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Tackling Obesities: Future Choices – Building the Obesity System Map

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Tackling Obesities: Future Choices – Building the Obesity System Map

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Contents

1 Introduction

This document reports the findings of the qualitative systems mapping exercise undertaken for the Foresight Obesity Project, 'Tackling Obesities: Future Choices'. It is intended for those who wish to explore the detailed methodology and results of this work.

The aim of the Foresight Tackling Obesities project was to 'produce a long term vision of how we can deliver a sustainable response to obesity in the UK over the next 40 years'.

In the **systems mapping work**, a qualitative, causal loop model has been developed in order:

- To help understand the complex systemic structure of obesity;
- To contribute to developing a tool that helps policy makers in the generation, definition and testing of possible policy options to respond to obesity.

After this brief introduction, **Section 2** of this report introduces the notion of the 'causal loop diagram' (or 'system map') and the general methodology employed to develop this kind of qualitative model. It also explains how the system map used in this project has been embedded in a framework of future scenarios to provide a conceptual platform for policy development.

Section 3 documents and describes the key features of the system map, and its many submaps (collectively making up an 'atlas' of the obesity system) – including those arising from embedding the map in the future scenarios.

Section 4 presents general conclusions from this qualitative modelling work.

The report is accompanied by two sets of **Appendices**. Appendix A (Tackling Obesities: Future Choices – Obesity System Atlas) brings together all the visual representations of the system map and its submaps. It also includes a glossary with a working definition of the component variables most model. Appendix B provides an overview of the process deployed to build the map during a series of interactive workshops, interspersed with focused modelling work by the contractor team (WS, Brussels).

2 Mapping the obesity system with a causal loop model

2.1 Mapping the obesity system

'*Never confuse a model with the complex reality underneath*'

Luc Hoebeke, *Making Work Systems Better, 1994*

A 'system' is one of the defining concepts in our Western, positivist worldview. It has been applied to establish an intellectual grip on natural, social, physical and abstract phenomena. Developing an understanding of how such phenomena are organised is essential if policy interventions are to be effective.

The notion of a 'system' is in itself open to a variety of interpretations. However, a general definition will serve our purpose. A system can be considered to be 'a structured set of objects and/or attributes together with the relationships between them'. The constitutive elements of a system are, therefore, its elements, the relationships between these elements, and the system boundary that distinguishes between what does and does not belong to the set. Systems mapping" is a loosely used term to denote the activity of conceptually representing a system.

The system under study in the present project is the 'obesity system'. Obesity is an attribute of a human being. For a given individual, obesity is associated with being over a normal body weight for their gender, age, height and build. A person is considered to be obese when their weight is 20% above its maximum desirable weight. A simpler measure that is helpful at the population level defines being obese as having a body mass index (BMI) over 30 kg/m^2 (see Tackling Obesities: Future Choices – International Comparisons of Obesity Trends, Determinants and Responses. Evidence Review for a fuller discussion of measures of obesity[2]).

Obesity is an important cause of a range of serious chronic illnesses such as diabetes and cardio-vascular diseases. The impact of these conditions is not limited to the individual. In a society that provides its citizens with an infrastructure for health care and social security, an increase in the incidence of ill health will increase pressure on the healthcare system and other state resources which support these services.

The key assumption underlying this qualitative mapping exercise is that obesity is the result of the interplay between a wide variety of factors, deriving, for example, from a person's physical make-up, eating behaviour and physical activity pattern. **The obesity system, therefore, is pragmatically defined here as the sum of all the relevant factors and their interdependencies that determine the condition of obesity for an individual or a group of people.**

A number of terms in our definition of the obesity system are in need of further explanation:

- What has been called a '**factor**' is an attribute (characteristic) of a person or their environment that has an influence on that person's level of obesity. 'Factors' are often referred to as '**variables**'. In this report these terms are used synonymously. The term 'variable' suggests that the corresponding attribute is measured against a qualitative (ordinal) or quantitative scale and can vary over that scale. Some of the factors are fairly straightforward to describe in measurable quantities (for example 'energy density' of food), whilst others are psychological, cultural or environmental attributes that are more difficult to quantify (for example, 'walkability of living environment', referring to a physical environment's suitability for movement on foot). As many of our variables are not readily quantifiable, we do not attempt to use the model to draw quantitatively-based conclusions, rather we consider overall trends and direction.
- '**Relevance**' is a pragmatic criterion for deciding which factors belong to the system:
  - In this project, relevance was chiefly determined by judgments of academic experts. The particular representation of the obesity system that has been developed constitutes our best understanding of the system within the given constraints of time and other resources in the project.
  - In addition, judgments with respect to relevance have been dictated by the geographical limitation of the project's terms of reference to the UK. The model therefore represents a UK perspective on the obesity system.
  - Also, the model has been developed as policy-neutral. That means that (existing or anticipated) policy measures to address obesity have not been included as variables in the system map to avoid limiting its scope for policy development.
  - Finally, the implications of obesity for health and health care have not been included in the map.
- The **interdependencies** that the definition refers to are of a causal nature. In other words, the obesity system is a set of relevant, causally linked variables that determine the condition of obesity. So, any link between variables a and b in the system needs to be interpreted as 'the level of a is causally linked to the level of b.' A distinction will be made between positive and negative linkages.
- The obesity system can be scaled at various **levels of aggregation** (individual, group, society), depending upon the level of aggregation of the constitutive variables. One can think of an obesity system operating 'around' an individual or a group of people. In the latter case, the variables represent average values for a given group.

2.2 Causal loop models

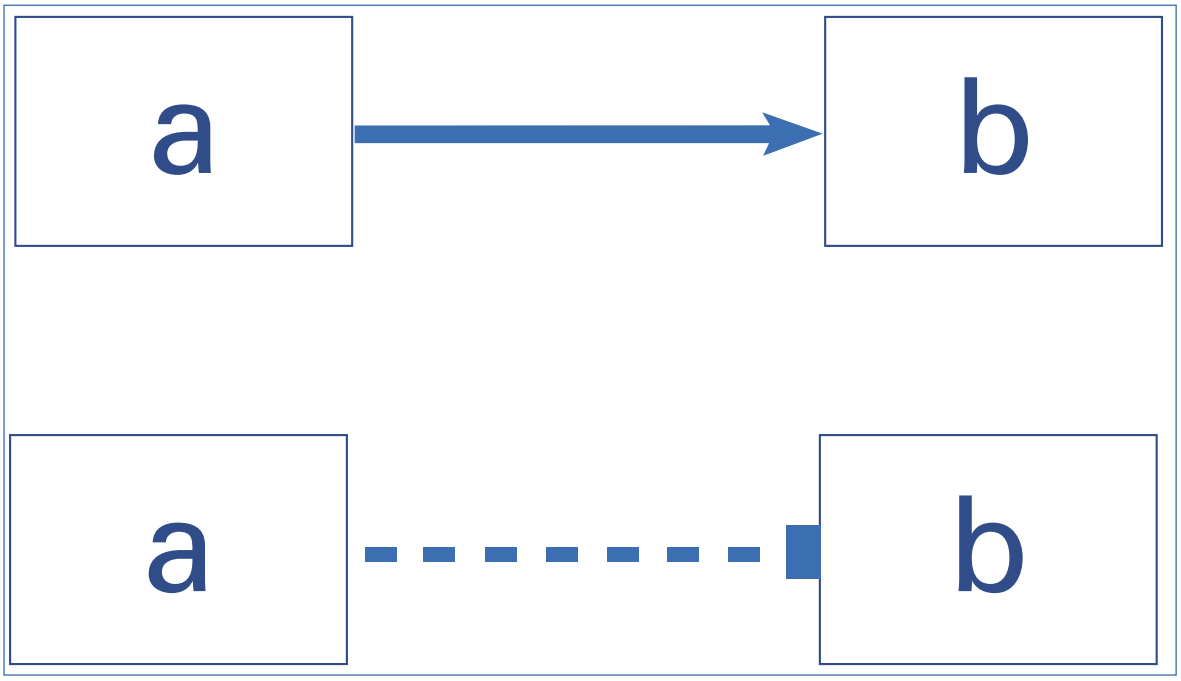
The obesity system, as defined above, has been visualised in a particular format: a causal loop model (or diagram).[3] In the remainder of this report, this causal loop model will very often be referred to as 'the system map'.

2.2.1 Variables and linkages

In a causal loop model, the system's elements (factors, variables) are represented by boxes, and the causal relationships between two variables are represented by arrows. The variable at the tail of the arrow has a causal effect on the variable at the point.

In addition, a distinction can be made between positive and negative causal relationships. A positive causal relationship implies that both variables will change in the same direction: if variable, 'a' (at the tail) increases, then also variable 'b' (at the point) will increase (and if 'a' decreases, then 'b' decreases). A negative relationship, on the other hand, implies that variables change in opposite directions (if 'a' increases 'b' will decrease and if 'a' decreases 'b' will increase). Figure 1 shows how this is visualised in a causal loop model:

Figure 1: Positive (above) and negative causal relationship (below) as visualised in a causal loop diagram



Causal linkages can be further differentiated by their strength and by the time delays to which they are subject. Strong linkages imply that even small changes in the tail variable will have impact on the level of the dependent variable. Weak linkages do not propagate these small changes as effectively. Causalities can also vary in the lengths of delays which occur before their effects are apparent. Time delays lags could not be incorporated directly into the obesity system map. However, they certainly have a bearing on the system and would need to be incorporated into any further editions of the map.

When building and working with causal loop models (system maps), a few caveats are in order:

- The **sign of the relationship** – positive or negative – is dependent on the particular conceptualisation of the variables. For example, a positive relationship can be surmised between 'social rejection of smoking' and 'smoking cessation'. However, this relationship will reverse sign when the tail variable is rephrased as 'social tolerance for smoking'. Whether a variable is phrased in a positive or a negative way is dictated by what the modeller thinks is most intuitively understandable.
- **Variables** are considered to vary over a scale. So variable names need to be selected in such a way that they can take on high and low values. Hence the presence of many variables prefaced with 'level of …', 'number of …', 'degree of …', 'importance of …'.
- The arrows between the variables represent causal **linkages**. These should not be mistaken for other kinds of linkages that are sometimes present in 'box and arrow' diagrams. Particularly given the biological nature of some subsystems in the obesity system, these connections could be mistakenly seen as mass, energy or information (signal) flows.
- The previous point implies that causal loop models **differ** in nature **from so-called 'system dynamics' models** (or 'stock and flow' models). The latter are built around material and information flows. The variables in a system dynamics model denote levels or stocks at a specific point in time (for example, a person's 'energy surplus' at time t). This important difference has implications for the way in which these two types of models are built and used (see section 2.4).

2.2.2 Feedback loops

The causalities discussed so far are linear causalities (from a' to 'b'). Circular causalities (e.g. from 'a' to 'b' to 'a') in systems maps are called **feedback loops**. They are an important feature of causal loop models because they help to explain the dynamic behaviour of the system.

There are two kinds of feedback loops: reinforcing (or positive) and balancing (or negative) loops. Reinforcing loops encapsulate exponential growth whilst balancing loops push the system towards an equilibrium value:

- An **example of a reinforcing loop** from the obesity system map is the following: if the 'demand for convenience' by consumers increases, the 'convenience of food offerings' from food manufacturers is likely to increase in response. If consumers then become habituated to these convenient products, their cooking skills are likely to diminish. Hence, an increase in the 'convenience of food offerings' triggers 'de-skilling' of people. And this, in turn, can be expected to increase the demand for convenience. And so on, until compromises on taste or price will flatten the dynamic.
- A **balancing loop** is at the very core of the obesity system: when human beings' 'level of available energy' decreases, they experience a 'physical need for energy'. The stronger that need is, the more effort will be invested in 'acquiring new sources of energy' or to 'preserving the energy' that is already available. This, in turn, will lead to a higher level of available energy, which will finally dampen the physical need for energy. By this means, the system remains in equilibrium. The primary purpose of this exercise is to understand how the broad range of variables influences energy balance, leading to it becoming imbalanced.

2.2.3 Causal loop versus system dynamics models

Working with causal loop models requires the user to adapt to their particular logic. A causal loop model is sometimes considered a naïve precursor to a genuine system dynamics model. However, this need not necessarily be the case. A causal loop model is an intellectual device that has a specific field of application within which it exhibits both weak and strong points.

The key purpose of building a causal loop model is to gain insight in the underlying structure of a messy, complex situation. A system map shows how 'variables interrelate' and where there are opportunities to intervene in the modelled system to influence its behaviour. A secondary objective could be to impart that insight to a wider audience. System maps are arguably one of the most effective tools with which to visualise complexity. In short, the essential contribution of a causal loop model is to summarise and communicate current trends, relationships and constraints that may influence the future behaviour of a system.

However, a causal loop model is not a predictive model. It does not allow future levels of system variables (and, hence, prediction of the level of obesity at a given point in the future) to be foreseen. System dynamics (or stock-and-flow) models are, however, predictive in nature. But their logic is different. The constituent elements of such a model are 'stocks' and 'flows' (or 'levels' and 'rates'). Changes in systems occur when levels in the stocks create changes in the flows, which

then change the stocks, and so on. The difference between the two types of models can be captured in the one liner: 'causal loop models are about levers, system dynamics models are about levels.'

The logic in a system dynamics model is more rigorous than in a causal loop model as it concerns flows of mass, energy and information. However the system dynamics model has less transparency and communicative power.

The two kinds of model also differ with regard to temporal factors. Time is explicit in a system dynamics model where the focus is on time-dependent modelling of a system. In a causal loop diagram, time is only implicitly present as causal effects are manifested. It is therefore not possible to do rigorous assessments on the state of a system using a causal loop diagram at a given point in time. Nevertheless, it is possible to visualise the effect of time by constructing maps at various future time horizons in a scenario (for example, 2010 - 2025 - 2050).

The same logic applies to visualising other categorical variables, such as 'gender' or 'socioeconomic class'. A causal loop model can visualise these variables by drawing different maps for different levels of these variables (e.g. separate maps for 'male' and 'female'). In a stock- and-flow model, these variables (or a quantitative proxy) could be integrated in the model itself.

2.3 Building a causal loop model

The process used to develop the obesity system map is fully described in section 3 of this report. In this section some general guidelines for building a causal loop model are presented.

2.3.1 Identifying a central 'engine'

The general approach is one of building from a core towards a periphery. At the beginning of the modelling process, a central 'engine' is defined. This is a single loop or a limited set of interconnected loops that captures the essential dynamic of the issue under study.[4] Once that engine is in place, it provides a basis for anchoring the remainder of the system map.

In practice it is not always easy to define the central engine. It is helpful to focus thinking at this very early stage of modelling by reflecting on the 'nodal variable'. The nodal variable is in effect a very pragmatic construct. It is the variable we basically want to understand. As such it is the anchoring point around which the central engine, and later the whole system map, will revolve.

In a complex system such as the obesity system, there may be several candidate nodal variables. The selection of a nodal variable can be based on:

- **scientific relevance:** to what extent does it cohere with observable facts?
- **decision-making relevance:** to what extent does it reflect relevant 'key performance indicators' which govern decision-making?
- **heuristic power:** to what extent does it help us make sense of the complexity?

In the obesity system, the nodal variable identified was, predictably, 'energy balance', i.e. the difference between energy input and output of a (group of) human being(s) (see Section 3.1). This nodal variable was subsequently translated into a set of three interconnected causal loops: the central engine (see Section 3.2).

2.3.2 Expanding the model

Once the central engine is in place, the model can be expanded to include all the relevant variables. Expansion of the model is an iterative process of compiling a database of model variables, prioritising them, integrating them in the model, validating the linkages and finally completing the variable database. Depending upon the complexity of the model, it is not unusual to cycle several times through these activities. Appendix B explains how this process of expanding occurs in practice. Once the model has found its approximate final shape, some fine tuning of the structure and visualisation of the model usually needs to be done. In a final phase, the model is documented for further use.

2.4 Using causal loop models

2.4.1 Generic purposes

- A causal loop model is a device to describe the systemic structure of a complex problem. As such it serves three very general purposes:
- **to make sense of complexity**: individuals who have been deeply involved in the construction or study of a causal loop model will appreciate its considerable heuristic power. In particular, once the top-level architecture of a model (rather than its fine detail) has been thoroughly absorbed, it becomes a powerful filter for identifying relevant variables and an aid to thinking about the issue.
- **to communicate complexity**: the anatomy of a system map – particularly with a fairly large number of variables and many causal linkages between them – is a clear confirmation of the inescapably systemic and messy nature of the issue under study. This approach highlights the need for broad and diversified policies or strategies to change the dynamics of the system.
- **to support the development of a strategy to intervene in a complex system**: careful study of a causal loop model will reveal features that help in deciding where to intervene most effectively in the system. These features are: leverage points, feedback loops and causal cascades. They will be discussed more fully in the following section.

2.4.2 System maps for decision making

2.4.2.1 Leverage points

Decision-makers need to focus on a system's leverage points if they are to effect change. Leverage points are variables in a system map that have an important effect on the system's behaviour. They can be recognised as 'hubs', where many arrows are leaving from and coming into different variables. Leverage points pick up changes from many variables and transfer these on to other parts of the system (first to those variables linked directly to the hub, and then further afield). Particularly important are those leverage points that are directly connected to the system map's central engine. These are called key variables. They will be sensitive conduits of change to the system's basic dynamic architecture. In the obesity model, four variables have been identified as **key variables**:

- the level of psychological ambivalence experienced by UK citizens in deciding lifestyle choices (food, exercise)
- the force of dietary habits preventing UK citizens from adopting healthier alternatives
- the level of physical activity UK citizens engage in
- the level of primary appetite control in the brain.

As such these four variables impose themselves as crucial elements of any obesity policy portfolio. It is perhaps noteworthy that there are four key variables rather than just two (eating and exercise) and that the key food variable focuses on habits rather than actual intake.

2.4.2.2 Feedback loops

Feedback loops are a defining feature of causal loop diagrams as they determine the dynamics of the system (see Section 2.2). Focusing, for example, on undesirable positive feedback loops may suggest useful options for policy by evaluating where balancing loops can be imposed or where linkages in reinforcing loops can be broken. Similarly, inflexible situations which are in equilibrium (lock-ins) could be countered by removing bottlenecks and restrictions in resources or by stimulating new reinforcing loops to undermine the status quo.[5]

In this study, the feedback structure of the obesity system map's central engine provides a useful basis for assessing opportunities for systemic diagnosis and intervention (see Sections 3.2 and 3.5–3.8).

2.4.2.3 Testing policy options

Studying feedback loops and leverage points in system maps can be a fertile basis for developing policy options. However, maps can also be used to study how a

given policy option might affect the system. First, an inventory is made of the variables in the system map that are apparently affected by the policy measure. Secondly, verification of how these measures causally propagate through the model and how they affect the feedback loops driving the system. By mapping out these causal cascades, it is often also possible to verify whether a given measure may at some point result in unintended consequences in another part of the system (see Section 3.9 for mapping a series of policy measures).

2.4.2.4 System maps and scenarios

As will be explained more fully in section 2.4.3 below, a system map can be embedded in a future scenario framework to test how the system would be affected by different sets of possible future conditions. This can provide insight into the options for policy-making in these different future worlds.

2.4.2.5 Segmenting maps

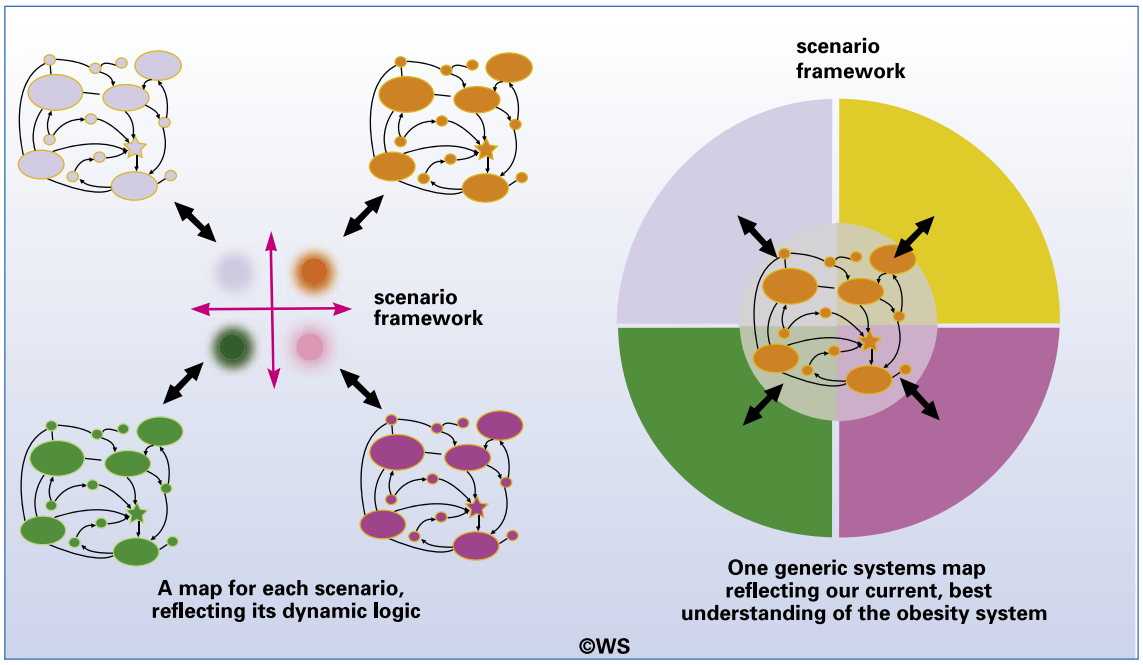
As we have seen, the analytic power of a causal loop model can be enhanced by segmenting the generic system map in a range of relevant submaps to account for specificities of relevant societal groups (segmented for example by gender, socio-economic group, life stage, ethnicity). The segmented maps reveal the relative weight of variables and causal relationships for specific groups. For example, a submap of the obesity system that is applicable specifically to children could be constructed. Arguably, in this map a variable such as 'level of de-skilling' would be less influential compared to adults (as children usually have limited food skills in any case), while 'children's control of diet' might assume a relatively greater weight. Accordingly, focused submaps can facilitate the development of a subgroup-sensitive set of policy portfolio (see Section 3.10 for an example).

2.4.3 System maps and scenarios

As part of the Foresight project a tool for policy development has been developed by joining a future scenario framework with a causal loop model. There are basically two ways to join a causal loop model with a scenario framework (see Figure 2):

- System maps can be used to make explicit the dynamics underlying the various scenarios in a set. In that case, each scenario is supported by a different system map.
- A generic system map can be embedded in a scenario framework. Here, the scenarios function as a set of different boundary conditions that are imposed on the generic map. The map can then be used to investigate policy options within the varying boundary conditions. This is the approach that is adopted in the present study.

Figure 2: Two ways to combine systems and scenarios

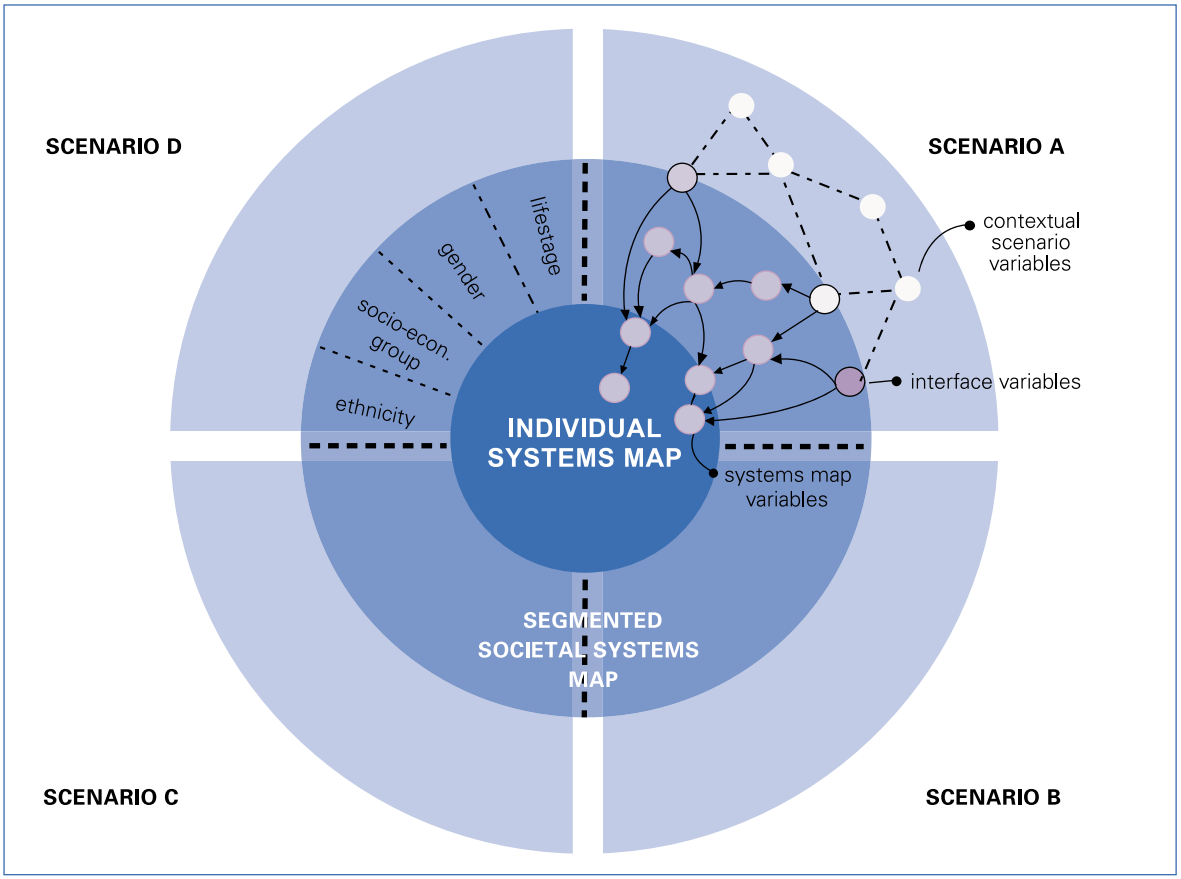


The integration of the generic system map with the scenarios needs to be undertaken very carefully. The basic approach that has been adopted in this exercise is to situate the scenarios and the system map at different levels of granularity:

- The scenarios need to remain contextual; they describe macroscopic, structurally different environments. Typically, the drivers for change underlying the scenarios may seem to be far removed from the daily experiences of most UK citizens. However this does not mean that they do not shape their lives in different ways.
- The system map reflects causal interdependencies between variables in the meso- and micro-obesogenic environment.

The system map and the scenarios connect via 'interface variables' (see figure 3). These are variables that are common to both the system model and in the scenario structure. They differ from scenario to scenario.

Figure 3: Linking up a system map with a scenario framework (consisting of four scenarios) via interface variables



The analysis in Section 3.8 of this report shows how different sets of interface variables are activated by embedding the system map in different scenarios. It also shows how these future worlds provide structurally different opportunities for policy development: in some of these scenarios it is more difficult to develop an effective strategy to counter obesity because of structurally limiting boundary conditions in that world (and vice versa).

Tackling Obesities: Future Choices – Qualitative Modelling of Policy Options report[6], documents more fully how system maps and scenarios can be used in conjunction to generate and test policy options.

3 The obesity system map

This section is devoted to a **comprehensive discussion of the Tackling Obesities: Future Choices – Obesity System Atlas**. These need to be studied in conjunction with this discussion.

A series of 34 maps were generated during this project and they are divided into ten clusters set out in the table below. The discussion about maps 1-18 is descriptive. The discussion of the remaining maps demonstrates the potential of the system map to support policy development in complex societal issues. Appendix A (the obesity system atlas) also provides a working definition of the variables in the model.

Table 1: List of system maps generated for Foresight Tackling Obesities Project

Group	Map number	Title/description
1 Full map	Map 0	Full generic map
2 Core system engine	Map 1	System engine: foundational loop
	Map 2	System engine: reinforcing loop (lock-in)
	Map 3	System engine: balancing loop (conscious control)
3 Thematic clusters	Map 4	Full generic map: thematic clusters (empty)
	Map 5	Full generic map: thematic clusters (filled)
	Map 6	Full generic map: physiology cluster
	Map 7	Full generic map: individual activity cluster
	Map 8	Full generic map: environmental activity cluster
	Map 9	Full generic map: individual psychology cluster
	Map 10	Full generic map: social psychology cluster
	Map 11	Full generic map: food production cluster
	Map 12	Full generic map: food consumption cluster
4 Relationships between clusters	Map 13	Full generic map: linkages between the physiology and physical activity areas
	Map 14	Full generic map: linkages between the physical activity and psychology areas
	Map 15	Full generic map: linkages between the psychology and food environment areas
	Map 16	Full generic map: linkages between the food environment and physiology areas
	Map 17	Full generic map: linkages between the psychology and physiology areas
	Map 18	Full generic map: linkages between the physical activity and food environment areas

Table 1: List of system maps generated for Foresight Tackling Obesities Project (*continued*)

Group	Map number	Title/description
5 Key variables	Map 19	Core engine + 4 key variables
	Map 20	Core engine + 4 key variables+ 1st-tier variables
	Map 21	Core engine + 4 key variables + 1st/2nd-tier variables
6 Leverage points	Map 22	Leverage points: education
	Map 23	Leverage points: tendency to graze
	Map 24	Leverage points: purchasing power
	Map 25	Leverage points:: stress
	Map 26	Leverage points: appropriateness of maternal body composition
7 Weighted linkages	Map 27	Weighted causal linkages
8 System map embedded in scenarios	Map 28	System map: embedded in Scenario 1 – a Affluent population
	Map 29	System map: embedded in Scenario 1 – b Less affluent population
	Map 30	System map: embedded in Scenario 2
	Map 31	System map: embedded in Scenario 3
	Map 32	System map: embedded in Scenario 4
9 Policy response ideas	Map 33	mapping of policy response ideas
10 Segmented map	Map 34	Segmented map: hypothetical map for children subgroup

3.1 Full map

In the obesity system, the nodal variable identified was 'energy balance', i.e. the difference between the energy input and output of a human (or group of humans). This forms the anchoring point around which the whole system map revolves.

Although unlikely to be complete, this map represents the currently best available broad view of the obesity system based on available evidence. To some extent, the number of variables in the different sections of the map reflects the level of available evidence – this is particularly obvious when comparing the food and activity sections.

3.1.1 Map 0: Full generic map

The full obesity system map consists of 108 variables and 304 causal linkages.

The basic architecture of the map is a core set of loops, or 'system engine', and a periphery of interconnected variables. The core is a system engine – constituted of interlocking feedback loops – that drives the dynamics of the obesity system and the resulting energy balance (of an individual or a group of people). The periphery

consists of a wide range of environmental variables that directly or indirectly contribute to the relative weight of the interlocking feedback loops in the engine. The map as a whole shows the causal interdependencies between the environmental and core engine variables. It reflects the complex systemic structure of the obesity system.

Gaining familiarity with the full system map is best achieved by focusing on its constituent parts first, as shown in Maps 1–18 below.

3.2 Core system engine

3.2.1 Map 1 – system engine: foundational loop

The foundational loop anchors the whole obesity system map. It is a balancing loop – or, more precisely, a combination of two overlapping balancing loops – of a fundamentally biological nature that links four variables:

- level of available energy →
- importance of physical need →
- effort to acquire energy/Tendency to preserve energy →
- level of available energy.

This loop could be described as a systems view of 'homeostasis'. The basic functionality of the loop is to replenish an energy gap in a situation of scarcity. People naturally burn calories, reducing their level of available energy. This engenders a physical need to replenish energy stocks. As this need becomes more acute, it triggers a higher effort to go out and acquire new energy. An alternative strategy to cope with this need is to engage in energy conservation (for example, by reducing physical activity).

If these strategies are successful (the correlation between 'effort' and 'success rate' is presupposed), the level of available energy increases, reducing the importance of the physical need. In this way, the system tends towards an equilibrium value.

3.2.2 Map 2 – system engine: reinforcing loop (lock-in)

Energy replenishment and conservation – encapsulated in the variables ‘effort to acquire energy’ and ‘tendency to preserve energy’ – are pervasive activities and central to human survival. They have brought about a whole series of psychological, social and biological mechanisms, behaviour patterns, environments, processes, technologiesregulations and institutions. Many of these features, for example, the way we regulate energy levels in our body in our body, the way crops are grown, food commodities traded etc - are deeply ingrained and evolve only slowly. Hence, in a situation of endemic energy scarcity, a situation

gradually develops that can be described as a 'lock-in'. The term 'lock-in' describes the establishment of ingrained mechanisms, behaviours and processes related to accumulating energy. In this situation of scarcity, the lock-in may prove to be an effective and efficient mechanism of energy acquisition and preservation strategies. It only becomes a problem when in an environment of energy abundance. Once this occurs the lock in effectively constrains the range of options to deal with unintended consequences of abundance.

The 'lock-in' dynamic has been captured by adding another reinforcing loop on top of the foundational balancing loop described in Map 1. The loop positively links both 'effort to acquire energy' and 'tendency to preserve energy' to a new variable 'strength of lock-in to accumulate energy'. A strong lock-in, in its turn, reinforces both the 'effort to acquire energy' and the 'tendency to preserve energy'. This reinforcing positive feedback loop effectively bypasses the role of the 'importance of physical need'.

3.2.3 Map 3 – system engine: balancing loop (conscious control)

The final element of the system map's core engine is a balancing loop that is driven by 'conscious control of accumulation'. This is a psychological variable that steers people's accumulation behaviours which is negatively driven by the 'importance of physical need'. When in a situation of energy abundance, the importance of physical need for energy declines, then the conscious control of accumulation ought to increase to keep the system in balance. As conscious control increases, the 'strength of the lock-in to acquire energy' is diminished. It also reduces the effort to acquire and preserve energy.

Summary of the core engine

The system map's core engine encapsulates the basic dynamic behind the obesity issue: an experienced energy deficit engenders a natural human tendency to acquire/preserve energy. The success of these activities brings the energy equation in balance but can also cause it to overshoot. A lock-in develops that continues to drive these acquisition/preservation strategies despite the absence of a physical need. This could be a useful survival strategy in situation of scarcity. However, in a world of abundance this reinforcing loop overrides accumulation and preservation of energy. This reinforcing dynamic, which brings the energy balance out of control, needs to be refined by a balancing loop driven by a conscious control of accumulation of energy.

A key question remains which loop is dominant over the others and under what circumstances, and concerns how a situation which is out of balance can be restored. Options might include influencing the core foundation loop, or trying to break the lock-in or strengthening the conscious control or all of

this. The complexity of the system suggests that, too much focus on one loop over any other is unlikely to lead to successful inventions. Effects of interventions may also be muted in their impact because they are muffled or diluted by complex relationships elsewhere. Only concerted effort across the system is likely to make a lasting difference.

However, despite this complexity, the map can suggest critical variables and points of leverage which might have greater impact than others if addressed in an integrated strategy. The map also highlights those subsystems and themes within the map (e.g. physical activity, food production) which can be addressed in isolation provided the interconnections between each subsystem are acknowledged and actively pursued.

3.3 Thematic clusters

3.3.1 Map 4 – full generic map: thematic clusters (empty)

Map 4 shows the core engine and sets out the major thematic clusters of variables. Its purpose is to give a first full view of the obesity system model and to highlight its macro-architecture: a core engine embedded in a dense network of interlinked variables belonging to eight distinct thematic clusters.

The eight clusters belong to four major areas:

- human physiology
- physical activity patterns
- human psychology
- the food environment.

Three of these areas are subdivided into two clusters: one group of variables that is linked to the individual – and which is close to the core engine – and a group that is more closely related to the societal/environmental context and further removed from the core engine. This results in the following set of seven clusters:

- individual physiology
- individual physical activity
- physical activity environment
- individual psychology
- social psychology

- food consumption
- food production.

Each of these clusters is highlighted in subsequent maps (Maps 5–12).

3.3.2 Map 5 – full generic map: thematic clusters (filled)

Map 5 gives a full overview of the generic obesity system with the thematic clusters outlined.

3.3.3 Map 6 – Full generic map: physiology cluster

The physiology cluster comprises a mix of metabolic, genetic, epigenetic, endocrinal and neurological variables that constitute the biological foundation of body weight management.

A major part of the core engine is part of the physiology cluster. It contains the biological variables and homeostatic processes that control the level of available energy and the importance of the physical need to acquire energy, a control that is also partially exerted through the level of satiety, which represents a parallel loop outside the core engine.

'Degree of primary appetite control' (by the brain) controls the energy balance through both 'level of satiety' and 'force of dietary habits'. It is the point where many physiological parameters come together and is thus the key variable of the physiology cluster.

The bottom of the cluster represents an important reinforcing loop that helps to maintain the appropriate and optimal body composition **from one generation to another**. Indeed the 'appropriateness of maternal body composition', which influences foetal and child growth as well as the quality of breast feeding, has a major impact on the offspring's ability to maintain 'appropriate nutrient partitioning' (i.e. the balanced storage of fats, proteins and sugars). This, in turn, reduces the 'strength of the lock-in', which again reinforces 'the appropriateness of the maternal body composition'. This loop represents a type of epigenetic effect.

Genetic predisposition to obesity plays an important role as it determines the level of activity of basic physiological variables which in turn directly influence the energy balance, appetite control and nutrient partitioning. Genetic factors could also be regarded as underpinning many of the other variables within the system.

The other variables in the cluster refer to human interventions in the biological system, either through medication, surgery or as a consequence of disease. Except for surgical interventions (digestive tract reduction) none of these have direct effects on the core engine (Note: While this is a generally accepted view of

the current obesity system, our ability to impact on the core engine through medical intervention will undoubtedly improve in the future[7].

3.3.4 Map 7 – Full generic map: Individual activity cluster

The individual activity cluster revolves around the **'(the level of) physical activity'** of an individual or a group of people. This consists of different activity components, all obviously positively connected to 'physical activity':

- level of recreational activity (leisure time)
- level of domestic activity (in the home)
- level of occupational activity (at work)
- level of transport activity (while moving).

Physical activity is locked into a reinforcing loop with **'(level of) functional fitness'**. This indicates that a particular level of fitness is required to engage in a particular level of physical activity. The higher the fitness, the easier it is to engage in physical activity, and vice versa. A higher activity level will obviously engender a higher fitness level.

There is also a variable **'(the level of) non-volitional physical activity (NEAT)'**, which is directly linked to the core engine's 'level of available energy'.

The remaining variables in this cluster refer to **innate qualities or learning abilities**, which determine a person's physical activity level:

- parental modelling of activity
- degree of innate activity in childhood
- learned activity patterns in early childhood
- degree of physical education.

All these are (directly or via the 'level of recreational activity') positively linked to physical activity.

3.3.5 Map 8 – Full generic map: Environmental activity cluster

This cluster contains 12 variables, almost all of which reflect **environmental enablers/disablers** (cost, safety, presence of infrastructure) of physical activity:

- opportunity for team-based activity
- access to opportunities for physical exercise
- cost of physical exercise

- perceived danger in environment
- dominance of sedentary employment
- walkability of living environment
- dominance of motorised transport
- safety of unmotorised transport
- opportunity for unmotorised transport.

They are quite straightforwardly linked into the various physical activity components of the individual activity cluster, and can be grouped into a number of themes. One theme worth highlighting here is the set of interconnected variables around transport, in particular the feedback loop connecting the dominance of motorised transport with the walkability of the living environment.

A second, smaller, group of variables reflects **cultural values that affect physical activity** patterns:

- sociocultural valuation of activity
- social depreciation of labour
- reliance on labour-saving devices and services
- ambient temperature (of indoor living environment).

Again, the linkages with the physical activity components are quite straightforward, except for the 'ambient temperature' variable which links via the physiological variable 'level of thermogenesis'.

3.3.6 Map 9 – Full generic map: Individual psychology cluster

This cluster contains 12 variables that refer to psychological attributes of individuals.

A first subgroup revolves around a variable that is, strictly speaking, contextual and interfaces with the scenario framework: **'(the level of) individualism (in society)'**. This variable affects 'self-esteem' and '(level of) face-to-face interaction' negatively and is positively linked to the '(level of) stress' experienced by people. **'Stress'** is a key leverage point (many inward- and outward-travelling arrows). It links positively with 'demand for indulgence/compensation' and 'use of medicines', and negatively with another key variable, '(the level of) psychological ambivalence', as well as other variables outside this cluster such as perceived lack of time.

'Psychological ambivalence' has been defined as the conflict between what people often desire (e.g. fatty, sweet foods) and the need to stay healthy.[8] It links

immediately and negatively with the 'conscious control of accumulation' of the core engine. This implies that reducing psychological ambivalence is one of the key strategies to activate the core engine's outer balancing loop. Via its connection to 'desire to resolve tension (between what they desire and what they need to stay healthy') it also affects another key variable, the 'force of dietary habits' (in the food consumption cluster).

Two variables are associated with the way health- and food-related messages are perceived by people: **'(degree of perceived) scientific inconsistency'** and **'level of food literacy'**. Increased levels of inconsistency and literacy increase the level of psychological ambivalence (the latter because increased literacy doesn't eliminate people's desire but does increase their awareness of what they ought to eat in order to stay healthy).

Two final variables relate to the **kind of relationships that are prevalent in families** with children: '(level of) parental control' and '(level of) children's control of diet'. This important dynamic will vary from family to family and is also discussed in the companion Foresight Tackling Obesities project scenarios.[9]

3.3.7 Map 10 – Full generic map: Social psychology cluster

This cluster contains 16 variables reflecting the environmental factors that affect the psychology of groups of people.

Two variables form a contextual mini-cluster (meaning that these variables are at the edge of the system map, with no inward-pointing arrows):

- (level of) education
- (level of) acculturation.

Education feeds positively into a media-environment-related group of five variables:

- media availability
- (level of) media consumption
- availability of passive entertainment options
- (amount of) TV watching
- (degree of) exposure to food advertising.

This is a cluster that links predominantly to variables in other clusters (notably food consumption and individual psychology). However, media consumption is, in this model, the sole determinant of **'sociocultural valuation of food'** (positively linked: if consumption increases, valuation increases), which, in turn, links into other food consumption variables. This is unlikely to be the only influence and suggests that this area should be examined more closely.

'Acculturation' (the degree to which there is a dominant culture) feeds a group of variables that reflect the pressure to conform to ideal images, particularly related to body size and shape:

- social acceptability of fatness (negative link with 'acculturation')
- importance of ideal-body-size image (positive link with 'acculturation')
- peer pressure
- conceptualisation of obesity as a disease.

These variables link further down into the individual psychology cluster.

Also the two variables related to (social pressure on) smoking behaviour could also be viewed as belonging to this group (smoking is relevant to obesity due to its effects on thermogenesis and appetite):

- social rejection of smoking
- smoking cessation.

There is a final set of two variables in this cluster that relate to **psychological pressures in family life**; both of these variables link further through to 'stress':

- perceived lack of time
- (degree of) parental control (over children).

3.3.8 Map 11 – Full generic map: Food production cluster

There are 17 variables in this cluster, the (contextual) anchor of which is **'pressure for growth and profitability'** on industrial actors. This drives a group of variables that encapsulate the governing business model of actors:

- (level of) effort to increase efficiency of production
- desire to minimise cost
- desire to maximise volume (sold)
- pressure to improve access to food offerings
- pressure to cater for acquired tastes
- cost of ingredients
- (level of) standardisation of food offerings
- desire to differentiate offerings.

All these cascade into the **'market price of food offerings'**, which links directly (negatively) into the core engine via the 'strength of lock-in' (i.e. as price goes down, lock-in becomes stronger). This is the core of the food production cluster.

Three contextual variables reflect the macroeconomic situation in the UK:

- level of employment
- (level of) female employment
- (level of) purchasing power.

The **employment variables** link into 'perceived lack of time' and further into 'stress'. 'Purchasing power' is negatively connected to 'force of dietary habits' and so into the core engine ('strength of lock-in').

The remaining three variables reflect **upstream consumption drivers**, which link directly into the food consumption cluster:

- (level of) societal pressure to consume
- (consumers') effort to increase efficiency of consumption
- demand for health.

Many of these variables link to the contextual issues discussed and explored in the scenarios such as different drivers for business, impact of new business models, and variations in societal pressures to consume.

3.3.9 Map 12 – Full generic map: Food consumption cluster

There are 15 variables in this cluster. One group of three variables characterises the **food market** in which consumers operate:

- (level of) food abundance (absolute amount of food available on the market)
- (level of) food exposure (pervasiveness of food products)
- (level of) food variety (range of products available on the market).

These variables are very much driven by upstream elements from the food production cluster. Downstream 'exposure' and 'abundance' link positively via **'tendency to graze'** into the strength of dietary habits. High values of these variables ultimately strengthen the lock-in. A variable that compounds this effect is **'(level of) alcohol consumption'**.

A second group of variables reflects **(health) characteristics of food products**:

- (level of) fibre content of food and drink
- nutritional quality of food and drink

- palatability of food offerings
- energy density of food offerings
- portion size.

They are causally linked to demand-side factors (**'demand for health'** and **'purchasing power'**) and supply-side variables such as **'cost of ingredients'**. They exert a strong influence on the central engine via two paths: (a) the 'force of dietary habits' into the strength of lock-in; and (b) the 'level of satiety' (in the physiology cluster) into the 'importance of physical need'. There is a final variable in this cluster which also positively affects the 'level of satiety' and that is the **'rate of eating'** (i.e. the speed with which people take their meals).

3.4 Relationships between clusters

As described above, variables in the system map have been segmented in four thematic areas and further into seven clusters (see Section 3.3). Studying the network of causal linkages *between* these clusters deepens the insight into the structure of the system. A brief glance at the map shows there are many linkages between these clusters. Six maps have been drawn to highlight these interconnections and some specific linkages. Each of them is discussed in brief below.

3.4.1 Map 13 – Full generic map: linkages between the physiology and physical activity areas

Six arrows link the physiology cluster to the physical activity and many others work in the opposite direction.

- The key effect of the physiology cluster on the activity clusters seems to be driven by a **physiological predisposition to activity**. Another effect is through the level of fitness, which is, in part, dependent on a person's level of thermogenesis and resting metabolic rate.
- The reverse influence – from activity to physiology – is primarily driven through the **level of physical activity**, which has a positive effect on a number of physiological variables, notably the degree of appetite control and the appropriateness of maternal body composition.

3.4.2 Map 14 – Full generic map: linkages between the physical activity and psychology areas

Linkages between these two areas are unbalanced, with more arrows coming into the activity area than leaving it. In part, this reflects the evidence base on which to build the analysis of physical activity:

- There is a fairly dispersed range of psychological variables that have an influence on physical activity patterns: education, perceived lack of time, media consumption, self-esteem, face-to-face social interaction and psychological ambivalence all determine the opportunities people see for and the value they associate with physical activity.
- The level of physical activity is itself causally linked to levels of stress and self-esteem.

3.4.3 Map 15 – Full generic map: linkages between the psychology and food environment areas

Linkages between these two areas are predictably dense, with 14 arrows going from psychology to the food environment and nine arrows in the other direction:

- Key tail variables in the psychology area are education, media availability, socio-cultural valuation of food, perceived lack of time, stress and food literacy. They link into demand-side factors such as demand for health and the social pressure to consume. But supply-side variables are also triggered: the food industry's business model is grafted onto what people want.
- Tail variables in the food environment area are dispersed, with one arrow only leaving each of the variables. They include food exposure, food abundance, social pressure to consume, and industry's desire to maximise volume. They drive three variables in the psychology area: exposure to food advertising, perceived lack of time, and psychological ambivalence.

3.4.4 Map 16 – Full generic map: linkages between the food environment and physiology areas

The mutual influence of these two areas is asymmetric, with three arrows going from the physiology cluster to the food cluster and 20 arrows coming in the reverse direction:

- Physiological variables have only a few points of direct influence on the food environment, the degree of primary appetite control and the level of satiety link into force of dietary habits and palatability of food respectively.
- The effect of the food product characteristics (particularly nutritional quality) on physiology is obviously greatly differentiated, confirming that dietary patterns have a broad influence on metabolic processes and are dependent on time of exposure during development (i.e. age of person).

3.4.5 Map 17 – Full generic map: Linkages between the psychology and physiology areas

Five linkages between these areas have been identified, leading from the psychological cluster to the physiological cluster:

- 'Scientific inconsistency' and 'conceptualisation of obesity as a disease' link positively into 'reliance on pharma remedies'. 'Use of medicines' links to 'side effects of drug use'.
- 'Stress' is positively linked to 'resting metabolic rate'.
- 'Perceived lack of time' determines the 'quantity/quality of breast feeding'.
- Direct links within the core engine (as discussed above) between the conscious control loop and the central balancing loop. This emphasises how psychological/physiological links are a core dynamic of this system.

3.4.6 Map 18 – Full generic map: linkages between the physical activity and food environment areas

The connections between these two areas are mostly between **contextual economic variables** and the **extent to which people make use of motorised transport**:

- Reliance on labour-saving devices causes de-skilling, while walkability of the living environment is positively linked to food exposure. Motorised transport may claim a significant part of people's available income and thus reduces purchasing power.
- Purchasing power is positively linked to dominance of motorised transport and access to opportunities for physical exercise. Demand for health is negatively linked with dominance of motorised transport.

3.5 Key variables

3.5.1 Map 19 – core engine + 4 key variables

The core system engine is surrounded by four key variables, each of which belong to a different thematic area:

- psychological ambivalence (as part of the psychology area)
- force of dietary habits (as part of the food environment area)
- degree of primary appetite control (as part of the physiology area)
- level of physical activity (as part of the physical activity area).

Each of these variables has several arrows coming in and leaving, demonstrating that they are leverage points in the system (see section 2.4.2.1). In addition, they

connect (almost) directly into the central engine. They are therefore conduits for wide-ranging and dispersed changes in the obesity system into its core dynamic. This suggests they would make effective anchors for an obesity policy portfolio.

The connections with the core engine are:

- 'Psychological ambivalence' is negatively linked to 'conscious control of accumulation': high ambivalence (tension) results in a low level of conscious control of energy accumulation.
- 'Force of dietary habits' is positively linked to 'strength of lock-in'. In addition, it links negatively into 'conscious control of accumulation'.
- 'Degree of primary appetite control' is directly and negatively linked to 'strength of lock-in'. In addition, there are important secondary links via 'strength of dietary habits' and so into 'strength of lock-in' and 'conscious control'.
- 'Physical activity' is negatively linked to the 'level of available energy' and also indirectly via 'primary appetite control' and 'force of dietary habits'.

The following map shows the key variables with all the variables that feed directly into them (1st-tier variables).

3.5.2 Map 20 – core engine + 4 key variables + 1st-tier variables

Forty model variables, the 1st-tier variables, are directly linked into the set of four key variables. This captures one-third of the total number of variables in the map. They also constitute a broad range of variables that could act as targets for policies aimed at influencing one or more of the key variables and could provide a useful focus for further analysis of possible responses.

Some of these variables are inevitably easier to influence than others. For example, it is probably difficult to influence directly people's 'self-esteem' to reduce their 'psychological ambivalence'. But it is certainly possible to reduce 'food exposure' (e.g. by removing vending machines from schools). So, **practical feasibility** is one of the criteria that would need to be brought to bear to develop a potentially effective set of policies from this collection of 1st tier variables. Another piece of information that would greatly facilitate this task **is insight into the relative impact and strength of the causal connections between these variables**. In section 3.7 a small sampling of experts' views on this point are presented. However, this material is preliminary and further expert analysis and more original research is required before a definitive view can be reached (see section 3.5.3 for a preliminary assessment of potential starting points for obesity-inhibitory interventions).

3.5.3 Map 21 – core engine + 4 key variables + 1st/2nd-tier variables

Moving a second step away from the core engine to include 2nd-tier variables increases the number of variables to 84. This captures roughly three-quarters of the total number of variables in the map.

The 2nd-tier variables demonstrate how the level of the 1st-tier variables and (one link further downstream) the key variables can be influenced. For example, 'self-esteem' is now seen to be influenced by the level of individualism in society, the level of 'peer pressure', the 'importance of ideal-body-size image', the degree to which obesity is conceptualised as a disease and people's level of fitness. Again, these causal connections suggest a range of strategies to ultimately influence the dynamics of the core engine, some of which may be occurring elsewhere for other reasons but may still contribute to obesity intervention. Feasibility (cost, required competences and technologies, social acceptability) and the relative strength of causal links will also provide useful criteria to prioritise options for policy.

Based on the expert views' solicited on the relative strength of causal links in the map, the following variables could offer starting points for potentially effective inhibitory interventions in the obesity system:

- To increase the level of physical activity
  - **a.** enhance the walkability of the living environment
  - **b.** reduce the dominance of sedentary employment
  - **c.** mitigate the dominance of motorised transport
  - **d.** improve access to opportunities for physical exercise.
- To reduce the level of psychological ambivalence
  - **e.** reduce the perceived level of scientific inconsistency around health messages
  - **f.** integrate health into the sociocultural valuation of food.
- To reduce the force of dietary habits
  - **g.** decrease portion size.
- To directly reduce the strength of lock-in to accumulate energy
  - **h.** increase satiety/degree of primary appetite control
  - **i.** minimise generational effects by optimising maternal body composition and improving the quality and quantity of breast feeding.

However, the preliminary nature of these suggestions for interventions needs to be stressed.

3.6 Leverage points

There are other variables in the system map that, by virtue of the number of arrows connected, suggest that they may offer possible intervention points. Maps have been produced that highlight the causal cascades within which these variables position themselves as leverage points and hubs. What cannot be deduced from this analysis is the level of impact and hence it is possible that any consequential change in the system could be either very large or minimal. This uncertainty highlights the importance of the need for further research to determine the strength of the relationships between variables. It should be noted that no one variable has emerged as a leverage point for physical activity. This is in part a reflection of the limited evidence base for physical activity which was available and it should not be assumed that there are no leverage points for physical activity. This is discussed in more detail in the review of the evidence base on the obesogenic environment.[10]

3.6.1 Map 22 – Leverage point: Education

Map 22 shows how the 'education' variable exerts its influence via several mechanisms, thereby activating most of the critical parts of the map:

- Via the media complex, it links to psychological/cognitive variables 'self-esteem' and 'food literacy', which connect directly to the core engine via 'psychological ambivalence' and 'conscious control of accumulation'.
- Via 'demand for health', it activates the food production cluster and so onwards to the physiology cluster (over 'nutritional quality of food'). Ultimately, this hits the core engine at 'strength of lock-in' and 'level of available energy'.
- Via 'social valuation of activity', it has a fairly direct impact on the level of physical activity.

3.6.2 Map 23 – Leverage point: Tendency to graze

Both behavioural variables ('TV watching' and 'parental control') as food environment variables ('food exposure' and 'food abundance') drive the tendency to graze, which then links straightforwardly into the 'force of dietary habits' and the 'level of available energy'.

3.6.3 Map 24 – Leverage point: Purchasing power

This variable is most directly linked to the food consumption cluster, via 'nutritional quality', 'portion size' and 'palatability of food offerings'. The effect on 'force of dietary habits' is ambiguous as this variable is partly reinforced, partly eroded.

It also feeds into the physical activity cluster, where the effect is similarly not unidirectional. Higher purchasing power triggers reliance on personalised and motorised modes of transport, reducing physical activity, while the greater access to recreational activity resulting from increased purchasing power has a beneficial effect on activity levels.

The implication is that different effects could be seen for different individuals or contexts suggesting that care should be taken when choosing to focus on 'purchasing power' without considering the underlying relationships and mechanisms in more detail.

3.6.4 Map 25 – Leverage point: Stress

Stress is determined by a variety of factors, including work- and relationship-related factors and the level of physical exercise. It links positively to psychological ambivalence and then onwards to the level of 'conscious control' and the 'force of dietary hatits' via 'use of medicines', it also affects the physiology cluster.

3.6.5 Map 26 – Leverage point: Appropriateness of maternal body composition

This is an interesting variable as it is positioned in a reinforcing loop that exerts its influence across generations. The 'appropriateness of maternal body composition', which influences foetal and child growth as well as the quality of breast feeding, has a major impact on the offspring's ability to maintain 'appropriate nutrient partitioning' (i.e. the balanced storage of fats, proteins and sugars). This in turn reduces the 'strength of lock-in', which again reinforces 'the appropriateness of the maternal body'. This loop in fact represents a type of epigenetic effect. From the expert assessment of the relative importance of these linkages (see below), it also appears that many of the causal connections in this loop are considered to be very strong and therefore very important in its effect on the obesity system.

3.7 Weighted causal linkages

3.7.1 Map 27 – Weighted causal linkages

The discussion of the obesity system map has, up to this point, not considered the relative importance and strength of the linkages between variables. These attributes of the causal interconnections are, nevertheless, significant when considering possible actions to intervene effectively in the obesity system as previously mentioned in section 3.5.

In the time available to this project, preliminary work has been undertaken to assess the strength of impact of all the linkages in the obesity system map based on expert judgement and using a qualitative scale of 0-5 (a rating of 5 or strong

meaning that small changes in the tail variable lead to large changes in the head variable). Linkages were assigned a rating where possible or left 'grey' where there was no information available on which to make a judgement (see key on Map 27).

As only a small group of experts could be consulted and the evidence base on which to form a view was relatively poor, care must be taken in interpreting the results. However a few points can be highlighted:

- The central, driving function of the obesity engine is clear.
- High impact links are scattered across the system map with no particular cluster favoured although a slight bias to the left hand side of the map is evident. This highlights the importance of a broad approach to tackling obesity.
- The importance of the key variables such as 'psychological ambivalence', 'degree of primary appetite control' and, to a somewhat lesser extent, 'physical activity' and 'force of dietary habits' is confirmed by the strength and importance of the causal connections linking into them.
- However, it is important to note that few of the linkages between the central engine and peripheral variables (including the key variables mentioned above) are considered as having a strong impact and as a result, there are no uninterrupted cascades of high-impact linkages connecting contextual variables with the central engine.
- Significant parts of the generational effect embedded in the physiology cluster (as described in the previous section) are considered to be strongly linked.
- Two sets of thematic clusters are connected by strong linkages: 1) the social psychology cluster with food consumption variables, and 2) physical activity cluster with physiological variables. There is no emphatically strong link between the social psychology cluster and physical activity-related variables – this may be a consequence of lack of evidence.
- Surveying the 1st and 2nd tier variables that are connected to the key variables, and overlaying these with the expert assessment of the linkages, a number of potentially useful starting points for obesity policy measures present themselves and have been listed in the previous section 3.5.3.

These are the few high level observations arising from an examination of the weighted linkages in the obesity system map. A renewed caveat is in order with respect to the extent of data available to underpin these observations. A more extensive assessment would be needed to draw stronger conclusions from this piece of work.

3.8 System map embedded in a scenario framework

The obesity system map has been embedded in a future scenario framework to explore how potential future conditions over a time span of 40 years could affect the obesity system, and what the resulting latitude for developing obesity-inhibiting policies would be. The scenario framework, developed in parallel with the work on the obesity system map, is discussed in Tackling Obesities: Future Choices – Visualising the Future: Scenarios to 2050.[9]

The framework consists of four scenarios, differentiated from one another by two major uncertainties: (a) the orientation of future behaviour and values, particularly the possible path to greater individualism versus more socially minded behaviour; and (b) the kind of approach taken to dealing with large external challenges, with resources and environment as major examples that could be addressed through fundamental adaptive change, or through reactive short-term actions.

The resulting four scenarios revolve around the following key drivers:

- **Scenario 1**: Fears of future resource shortages and environmental change create awareness of the importance of long-term change. Individual responsibility and motivation dominate. Thus challenges are picked up by a market that is driven by individuals and single-interest groups, with a light touch from government.
- **Scenario 2**: Anxieties over the future, such as severe weather patterns and fears of future resource shortages, create a sense of the need for long-term change. Reaction against individualisation creates a growing sense of responsibility to the community. In this scenario, the challenge of making large-scale systemic change happen is addressed by the Government and communities.
- **Scenario 3**: There is a perception that environmental and resource-related issues can be dealt with on a case-by-case basis and that there is no pressing case for fundamental change. Trust in markets is weakened. A sense of a need for communities to work together on an ad-hoc basis on some issues sees a shift away from 'me first' individualism. Tensions between communities can increase as some take successful action and others do not.
- **Scenario 4**: Despite awareness of resource challenges, there is an abrogation of personal responsibility. An ethos of immediate reward and survival of the fittest dominates. There are no long-term investments in change. Markets deal with short-term challenges opportunistically, innovatively and effectively.

These scenarios obviously hold implications for future developments in levels of obesity. They are, in essence, contextual stories, which explore dynamic interconnections between societal drivers that are at the edge of the system map (such as the level of individualism in society) or even beyond the scope of the causal loop model (such as the impact of anticipated resource shortages). In

addition, by taking as a key structuring variable the way society deals with systemic crises, the scenarios are relevant to the obesity policy domain (as obesity can be seen as one of the systemic challenges society has to address). Hence, the combined logic of the scenarios acts to constraint potential interventions that might be available to different actors and allows exploration of what might work under different conditions.

The implications of these scenarios for obesity have been partly explored in the companion scenarios and qualitative modelling reports analyse this in more depth.[6,9] In this report, the impact on obesity is studied by using each of the scenarios as a set of boundary conditions that are imposed on the generic system map (see Section 2.4.3). In other words, each scenario is seen to prescribe particular levels for a set of variables in the system map. These variables are called 'interface variables' as they link the obesity system map into a particular future, contextual, environment. Once these levels have been fixed, their downstream implications on the obesity system, and particularly its key variables and core engine, can be investigated.

3.8.1 Maps 28/29 – Full generic map: embedded in scenario 1

In this scenario social inequalities are widening between a competitive, relatively affluent majority and a relatively small disenfranchised minority. The impact of this scenario on the system map therefore has to be differentiated for these two broad societal groups.

For the relatively affluent majority (Map 28), a series of drivers come into play that work strongly to ultimately reduce people's 'psychological ambivalence' (thus strengthening the 'conscious control of energy accumulation') and to diminish the 'force of dietary habits' (thus eroding the 'strength of lock-in'). On the other hand, there are also developments that run counter to these mainstream drivers and partly neutralise their beneficial effect on the core system's engine. For example, in the first decade of the time span covered by the scenario, psychological ambivalence rises sharply due to the proliferation of choice and the compulsion to choose between interests. However, as time progresses, people's desire to come to grips with this tension between what they really prefer and what they know is good for them increases as well. What people prefer is, within this time window, basically an invariant. However, what shifts the balance towards a successful resolution of this tension (and a concomitant lowering of the psychological ambivalence) is that individuals will be better informed about potential long-term costs of short-term behaviour, that these costs become more important to them and their willingness and motivation to shoulder individual responsibility to avoid these costs increases. This leads to the formation of new habits including diet and physical activity behaviours in individuals but also different approaches at organisational levels as these attitudes filter into the workplace.

In this scenario, people are particularly concerned about long-term health implications for them and their children, suggesting that the physiological cluster may also begin to be refined as intergenerational effects start to be addressed for some individuals.

Table 2 lists the drivers playing out in this scenario; the interface variables in the system map that are affected by them; the level at which they are locked in (for example, whether 'individualism' is high or low); and the downstream effect on the core engine. Drivers have been further segmented into those that positively impact on the core system engine and those that do not.

Table 2: Impact of scenario 1 drivers on system map

Driver	Manifestation of driver	Interface variables	Level of interface variable	Downstream effect on core engine
Individualism	• Priority of individual over community; 'me first' culture, competition	• Individualism • Face-to-face social interaction • Stress	• High • Low • High	Increases strength of lock-in Decreases conscious control of accumulation
Individualism	• Materialistic values	• Social pressure to consume	• High	Increases ambivalence and decreases conscious control of accumulation
Standard of living	• Majority able to raise their standard of living	• Purchasing power	• High	Reduces strength of lock-in
Resource constraints	• Awareness of the need for long-term change	• Psychological ambivalence	• High early on in the scenario, low later on.	Ultimately increases conscious control of accumulation
Individualism	• Individual responsibility and motivations dominate	• Desire to resolve tension	• High	Reduces strength of lock-in
Willingness to take responsibility to pre-empt long-term challenges	• People take responsibility for their own health • Healthcare insurance is encouraged	• Desire to resolve tension • Demand for health • Reliance on surgical interventions/ pharma remedies	• High • High • Low	Reduces force of dietary habits and strength of lock-in Increase conscious control (?)
Social valuation of food	• Redefinition of the social mores around eating: knowledge instead of quantity as luxury	• Social valuation of food • Portion size	• High • Low	Lowers pressure to cater for acquired taste and decreases strength of lock-in Decreases strength of lock-in

Table 2: Impact of scenario 1 drivers on system map (*continued*).

Driver	Manifestation of driver	Interface variables	Level of interface variable	Downstream effect on core engine
Sustainability	• Sustainability becomes an integrative element of profitable business models	• Pressure for growth and profitability • Desire to differentiate food offerings • Pressure to cater for acquired taste	• High • High • Low	All three together work to reduce the strength of lock-in
Education	• Private schooling with emphasis on making choices	• Food literacy • De-skilling	• High • Low	Increases conscious control Decreases force of dietary habits and strength of lock-in
Education Media availability	• Ubiquity of trustworthy information to facilitate choices • Business as life coach and educator	• Scientific consistency • Media availability • Media exposure • Psychological ambivalence	• High • High • High • High early on in the scenario	Ultimately increases conscious control of accumulation
Individualism	• A polarisation between socioeconomic groups, with normalisation at the lower end and stigmatisation at the upper end, seems likely	• Social acceptability of fatness • Peer pressure	• Low • Low	Decreases conscious control of accumulation
Individualism	• Desire for flexibility and isolation in transport infrastructure ('pod' approach)	• Dominance of motorised transport	• High	Decreases physical activity Increases level of available energy
Resource constraints	• Pressure on usage of powered transport	• Dominance of motorised transport	• Low	Increases physical activity Decreases level of available energy
Resource constraints	• Transformation of built environment in line with more effective use of energy resources; improvement of opportunities for lower-energy forms of transport	• Walkability of living environment • Dominance of motorised transport	• High • Low	Increases physical activity Decreases level of available energy

The picture is very different for the less affluent part of society (Map 29). Here, people remain locked in behavioural patterns dictated by short-term goals or because they find it difficult to put long term plans in place because of a dearth of financial resources, opportunities, information and awareness. The force of dietary habits remains much stronger and the conscious control of accumulation much weaker. The whole struggle to deal with psychological ambivalence and to resolve that tension in favour of longer-term imperatives, is largely beyond their horizon. Therefore the key drivers in this case are:

- low purchasing power
- low education
- low level of employment
- low demand for health
- high stress.

The impact on physical activity patterns is unclear. Increased walkability of urban areas might lead to an increase in activity, but this may be countered by many other drivers such as a low sociocultural valuation of activity (for that group), an increased perceived danger of the environment, lower functional fitness and a lower degree of physical education.

Overall for this scenario, it is likely that, over a longer period of time, an effective strategy unfolds to deal with obesity. The pivotal point is people's willingness to take responsibility for themselves. The map shows how this has two major impacts:

- It ultimately reduces psychological ambivalence, thus loosening the force of (unhealthy) dietary habits and a higher level of conscious control of energy accumulation.
- It triggers a demand for health that ultimately reconfigures food consumption and production towards innovative, healthier offerings.

The net effect on obesity can't be read from this causal loop model or the time taken to see an impact. It depends on the relative weight of drivers countering these mainstream effects and on the relative sizes of the more affluent majority and disenfranchised minority.

3.8.2 Map 30 – System map: embedded in scenario 2

Scenario 2 shares a similar, proactive outlook on how to deal with resource challenges and other systemic crises. However, markets are not the vehicle of choice to harness societal resources and energies. Instead, change is driven by communities, supported by Government. Inequalities within communities narrow

in this scenario so it is not necessary to segment the impact of the scenario on the system map according to socioeconomic class (as was the case with Scenario 1).

Although the actors driving change are different, the external conditions imposed on the system map lead to a dynamic that is similar to that of Scenario 1. An increased awareness of the medium-term implications of global challenges leads initially to a higher psychological ambivalence and an increased desire to resolve that tension. Peer pressure, anxiety and the desire to belong in the face of a hostile environment are key factors that trigger a behavioural change and an ultimate decrease in psychological ambivalence. From there onwards, it becomes easier for conscious control of energy accumulation and preservation to loosen the force of dietary habits and increase physical activity. Also, food production and the built environment are affected, but these changes are driven less by bottom-up demand-side factors than by top-down regulation and investment (including fiscal measures).

Table 3 lists the key scenario drivers, their linkages into the system map via interface variables, the levels at which these are fixed and the ultimate impact on the system map core engine.

Table 3: Impact of scenario 2 drivers on system map

Driver	Manifestation of driver	Interface variables	Level of interface variable	Downstream effect on core engine
Pressure on resources	• People huddling in communities to face urgent global challenges	• Individualism • Face-to-face social interaction	• Low • High	Increases conscious control of accumulation
Communitarianism	• Increased neighbourliness, less materialistic values, better work–life balance	• Face-to-face social interaction • Self-esteem • Stress • Perceived lack of time	• High • High • Low • Low	Increases conscious control of accumulation Decreases force of dietary habits and strength of lock-in
Education Media exposure	• Media campaigns, social marketing around global challenges	• Social pressure to consume • Food literacy	• Low • High	Increases conscious control of accumulation Decreases force of dietary habits and strength of lock-in
Communitarianism	• Health emerges as 'civic duty'	• Social acceptability of fatness • Peer pressure • Social rejection of smoking • Demand for health	• Low • High • Low • High	Increases conscious control of accumulation Decreases force of dietary habits & strength of lock-in

Table 3: Impact of scenario 2 drivers on system map (*continued*)

Driver	Manifestation of driver	Interface variables	Level of interface variable	Downstream effect on core engine
Regulation	• Restricting individual choice (e.g. zoning for public health)	• Pressure to improve access to food offerings • Food exposure	• Low • Low	Increases conscious control of accumulation
Pressure on resources	• Focus on health prevention	• Demand for health • Reliance on surgical/pharma interventions	• High • Low	Reduces force of dietary habits and strength of lock-in
Pressure on resources	• Re-engineering of public infrastructure towards energy efficiency	• Walkability of living environment • Dominance of motorised transport	• High • Low	Decreases level of available energy
Regulation	• Fiscal incentives for food industry to switch to more healthy food offerings	• Market price of (healthy) food offerings • Nutritional quality of food and drink • Energy density of food and drink	• Low • High • Low	Reduces force of (unhealthy) dietary habits and reduces strength of lock-in
Information provision	• Funding of long-term health studies; willingness to act on incomplete evidence	• (degree of perceived) Scientific inconsistency	• Low	Increases conscious control

Similar to Scenario 1, this scenario provides a canvas on which to unfold an effective strategy to deal with obesity. Given a more uniform distribution of economic wealth/opportunities and an absence of individualistic and consumerist reflexes and a willingness to undergo significant change, its effectiveness will probably be higher than that of Scenario 1.

3.8.3 Map 31 – System map: embedded in scenario 3

Scenario 3 is a world where people are focusing on their own personal, short-term needs. In order to make do with gradually shrinking resources, small-scale and local communities grow, with collective decision making and consultation increasing in importance. Ownership of nationwide challenges are, however, delegated to Government and, to a lesser extent, business. Decisions are made

on a case-by-case basis when necessary. There is little or no structural change in infrastructure or in lifestyle. This society clings to the status quo, whilst deepening values of inclusiveness and prudence.

This scenario features many drivers that act to strengthen the lock-in. The key mechanism is the persistence of psychological ambivalence as a result of persistent stress and anxiety in the face of pressing neighbourhood issues (cost of living, immigration). This society is also highly risk-averse. It keeps decision in suspension as long as there is no conclusive evidence, increasing once more the level of psychological ambivalence. Fragmentation in viewpoints and assessments makes consensus often elusive.

Relatively low purchasing power and low regulatory pressure also keep the food production and consumption systems at a status quo, strengthening the pressure to cater for acquired taste and thus the force of dietary habits (See Table 4).

Table 4: Impact of scenario 3 on system map

Driver	Manifestation of driver	Interface variables	Level of interface variable	Downstream effect on core engine
Environmental pressures	• Numerous concerns for the individual: cost of living, employment, immigration • Health is not a prime cause for concern • Media amplify issues to be worried about	• Self-esteem • Stress • Demand for health • Media exposure	• Low • High • Low • High	Decreases conscious control of accumulation Increases force of dietary habits and strength of lock-in
Communitarianism	• Co-operative communities to deal pragmatically with concerns • Families integrate vertically • People identify strongly with neighbourhood	Individualism • Face-to-face social interaction • Peer pressure	• Low • High • High	Increases conscious control of accumulation Decreases force of dietary habits and strength of lock-in
Fragmentation	• Multiplicity of voices, no privileged point of view • Expert views are drowned out by the cacophony	• (degree of perceived) Scientific inconsistency	• High	Increases psychological ambivalence and decreases conscious control

Table 4: Impact of scenario 3 on system map (*continued*)

Driver	Manifestation of driver	Interface variables	Level of interface variable	Downstream effect on core engine
Health care	• Health care is led by public sector, in a curative mode. There is a focus on quick fixes • Treatment options multiply	• Reliance on pharma remedies	• High	Increases force of dietary habits and strength of lock-in
Perception of risk	• Society is risk-averse. Focus is on reacting to emerging problems. No action is taken unless solid evidence exists	• Desire to resolve tension	• Low	Decreases conscious control of accumulation
Regulation	• Food sector is not under pressure to change and responds to haphazard regulation	• Pressure for growth and profitability • Pressure to cater for acquired taste • Demand for health • Exposure to food advertising	• High • Low • Low • High	Increases force of dietary habits and strength of lock-in
Standard of living	• Purchasing power is in decline	• Purchasing power • Market price of food offerings	• Low • Low	Increases force of dietary habits and strength of lock-in
Impact of events	• Olympics trigger a (short-lived) surge in interest in sport	• Social valuation of activity • Opportunity for team-based activity	• High • High	Increases physical activity Decreases level of available energy

This scenario doesn't seem to harbour a climate where it will be easy to tackle the obesity challenge as most of the drivers reinforce the lock-in in unhealthy eating and physical activity patterns and keep the conscious control loop from kicking into action.

3.8.4 Map 32 – System map: embedded in scenario 4

Scenario 4 is a highly competitive, individualistic world where the long-term perspective is largely absent and where individuals abrogate responsibility to take on the big challenges of the times. Self-reliance is the mantra of the scenario, financial success is the key performance indicator and social inequality is high.

Many drivers in this scenario work on the reinforcement of psychological ambivalence, the erosion of the desire to resolve this tension and the demand for indulgence and compensation. All this undercuts the conscious control of accumulation and solidifies the lock-in to unhealthy, short-term dietary and activity patterns. Many drivers also impact on the opportunities for physical activity and food choice and will affect attitudes towards thinking about intergenerational physiological effects. This scenario would see a rise in reliance on pharmaceutical remedies through an emphasis on treatment. (See Table 5.)

Table 5: Impact of scenario 4 drivers on system map

Driver	Manifestation of driver	Interface variables	Level of interface variable	Downstream effect on core engine
Environmental pressures	• Individuals are focused on coping with constant change and time pressures	• Stress • Demand for convenience	• High • High	Decreases conscious control Increases force of dietary habits
Individualism	• A continued and rapidly rising sense of individualism	• Individualism	• High	Decreases conscious control
Choice	• Choice and freedom of choice are valued above moral and ethical debates in society	• Psychological ambivalence	• High	Decreases conscious control
Risk perception	• A 'live for the day' attitude dominates	• Desire to resolve tension	• Low	Increases strength of lock-in
Individualism	• High expectations, intense desire for success, ruthless competition for the top spot	• Self-esteem • Stress • Societal pressure to consume • Demand for indulgence	• High • High • High • High	Decreases conscious control Increases strength of lock-in
Social equity	• Rising gap between haves and have nots • Loosening social fabric • Rising crime and perception of being unsafe; possible social unrest	• Individualism • Face-to-face social interaction • Perceived danger of environment	• High • Low • High	Decreases conscious control Decreases physical activity

Table 5: Impact of scenario 4 drivers on system map (*continued*)

Driver	Manifestation of driver	Interface variables	Level of interface variable	Downstream effect on core engine
Choice	• Massive food choice is on offer: innovative foodstuffs for premium markets and continued supply of cheap, convenient food	• Food abundance • Food exposure • Food variety	• High • High • High	Increases force of dietary habits and strength of lock-in
Technology	• Technology caters for the need for quick fixes, personal enhancement, luxury and indulgence • Increasing dependence on technology • New forms of palliative treatments and protection	• Demand for indulgence • Availability of passive entertainment options • Reliance on labour-saving devices • Dominance of motorised treatment • Use of medicines • Reliance on pharma/surgical interventions	• High • High • High • High • High • High	Increases strength of lock-in Decreases physical activity and increases level of energy available Increases strength of lock-in
Media	• Short-term, headline-seeking media reinforce social climate • Guided by commercial opportunism: what sells, wins	• Media availability • Media consumption • Exposure to food advertising • Food literacy	• High • High • High • Low	Decreases conscious control
Public services	• Public services in decline • Switch to private solutions	• Walkability of living environment • Access to opportunities for physical exercise	• Low • Low	Increases level of energy available
Economics	• Global competition • High pressure on growth and profitability • High pressure on individual performance	• Pressure on growth and profitability • Pressure on job performance • Demand for health	• High • High • High	Decreases conscious control Decreases strength of lock-in

Table 5: Impact of scenario 4 drivers on system map (*continued*)

Driver	Manifestation of driver	Interface variables	Level of interface variable	Downstream effect on core engine
Food industry	• High pressure on growth and competitiveness • High pressure to cater for acquired taste • High demand for convenient food offerings	• Pressure to cater for acquired taste • Pressure to improve access to food offerings • Demand for convenience	• High • High • High	Increases force of dietary habits and strength of lock-in

Although there is big gap between the wealthy and less well off in Scenario 4, each group's way of coping with obesity differs in degree rather than nature (which is different from Scenario 1). Very few people in this world are able to transcend the psychological ambiguity to which they are exposed in lifestyle choices. The competitive, affluent elite is, to an even higher degree, exposed to this ambiguity, vacillating between a pronounced craving for indulgence and spiralling expectations and the realisation that health is a very precious commodity (and a symbol of status) in an intensely competitive world.

Clearly, Scenario 4 does not offer a lot of levers that can be used in the obesity challenge. It's therefore unlikely that, in this world, there would be a trend break in the long-term development of the obesity epidemic.

3.9 Policy responses

3.9.1 Map 33 – Full generic map: mapping of policy measures 1–6

During this project, an initial set of 56 options for policy was built up through analysis of the set of future scenarios, desktop research and ideas based on the system map. These were narrowed down to a selection of 17 options representing the desired breadth and depth for further analysis in a qualitative modelling exercise.[6]

The next section discusses how these 17 options could be mapped on the system map and how they might affect the system itself. There are a number of places or 'levels' within a system where an intervention could be effective. Table 6 shows the response options grouped according to the level at which they impact on the obesity system which sets out a ladder of system levels where intervention could leverage change and ranks these in order of effectiveness (as described in Meadows 'systems ladder' approach).[11] The responses in Table 6 are listed in order of effectiveness, but feasibility is not accounted for.

The policy options have been mapped onto the system map in Map 33. First, the variables targeted by the response were identified. Subsequently, their downstream impact on the core engine of the model were highlighted. Not all of the options can be mapped on the causal loop model. As the system ladder shows, this is because some of the responses are concerned with changing the focus of policy or the way it is developed (i.e. focused on whole system change rather than on one particular variable). For example, investing in a 'magic pill' would, in effect, act downstream of the obesity system map and alter the perception of the whole obesity system and the priority given to prevention of obesity.

The map shows that this set of policy measures activates (impacts on) almost all areas of the causal loop model. In this sense, the set of options can be considered to be fairly balanced. There are, perhaps, two areas that are not activated, the small ('quality of life') cluster around 'individualism' – 'face-to-face social interaction' – 'self-esteem' – 'perceived lack of time', 'stress' and the cluster that captures the food industry's business model (driven by 'pressure for growth and profitability').

Referring back to the earlier discussion in Sections 3.5 and 3.6, it appears that:

- There is an overlap between this set of policy options and the series of measures that have been suggested by a preliminary investigation of how key variables could be most effectively steered. Measures focused on enhancing walkability, reducing dominance of motorised transport, changing sociocultural valuation of food, reducing food exposure and mitigating (mother–child) generational effects appear in both sets.
- Most of the additional leverage points identified in Section 3.6. are affected by the suggested policy options (apart from 'stress').

A more substantive assessment of the potential effectiveness of the policy options would need more expert evaluation of the relative impact and strength of the causal linkages in the system map.

Table 6: Systems ladder (from Meadows' systems ladder approach)[11]

LEVEL OF INTERVENTION IN SYSTEM	IMPACT ON OBESITY SYSTEM	POLICY OPTIONS
Build/reroute flows (of people)	IMPROVE SAFETY AND WALKABILITY OF INFRASTRUCTURE	**2** Improve perceptions of safety (both from the point of view of traffic and of crime)
		3 Increase 'walkability' and 'cyclability' of the built environment (urban and rural
Control/reroute mass flows	REROUTE FOOD FLOWS	**13** Control availability and exposure to obesogenic food and drinks
		9 Introduce a tax on obesity-promoting foods
Design negative feedback loops	INTRODUCE NEW ACCOUNTABILITIES	**17** Penalise parents for the unhealthy lifestyles of their children
		10 Use fiscal levers to increase responsibility of key institutions for health
Design positive feedback loops	INTRODUCE NEW REWARD STRUCTURES	**11** Use individually targeted fiscal measures to promote healthier living
Enhance information flows	ENHANCE INFORMATION FLOWS AND FEEDBACK	**15** Invest in technology to support informed individual choice
		8 Introduce evaluation toolkits (to evaluate the success of obesity interventions and policies throughout the whole of the delivery chain)
Change the rules of the game	DESIGN APPROPRIATE INTER-VENTION PROTOCOLS	**1** Introduce health as a significant criterion in all planning procedures (including upgrading current infrastructure)
		16 Promote/implement a programme of early interventions at birth or infant stages
		4 Focus on targeted interventions (exploiting 'windows of opportunity' i.e. young children, and targeting those most 'at risk')
		5 Implement population-wide interventions i.e. focus on improving the health and well-being of the population as a whole

Table 6: Systems ladder (from Meadows' systems ladder approach)[11] (*continued*)

Order of effectiveness increasing

LEVEL OF INTERVENTION IN SYSTEM	IMPACT ON OBESITY SYSTEM	POLICY OPTIONS
Improve system's capacity to self-organise	IMPROVE FOOD LITERACY AND SKILLS	**12** Introduce programmes to increase food literacy and food skills
Change mindset (goals of system)	REFRAME THE ISSUE OF OBESITY	**6** Focus on the consequences (e.g. diabetes) rather than obesity
		7 Invest in the search for a highly effective post hoc solution to obesity (e.g. 'the magic pill')
		14 Take a directive approach to changing cultural norms i.e. establishing healthy living as an everyday aspect of UK society

3.10 Segmented map

3.3.1 Map 34 – Segmented map: hypothetical map for children subgroup

Epidemiological studies indicate that there are significant differences in levels of obesity in different groups of the population. It is therefore helpful to think in a more targeted way about how this variation could affect the obesity system. As has been indicated above, the generic system map in itself focuses on the effects of belonging to a particular population subgroup (whether this is based on gender, socioeconomic class, life stage or ethnicity). In order to study these effects, the map would need to be segmented into relevant submaps that indicate the relative strength and importance of variables and linkages for that group.

A questionnaire submitted to experts which aimed of mapping the effects of class, gender, ethnicity and life-stage on the causal linkages in the model revealed that the generation of submaps is currently not possible as a lack of data leads to highly fragmented resulted.

However, in order to demonstrate the principle of working with segmented maps, an example is provided here of a submodel for a life-stage-determined group: children aged 6–16 years (another example, segmenting two socioeconomic classes, has already been shown in Section 3.8 to illustrate how the system map is embedded in Scenario 1). The map is only provided by way of example and is

not substantiated by extensive research. However, some preliminary research (based on internal WS research and unpublished data) points to relevant characteristics in today's (European) children's lifestyle that can be mapped onto the obesity system map (map variables shown in brackets):

- Parent–child interactions have been in decline (parent control, parental modelling of activity).
- Children have increasing influence on family decision processes (parent control, children's control of diet).
- Children are increasingly subjected to the phenomenon of 'age compression': they are adopting patterns of adult lifestyles early on in life (with concomitant stress, time constraints and anxiety about self-esteem).
- Divorce rates have risen over the last four decades, causing disruptions in family life (stress, anxiety about self esteem).
- Peer influence is an increasingly important formative element in childhood and, according to some studies, seems to supersede parent influence from age 10 onwards (parental control, peer pressure).
- Many children have increased purchasing power (£70 million a year in the UK). Most of it is spent on impulse purchases, including snacks, soft drinks and confectionery (purchasing power).
- Changes in how children spend their time: less free to roam outdoors, more passive entertainment and scheduled events (perceived danger in environment, degree of innate activity in childhood, learned activity patterns in early childhood, access to opportunities for physical exercise, walkability of living environment, functional fitness).
- Children are exposed intensively to a range of media (often more than one at a time; the 'multitasking generation') and to commercial messages (20,000 to 40,000 commercials each year) (media availability, media exposure, availability of passive entertainment options, TV watching, exposure to food advertising, food exposure, food literacy).
- In terms of dietary habits, children's consumption of regular meals has declined and the number of snacking occasions has risen. Palatability is a key driver of choice in dietary choices (eating rate, demand for indulgence, tendency to graze, nutritional quality of food and drinks).
- There is a negative correlation between unhealthy behaviour and social class: consumption of soft drinks, smoking, and lack of physical exercise are more prevalent in lower social classes (social rejection of smoking).

- Many children understand the basic features of a healthy diet (see Tackling Obesities: Future Choices – Perspectives of 10-13-Year-Olds[12]). They also understand that being overweight is due to a combination of unhealthy diet and lack of physical exercise. In other words, children are subjected to a significant level of psychological ambivalence but are living in an obesogenic environment that tends to inhibit the desire to resolve that tension (psychological ambivalence).

The drivers listed above activate most areas of the map negatively, ultimately leading to a high level of available energy, a strong lock-in to unhealthy accumulation and preservation patterns and a low conscious control over this process. This analysis confirms the systemic nature of child obesity, necessitating a very broad and long-term policy approach to counter it.

4 Conclusions

A system model and map (Note: the terms 'model' and 'map' can be used interchangeably but, strictly speaking, the map is the graphic, visual representation of the model) have been designed as a conceptual representation of the causal interdependencies in the UK obesity system as a whole. The model has been based on focused contributions from a wide multidisciplinary range of experts. At this point, the obesity system map arguably represents the most comprehensive 'whole system' view available. The map has been used to visualise how a set of qualitative future scenarios and a diverse series of options for policy activate the obesity system.

4.1 Structure of the obesity system

The map is centred on the nodal variable of 'energy balance'. The key elements of the system map's architecture are a core set of loops, or 'system engine', and a periphery of interconnected variables:

- The **core** is a central dynamic 'engine' of interlocking feedback loops that determine the basic dynamics of the obesity system and the resulting energy balance at an individual or an aggregate level. The constitutive feedback loops are:
  - a core balancing loop that is biological in nature and revolves around activities of metabolic energy acquisition and preservation
  - a reinforcing loop (superimposed on the biological loop) that locks the obesity system in an escalation dynamic (positive feedback), a loop that spills over into psychological, social, environmental and institutional factors
  - a third loop is superimposed on these two loops: a cognitively driven effort to break the lock-in and which also captures the fundamental psychological ambivalence that characterises many of those who live in a food-abundant, post-industrial society.
- The **periphery** consists of 108 variables that drive the core engine via an intricate network of causal interdependencies. These variables can be divided into thematic clusters: physiology, individual physical activity, the physical activity environment, food consumption, food production, individual psychology and social psychology.

The anatomy of the system map, with its large number of variables and many causal linkages between very different drivers, is a clear confirmation of the inescapably systemic and complex nature of this issue. The importance of the multiple interconnections between the different variables driving the system, suggests that only a long-term, broad and diversified approach to policy will be able to address to stem the rising incidence obesity. However, despite this complexity, the map can suggest critical variables and points of leverage that

might have greater potential for impact than others if addressed in an integrated strategy. The map also highlights important subsystems and themes within the map (e.g. physical activity, food production) that can be addressed in isolation provided the interconnections between each subsystem are acknowledged and actively pursued.

4.2 Intervening in the obesity system

- The system model shows that the basic 'energy balance' engine is driven by four main variables, themselves driven by a complex network of interdependencies:
  - the level of **psychological ambivalence** experienced by a UK citizen in deciding lifestyle (food, exercise) options
  - the **force of dietary habits** keeping UK citizens from adopting healthier alternatives
  - the **level of physical activity** in which UK citizens are engaged
  - the **level of primary appetite control** in the brain.

These variables are conduits of dispersed changes in the obesity system into its core dynamic. They are therefore prime targets for policy-related interventions:

- Exploring the **upstream variables** that are directly connected to the main variables (1st-tier) or are two links removed from them (2nd-tier) yields a database of potential intervention points in the obesity system. These need to be prioritised according to, for example, feasibility and effectiveness.
- Assessing the effectiveness of a given intervention hinges on having knowledge about the relative impact and strength of the causal connections between these intervention variables and the core engine. Only limited data could be gathered on this in the framework of this project. However, a preliminary assessment shows that the following variables offer starting points for potentially effective inhibitory interventions in the obesity system:
  - To increase the level of physical activity
    - **a.** enhance the walkability of the living environment
    - **b.** reduce the dominance of sedentary employment
    - **c.** mitigate the dominance of motorised transport
    - **d.** improve access to opportunities for physical exercise.
  - To reduce the level of psychological ambivalence
    - **e.** reduce the (perceived) level of scientific inconsistency around health messages
    - **f.** integrate health into the sociocultural valuation of food.

  - To reduce the force of dietary habits

    g. decrease portion size.

  - To directly reduce the strength of lock-in to accumulate energy

    h. increase satiety/degree of primary appetite control

    i. minimise generational effects by optimising maternal body composition and improving the quality and quantity of breast feeding.

- The system map has been **embedded in a set of four different future scenarios** (see the Future Choices – Visualising the Future: Scenarios to 2050 project report.[9]) The scenarios essentially impose sets of contextualised boundary conditions on the system map. Each constrains the dynamics of the obesity system and hence the latitude in policy that is available in different ways. Critical insights from this analysis are:

  - In Scenarios 1 and 2, long-term challenges are dealt with proactively, either by the individual (via markets) or the collective (via communities and governments) accept responsibility. In both cases, this step leads to a reduction in psychological ambivalence, which clears the way for an effective strategy to deal with obesity that hinges on increasing people's conscious control of energy accumulation/preservation and erodes the force of dietary habits. These scenarios also allow the intergenerational effects to be tackled. Given a more uniform distribution of economic wealth/opportunities, an absence of individualistic and consumerist reflexes, and the ability to intervene in the wider environment, the effectiveness of an obesity-countering strategy will probably be higher in Scenario 2 than in Scenario 1.

  - Scenarios 3 and 4 do not seem to offer a climate that is conducive to tackling the obesity challenge as most of the drivers reinforce the lock-in to unhealthy eating and patterns of physical activity and keep the conscious control loop from becoming activated. Again, a critical mechanism is the persistence of psychological ambivalence arising from persistent stress, anxiety, risk-averseness and fragmentation as well as peripheral variables related to the opportunities to act or change behaviour (played out in different areas of life in the two scenarios).

  - Socioeconomic differences are particularly wide in Scenarios 1 and 4. These differences result in alternative approaches to tackling obesity in the various societal groups in Scenario 1, as shown in the two versions of the system map produced for this scenario. More affluent groups have opportunities to take a longer-term approach to their health. However, the less affluent remain tied to behavioural patterns dictated by short-term goals or difficulties in putting long-term plans in place because of a lack of financial resources, opportunities, information and awareness. In Scenario 4, where there is perhaps a bigger gap between the wealthy and the less well off, the approach to coping with obesity differs in degree rather than nature and therefore doesn't alter the system map.

- A series of **policy options** have been tested in a response testing exercise (see Qualitative Modelling and Policy Option Testing report[6]). In addition, most of these ideas have been **mapped on the obesity system map**. This mapping shows which variables the measures are directed at and how they connect to the model's core engine.
- Ideally, the generic system map would be **segmented**, indicating the relative strength and importance of variables and linkages for relevant, population **subgroups**, whether based on gender, socioeconomic class, life stage or ethnicity. This would allow targeted thinking about policy measures directed at combating obesity in particular groups. However, the data on which to conduct this analysis is too sparse and fragmented to support reliable submodels of the generic map. So in this study, a submap has only been drawn to show critical influences for children to demonstrate the principle of working with segmented maps.

Appendix A – Future Choices – Obesity System Atlas

Click to go to Tackling Obesities: Future Choices - Obesity System Atlas

Appendix B: The process of building the obesity system map

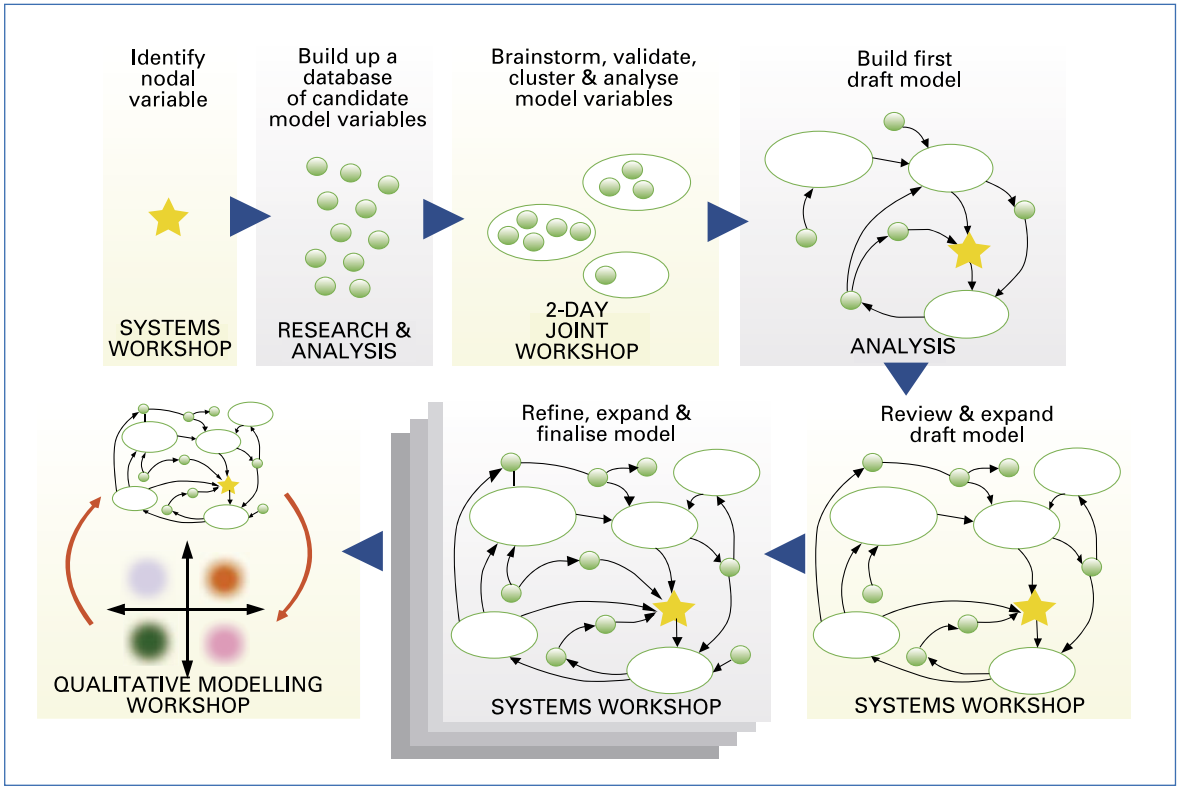
The development of the obesity system map occurred in broadly two phases: a very focused phase punctuated by a series of interactive workshops with experts, followed by a second phase of gradual streamlining of the work into the final version of the model.

Key **milestones** in this first phase of the process have been the:

- first systems workshop: laying the foundations of the system map
- joint systems and scenarios workshop: identifying model variables
- third systems workshop: review of first draft model
- fourth systems workshop : review of physiology subsystem.

Workshops were mainly attended by experts from a variety of disciplines, complemented by other stakeholder organisations, including policy makers and business/civil society representatives.

Figure 4: Workflow for the systems mapping



Throughout the whole development phase, the contributions from experts were introduced into the emerging causal loop diagram by focused modelling work.

The **knowledge base** on which this system map is founded consists essentially of three components:

- interactive contributions from experts during workshops and bilateral exchanges with the systems contractor
- a collection of papers (Foresight Tackling Obesities project short science reviews – commissioned from academic experts – providing an up-to-date state of the evidence base for obesity)[7]
- targeted fact-finding and research by the systems contractor while the modelling work was continuing.

Figure 4 sets out the overall workflow of the systems mapping work package, up to and including the final qualitative modelling workshop.

In the remainder of this appendix, critical findings from each of the workshops are briefly discussed.

1 First workshop: Foundations

The first workshop was designed to provide the foundations for the system map by focusing on two tasks:

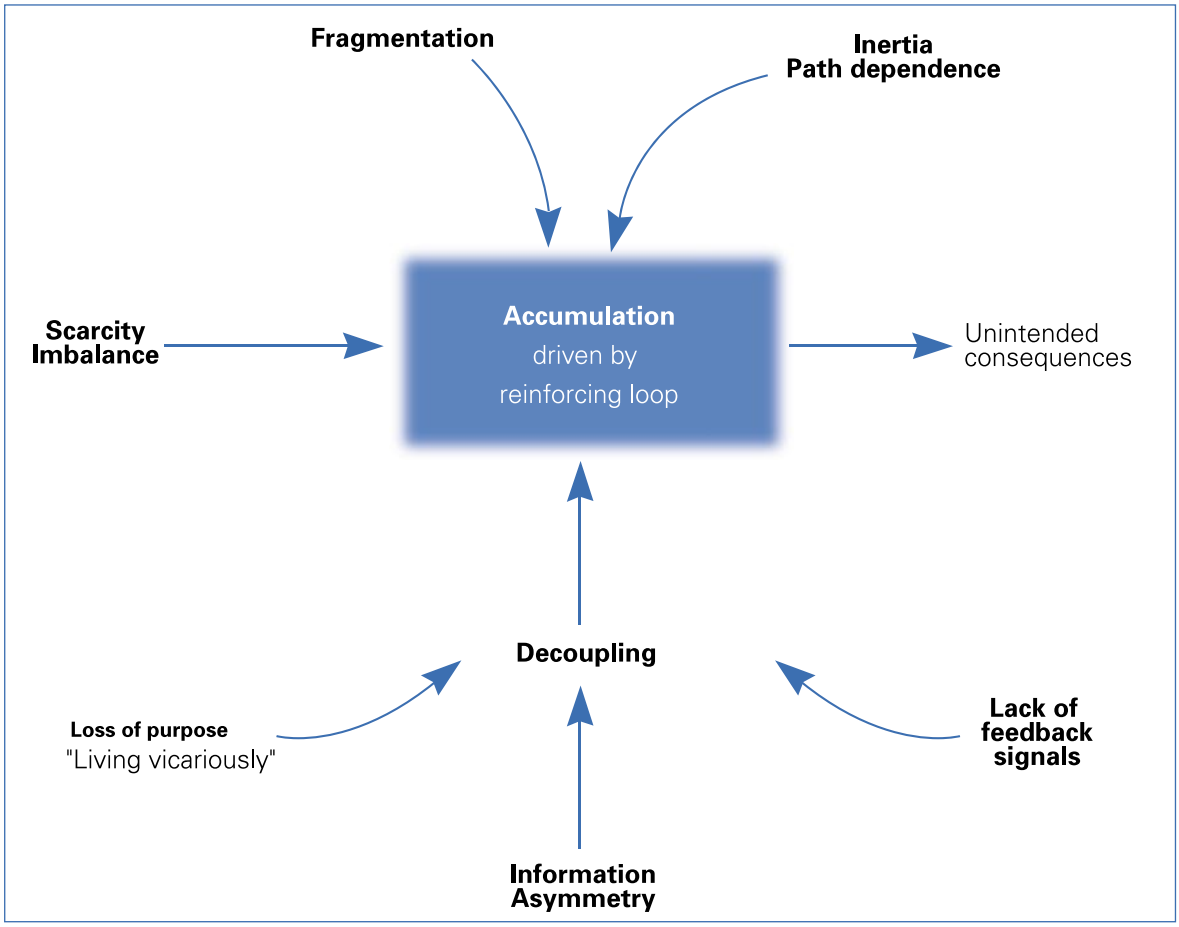
- identifying the system map's **nodal variable**; as explained in Section 2.3.1, this is the conceptual anchoring point around which the system map is meant to revolve
- exploring the basic characteristics of the **obesity system's anatomy and dynamic behaviour** by identifying suggestive metaphors that 'shed light on an essential aspect of the obesity system' and exploring systems archetypes to investigate basic dynamic characteristics of the obesity system and its subsystems. (Note: 'Archetypes' are simple system dynamical diagrams that describe common patterns of system behaviour. Four of these archetypes were selected as a basis for discussion: Tragedy of the Commons, Fixes that Fail, Limits to Growth, and Growth and Underinvestment.[13])

The two key results from these discussions were as follows:

- The **nodal variable** for the system map was defined as 'energy balance': the difference between energy intake and expenditure at different levels of aggregation (from the individual to societal groups and UK society as a whole). This definition was based on the following:
  - A distortion of the energy balance is seen as the observable, measurable basis for overweight and obesity.

  - By focusing on factors contributing to intake and expenditure respectively, it will be possible to draw a large number of contributing variables into the model.
- An overall picture of the obesity system emerged through the workshop exercises, as shown in Figure 5.

Figure 5: Conceptual picture emerging from a metaphor brainstorm exercise in first workshop



The **basic logic** represented in Figure 5 can be summarised as follows:

- At the origin, there is a situation of scarcity, an imbalance between the need for calories and calories available.
- A process of accumulation ensues. This process of accumulation is driven by a reinforcing loop. There is an overshoot into a situation of abundance. This overshoot is an unintended consequence which is driven by the original imbalance.
- There are various fundamental drivers that sustain this reinforcing dynamic:
  - path dependence: there is an inertia in the system, leading it to persist with a behavioural pattern even if it is clear that it is destructive

- fragmentation: there is no single, shared perspective on root causes and ways to deal with them and so there is no concerted action to stop the system from spinning out of control
- decoupling: there is limited information about the actual status of the system, restricting the scope for targeted and effective interventions to change its dynamic behaviour
- the decoupling relates to a number of phenomena: there is a lack of short-term feedback signals. The system has a long time constant. There is a long interval between cause and effect.
- the decoupling may also derive to an extent from information asymmetry: many people do not have the requisite data to make informed decisions about what to do (while some may have that information but are not prepared to share it)
- there is an even more fundamental logic of decoupling in the sense that individuals may suffer from a general loss of purpose and or changing priorities. Increasing number of people live vicariously, offloading responsibilities and goals in life to third parties (intermediaries, role models).

With hindsight, we can confirm that these two results, the nodal variable and the key logic and dynamics underlying the obesity system, have effectively been a solid foundation for the systems work which follows.

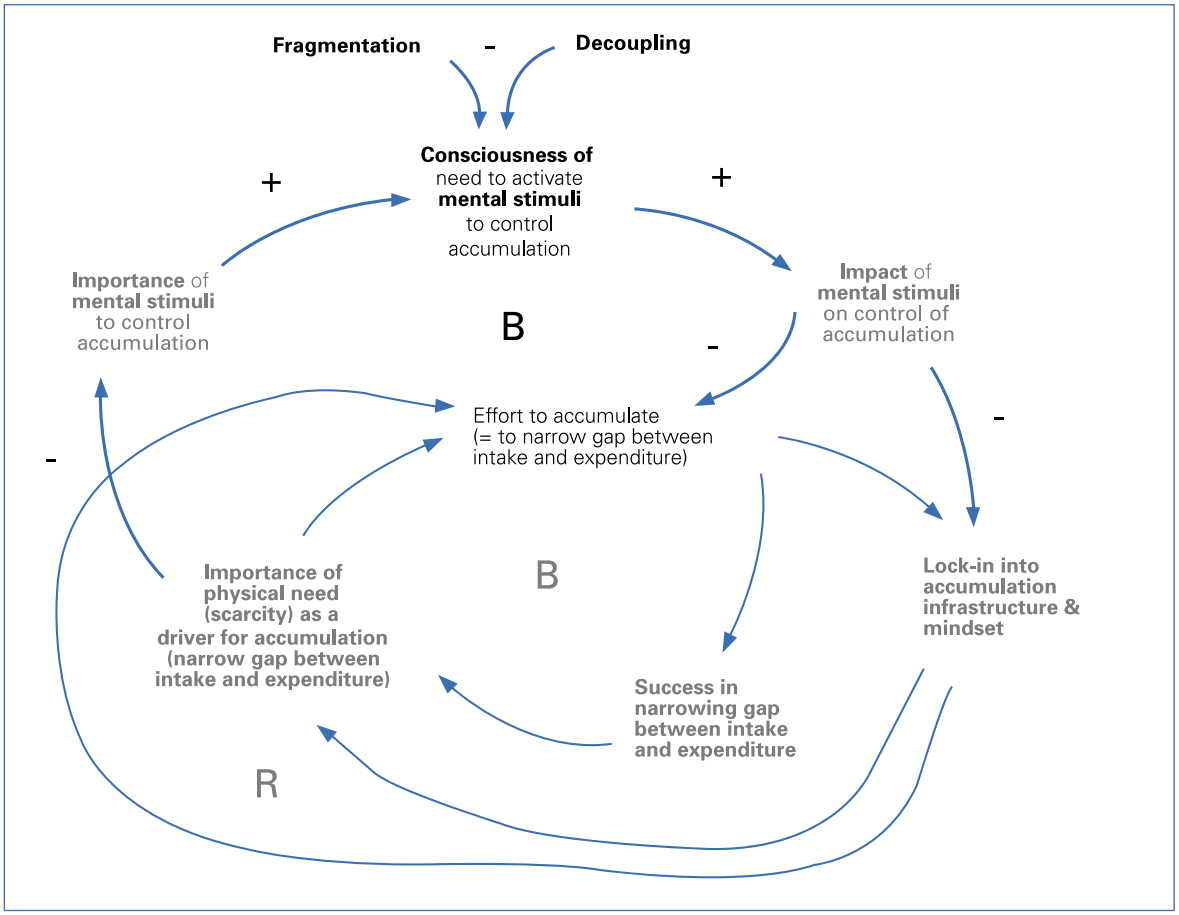
2 Interim modelling work

2.1 Sketching a first core causal loop diagram

Based on the results of the first workshop, WS proceeded with the development of a first, embryonic causal loop model, the core system engine (see Section 3.3.1), which captured the features of the general obesity system described in the previous section.

This first rough sketch of the core system map is shown in Figure 6.

Figure 6: Causal loop version of the conceptual diagram shown in Figure 5



Its basic logic can be summarised as follows:

- First, there is a **balancing loop**: a physical need for energy replenishment triggers a process of energy accumulation in the form of food in order to narrow the gap between energy expenditure and intake. The more effort people put into accumulating energy through food, the more successful they are likely to be in narrowing the gap between expenditure and intake. If people are successful in maintaining this energy balance, we can assume that the physical need, and therefore the drive to accumulate energy, will become less acute, leading to a dampening effect (balancing dynamic).
- Then a second, **reinforcing, loop is activated** and neutralises the dampening effect of the fulfilment of the physical need: if people devote a lot of time, attention, skill and effort to accumulating energy in the form of food, these patterns may become ingrained (at a biological, social, institutional level). A lock-in develops (path dependence). The lock-in triggers the established accumulation patterns and practices, independent of the presence of a physical need. Hence the effect of scarcity is short-circuited. A reinforcing loop takes over and drives an incessant process of accumulation.

- In a situation of energy abundance, **another balancing mechanism** needs to be activated to stop the dynamics from spinning out of control. This mechanism is based on mental/social (non-physical) stimuli. These signals can have a dampening effect on the overall system dynamics by reducing the drive to accumulate and eroding the lock-in. In the present situation, powerful mechanisms of 'fragmentation' and 'decoupling' keep these mental/social stimuli from rising to consciousness and from exercising their dampening effect.

2.2 The database of model variables

In addition to developing a draft core causal loop diagram, WS prepared an initial database of model variables drawn from all the Foresight science reviews available to date. Around 150 causal linkages mentioned by the reviews' authors were identified. Causalities were rephrased in terms of influence on either 'energy intake', 'energy expenditure' or 'obesity' (when it was unclear where exactly the variables link into, or when the influence is on both expenditure and intake).

The database of linkages was segmented into four thematic groups:

- food and food environment
- cultural and psychological
- socioeconomic
- physiological.

3 Second workshop: Model variables

Experts focused on two system-oriented tasks in this joint scenario–systems workshop:

- reviewing the draft causal loop diagram discussed in the previous section

evaluating the preliminary database of causal links drawn from the Foresight Tackling Obesities short science review papers[7].

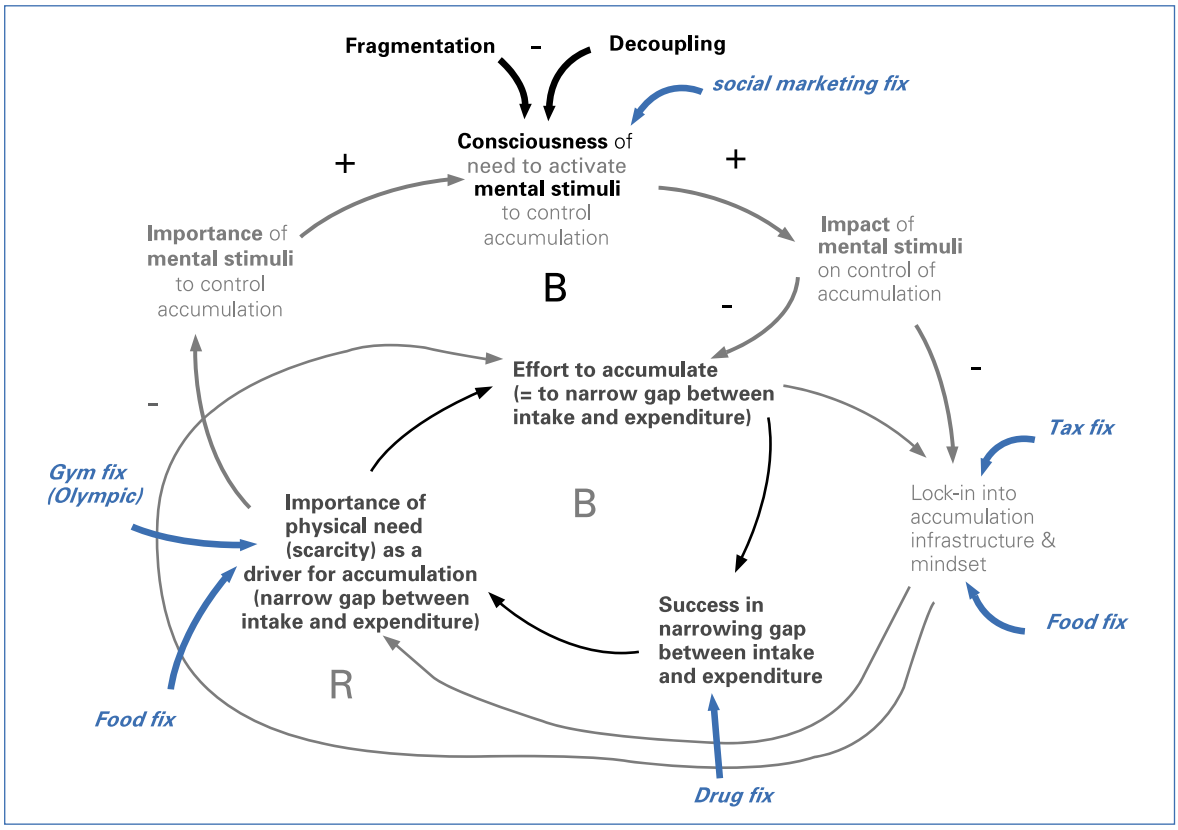
3.1 Review of the draft causal loop diagram

The draft model was reviewed in the workshop. The key observations were:

- The proposed embryonic core system model (which later came to be known as 'the engine' of the obesity system) seemed to be a robust basis for a first full-draft model of the obesity system. Its overall logic was clear and compelling and it seemed to provide a means of capturing the basic dynamics of the obesity system.

- During the discussions in the workshop, it also proved to be a powerful heuristic device to integrate many relevant variables into the model.
- The model also seemed to be an interesting tool to think about where current interventions in the obesity system were taking place and where future interventions ought to take place. This was the first evidence that the model could grow into a tool which could be useful for policy makers. Figure 7 captures a discussion about how various organisations could intervene with a variety of interventions.

Figure 7: Possible interventions by different actors in the obesity system



- The variable 'impact of mental stimuli' was considered to be non-essential and was eliminated from the model.

3.2 Evaluation of the preliminary database of causal links

With respect to the evaluation of causal links, experts were more specifically asked to comment on the following aspects:

- What is the **direction** of the causality?
- What is the **strength** of each link?

- What is the **impact** of each link on the dynamics of the obesity system as a whole?
- What is the **certainty** we have about each causal link?
- What is the **key mechanism** that explains the causal link?

Subgroups of experts considered the causal links within the 'food/food environment', 'cultural/psychological', 'socioeconomic' and 'physiological' themes.

The evaluation of causal linkages across strength, impact and certainty led to the identification of about 25 key linkages with energy intake, expenditure or obesity in general (Tables 7–9).

Table 7: Key linkages for food and food environment theme

Variable	Impacts on	Direction of causality
Energy density of food on energy intake (+)	Energy intake	+
Sugar content of drinks (soft drinks)	Energy intake	+
Portion size	Energy intake	+
Attractiveness of energy-dense food	Energy intake	+
Habit formation	Energy intake and expenditure	+/–
Palatability	Energy intake	+
Learned behaviour	Energy intake	+/–
Food exposure	Food choice	+
Cost of food	Energy intake	+?
Outsourcing of food preparation/convenience	Energy intake	+

Table 8: Key linkages for cultural and psychological theme

Variable	Impacts on	Direction of causality
Parent obesity	Child obesity	+
Over-nutrition at early life stages	Adult obesity	+
Habit formation	Energy intake	+
Importance of societal and personal rituals (low score for available evidence)	Obesity	–
Importance of price in consumers' purchasing behaviour	Energy intake	+
Cultural valuation of food	Food choice	+
Degree of conflict between what people desire and what they need to stay healthy	Food choice	+

Table 9: Key linkages for socioeconomic theme

Variable	Impacts on	Direction of causality
Affordability of energy-dense food	Energy intake	+
Affordability of health food	Energy intake	–
Ethnicity	Energy intake and expenditure	+/–
Income level	Obesity	–
Educational level	Energy intake	–
Presence of inequalities	Energy intake	+

Additional observations were made with respect to the way these variables could link into the core causal loop diagram (the 'engine'):

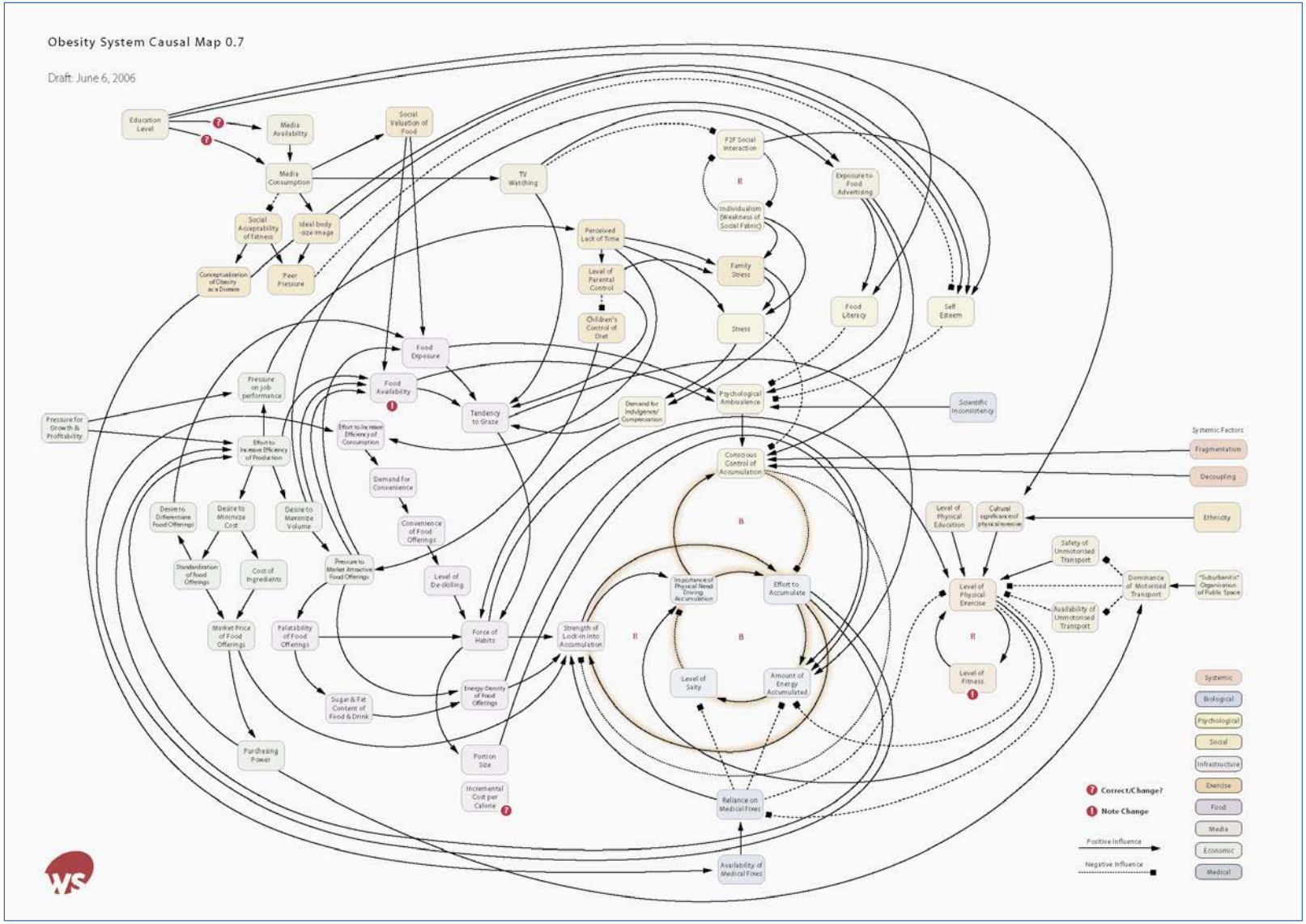
- The majority of linkages in the food (environment) group were positively oriented and linked into 'energy intake' or 'obesity'. This reinforced the perceived importance of all the factors that feed the lock-in (the reinforcing loop in the core system map) or keep the cognitive balancing mechanism from kicking in.
- A similar analysis could be made for the cultural and psychological drivers linking into obesity. Habit formation, the importance of rituals and strong cultural determinants such as parental obesity and over-feeding at an early age could all be considered to contribute to the lock-in. Price and cognitive conflict between what is desired and what is needed most likely fed into the cognitively driven loop.
- Very few variables linked into 'energy expenditure'. This was an primarily because the short science reviews focusing on physical exercise were not yet available for this workshop. This was remedied when the reviews became available. However, the lack of linkages also reflects an absence of available data on which to base judgement.

At this stage the model was still at an early stage. The next step was to refine the terminology used, to streamline its causal logic and to include many more variables in the obesity system.

4 Interim modelling work

The prioritisation of the database of causal linkages and the resulting set of key variables provided a starting point for developing a first, extended, system map on the core causal loop diagram (the basic 'engine'). In preparation for the third systems workshop a draft system model was produced (version 0.7) as shown in Figure 8.

Figure 8: Draft obesity system model (version 0.7)



The causal linkages in the engine of the system model are overlaid with thicker blue lines.

The variables included at this stage of the model building are listed below. They include the key set identified in the second workshop plus many more selected from the initial database to fill in gaps in the causal logic.

List of model variables in version 0.7 of the system model

1 Education level
2 Media availability
3 Media consumption
4 TV watching
5 Exposure to food advertisement
6 Social acceptability of fatness
7 Ideal-body-size image
8 Conceptualisation of obesity as a disease
9 Peer pressure
10 Social valuation of food
11 Face-to-face social interaction
12 Individualism (strength of social fabric)
13 Family stress
14 (Individual) stress
15 Self-esteem
16 Psychological ambivalence
17 Food literacy
18 Scientific inconsistency
19 Perceived lack of time
20 Level of parental control
21 Children's control of diet
22 Purchasing power
23 Demand for indulgence/compensation
24 Tendency to graze
25 Food exposure
26 Food availability
27 Reliance on medical fixes
28 Availability of medical fixes
29 Effort to increase efficiency of production

30 Effort to increase efficiency of consumption
31 Pressure on growth and profitability
32 Pressure on job performance
33 Desire to differentiate food offerings
34 Desire to minimise production cost
35 Desire to maximise (sales) volume
36 Standardisation of food offerings
37 Cost of ingredients
38 Portion size
39 Market price of food offerings
40 Pressure to market attractive food offerings
41 Palatability of food offerings
42 Sugar and fat content of food and drink
43 Energy density of food offerings
44 Demand for convenience
45 Convenience of food offerings
46 Level of de-skilling of consumers
47 Force of habits
48 Level of physical education
49 Cultural significance of physical exercise
50 Level of physical exercise
51 Level of fitness
52 Safety of unmotorised transport
53 Availability of unmotorised transport
54 Dominance of motorised transport
55 'Suburbanitis'/organisation public space

5 Third workshop: Review of the draft model

In the third workshop, experts were invited to contribute to two tasks:

- supplementing the database of variables included in this draft version of the obesity system map
- reviewing the draft version of the model.

5.1 Supplementing the database of variables

For the first assignment, experts were simply presented with a list of variables included in the model and were asked which variables they thought were missing.

This exercise led to the following list of suggested variables (labelled with Roman numerals to distinguish them from the variables already included in the model):

List of additional variables suggested by experts

I Reliance on medical fixes for obesity
II Reliance on medical fixes for consequences of obesity
III Level of infections
IV Social environment
V Symbolic valuation of food
VI Proportion of women working
VII Level of employment
VIII Income level (relative)
IX Perceived safety of environment
X Degree of access to resources (financial, material, knowledge, etc.)
XI Level of acculturation (incorporation of ethnic influences)
XII Level of impact of smoking cessation
XIII Strength of norms
XIV Activity/exercise
XV Level of activity at work (activity-inducing/preventing working environments)
XVI Walkability
XVII Level of physical activity
XVIII Level of activity during leisure time
XIX Level of access to opportunities for physical activity
XX Degree of environmental opportunity/encouragement of physical activity
XXI Degree of innate activity during childhood
XXII Degree of learned activity patterns in very early childhood
XXIII Degree of opportunity for team-based activity (peer-pressure mechanism)
XXIV Cost of physical activity (financial, time, as well as social barriers?)
XXV Responsiveness to food environment
XXVI Nutritional value of food available in schools
XXVII Quality of maternal nutrition
XXVIII Sensory specific satiety
XXIX Fibre content of food
XXX Degree of political promotion of consumption
XXXI Food monoculture (degree to which access, advertisement and food as lifestyle element dominates food choices)

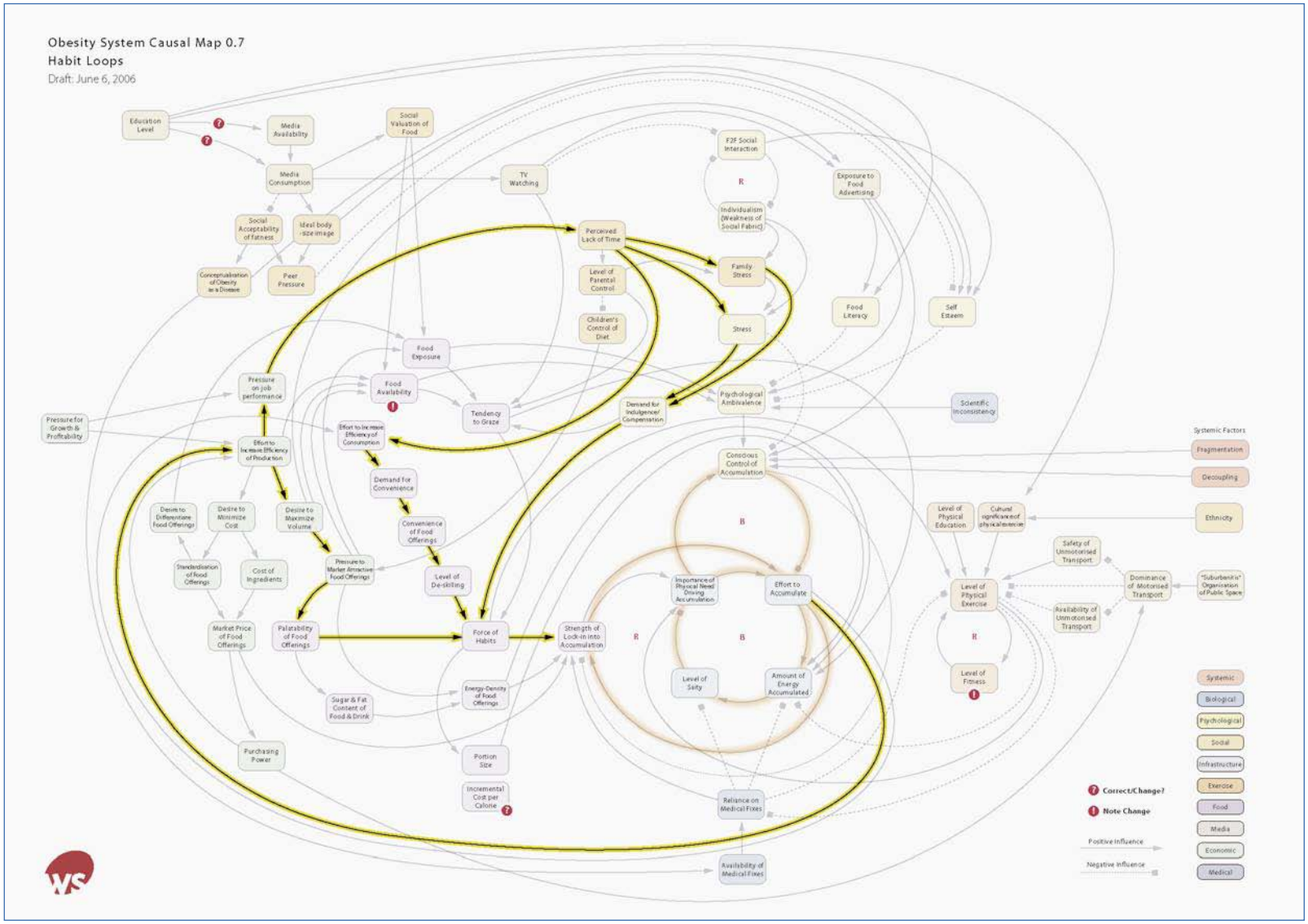
XXXII Level of alcohol consumption
XXXIII Predisposition of children
XXXIV Age at adipository rebound (marker or variable?)
XXXV Time span of breast feeding
XXXVI Level of practice and quality of weaning
XXXVII Quantity and quality of maternal nutrition
XXXVIII Level of genetic responsiveness to obesity
XXXIX Understanding of obesity determinants
XL Responsiveness to satiety
XLI Provision of oral hygiene
XLII Thermally neutral environment.

5.2 Review of the draft model

The review of the model was done in two stages. First, the model was presented to the experts who were invited to comment in a plenary session. A discussion of individual loops in the draft system model then followed. These loops had been identified by WS as useful starting points to study the different areas of the system map (by way of example, only the habit loop is shown in Figure 9). The loops were preliminarily labelled as:

- Transport loop
- Medical fix loop
- Education loop
- Parental control loop
- Convenience loop
- Stress loop
- Grazing loop
- Habit loop
- Food production loop.

Figure 9: Example of a loop ('habit loop') as discussed in the third workshop



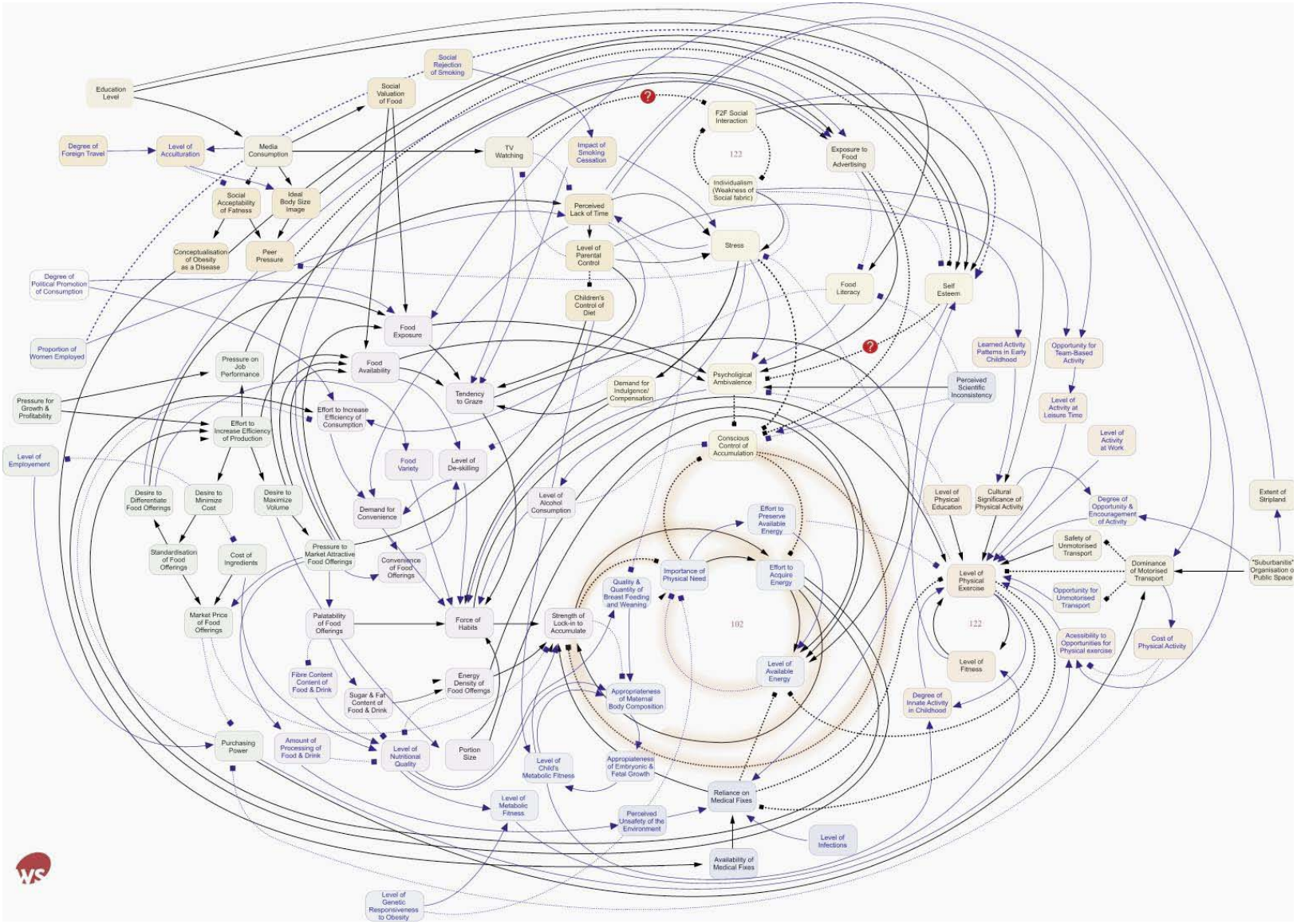
The results of these discussions can be summarised as follows:

- In general, the draft system model was endorsed. The basic architecture of the model was considered valid.
- The experts suggested a number of additional linkages to the model:
  - an additional link between 'importance of physical need' and 'net amount of energy accumulated' via 'effort to preserve energy'. This link also allows the inclusion of the variable 'activity level', which then allows linkage to many of the physical-activity-related variables.
  - an additional mechanism that predisposes child development to obesity as a consequence of inappropriate nutritional patterns at conception, pregnancy, breast feeding and weaning.
  - an unbundling of media influences with a positive effect, supportive of a health lifestyle, and a negative effect, leading away from a healthy lifestyle. Likewise, an unbundling of retailers' strategies into those that support a healthy lifestyle (as part of a differentiation strategy) and those that do not (by focusing on cheap, high-volume food products).
- There was a concern that the model might become too complex to be useful for analysis and decision making.
- It was clear that utmost care needs to be taken in the wording of the variables and loops in the map. This needed to be refined in subsequent iterations.

6 Interim modelling work

The system map was updated according to the outcome of the workshop.

Figure 10: Updated system map after the third workshop



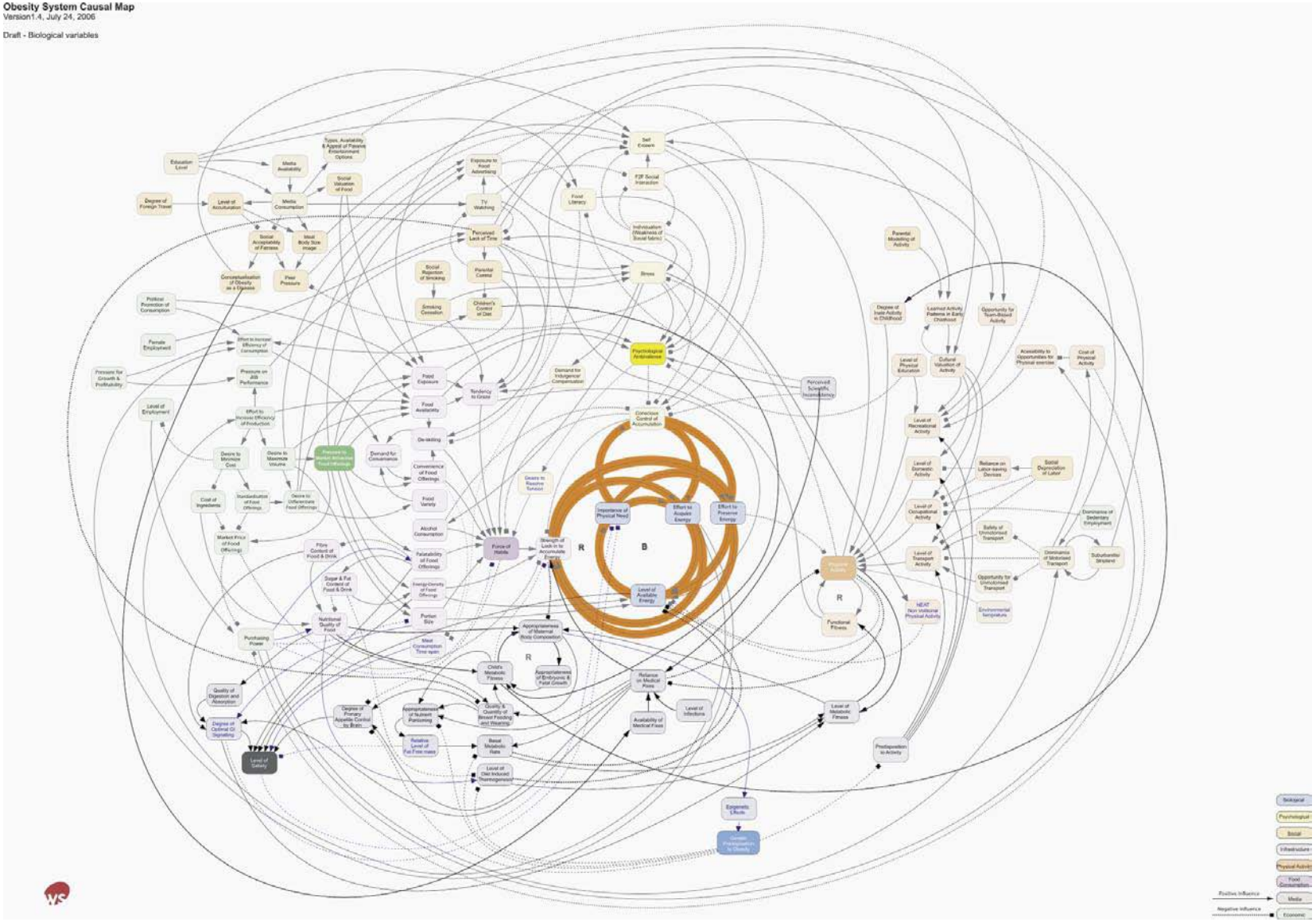
7 Fourth workshop: focus on physiology aspects

Despite numerous additions arising from the second workshop, the physiological part of the map remained somewhat underdeveloped. Therefore the initiative was taken to organise a focused work session with a limited number of physiology experts to review, streamline and expand this particular aspect of the emerging obesity system map.

Following this discussion, a number of variables in the physiology-related part of the map were renamed, others were added (degree of control GI signalling, level of fat-free mass, non-volitional physical activity, epigenetic effects), eliminated or reinterpreted (particularly genetic predisposition). As a result the physiology-related area of the map was made significantly more robust and comprehensive. It now encompassed metabolic, genetic, epigenetic, endocrinal, neurological and inherited effects.

The overall architecture of the obesity system map remained intact. Figure 11 shows the updated map after this process.

Figure 11: Updated system map after physiology workshop



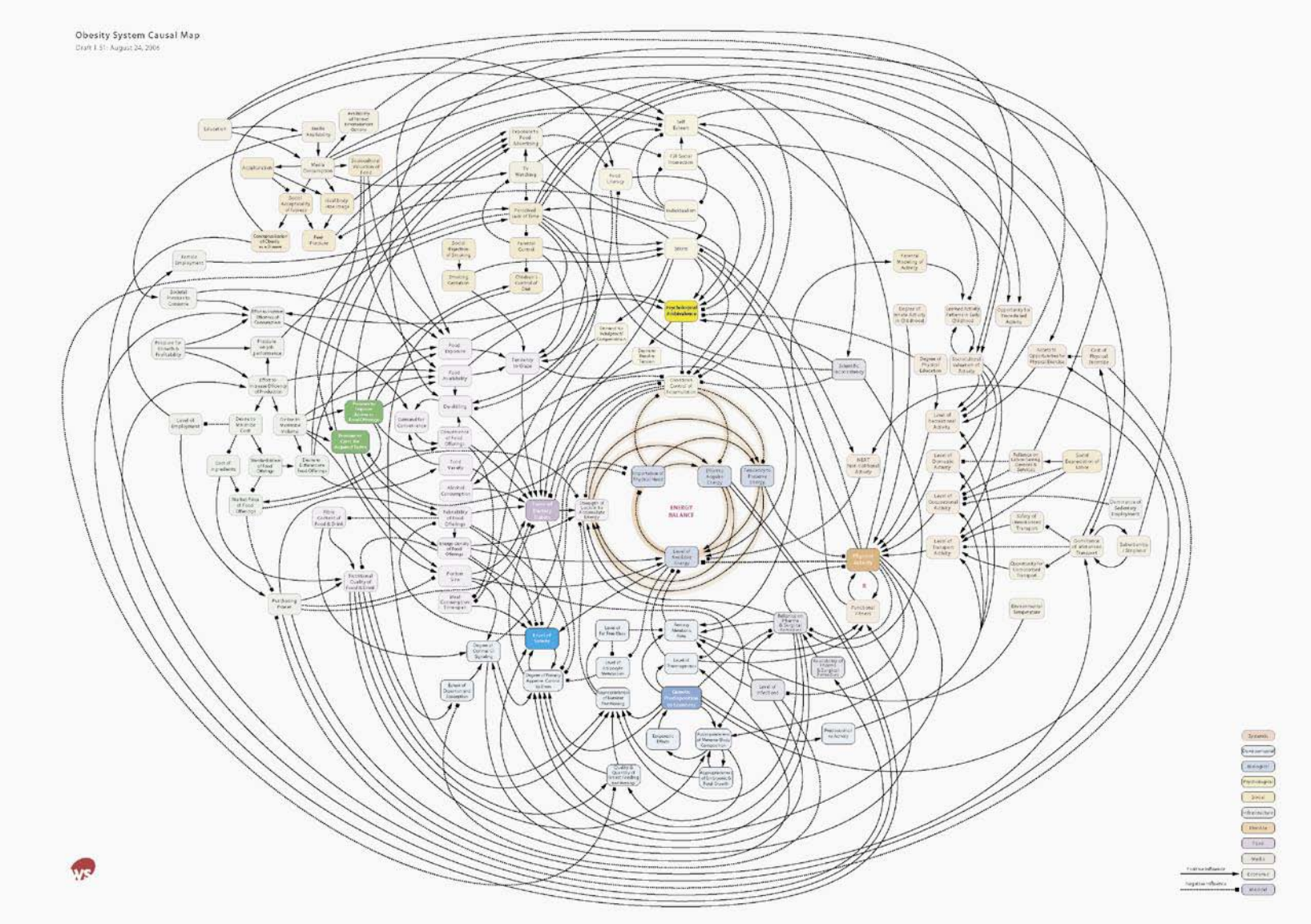
8 Interim modelling work

The basic architecture of the map was then further refined through numerous bilateral interactions between the experts, Foresight and WS. Attention was also given to ensuring a meaningful link between the system map and the developing scenario framework.

Detailed expert review of the map was sought through a questionnaire (see overpage). This was intended to gather experts' opinions on the strength, impact and certainty of all the causal linkages in the map so as to come to an overall assessment of their relative importance.

Further suggestions for refinement from the Foresight science advisers and substantial visual streamlining led to another update of the system map (Figure 12) to use with this questionnaire. The interactions with experts in conjunction with the questionnaire and in the run-up to the final (qualitative modelling) workshop provided further opportunity for adjusting the system model.

Figure 12: Updated system map as basis for expert questionnaire



9 Expert questionnaire

The purpose of the expert questionnaire was to gather qualitative data on the relative importance of the causal linkages featured in the system map (not to expand or question the architecture of the map).

The assignment was similar to the work performed by the experts. In both cases, the aim of the review was a qualitative prioritisation of the causal linkages in the obesity system. However, this time the linkages were based on a near-final version of a complete obesity system map.

Experts were asked to evaluate each linkage (within their area of expertise) based on a qualitative assessment of the **strength** of linkage ('strong' meaning that small changes in variable 'a' lead to changes in 'b')

In addition, experts were asked to judge to what extent these characteristics were subject to gender, age, ethnicity and socioeconomic class effects. So, four additional columns in the questionnaire asked for:

- binary assessment (Y/N) of a given linkage being subject to a gender effect (is the linkage stronger/weaker depending on gender?)
- binary assessment (Y/N) of a given linkage being subject to an age effect)
- binary assessment (Y/N) of a given linkage being subject to an ethnicity effect
- binary assessment (Y/N) of a given linkage being subject to a class effect.

Those with expertise in the various key areas of the system map (physiology, physical activity, (social) psychology, and the food environment) were invited to comment.

An initial view can be generated from the response. However, the exercise was challenging because of the lack of robust data on which to base a view in many areas. Scarcity of data becomes an important structural issue for the exercise when trying to link up different research areas as this system map aims to do. With regard to gender, age, ethnicity and class effects, the input was too patchy and it was not possible to use the exercise for even an approximate assessment. Unfortunately, this aspect will remain unexplored within the scope of the present analysis but highlights an area for future investigation. For demonstration purposes only a map has been included that shows how the obesity system would appear for the subgroup of children aged 6–16 years.

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