 of domestic water consumption in the East Anglian region. Its goals were to provide notably an explanation of the factors that determine unmeasured demand, details of the patterns of water consumption, estimates of demand responses to various tariffs structures, and detailed cost of metering. The descriptive statistical analysis provided an important database of information and constituted a starting point for an analysis on a household level (Edwards (1996)).

In 1990, Tate published an in-depth review of water demand management in Canada for four water use sectors: municipal, industrial, agricultural, and non-withdrawal uses (Tate and Canada Inland Waters Directorate (1990)). Their review gives a global idea of water demand management, dealing with implementation techniques and evaluation criteria of the result.

The implementation can be achieved through different methods, such as:

1. Economic techniques: monetary incentives (rebates, tax credits...) and disincentives (higher prices, penalties, fines...) to relay to users accurate information about the value of water. Prices send signals to both consumers and producers about the economic value of the resource use.

2. Structural and operational techniques: structural techniques are those that alter existing structures to achieve better control over water demand (metering, recycling...), whereas operational techniques are actions by water users to modify existing water procedures to control demand patterns more effectively. They recommend water saving devices, and even increased prices to push towards maintenance in the household. They also evoke a dual water system, with grey water for secondary use, and then save some chemical pollution.

3. Socio-political techniques: it refers to policy and related measures that can be taken by public agencies to encourage water conservation. They mainly focus on water pricing, public education, and privatisation.

Of course, any policy has to be evaluated. Several criteria can be used for that purpose.

1. Technical evaluation: it may involve “engineering efficiency”, basically measuring the ratio water pumped into a system / water delivered to consumers or end uses, but also economic and environment factors.

2. Economic evaluation: engineering efficiency cannot address the value of any specific use of water (residential use / industrial use). Economic efficiency in resource use is for them a major economic policy aim (maximum productivity).

3. Financial evaluation: the rate of return should be greater than the cost of the capital.

4. Environmental evaluation: quality of life, decreasing wildlife populations, aesthetics, etc.

5. Social / political / institutional evaluation: according to Tate (Tate and Canada Environment (1989)) political acceptability was probably the most important criterion in the setting of water rates. Equity of the payments is also a concern. Though they have not found yet the absolute criteria, the authors argue that equity should drive demand management measures.

These ideas raise new problems about the evaluation of a policy, and although it might be easier to assess a policy purely in terms of water use, it is harder to evaluate its level of equity or environmental effects. For all that, water demand management is looked at for some given purposes. In Canada, its essential feature is the attempt to make water development funds cover as many initiatives as possible (Brooks, Peters et al. (1988)).

The recommendation of a cost-benefit analysis is of course difficult when it deals with economic and financial problems (*e.g.* the cost of improving the water-related part of municipal infrastructures). This may be due to the uncertainty on both the final cost of necessary investments (as well as the fact that they are not always paid by the same part), and the evaluation problem of the results above.

Consequently, as one can see, the pricing policy and the way to implement the appropriate measures are the main issues here. It is a more static view than mathematical modelling in that it is looking at the relations between parameters or characteristics of the participants. It is trying to build a theory, or at least make assumptions on these links, but it is most of the time unable to validate them and their eventual evolutions.

2.3.2.2 Quantitative approaches

Econometrics is the main type of quantitative model of water demand management. This consists in linking “external” data to a particular water demand (average, highest, etc.). Most of these are weather effects. Those commonly used are:

- Temperature: average daily maximum, average daily mean temp, average daily temperature 7 days before the peak 7 days, average daily temperature during the summer 6 months, highest daily temperature during the peak 7 days, average daily maximum temperature during the peak 7 days (Males, Turton et al. (1979), Herrington (1996)).

- Rainfall: total monthly rainfall, total rainfall during the peak 7 days, average monthly summer rainfall, number of days since 2 mm of rainfall or more, weighted rainfall measure 7 days before peak, weighted rainfall measure 10 days before peak

- Sunshine: average daily hours of sunshine, average daily hours of sunshine during the 7 days before peak, average daily hours of sunshine during the peak 7 days, average daily hours of sunshine during the summer 6 months (Herrington (1996))

- Other weather characteristics: frost, soil moisture deficit (Males, Turton et al. (1979), Herrington (1996))

The type of data that will be used in a model will depend on the time horizon involved (months, weeks, seasons, etc.).

The Herrington report (Herrington (1996)), investigates which climate variables seem to be more closely related to water demand, and the quantitative responsiveness of the latter to climatic changes. However the water shortages observed might have several explanations. It can be a "wrong" estimate of water consumption, not being an unrestricted demand. That is why some extreme data are removed from the study. This is not without consequences though[5]. In the UK, despite the importance of the climatic effects upon the demand, no data are available. Hence the reference to some studies and their treatment, making use of annual average data, selective or consecutive weekly consumption data under different forms, and series of peak seven days ratios. Unfortunately, the UK led studies seem to have statistical problems, from suspected multicolinearity to the inadequacy of the methods used (*e.g.* non-stationarity in Smith, Turton et al. (1978; Smith Robert, Turton et al. (1978)). Still the conclusion from every study is that sunshine seems to be the least useful variable (although it is also the least tried), whereas both rainfall and temperature are often significant.

Temperature and moisture deficit vary a lot in the studies, which is not very surprising due to their very different natures. But as for rainfall, except for some specific classification, those that can be compared show some similarities: for 21 of the 22 elasticities taken into account, they are symmetrically distributed within a range from –0.013 to –0.110, centred around –0.075 for US and –0.047 for Australia. Note that this is the same order of magnitude as the UK rainfall elasticities also quoted (-0.04 and –0.06).

[5] The removal of extreme data, as indicated later, might change the whole nature of the analysis, and reveals moreover the choice of adapting the data to the technique, or the technique to the problem.

Some other noticeable factors, on top of rainfall itself, are the number of rain days and the number of days since the last significant rainfall.

Unfortunately there are flaws in this approach which result from the forecasting limits of econometrics.

In econometrics, the explanatory value of an estimation is expressed by the “goodness of fit” function. This is because it compares the data generated with the original ones; it is *the* most important indicator for the econometric model. The issue being that there are many different goodness-of-fit testing procedures producing different results. Hence the choice of the function is difficult and certainly of high importance.

Also, amongst the multiple econometric models used by then, Mayer (1975) showed that the results of several econometric models were highly specific to the period they were computed. This issue probably arises because no behaviour or interaction itself is taken into account by an econometrics model. The lack of interactions in the long run between components of different scale is certainly an issue, as shown below.

Herrington (1996) reached the same conclusion, noting that the best estimations for the period from 1960 to 1980 “gave poor results for that part of the 1980s decade where the absence of supply restrictions allowed the exercise to take place”. The conclusion was even stronger, noting that “in general, the better the original forecasting, the worse the prediction” (p.78).

Attempting to describe the numerical relationships between key economic forces such as capital, interest rates, and labour, econometrics is not necessary appropriate for every case. Econometrics has great difficulties dealing with the issues of interest here, while a modelling approach can be successful with a Multi Agent System.

The distinction made in the literature is based on the fact that that while most of the necessary analysis of the consumer behaviour is qualitative, relying mostly on in depth interviews, when it comes to water consumption, most of the existing studies are empirical and quantitative. The extent to

which a different kind of modelling offers the possibility to overcome this cleavage between qualitative and quantitative issues is one of the purposes of this work.

These approaches are only dealing with some aspects of the problem. The current issue is not single faceted though, and that is why each of these methods can only bring a partial view of it. Hence the point to demonstrate here is that water demand management based on understanding the social influences is a viable and complementary approach.

2.3.3 Examples of water demand management

In North America, several different techniques of water demand management have been used.

The economic techniques rely solely on prices and have been presented earlier. It is working partially because water is very cheap, and immediately available, unlike other liquid beverages like cola (1500 times more expensive), milk (1900 times) and so on. Some structural changes are necessary, such as the installation of generalised metering, and leakage detectors, and improving sprinkling requirements.

Socio political techniques refer to the measures and policies taken by the regulating institutions, which are generally public agencies.

They do not represent a single answer to a problem, but a range of answers, since they can be viewed and used as an interrelationship of techniques, as described by Postel and Worldwatch (1985): “Successful efforts to curb per capita demand invariably include some combination of water saving technologies, economic incentives, regulations and consumer education. These measures are mutually reinforcing and they are more effective when implemented jointly”.

In Canada, where these techniques have been applied, the inelasticity of the fixed costs of providing water has created a strange phenomenon. While households were reducing their demand, the water companies could not reduce the corresponding bills, due to the presence of these costs. The

implementation of a dual pricing structure solved the issue, having one block pay for the fixed costs of system operation, and the second block being a constant unit commodity charge.

To some extend, many of the developed countries already have a kind of demand management policy in place. It generally is under the form of metering and the associated price scheme. This policy is adopted by some developing countries, while some like Belgium, Greece, Italy, Japan, Portugal and Switzerland are using increasing charges[6] to apply the same equity principle that the rich use more water than the poor.

2.4 Actors and purposes

The current situation for the water supply in the UK involves different actors. From the consuming households to the regulators, there is a hierarchy in the water supply process, with regulation parties and executive parties. The executive parties are the water companies providing water, while the regulative parties include the various institutions that are imposing necessary requirements.

2.4.1 The different actors in water demand management in England and Wales

In this work the word stakeholder is used as a generic term. It covers the households as well as the different institutions, including the water companies. It is necessary to specify here their nature and aims.

The Environment Agency is the central body with responsibility for long-term water resources planning in England and Wales. Part of its duty is "*to conserve, augment, redistribute and secure the proper use of water resources in England and Wales*" (Environment Agency (2001)). It involves different aspects of water, such as navigation on some rivers, flood defence, waste minimisation, and water quality. Its aims are multiple. Introduced by the water resource act in 1963, its powers and role strengthened with the water resources act in 1991. In 1995, its duties were extended under the

[6] Variable charges are often encountered as part of an increased block tariff scheme, where the volume charge per unit increases as consumption rises

Environment Act to “contribute to sustainable development and to promote the conservation and enhancement of the natural environment”, as well as to “(…) take account of costs and benefits in exercise of its functions, and to have regard to the economic and social well-being of rural communities” (Environment Agency (2000)).

It is responsible, amongst other things, for setting up drought plans, the review of water companies’ water resources plan and drought plans, and setting out the Agency’s vision for the long-term management of water resources in each region as well as globally for England and Wales.

Because of its institutional status, it has additional responsibilities, expressed through three principles (Environment Agency (2000)). The first two principles are the recognition of the need for development of new water resources as well as the value of water in the environment. The result is that increasing effort must be applied to the efficient use of water, as more resources development is required. The robustness to uncertainty and change means that it is necessary to identify a way forward that is both flexible and robust to a range of possible futures. Finally, the precautionary principle states that when there is uncertainty about the consequences of an action, decisions should be taken cautiously and the source of the uncertainty should be clarified.

The Office of Water Services (OFWAT) is the economic regulator for England and Wales. The water companies produce plans of how they intend to develop and manage their supply system. The OFWAT determines prices to customer so companies have sufficient income for the parts of the plan that are considered justified.

Water companies provide the public water supply. Each of them must develop and maintain an efficient and economical water system for water supply in its area. They “*make decisions about the way they want to manage their supply-demand balance according to the values of the company and their understanding of the needs of their customers*” (Environment Agency (2001)).

It is not unlikely that institutions and water companies themselves use scenario approaches in order to assess the impact and/or evolution of specific variations of driving components on their respective objectives. The Environment Agency has taken some scenarios from governmental studies to devise various likely environmental futures for England and Wales. It is on these likely futures that some important decisions can be taken and they therefore need to be as sound as possible.

2.4.2 Scenarios and environment

2.4.2.1 History of Scenarios

The user of scenarios for planning is quite common. Used by industries, nations, shop chains, technologies, they are a specific approach. While dealing with uncertainties, one can either consider the whole (frequently continuous) range of alternatives, or specify particular cases that would capture key properties of this range.

From their appearance in the literature in the 40s, scenarios have been more and more frequently used. Past data and previous assumed relationships were extrapolated to generate scenarios till the 80s, when the studies in innovation and diffusion showed that the future is dependent on changes in social and economic systems where paths are multiple, and indeed not fixed, but evolving themselves. The goal of scenarios then became the analysis of some trends within a “possibility space”, and eventually the reduction of that space finding potential discontinuities in order to improve the decision making process.

The first example of the use of scenarios for forecasting purposes is from Shell in the 1970s. A major international company mainly focused on petrochemicals, they needed guidelines in order to constrain the uncertainties, and therefore plan in accordance to a specific evolution of the world.

They needed a view that could be used specifically, although being devised on a more global point of view. They started developing scenarios that would present a consistent situation regarding sustainability and emissions. Scenarios were then “*carefully crafted stories about the future*

embodying a wide variety of ideas and integrating them in a way that is communicable and useful"[7].

Not dissimilar to game theory, a scenario approach consists in weighting the eventualities, providing more than a mono-disciplinary insight, to achieve a synthetic, plausible description of a future.

Scenarios take into account a wide range of phenomena and ideas. Due to the number of aspects included, the analysis undertaken is hence different to game theory, which is composed of an in-depth analysis of an often simple problem.

The process of devising scenarios has a focus point on the moment the uncertainty is defined, and different paths can be identified. These paths, or branching points, will constitute the basis of the scenarios. In the case of Shell, the selection of the paths investigated was made "*on the basis that they help […] to examine the risks and opportunities for policies and strategies*" (Shell (2003)).

Based on a sensible definition, scenarios would provide the description of a plausible situation and be the ground of a discussion regarding the policies, actions, reflections and commitments that it raises.

As expressed by Ged Davis, "*scenarios are particularly useful in situations where there is a desire to put challenges on the agenda proactively (for example when there are leadership changes and major impending decisions) and where changes in the global business environment are recognised but not well understood (such as major political changes and new emerging technologies)*" (Davis (2002)).

The benefits of scenarios are even more visible when one begins to imagine the many aspects of a problem involving natural resources, and society. As expressed earlier, the interconnections between the components of the system studied can lead to increasing difficulty, should one try to take

[7] Cf www.shell.com/scenarios

into account the many influences upon what would become the structural of one's representation.

Scenarios can be refined and tuned with respect to their purpose.

It is the case for climate change and social behaviour through time. Scenarios are used because the future is uncertain, and the ability to adapt to these future changes might have effects upon the longer term (*e.g.* technological changes).

2.4.2.2 Scenarios for the Environment

Scenarios have already been used for climate change issues. For example the ECLAT international project[8] is focusing on the environmental impacts of climate change and climate change modelling. Artificially created scenarios integrate uncertainties at different levels: the theories they are using (*e.g.* marketing or sociological), the data (through collection and treatment), the assumptions that are made in order to generate the scenarios, and consequently, the scenario itself, that puts these components together, and for which some options are chosen while others are discarded.

[8] This Concerted Action Initiative has two specific objectives: to improve the understanding and application of results from climate model experiments, and to monitor the availability of results from new climate change experiments performed in Europe and worldwide. For more information see http://www.cru.uea.ac.uk/eclat/

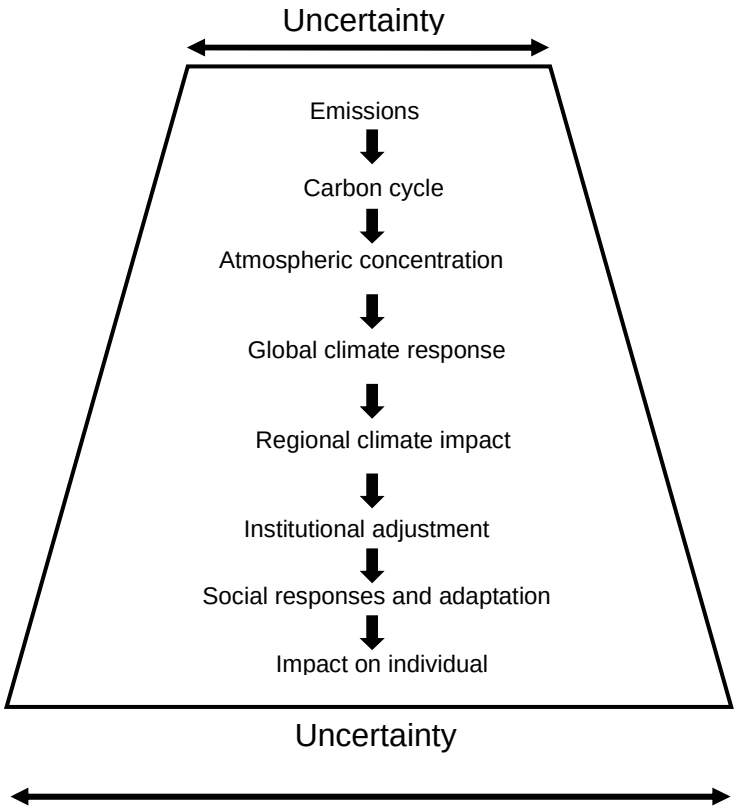

Figure 1: Addition of uncertain phenomenon

This diagram from the CCDEW report by Downing, Butterfield et al. (2003) shows the increasing uncertainty as the different components are integrated into a model.

Multiple scenario frameworks are built on the Environmental Futures scenarios from the UK Foresight programme (Berkhout and Hertin (2002),Berkhout, Eames et al. (1998), Department of Trade and Industry (1999)). This programme tries to look beyond normal commercial horizons to identify potential opportunities from new science and technologies.

The Foresight Future scenarios have been created for the UK Foresights programme, and the project was funded by the Department of Trade and Industry, as well as the Department of Environment, Transport and the Regions. The research was led by the Science and Technology Research Policy for the UK Foresight Programme (SPRU) from the University of

Sussex. These scenarios represent a tool for forecasting, enabling institutions, businesses, and more generally users, to apprehend possible futures in order to improve their decision making.

Generated via an iterative participatory process, the scenario framework also draws on pre-existing work such as the scenarios developed by the Intergovernmental Panel on Climate Change (2000) that is trying to estimate future greenhouse gas emissions (Zinyowera, Watson et al. (1996)).

The UK Climate Impacts Programme (UKCIP[9]) scenarios use computer estimations of climate change, and are attempting to assess their impact upon the UK's socio-economic structure (UKCIP (2000)). They differ from the Foresight scenarios by being specifically designed for the timescale of the associated climate scenario provided, and by providing details likely to be of use for regional and sectoral studies. For example, they give greater emphasis to the possible changes to regions and to certain types of geographical domain. Classified according to governance system and social values, their denomination is equivalent to the Foresight scenarios apart from the Provincial Enterprise, renamed National Enterprise. Every scenario describes a plausible future, and the shape of water demand, agricultural trends, future transport, and economic development.

The scenarios presented by the Environment Agency are based upon the UKCIP scenarios, themselves based on the Foresight scenarios. The Foresight scenarios were devised taking into account various sectors of the economy. The UKCIP focused on the climate change impact, and the EA focused further on water resources.

[9] The UK Climate Impacts Programme (UKCIP) provides scenarios that show how climate might change and co-ordinates research on dealing with our future climate. It provides free information to organisations in the commercial and public sectors to help them prepare for the impacts of climate change.

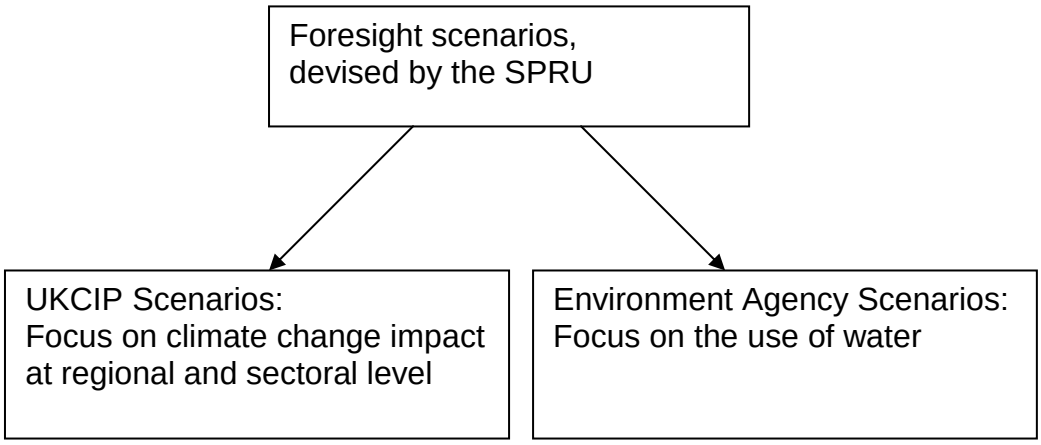

Figure 2: Origin of scenarios

Four distinct Foresight scenarios were retained as archetypical cases. They are classified according to a couple of main indicators or drivers of change: the social values of the individuals and the governance structure in place.

Social values go from individualistic to more community oriented, while the system of governance, dealing with the structures of the government and the decision making process go from autonomy (power remaining to national level) to interdependence (power moves to institutions, *e.g.* from the EU to regional government).

Values	Individual	Community
Governance		
Interdependence / Globalisation	World Markets (B)	Global Sustainability (C)
Autonomy / Regionalisation	Provincial Enterprise (A)	Local Stewardship (D)

Table 1: The four scenarios

The scenarios have specific general characteristics, presenting the general trends, and more details regarding economic and sectoral trends,

employment and social trends, regional development, health, welfare and education, and the environment.

The Department of Trade and Industry, which originated the Foresight scenarios, characterises them as follow. Each is described in terms of a short qualitative description which is supposed to be indicative of that scenario.

World Markets

This is characterised by individualism and globalisation.

In this scenario, people aspire to personal interdependence, material wealth and mobility to the exclusion of wider social goals. Integrated global markets are presumed to be the best way to deliver this. Internationally co-ordinated policy sets framework conditions for the efficient functioning of markets. The provision of goods and services is privatised wherever possible under a principle a ‘minimal government’. Rights of individuals to personal freedoms are enshrined in law.

Provincial Enterprise (National Enterprise for the UKCIP framework)

This is characterised by individualism and regionalisation.

In this scenario, people aspire to personal independence and material wealth within a nationally rooted cultural identity. Liberalised markets together with a commitment to build capabilities and resources to secure a high degree of national self-reliance and security are believed to best deliver these goals. Political and cultural institutions are strengthened to buttress national autonomy in a more fragmented world.

Global responsibility

This is characterised by community and globalisation.

In this scenario, people aspire to high levels of welfare within communities with shared values, more equally distributed opportunities and a sound environment. There is a belief that these objectives are best achieved

through active public policies and international co-operation within the European Union and at a global level. Social objectives are met through public provision, increasingly at an international level. Markets are regulated to encourage competition amongst national players. Personal and social behaviour is shaped by commonly held beliefs and customs.

Local Stewardship

This is characterised by community and regionalisation.

In this scenario, people aspire to sustainable levels of welfare in federal and networked communities. Markets are subject to social regulations to ensure more equally distributed opportunities and a high quality local environment. Active public policy aims to promote economic activities that are small scale and regional in scope, and acts to constrain large-scale markets and technologies. Local communities are strengthened to ensure participative and transparent governance in a complex world.

Every scenario is based on different assumptions, and this results in different numerical indicators such as the UK GDP growth (Department of Trade and Industry (1999)). From these indicators and the assumptions behind them, the Environment Agency has provided a detailed description of the scenarios in terms of economic and social situations as well as the more direct drivers. These are presented in the tables below.

Scenario	Drivers		
	Social values	Governance structures	Role of policy
World Markets	internationalist libertarian	weak, dispersed, consultative	minimal, enabling markets
National enterprise	nationalist, individualist	weak, national, closed	state centred, market regulations to protect key sectors
Global responsibility	internationalist, communitarian	strong, coordinated, consultative	corporatist, political, social and environmental goals
Local Stewardship	localist, cooperative	strong, local, participative	interventionist, social and environmental

Table 2: Global view of UKCIP scenarios' drivers

Scenario	Economic trends			
	Economic development	Structural change	Fast growing sectors	Declining sectors
World Markets	high growth, high innovation, capital productivity	rapid, towards services	Health and leisure, media and information, financial services, biotechnology, nanotechnology	manufacturing, agriculture
National enterprise	medium-low growth, low innovation, maintenance economy	more stable economic structure	private health and education, domestic and personal services, tourism, retailing, defence	public services, civil engineering
Global responsibility	medium-high growth, high innovation, resource productivity	fast, towards services	education and training, large systems engineering, new and renewable energy, information services	fossil fuel energy, traditional manufacturing
Local Stewardship	low growth, low innovation, modular and sustainable	moderate towards regional systems	small scale manufacturing, food and organics farming, local services	retailing, tourism, financial services

Table 3: UKCIP scenarios and underlying economic trends

Scenario	Social trends			
	Unemployment	Income	Equity	Areas of conflict
World Markets	medium-low	high	strong decline	social exclusion, immigration / emigration, political accountability
National enterprise	medium-high	medium low	decline	unemployment, poor public services, inequality
Global responsibility	Low	medium-high	Improvement	structural change, change of skills, political accountability, institutional rigidity
Local Stewardship	medium-low (larger voluntary sector)	low	strong improvement	land use, under investment, environmental restrictions

Table 4: UKCIP scenarios and underlying social trends

Assumptions upon the events happening in each scenario are inferred from the global drivers and trends. These assumptions refer to the formal parameters that permit to distinguish between scenarios. Referring to this more formal level, the scenarios vary depending on:

- Market penetration of devices (rhythm of diffusion)

- Ownership and volumes (frequency generally supposed stable)

- Absence or presence of future saving technologies regulations

- Proportion of metered households

The effects of the latter are still not clear. Studies are in progress to provide a robust answer, but are still unavailable at the present time. This is developed further in section 4.2.4.

The Environment Agency has used the Foresight scenarios as a starting point to develop specific water demand scenarios. As they are not officially part of the foresight scenarios, they changed their names into

Provincial Enterprise	A
World Markets	B
Global Sustainability	C
Local Stewardship	D

Building a scenario requires the preliminary analysis of the system or phenomenon, its drivers and the relationships between its components. In the case of water demand management, assuming particular (maybe extreme) measures or policies, they could result, when combined, in a socio-economic environment that was not previously considered. As a consequence of this possibility, specific and original paths can be devised, hence expanding the range of possible outcomes. Considering this multiplicity, the strategy devised or considered after studying these outcomes, even if not directly involved in the main question, could become if not more robust, possibly more thought out.

It is important to know how correct these scenarios are. As a basis for decision making, and often the reason for policy choices, they should be as sound as possible. It is difficult to have the knowledge of what the future will be, and hence to recognise for sure the evolution of a society. Since it is not possible to validate a prediction till the moment in time it is supposed to happen, it is not possible to validate a scenario describing what a future socio-economic situation will be. Qualifying a society and its water use is subject to debate even ex-post, when statistics and observations are available. Without an ex-ante validation of a scenario for the future, the other reasonable way is to assess the method with which the scenario is produced.

Therefore, a reflection must be engaged during the scenario creation that will evolve during its process. The Environment Agency is aware of the

potential and limitations from these scenarios, as demonstrated by the reasons for their development.

2.4.2.3 The history of Environment Agency scenarios

The scenarios used in this research have been developed by UK Foresight, and then tailored by the Environment Agency. This is in order to represent how general tendencies regarding social values and governance could be reflected in overall principles of daily behaviour for households, and consequently their characteristics.

To assess the reasons why the Agency has used scenarios and what their expectations were, it was necessary to ask them directly This would also be an opportunity to discuss what future scenarios forecasting might have, as well as the evolution in their methods.

To answer these questions, a meeting was organised with Rob Westcott, Policy and Process Advisor for Water Demand Management, who took part in the previous forecast project, as well as the writing of the reference publication, “Water Demand Forecasting, a Scenario Approach for England and Wales”.

They developed scenarios in order to obtain consistent sets of assumptions, and observe their interactions in the long run.

The Environment Agency “*consciously developed scenarios of possible futures, as the Foresight programme intended its framework scenarios to be used, to help policy makers think about changes not only in the obvious sectoral drivers but also how perceived "givens" (governance and society) might change over the long term. Basically our scenarios are possible future outcomes. The way in which we evolve to get there was not our primary objective. For us "what could ultimately happen" was the key question to be addressed. Then we wanted to explore "what can we do about it?” That is, what needs to be done and by whom to ensure sustainable (read that as our "desired") outcomes might be achieved. Where possible these became specific actions required in order to deliver our strategy.*”

The expectations from scenarios were "*not predictions as such. We know that any one of the four scenarios will not be universally applicable to the […] situation [in England and Wales]. The future will include elements from all of the scenarios with a net effect somewhere within the envelope we suggested.*"

An important use of scenarios is the fact that they are flexible both in size and timescale. The Environment Agency had the desire to select the best approach for their purposes, and hence decided to improve upon their previous work on forecasts since "*previous forecasts we had developed/were developed by water companies were not suitable. The National Rivers Authority (NRA) forecasts were limited by generalised assumptions that were little more than sensitivity testing of key parameters (metering, leakage, demand growth) and climate change. The water company forecasts could not be compiled on any reliably consistent basis (assumptions varied, were not transparent, reflected company policies/business aspirations, and commonly influenced by revenue forecast aspirations). Also some issues over data protection and confidentiality limited explicit use of their forecasts.*"

The Environment Agency wanted to use assumptions consistently reflecting regional/local variations where possible. The objective was "*to access all water uses not just public water supply, thus the issue of scale and representativeness raised its head early on. We wanted explicitly to explore impacts of metering, changing occupancy, innovation and changes in appliance use, behavioural aspects, changes by sector in water consumed by non-households, potential leakage levels, and opportunities for efficiency across these sectors*".

The set of Foresight scenarios "*gave […] a framework from which to build a set of alternative futures. But to reflect the impact of some of the drivers in the scenarios it was clear that the level of disaggregation of demand components had to be extensive. This meant micro-component for households, sectoral characterisation for non-household, spray irrigation defined by crop and alternative methods of leakage control*".

To generate these scenarios, they tried to make an example of best practice, and incorporated the latest tendencies and tools in their assumptions, according to practical limitations.

The methods and techniques were limited by data and ability to define assumptions at a reliable scale (anything other than global).

This "*resulted in some components not taken into account for every effect they might have. For example, climate change was not considered internally within the household forecasts but the spray irrigation forecasts were able to test the effects.*"

But for the Environment Agency, scenarios are simply a means to achieve their aim.

"*The Environment Agency needs to secure the proper use of water resources. A long-term (+25 year) view is necessary due to the nature of water resources planning and time to implement resource options. In order to promote sustainable solutions our strategies need to consider all significant demands on the water environment and how these may change. Operating at a macro-scale, Agency planning benefits from the use of scenarios to test implications of changes to key demand drivers and also assumptions about their future significance. Their limitation is that they can only generalise and do not easily translate to the local level.*"

2.5 Conclusion

This chapter introduces the concept of water demand management and describes the institutions involved and the origin of the scenarios they use for their forecast.

Section 2.2 presented water management. It defined management as equivalent to water conservation, or "any beneficial reduction in water use or in water losses". It explained that for developed countries supply is not the only aspect of water that can be influenced. Amongst other reasons, the concern of climate change and the decreasing relative availability of natural resources have resulted in a recent focus on water demand.

Section 2.3 distinguished the soft approach of water demand management from the hard approach of water supply management. While the former focuses on behaviours and uses, and remains immaterial, the latter consists of supplying more resources via new structures such as dams or reservoirs. The section also describes exclusively qualitative and exclusively quantitative approaches that can be used to address water demand, and provides examples where they have been used.

Section 2.4 presented the regulators involved in the management of water resources. It explains that as a regulator, the Environment Agency must set out its vision for the long-term management of water resources in each region as well as globally for England and Wales. Uncertainty regarding the future must be taken into account when forecasting. In order to achieve this, the Agency has defined four scenarios characterised according to social values and governance structure, and where the driving components of the water demand are: the environment, the interactions within agents, and the diffusion of new devices.

It is necessary to put the consistency of the scenarios the Environment Agency has generated to the test. Some traditional well-known and well-developed tools are available. Unfortunately, as it will be shown in the next chapter, they focus on one aspect of the problem only. It is here necessary to represent multiple facets of the issue and a review of the existing methods shows that Multi Agent Systems could provide a more appropriate and more exhaustive tool for such an analysis.