Transfor**m**ing Urb**an** Foo**d** Systems for Planet**a**ry and Popu**l**ation He**a**lth
~ The Mandala Consortium ~

Start date and duration

22/03/2021, 60 months

Investigators

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Summary

In this proposal we set out our vision for five years of research that will help bring about important changes in the food system. The changes aim to make food healthier, more affordable, less harmful to the environment, but still acceptable to businesses. The work will involve many different types of researcher, who do not usually work together, as well as commercial companies, a city council, and civil society organisations. Our findings will influence local and national governments, food companies and other organisations that play important roles in bringing healthy, affordable and sustainable food to communities.

The research will focus on Birmingham, a large English city with a diverse population. The work will be divided into six work packages that will be closely connected. The research team will work together on each of the work packages and share their findings regularly. This will help to ensure that our work achieves effective food system change in Birmingham and can be used by other places trying to make similar changes.

In the first work package, we will work with communities and people from the local council and food businesses to create a map of the current food system. This will show the different types of

businesses and other organisations involved, what they do and how they work together to deliver food to communities. We will explore how money and food flows through the system. We will have meetings with community members and people from the relevant organisations to ensure we properly understand the whole of the food system.

We will use our 'system map' to work out what information we can use to measure how the food system works. Where possible, we use data that is already collected that we can use creatively and efficiently. We will collect new data when necessary using new methods. We will look for ways to bring different types of data together so that it can be used to measure changes in the food system over time and in response to new policies or programmes. We will analyse the information to see what it tells us about how the food systems works.

Once we have a map of the food system, and an understanding of how it works, we will help Birmingham City Council develop plans to change the food system. The aim of changes will be to make food more healthy, more affordable and better for the environment without negatively affecting businesses. The plans will include actions that are practical, affordable, likely to achieve our aims and compatible with other national and local policies. Possible actions might include changing business rates to encourage sale of healthier foods, or developing online systems to help local businesses find and use more locally grown food.

The next stage of the research will be to implement the plans and explore which of the actions work best to achieve our aims – both singly and in combination. Because the programme of work will only run for five years, we will not be able to study long term impacts of actions. Instead we will build a computer model to predict how the actions that are tested in real life are likely to affect health, the environment, the economy and food business in the future. The model will also provide a useful tool for local councils and food businesses in other places to explore how different actions might impact differently on health, the environment, the economy and businesses. The results will help make plans for changing the food system in other cities and regions.

Throughout the five years, we will talk regularly to other scientists and people in food businesses, the council and the community. We will share our thinking and findings and seek their views on how our work is evolving. We will develop a number of attractive ways to share this information, including films and blogs, newspaper articles and scientific papers.

Objectives

OUR VISION

Our vision is to catalyse urban food system transformation, focusing on the City of Birmingham as a scalable case study. We will partner with citizens and food system stakeholders to create a reproducible, collaborative change process. Together, we will forge a novel, local research ecosystem to ensure the co-production of evidence-informed solutions to current food system challenges. The food system interventions generated will lead to substantial positive health, environmental, economic and societal impacts. The body of knowledge generated will be used to influence action in cities across the UK and internationally.

AIMS & OBJECTIVES

Our interdisciplinary consortium includes international experts in population health, food and nutrition, environmental sustainability, health economics and commerce, renowned for their disciplinary expertise, theoretical and methodological developments, and capability for strategic leadership. The consortium aims to undertake world-leading research, systematically generating evidence on urban food system transformation with the aim of achieving a healthier, more sustainable, more equitable and economically viable food system. We will consider the current food system as complex and adaptive, applying system thinking to develop our programme of transformational research. We will realise our vision and achieve this aim by delivering six, interconnected work packages (WPs) framed by the following objectives:

WP1

1. Engage professional stakeholders and citizens to foster dialogue, co-production of the programme of research and drive food system transformation
2. Generate a map of the Birmingham food system and identify key challenges, desired outcomes and leverage points for potential interventions

WP2

3. Undertake evidence syntheses to support system mapping, identification and prioritisation of food system interventions, and parameterisation of models to simulate the impacts of food system change on environment, health, equity and economy
4. Curate data resources to inform and facilitate food system transformation, evaluations and modelling studies, using routinely available sources, data science methods and primary data collection

WP3

5. Support Birmingham's food system stakeholders and citizens in the generation of a vision for a future food system that is healthier, more economically and environmentally sustainable, offers coherence and complementarity between local and national policy, and delivers accessible and affordable food for all
6. Identify the most powerful levers for change in the food system, co-develop system innovations with stakeholders and citizens, and prioritise interventions for delivery and evaluation

WP4

7. Evaluate the impact of flagship interventions, delivered to achieve rapid food system transformation in Birmingham for the benefit of health, equity, economy and environment
8. Monitor and evaluate change at a whole system level, including system characteristics and citizens' responses

WP5

9. Co-develop integrated food system, population health, economic and environmental models to characterise and understand the food system, and its interactions with populations and environments
10. Simulate the long-term, sustainable impacts of novel interventions to inform local and national policy making and business practice

WP6

11. Synthesise findings across work packages, draw conclusions and identify implications for research, policy and practice
12. Develop practical tools for city actors across the UK, and use multi-channel communications to share theoretical and methodological innovations, and ensure our evidence is used and delivers impact.

Strategic relevance

In the UK, many struggle to afford sufficient nutritious food and experience obesity and diet-related diseases. Poor diet is strongly socio-economically patterned. Healthier foods such as whole grains, fruits, vegetables, nuts and seeds have lower environmental impacts than less healthy foods, such as red and processed meats.[2] Intensive food production has major impacts on biodiversity, habitat loss, and air and water pollution. Obesity and climate change represent a global syndemic with common causes, and substantial external social costs.[3] Achieving healthy and affordable diets from an environmentally sustainable food supply requires co-ordinated food system transformation.

Covid-19 has exposed substantial food system fragility. It has resulted in deaths of people with diet-related diseases, increased food insecurity,[4] challenged food supplies and threatens many food businesses. We will be sensitive to the need to rebuild food systems throughout our work.

In the UK, 83% (54m) of the population lives in urban areas. Cities bring together complex, interacting systems that drive social, health, environmental and economic outcomes. Globally, city authorities are leading policy debate on food system transformation, and pioneering approaches

that integrate health and environmental considerations. National and international networks of cities offer vibrant, evolving communities of practice. In this context, we propose an ambitious programme of interdisciplinary work, co-produced with Birmingham, the UK's second largest city (population 1.2m). Birmingham will serve as a living laboratory in which interventions to deliver healthier, more sustainable and affordable food will be co-designed, delivered and evaluated.

Cities in general, and Birmingham in particular, offer unique advantages for achieving food system transformation. Their scale is large enough to leverage change, but small enough to enable truly joined up thinking across health and environmental policy. Their influence over key areas of food policy (e.g. food procurement in schools; food advertising on transport networks; environmental health etc.) offers opportunities for real change. Birmingham has made a unique commitment to food system change, embedding this commitment throughout many policy areas.

Working closely with our partners, we will support a unique process to diagnose challenges, generate ideas, co-produce solutions and evaluate their impacts on health, economic, equity and environmental outcomes. Interventions will target food retailing, procurement and supply chains; and influence food production by shifting demand. We will ensure economic viability enabling a vibrant food economy. We will consider the food sector as a complex adaptive system, developing understanding of structures, processes, interrelationships, feedback loops, and emergent properties.[5] We will identify the most powerful levers for system change, model the impacts of interventions on these, and design and evaluate interventions singly and in combination. Findings will be synthesised to maximise generalisable causal inference and ensure wider applicability.

Birmingham provides an ideal context for this transformational experiment because of its large and dynamic food system, and proximity to major food producing areas (e.g. Vale of Evesham); culturally and ethnically diverse population (42% of residents are ethnic minority), which includes pockets of severe disadvantage; and high prevalence of less healthy diets, food insecurity and associated morbidity and mortality. Birmingham City Council (BCC) has ambitious plans for food system transformation. Substantial investment has been leveraged by BCC to trigger change over the next 10 years, and the city has been selected by government as a childhood obesity trailblazer. BCC is stimulating public engagement in the development of its Healthy & Sustainable Food Economy strategy ('food strategy'), especially with marginalised communities. Outputs have influenced our proposal and public engagement features throughout our work. BCC has also, with 10 other cities, been awarded an EU Horizon 2020 programme grant (€11.9m) to co-design pilot projects for integrated urban food policies, which will complement and enhance this programme.

Our research will thus integrate with Birmingham's food strategy. We will also seek to become a strategic delivery partner for the forthcoming DEFRA National Food Strategy (NFS), building on established relationships between BCC, The Food Foundation, CEDAR and the NFS team. Our proposed programme offers the potential for NFS proposals to be optimised in Birmingham before national scaling. Our work will thus be relevant to many local and national policy priorities embedded in existing legislation and strategies, including: reducing obesity and diet-related chronic diseases; achieving net zero greenhouse gas emissions by 2050; and reducing the impacts of agriculture and food production on soil health, air quality, water quality and biodiversity.[6-10]

Background

Food system transformation is a uniquely interdisciplinary challenge. The current misalignment of commercial and societal goals, characterised by big health, social and environmental externalities that are not accounted for by the food economy, indicates that change is urgently needed.[11,12] Shifting the commercial food sector towards practices that better align with the creation of population health, social good and environmental sustainability is central to this programme.

The challenges of achieving such shifts in commercial food systems are huge and there are few examples of success. Voluntary programmes have been largely unsuccessful, with some notable exceptions such as the UK's salt reduction programme, and supermarkets' own policies to remove 'junk' food from checkout areas.[13] Regulatory measures have yielded greater impacts, especially those that have explicitly aimed to change industry behaviour, such as the UK's Soft Drinks Industry Levy.[14] Choice architecture experiments have also shown promise in reducing meat consumption, and hence environmental impacts, in food service contexts.[15] However, these are all examples of single policy initiatives that may have limited impacts on wider food systems.

Food system transformation requires multiple, co-ordinated actions, using population level

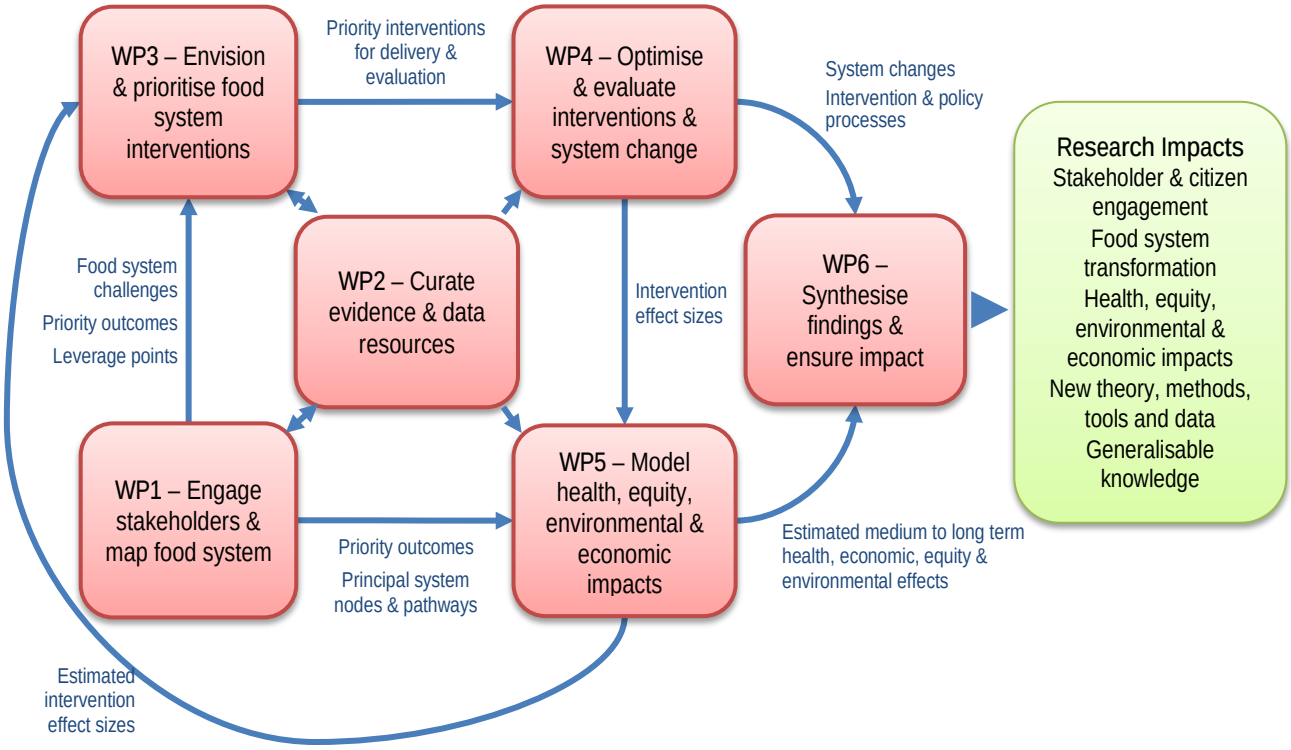
interventions that minimise demands on individuals.[16] Some attempts at urban transformation for health have been attempted (e.g. Healthy Towns, London 2012 Olympic Legacy) but few have proven successful. Evaluation of the Healthy Towns initiative revealed that programmes lacked integration and civic authorities were risk averse, relying on poor existing evidence rather than sound theory and modelling.[17,18] Lack of engagement with systems thinking has prevented effective definition of challenges, identification of plausible solutions and rigorous evaluation.[5]

We will build on our record of world-leading science on complex systems, population health, commerce and sustainability to demonstrate what can be achieved by applying cutting-edge theory and methods to co-produce innovative food system transformation in a major UK city.

Research programme and methods

Our programme will be organised in six interconnected work packages (WP). Objectives and milestones are described in other sections of the application. The dynamic inter-relationships between WP are shown in Figure 1. In WP1, we will engage stakeholders, including citizens, to work with us throughout. We will map Birmingham's food system, identifying organisations and their relationships. We will identify prevailing challenges and envision a future food system that helps achieve a healthier, affordable and sustainable diet for all. The system map will inform the curation of evidence and data to help us understand the food system and evaluate changes (WP2). With stakeholders, we will identify the most powerful leverage points to achieve the vision and prioritise interventions to deliver and evaluate (WP3). We will co-develop promising interventions and evaluate flagship interventions as well as wider system change (WP4). In WP5, we will use modelling to better understand the food system defined by our system map, and simulate impacts of interventions on health, equity, environment and economy to create an iterative dialogue with stakeholders in WP3. We will also model the long term effects of interventions evaluated in WP4, and their likely impacts in other contexts. The generalisable knowledge generated by WP4 & 5 will by synthesised and shared widely to maximise impact (WP6).

Figure 1: Relationships between work packages, outputs/inputs and research impacts



WP1 – Stakeholder engagement and system mapping

Leads: White (overall, 1.3 & 1.4), Taylor (1.1), Nicholas & Cummins (1.2)
Other key contributors: Dicks, Frew, Smith, Srai

In WP1 we will establish a shared understanding of how the current food system works and how it might be changed for the better. We will engage professionals and citizens to generate a map of Birmingham's food system, determine what needs to change and how that might best be achieved.

1.1 Engaging key food system stakeholders

We will recruit 25 stakeholders in each of four groups (total n~100) to work with over five years. The four groups will comprise: adult citizens, and business, public sector and voluntary sector actors in the food system. We will secure groups with: (a) diversity of experiences, (b) commitment to food system change, and (c) unique food system insights. All interactions will be governed by a policy to manage conflicts of interest, particularly those arising from the potential for commercial gain.[19,20] Members will serve as experts regularly informing and co-producing the programme's research, and acting as change-makers in their spheres of influence. These processes will build on Birmingham's online citizen survey and its year of food conversations in 2019, which engaged "seldom heard voices". A Healthy & Sustainable Food Economy Forum, established to engage leaders in the city's food economy, will help steer this work. Long term engagement will be maximised by ensuring a focus on stakeholders' interests and needs throughout.

1.2 Mapping the Birmingham food system

In a series of workshops with our four stakeholder groups we will map the food system and relevant sub-systems across Birmingham, as well as links to the wider food economy. We will consider the food system as complex and adaptive, applying systems thinking to explore structures, relationships and dynamics. This will allow us to capture critical attributes including: context, resources, activities, processes, actors and interdependencies[21] in terms of linkages and flows. Mapping will be iterative, with critical input from stakeholders in four phases. The resulting map will provide a foundation for: (a) identifying problems that need to be fixed (WP1.2-3); (b) locating key leverage points for the application of interventions (WP1.4); (c) selecting and validating data sources to understand, monitor and evaluate interventions (WP2); hypothesising modifiable causal pathways for interventions (WP3) to underpin evaluative studies (WP4) and generalisable causal inference (WP6); and (d) modelling studies to simulate the long term effects of potential interventions on food supply, diet, economy, health and environment (WP5).

Phase 1: A 'static' conceptual map of Birmingham's food system and sub-systems will be co-produced with stakeholders, drawing on their experiences, as well as data, evidence reviews and case studies (from WP2). Explanation will be aided by interactive visualisations such as trade flows, word clouds and heat-maps developed using open-source and specialised software. The resulting 'sketch' will highlight key uncertainties and take an engaging visual form that can be validated, developed and refined to derive a representation instantly recognisable to stakeholders.

Phase 2: Group Model Building (GMB)[22] is an engaging method that facilitates development of causal loop diagrams and qualitative system dynamics models. We will hold a series of participatory workshops to refine the Phase 1 map to produce a more detailed and accurate representation of the Birmingham food system(s). GMB improves understanding of the problem, increases participation and will build confidence in the idea that action on healthy and sustainable diets requires systems thinking, and develop consensus for action amongst diverse stakeholders. Causal loop diagrams will characterise system properties and represent dynamic relationships between system components, such as organisations, sectors, supply chains, stakeholders and citizens. Where feasible, we will limit complexity and identify and quantify uncertainty.

Throughout we will combine a rigorous scientific approach whilst providing an illuminating and engaging process for stakeholders. For example, to provide sufficiently structured syntax and semantics to ensure consistency in the interpretation of supply chains, physical 'walkthroughs' of the food system will be performed to capture salient flows and the associated information logistics using the Business Process Model and Notation (BPMN) approach.[23] These models identify business processes and information flows in case studies (see Table 1 for examples), and can be used to identify vulnerabilities and opportunities for intervention to improve system resilience.

Phase 3: Reducing critical uncertainties – Uncertainty about impacts of change is inherent in any GMB exercise. We will identify which uncertainties are critical to achieving outcomes and explore

how these can best be minimised using existing data. To maximise engagement, interpretive structural modelling gamification tools[24] will be used to capture stakeholder views on the complex relationships between food system parameters. Structures and their inputs, outputs, flows and transactions will be operationalised with expert input to explore future transformations. This will iterate with WP2 (Evidence and Data Resource) and WP5 (Modelling) to generate a dynamic food system model. Data that describes connections between food system structures, and flows of goods and revenues, will shed light on key linkages that maintain system equilibrium and offer leverage points for desirable change. There will necessarily be a trade-off between detail and uncertainty. Some aspects of the system where we have greater certainty may be treated as larger, more complex entities in themselves without the need for further detail. Others may be prioritised for more detailed development to underpin development and evaluation of interventions.

Phase 4: In principle testing of the system map – We will identify a set of concrete 'use cases' to 'sense test' the system map and its utility for stakeholders (see examples in Table 1). These examples will be used to explore the potential effects of leverage points in the system (see 1.4 below) through formal modelling (in WP5), helping to define likely successes and failures, and supporting ranking of potential interventions for prioritisation in WP3.

1.3 Determining desired outcomes of food system change

In stakeholder workshops we will determine outcomes of relevance to the programme. These will be specific and measurable and relate to the key domains of interest: sustainability, health, equity and economic viability (e.g. a specific absolute increase in vegetable consumption; or a specific relative reduction in life cycle greenhouse gas emissions associated with food). While derived locally, outcomes will align closely with national priorities (e.g. in the National Food Strategy). Similar methods will derive impact targets, to ensure accountability and achieve political support.

Table 1: Examples of potential interventions in relation to work packages

	Potential interventions		
WP	*Maximising public procurement as a lever for change*	*Variable business rates based on health & environmental criteria*	*Development of a digital market place for fresh, local produce for SMEs*
1	Map public sector supply chains. Identify procurement leverage points.	Map food business economy. Identify leverage points for fiscal measures.	Map grocery SMEs supply chains. Identify leverage points for enhancement.
2	Identify data to measure change in supply chains, consumption, consumer responses, sustainability & health.		
3	Detail interventions at key leverage points (e.g. School Food Plan). Develop theories of change. Prioritise measures to implement & evaluate	Determine policy enablers (e.g. clear rules, responsiveness to fiscal stimuli, business acceptability). Develop theories of change. Prioritise measures to implement & evaluate	Develop prototype linking regional producers & suppliers to SMEs to shorten supply chains, allow greater flexibility of supply, & provide key metrics on provenance, sustainability & health.
4	Design & deliver process & outcome evaluation (e.g. dietary change, acceptability, economic viability, environmental impact).	Design & deliver process & outcome evaluation (e.g. corporate behaviours, consumer demand, impacts on businesses & wider economy)	Design & deliver process & outcome evaluation (e.g. contextual influences, impacts on production & supply businesses & wider economy)
5	Model the chances of people modifying their behaviour to accept/avoid the intervention. Model the associated longer term QALY benefits or losses	Model the chances of establishments adopting change, and the rebalancing of their demand and prices. Model the associated reduction change in emissions and health benefits.	Model the benefit to SMEs of local vs wholesaler supply e.g. in time saved buying food, and satisfaction in having food of known origin. Model biodiversity impacts of less reliance on global food chains.
6	Determine generalisable lessons of policy process. Disseminate findings via multiple channels.		

1.4 Identifying leverage points for system change

Revisiting the system map in further stakeholder workshops, we will identify key leverage points where change might be initiated. Each of these will be considered in terms of potential impact,

seeking to identify the most powerful levers that could achieve change in existing paradigms, structures and goals, rather than lower level entities and behaviours.[25] This is likely to yield multiple options, which will be prioritised in terms of their potential for viable interventions, likely positive and negative impacts, feasibility and costs. Identifying and appraising interventions to act at key leverage points will take place in WP2.3 & 3 respectively, with simulated outcomes derived in WP5.

WP2 – Creating an integrated data and analytics platform

Leads: Cummins (overall lead and data collection and curation), Dicks (evidence synthesis)
Other key contributors: Adams, Burgoine, Loopstra, Srai, Smith

We will create a novel, integrated and flexible data and analytics platform for Birmingham and comparator areas (described in section 2.2). We will collect primary data and exploit multiple secondary data sources, alongside rapid evidence syntheses to inform system maps, model building, and prioritisation of interventions. All data will be made publicly available, except where there are contractual or ethical obligations for confidentiality. Our aspiration is to develop the platform into a data and visualization dashboard with stakeholders. This will require long term ownership and legacy plans which we will explore in WP6. The platform will allow us to:

- Assess the food system and its outcomes, and identify areas of need and challenge (WP1)
- Develop theories of change and evaluate impacts of interventions on diet and environmental sustainability, overall and in population sub-groups (WP3.2, WP4.2)
- Evaluate the impacts of interventions on food system characteristics (WP4.3)
- Generate rich data on intervention implementation and explore the lived experience of interventions to enable optimisation and scale-up (WP4.2, WP4.3).
- Provide quantitative and qualitative data to inform and parameterise food system models to simulate the medium to long term impacts (WP5)

2.1 Evidence synthesis

Rigorous evidence syntheses will support tasks throughout the programme, using three main methods: *(a) Solution scanning:*[26] to identify the widest range of possible interventions to match leverage points identified in WP1.4 and provide critical input to WP3.1. We will generate exhaustive lists of interventions to induce city-level food system change (see table 1 for examples). Starting with lists derived from literature, established frameworks and databases (e.g. the Nourishing database), we will consult our stakeholders and wider networks (e.g. Sustainable Food Cities Network, the Milan Urban Food Policy Pact cities, the C40 and Euro Cities initiatives) to develop long lists of possible interventions. (b) *Causal criteria analysis:* synthesizes understanding of causal linkages in a system by assessing causal mechanisms against a set of pre-defined criteria.[27] We will apply this to key elements of the food system map. Finally, (c) *Rapid evidence assessments:*[28] will be conducted to help appraise and prioritise candidate interventions in WP3, develop theories of change in WP4, and key inputs (e.g. effect sizes) for models in WP5. Throughout we will actively seek evidence from all relevant disciplines.

2.2 Population, consumer, food chain, stakeholder and environmental data

We will collate data from Birmingham and comparator local authorities. Comparators will be Birmingham's 'statistical neighbours' as defined by the Chartered Institute of Public Finance and Accounting and determined by matching on 41 socio-economic indicators. Comparator areas will enable contextualisation of Birmingham data at baseline and provide evaluative 'controls'. Data will be collated in four broad domains, as follows.

Domain 1: Population and consumer data

Population data: We will commission an online, annual, longitudinal panel study comprising a representative sample of adult residents in Birmingham (n=2000) and comparator areas (n=2000), modelled on the International Food Policy Study, for which Adams and White are UK lead investigators.[29] Data will be collected in three annual waves (2022-24), allowing us to evaluate the impacts of interventions (WP4) and inform modelling (WP5). Participants from previous waves will be invited to take part in subsequent ones, with replacement where necessary. We will collect self-reported data on socio-demographics; food and environmental knowledge and attitudes; food access and spend; food insecurity; local food environment use; diet (using Intake24)[30] and physical and mental health. A sample size of 4000 is robustly powered to detect relevant differences.

Consumer data: We will use Kantar WorldPanelPlus (KWPP), a representative consumer panel on household food and beverage purchases, to evaluate impacts of interventions on household food

purchases (WP4) and their subsequent environmental impacts (WP4, WP5, Domain 4 below). A time-series from Birmingham (n=1,800) and comparator areas (n=1,800) will be available and temporally aligned with the longitudinal panel study (2022-24). KWPP collects objective data on all foods and beverages purchased via scanned receipts collected through a mobile app (Shopix). Data is collected at the food and beverage item level and linked to self-reported household socio-demographic data, purchase location and nutritional information (e.g. fat, salt, sugar content).

We will also collate routine, spatially referenced, small area administrative (e.g. population, built environment, neighbourhood deprivation), food environment (see Domain 2) and routine health data (e.g. hospital admissions, childhood obesity). These will provide inputs to modelling (WP5) and enrich population and consumer panel data through address-level geocoding linkage.

Domain 2: Food production, manufacturing & retail data – We will collect dynamic, time-stamped data on food production, manufacturing and retail systems in Birmingham and comparator areas to parameterise models (WP5) and evaluate interventions (WP4). In addition to being a stand-alone resource, this data will enrich Domain 1 data. Over time, this will become a unique and powerful resource, as data cached may not be available retrospectively from its original source.

Manufacturing & production: We will curate data on food supply chains using combinations of Enterprise Resource Planning Systems, Wholesaler Stock Systems and other digital platforms in supply systems. We will seek access to data from procurement channels in the public sector (e.g. NHS, schools, prisons). This will provide information on supply from food distributors and producers (using procurement data) and delivery (through logistics providers). The impact of food (and nutritional) choices on demand and supply patterns will be modelled in WP5.

Retail & provisioning: A variety of sources will be combined to generate a novel food retail and provisioning dataset. Routine sources will include Ordnance Survey Points of Interest and Food Standards Agency Environmental Health data. Non-routine sources will be accessed through the Google Places API, meta-data from supermarket and food-delivery websites and FoodDB - an open database of foods and drinks available in six online UK supermarkets.[31] Data will be collected using previously developed automated extraction and storage tools. Data will include location and category of outlets, opening hours, hygiene rating, delivery options, menus and prices. Data on non-retail sources of food provided to marginalised groups will also be collated (e.g. food banks).

Domain 3: System actor, stakeholder & citizen data

System cohort: We will establish a novel 'system cohort' of food sector stakeholders (n~60) to qualitatively track, monitor and evaluate overall food system change. They will be purposively sampled to achieve breadth of coverage across sectors and roles and will complete a regular online survey. A sub-sample (n~20) will take part in annual in depth, qualitative interviews to provide detailed narratives on change processes, barriers, facilitators and outcomes.

Citizen data: We will create a participatory panel to capture citizen voices, their engagement with food and the food system, its challenges and change over time. Data will be generated using a custom digital platform and will include photos, text, and food environment data. Participants (n~100) will be purposively sampled to achieve maximum variation with respect to age, sex, ethnicity, socio-economic position and geography. We will enable data sharing between panel members to stimulate discussion and debate – which will form additional data for analysis.

Domain 4: Environmental data – To assess the environmental and sustainability impacts of consumer behaviour and food system changes, three sets of environmental data will be collated.

Life Cycle environmental impact: Using meta-analytical methods,[32] we will spatially partition global data on the full Life Cycle environmental impacts of >40 product groups, to differentiate these impacts according to source region, at the finest spatial resolution possible (continental or smaller).

Country and place of origin food: We will use existing crop production and trade data[33] to estimate relative proportions of foods consumed in the UK that are produced in different locations. This will enable weighted average life-cycle impacts to be calculated for foods, which we will refine further with more detailed information about Birmingham's food provenance derived from Domains 1 & 2.

Biodiversity impacts of food production: Using a recently developed method,[34] we will compile data on the proportional overlap between aggregated food source locations and species' spatial distributions to estimate the global biodiversity footprint of specific food products from different sources, in terms of enhanced extinction risk to more than 20,000 species.

2.3 Data preparation, integration, analysis and presentation

All data will be time-stamped and georeferenced where feasible to enable linkage and flexibility. The nested, multi-level structure of the resources will allow derivation of bespoke datasets that can be analysed at appropriate scales (individual, household, neighbourhood or system) to answer specific questions throughout WPs 3-5. The platform will be an important legacy in its own right, as we aim to provide all collected data in an open and accessible format for future use. We will explore the potential to develop the platform into a data and visualization dashboard in WP6.

WP3 – Envisioning and prioritising interventions

Leads: White, Balmford
Other key contributors: Adams, Cummins, Nicholas, Prabhu, van Rens, Taylor

Building on WP1, our stakeholders will generate a vision offering coherence and complementarity between local and national policy, and delivering sustainable, healthy and affordable food for all in an economically viable food system. We will identify coordinated actions that will push consumer demand for healthier and less environmentally damaging food over a tipping point that triggers its economically sustainable supply, and stimulates whole system transformation.

3.1 Identifying and characterising interventions for leverage points

From the solution scan of all possible interventions (WP2.1), we will characterise interventions by key target groups, actors, settings and likely costs and benefits. Rather than focusing on the *form* of interventions (e.g. vouchers for free vegetables) we will consider intervention *functions* (e.g. increasing affordability of more sustainable and healthier food). This will increase transferability of knowledge: whilst it may not be feasible or desirable for other cities to deliver the same *forms* of interventions, greater understanding of the intervention *functions* that achieve specific impacts should allow others to develop locally-specific interventions that achieve the same functions.

In stakeholder workshops, we will determine which combinations of interventions have the greatest potential to induce transformational, economically viable, change in both supply and demand. This will allow us to reduce the solution scan to a shortlist of promising interventions to explore further.

3.2 Developing theories of change for interventions

Prioritising interventions for delivery and evaluation will be guided by theories of change (ToC). These will hypothesise the causal mechanisms by which interventions (or intervention functions) achieve their intended and unintended impacts. ToC will be guided by systems thinking, aiming to envision potential direct and indirect impacts, and barriers to implementation (e.g. political, technological etc.). ToC will also help identify potential synergies and dampening effects between interventions, and anticipate ways in which system(s) might respond in ways that negate potential benefits. This will allow us to target mitigating actions to maximise intervention potential.

ToC will draw on rapid evidence syntheses (WP2.1) of effectiveness as well as theory and mechanistic evidence. Stakeholders will inform decisions about deliverability, guide evaluative questions, and help interpret emergent findings. ToC will be revised in light of evaluative findings.

3.3 Assessing deliverability and evaluability

Rapid, in-principle, feasibility assessments of proposed interventions will be undertaken, where this helps to reduce uncertainty and inform decisions concerning deliverability and evaluability. The potential costs of interventions will be estimated using standard methods, taking into account the sectors on which they will fall. Acceptability of interventions will be formally assessed by our four stakeholder groups from a range of perspectives. Modelling (WP5) will be used to estimate impacts of interventions where feasible, and offer insights into potential benefits to health, sustainability, economy and society. This process will help narrow our intervention shortlist even further.

Interventions considered potentially viable will be prioritised by stakeholders on the basis of criteria agreed at the outset (see WP1). These criteria will likely include impacts on health, environment and equity, economic viability, potential for disruptive innovation in the food system, coverage of elements of the food system, practicality of delivery, and cost. Consideration of synergies between interventions will be encouraged. Formal, qualitative deliberative methods[35] will be used with our four stakeholder groups to prioritise shortlisted interventions for development and/or delivery.

Not all interventions prioritised for development and delivery will be subject to large-scale evaluation. We will use 'evaluability assessment',[36] working with stakeholders to identify key scientific and policy uncertainties and their relative priority. We will then focus our evaluative efforts

on reducing key uncertainties identified by our stakeholders to help them prioritise interventions for early delivery that will achieve the most transformative change.

We will ensure evaluations capture a broad range of interventions, adhering to the principles described in WP4. In particular, we will aim to evaluate interventions that together have potential to achieve both health and environmental goals; stimulate change in public and private sectors; influence both supply of and demand for healthy and sustainable food, and change within food production, processing, and retailing sectors; and those that have more and less potential to interact with other parts of the food system (described in WP1) in non-linear and reinforcing ways.

WP4 - Evaluation

Leads: Adams (overall), Frew (economic evaluation), White (system evaluation)
Other key contributors: Cummins, Balmford, Burgoine, Prabhu, van Rens, Loopstra

We will evaluate the impacts of interventions prioritised in WP3, using the ToC to help us identify and capture expected and unintended effects. We will consider intervention impacts on the wider system, noting their points of interaction and synergies. Rather than presupposing which interventions will be prioritised in WP3, here we elaborate our strategic approach to evaluation. In addition, we will conduct a broader evaluation of the programme as a whole, enabling learning on systems approaches to transformative change. Results will feed into WP5 & 6.

4.1 Intervention development

It is likely that most interventions will be developed and delivered within the food sector, working closely with BCC, although there may be national polices that deserve local evaluation. We will offer the expertise of the full range of investigators to support the co-production and optimisation of interventions, drawing on ToC developed in WP3 and modelling of potential outcomes in WP5.

4.2 Evaluating interventions

Evaluating all aspects of all interventions prioritised in WP3 will be infeasible. Instead we will prioritise interventions which are most likely to achieve their aims. We are unlikely to conduct more than four large-scale evaluations. Where appropriate, additional funding will be leveraged to support further evaluative work. We will apply five strategic principles in designing evaluations.

Delivering efficient research – We will maximise efficiency by making use, where possible, of existing data (WP2). However, we will not be limited by data availability and will collect new data where this is the only way to reduce a prioritised uncertainty and supplement WP2 data.

Overall & differential impacts on common, proximal outcomes – Evaluations will focus on short to medium term (12-24m) changes in proximal outcomes, with longer term impacts on more distal outcomes modelled in WP5. As far as possible we will focus on a set of common primary outcomes (e.g. change in purchasing and consumption of vegetables and red & processed meat) whose relationship with longer term outcomes of interest in WP5 are known.

As well as overall impacts, we will explore inequalities by investigating differential effects between population sub-groups, including socio-economic position and ethnicity. We will be mindful of intersectionality and the potential for differential impacts to be multiplicative.

Randomisation where possible – Where feasible, we will pursue well-designed (cluster) randomised designs. Random allocation to intervention or control conditions reduces the impact of known and unknown confounders and can provide the strongest evidence of causality. For example, an intervention that trains catering staff to deliver healthier and more environmentally sustainable food in ways that are attractive to customers could be randomised at the outlet-level, with sales data collected from outlets and dietary data from customers clustered within outlets.

Embracing quasi- and natural experimental methods – Many food system interventions are likely to be delivered at a city-wide level, making randomisation within Birmingham infeasible. In other cases, randomisation may not be ethical or acceptable. For example, an intervention that provides independent convenience stores with easy, affordable access to regionally grown produce could technically be randomised at the store level. But, suppliers may not be willing to engage unless it is delivered at the scale of all independent convenience stores across the city.

Where randomisation is not feasible or practicable, we will embrace quasi- and natural-experimental methods using routine data[37] generated in WP2.2. Such studies have greater external validity than many trials and may be the optimal method to generate causal evidence on system-level interventions. Where substantial time-series data are available, we will use

interrupted time series methods with a counterfactual estimated from pre-intervention trends, with or without adjustment for trends in a control area with similar pre-intervention trends to Birmingham. Control areas with no intervention will be identified from out comparator areas described above. We will consider synthetic controls calculated from weighted averages across multiple non-intervention areas where appropriate. Where time-series are not available, we will use difference-in-differences methods comparing pre- and post-intervention differences in outcomes in intervention and control areas. Repeating analyses for outcomes unlikely to be impacted by interventions (e.g. purchasing of toiletries) will increase confidence in the specificity of findings.

Process evaluation of mechanisms of change – ToC will help us identify and test hypothesised mechanisms in process evaluations.[38] Confirming in a quasi-experiment that an intervention was associated with a change in the outcome could be considered relatively weak evidence of causation. Additionally confirming that aspects of the hypothesised mechanism of change occurred will increase confidence of a causal effect. We will make use of quantitative, qualitative, and mixed-methods approaches in process evaluations as demanded by research questions.

4.3 Evaluation of System Change

In parallel with intervention-specific evaluations, we will conduct a system-level evaluation of the overall impacts of the programme, to track changes in: (a) food system structures and processes; (b) food supply; and (c) food behaviours and dietary consumption.

Changes in the food system – We will undertake a multimethod, longitudinal analysis using Process Tracing[39] to understand whether and how food system change was achieved, and establish what worked, how and for whom. Analyses will draw on our system cohort (WP2.2), which will yield rich qualitative data on the emergence of system change over time. We will also gather and analyse documentary evidence of decision making and change throughout.

Analysis of changes in food supply – We will use supply chain and retail data (WP2.2) to create a monthly time series of change in food supply to Birmingham, with a focus on key categories (e.g. vegetables, red & processed meat), to provide an overall assessment of change in healthiness, affordability and environmental impacts. We will partition analysis into key segments of the grocery and out of home markets to differentiate the impacts of interventions by retail sector.

Food behaviours and dietary consumption – We will use our online, annual, longitudinal panel study (WP2.2) to provide data on food planning, source, preparation, and consumption; and attitudes to the food system and associated policy changes. Analyses will seek to identify secular trends, changes related to system change, and differential impacts for population sub-groups.

WP5 – Modelling

Lead: Nicholas (overall), Srai (food supply chains), Dicks (environmental impacts), van Rens, Frew, Smith (economic impacts), Mytton (health impacts),

Other key contributors: White, Balmford

WP5 will use modelling to: explore dietary and food supply consequences of hypothetical interventions, including supply chain reconfiguration; and simulate their medium to long-term effects on health, equity, environment, and economic outcomes. Our approach to modelling will be modular, bringing together established modelling methods from epidemiology, economics and environmental sciences, guided by an underpinning systems science approach. Health, economic, environmental and population models have previously been united,[40] but there is a risk that combining these elements in a model for Birmingham may be challenging; in which case we will develop separate, possibly simplified, models appropriate to the different outcome domains of the programme, and caution that while their results may not be definitive, they should be indicative.

5.1 Building a model of the food system and modelling impacts of candidate interventions

Using the system map (WP1) and ToC, we will build mathematical models to synthesise opinions and a variety of data, to quantify potential impacts (by socioeconomic group and overall) and likelihood of intervention success before trialling (for use in WP3). We will assess these models for bias, revise them, and highlight feedback loops that may diminish or enhance effects over time.

To hypothesise changes in diet and food supply resulting from potential interventions, our models will be derived from expert opinion, the system maps (WP1.2), published evidence (from WP2.1) and supply and demand models (WP1.2); using Bayesian methods to synthesise data together with supply and demand modelling. The system map will help us to identify and parameterise

critical pathways and use Bayesian network analysis[41] to assign probabilistic relationships to these quantities. Thus interventions applied hypothetically at one or several points in the map will give rise to a modelled probabilistic response at other points in the map (e.g. changes in dietary intake). Assessment of feedback, if not quantified, will qualitatively indicate likely impacts on diet over time.

5.2 Modelling medium to long term impacts of interventions

To quantify outcomes we will use: life cycle analysis, together with a novel biodiversity model for environmental outcomes; proportional multi-state life table modes for health outcomes; equilibrium modelling of demand and supply, together with analysis of supply chains to assess economic outcomes. We anticipate trade-offs between diet, sustainability and affordability outcomes and will make these explicit. We will use dietary change and supply chain countries of origin (WP2.1) as inputs to life cycle analysis.[42] Life table modelling of UK diets will use the PRIMETime model,[43] drawing on routine population data. This can model costs associated with health outcomes including Quality Adjusted Life Years gained. Equilibrium modelling of price adjustments[44] and supply will allow affordability and supply chain activity to be quantified.

5.3 Stakeholder engagement

The results of modelling will be presented to stakeholders to select scenarios for prioritisation. For environmental impacts we will create a stand-alone tool, using a user-centred design approach,[45] to translate food choices into information about ingredients and their geographic origins, life cycle greenhouse gas emissions, acidification and eutrophication potential, water use and land use change, and associated species extinction risk. Similarly, health consequences of dietary change using life table models will be implemented as an online tool. Finally, we will create and populate a database of results for each intervention, and share this with stakeholders in spreadsheet form and as an online tool if feasible. These will enable stakeholders to envision food system changes and their consequences for the economy, population and planet.

5.4 Modelling wider impacts of intervention beyond Birmingham

We will build models from modular components, maintain a dictionary of model parameters, and place software in an online repository for reuse in other city contexts and for larger scale models. Our outcome model components are driven by diets and dietary change, and hence broadly reusable in a UK context, with some changes (e.g. population risk factors). They will also be scalable to the UK, using national surveys of diets. Our models of diet and food supply responses to interventions will be more Birmingham-specific, and it is difficult to anticipate how reusable these models will be, but we will maintain separation between generic elements and specific ones.

WP6 – Synthesis and Impact

Leads: White (overall and synthesis), Taylor, Francis (knowledge exchange & impact)
Other key contributors: Adams, Dicks, Frew, Prabhu

In WP6 we will: (a) synthesise programme findings to derive generalisable learning for Birmingham and other cities within and beyond the UK; (b) achieve impact through knowledge exchange.

6.1 Synthesis of findings from evaluations and modelling

We will synthesise findings from across all WP to draw unified conclusions and identify implications for future research, policy and practice. The primary method will likely take the form of narrative synthesis, but the potential for meta-analytical methods will be explored. This work will be guided by our System Map (WP1), our overarching ToC and intervention-specific ToC (WP3). Evidence synthesis across WPs will help refine the systems map and ToC and will identify generalisable evidence for food system change that can be applied in other cities in the UK and beyond.

6.2 Knowledge exchange and Impact

Drawing on the dedicated expertise and experience of Taylor (Food Foundation) and Francis (MRC Epidemiology Unit, Cambridge), we aim to achieve impact in five realms:

Within Birmingham – where the research will be a driving force in the design and delivery of transformative food system actions. We will achieve this by embedding the research programme within BCC and via the change-makers in our stakeholder groups (WP1.1). Guided by our overarching ToC, the research programme will become a key source of evidence informing food system decision making in Birmingham, delivering both evidence of need through observational and modelling work, and of effectiveness through evidence syntheses and evaluations.

In other UK cities – We will reach other UK cities via a knowledge exchange network built from the

outset. The Food Foundation will expand its existing relationships with major metropolitan local authorities, including Coventry, Wolverhampton, Bristol, Bradford, Liverpool, Leeds and Sheffield. Early in the programme we will explore the current state of food policy in these cities and identify opportunities for mutual learning with Birmingham. We will deploy the Food Foundation's food policy audit tool to generate baseline data and create the starting point for ongoing engagement.

During the course of the programme we will arrange 'food system tours', show-casing progressive policy measures, healthy food environments, more environmentally sustainable supply chains etc. for councillors, officers, business and community leaders within Birmingham and other cities to enable peer learning and inspiration. In the final year we will hold a major event in Birmingham to show case the evidence generated and the interventions that have been successful. This will involve visits, curated interviews and films, stakeholder debates, and data journeys. We will aim to host delegations of at least three stakeholders from each city. We will also use a number of existing fora to disseminate our approach, learning and findings continuously. These include the London Borough's Food Group (which Food Foundation already attends), the Sustainable Food Places annual event (a national programme involving 57 local authorities), annual events of the Milan Urban Food Policy Pact (209 cities worldwide), WHO European Healthy Cities Network (30 national networks, 100 flagship cities), the C40 climate change network and the EAT Foundation.

Among key national actors – We will inform key national influencers, as well as those providing guidance on food policy to local authorities and metropolitan areas, such as the Local Government Association, Town and Country Planning Association, Public Health England, Food Standards Agency, key departments in national government (DEFRA, DHSC, BEIS, MHCLG) and devolved governments in Northern Ireland, Scotland and Wales. We will develop relationships with these bodies from the outset, identifying areas for collaboration throughout the programme, ensuring our research findings are used in the development of national guidance and best practice.

With the media and the public – We will use local, trade and national media to build a strong reputation for the programme and its outputs, strengthening our impact through direct engagement. We will deploy a range of content, including film material, impactful stories, visuals and animations that demonstrate the need and potential for change, a documentary charting the process of system change and its impact on people's lives, personal stories of why the food system needs to change, and strong social media channels. Visualisations, data interactives, and gamification resources will be adapted from WP2, WP4 and WP5 outputs for different publics. We will work with key food writers and journalists with whom we have existing relationships (e.g. Bee Wilson, food writer; Sheila Dillon, BBC Radio4 Food Programme; Patrick Butler, Guardian Social Policy editor).

Within the research community – Scientific dissemination through journals, conferences, seminars and webinars will be undertaken throughout the programme. It will be shaped by the consortium's expertise in knowledge exchange and a clear strategy, aiming to maximise impact nationally and internationally. We will make extensive use of digital media to broaden reach in a timely way.

Impact summary and proposed interventions

Proposed interventions

As described in WP3-4, we will work with stakeholders to identify, prioritise, develop, deliver and evaluate interventions. Interventions will likely involve both positive and reinforcing actions (e.g. changing food procurement across the public sector, upskilling the catering workforce), regulatory mechanisms (e.g. regulating food advertising on public transport), fiscal measures (e.g. variable business rates for food businesses), voluntary actions (e.g. collaboration across retailing within the Food Foundation's Peas Please initiative) and disruptive innovations (e.g. new uses of digital technologies in the food supply chain).These innovations will vary in their transformational potential and stakeholder prioritisation will be guided by their appetite for risk, tempered by evidence generated in WP2 and simulated impacts in WP5. Whilst we do not presuppose what interventions will be selected here, Table 1 (WP2.1) illustrates our strategic approach using three examples.

Impact

As described in the ToC the intended programme impacts are improved human health in Birmingham's 1.2m citizens and improved planetary health and resilience. Impact will be achieved through a strategic programme of embedded knowledge exchange (WP6) targeting key actors, inspiring and building capacity among change leaders throughout the food sector, engaging the

public and leveraging the change potential of our stakeholders (WP1). The programme will support Birmingham to develop and deliver its vision for a Healthy Food City, delivering transferrable knowledge that will inspire and inform food system transformation in other major cities in the UK and beyond. BCC leadership (Council Cabinet member for Health & Social Care; Director of Public Health) will prioritise food system transformation, ensuring research findings fall on fertile soil.

Immediate beneficiaries include our research and intervention partners in local government, and commercial partners in food retail and product innovation. Local government will benefit by applying co-produced research to develop and deliver its vision to improve the local food system. Commercial partners will benefit by gaining insight to help develop practices, tools and products that will promote healthier and more sustainable offers for their customers. These partner benefits will impact on citizens who will have access to healthier and more sustainable and affordable diets.

Wider impacts include benefits for health, well-being, food security, environmental sustainability and the economy. These will be modelled in WP5. Longer term and wider impacts will arise from knowledge transfer to other cities and food systems in the UK and internationally. We anticipate our research will produce generalisable and scalable examples for healthy and environmentally sustainable urban food system transformation. As well as lessons learned in strategy, skills-development and specific interventions, our evidence, data platform and simulation models will be open source. Regional and national beneficiaries with influence on local food systems in the UK include government departments and agencies (e.g. PHE, DEFRA, DHSC, FSA).

Pathways to impact will be informed by our overarching ToC. This will inform the impact methods chosen, which will include a range of content, tools and messages delivered through multiple channels. Learning from Birmingham will be taken to wider audiences through a wide range of media and materials developed throughout the programme and described in WP6.

Theory of Change

Our *long term goals* are improved human health, particularly decreased obesity and dietary-related non-communicable diseases; and improved planetary health and resilience to support diverse life on earth. Achieving these goals will also reduce the externalities of poor human and planetary health including healthcare, social, economic and environmental costs. We will work to achieve these goals in Birmingham through a programme of interdisciplinary research and food system transformation, co-produced with food system stakeholders across the city. Knowledge exchange will enable our goals to be achieved in other cities in the UK and beyond.

The *preconditions* needed to achieve our goals are habitual consumption of healthier and more sustainable foods and diets. Whilst we will co-determine specific outcomes to quantify these preconditions with stakeholders, examples include decreased consumption of red and processed meat, and increased consumption of wholegrains, vegetables, legumes, nuts and seeds.

These preconditions will be achieved via *interventions* that decrease the demand for less healthy and sustainable foods, and those that increase the demand for healthier and more sustainable foods. There are likely to be positive feedback loops such that greater consumption of healthier and more sustainable foods and diets increases preferences and social norms for these, and so drives demand further. Such changes in demand should lead to closer alignment of commercial food system goals with those of public health, equity and environmental stewardship and hence a food system that increases supply of affordable, healthier and more sustainable foods and diets.

We will work with stakeholders to co-design interventions to achieve these preconditions. Some key hypotheses will drive our selection of potential interventions: that actions on powerful levers for system change (i.e. that will lead to shifts in paradigms, structures and goals) will be more effective than interventions that seek to change individuals behaviours; that multiple, complementary interventions are likely to be more successful than single approaches; and that those that require the least effort from individual consumers will likely achieve more equitable effects.

Through a process of co-production we will identify feasible interventions that have the greatest potential for achieving change at key leverage points in the food system. We do not presuppose which interventions will be supported by evidence and prioritised by stakeholders. However, we will ensure that delivered interventions have the potential to achieve both human and planetary health goals; stimulate change in the public and private sectors; influence both supply of and demand for

healthy and sustainable food; and achieve change within the food production, processing, and retailing sectors. Three illustrative examples are described in the Case for Support:

- altering public procurement policies to ensure that food served in public sector organisations (e.g. schools, the NHS, local authority buildings) is affordable, healthier, and more sustainable
- introduction of variable business rates for food businesses based on the healthiness and sustainability of their food offerings
- development of a digital market place for small and medium sized food retail businesses, linking them to suppliers of healthier, more sustainable fresh, local produce.

Inputs required to achieve our co-production process include the efforts of our interdisciplinary research team working in partnership with Birmingham City Council (BCC) and a stakeholder panel of 100 citizens and food systems actors and potential change makers working in the public, private and voluntary sectors. The commitment of BCC and some commercial partners has been secured and stakeholder panel members will be selected, in part, based on their agreement to the process. The context for the research, the city of Birmingham, represents a living laboratory in which we will conduct large scale experiments to generate evidence for food system change.

Our *theory of change* is shown diagrammatically below. This summarises our initial, overall programme theory hypothesising the interactions between the research consortium and our stakeholders required to achieve our long term goals. This programme level theory of change will be elaborated further with our stakeholders as the programme evolves, theorising and evaluating interventions as events in a complex, adaptive system. It will be supplemented with intervention-specific theories of change, enabling detailed theorisation of impacts and design of evaluations and modelling studies. Capturing the process of change will be as important as measuring outcomes. We will develop a reproducible, collaborative model for food system transformation involving policy, practice and research within the food system. We will document and transparently report this way of working so as to provide guidance for other urban areas in the UK and internationally.

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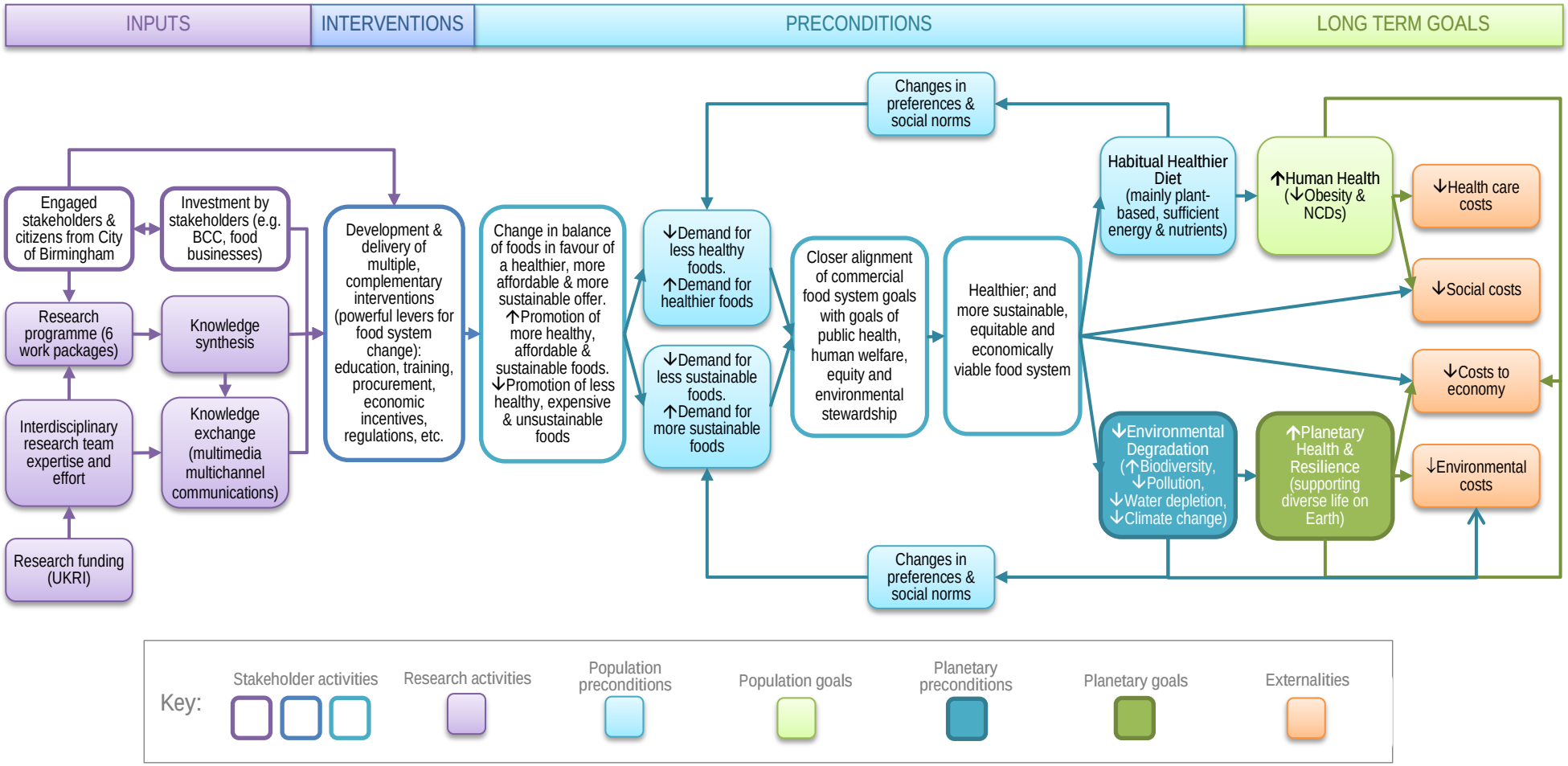
Overall Theory of Change for the Mandala Consortium programme of work



Diagrammatic Work Plan

The programme of work is divided into 6 interacting work packages. The relationships and dependencies between work packages are shown in Figure 1 and described throughout the Case for Support. Here we describe timing of the research, which is shown diagrammatically in the Gantt chart below, key deliverables and milestones.

WP1 – Stakeholder engagement and system mapping
One member of staff (Post 1) will be recruited before the start of the programme. During the first 3 months of the programme we will embark on citizen and stakeholder engagement, which will continue throughout the 5 years. We will establish our four stakeholder groups, undertake orientation and initiate discussion with them about the tasks ahead *(Milestone (MS) 1, Month (M) 3)*. We will also recruit further research staff during this 3 month period and start to make plans for governance requirements of our research including ethical approvals *(MS2, M3).* From months 4-15 we will engage our stakeholder groups in the system mapping and group model building tasks, leading to identification of leverage points for food system change *(MS3, M15).*

WP2 – Creating an integrated data and analytics platform
Evidence synthesis tasks will commence in month 4 and continue for 2 years, feeding in to WPs1, 3, 4 and 5 *(MS4, M27).* Some evidence synthesis may be required later on to support continual development of interventions (WP4) and models (WP5). The process of data curation will also start in month 4 and potentially continue until month 57 to support evaluative studies (WP4) and modelling (WP5), although work will be most intensive in the first 2 years *(MS5, M27).* From month 7, primary data collection will start using our population panel study, citizen science study and system cohort. These will continue until month 57. There will be intensive work to set up these studies in the first year, and then less intensive work to maintain them thereafter, but with a growing emphasis on data management and analysis *(MS6, M22 – panel study established; MS7 and MS8, M15 – citizen science study and system cohort established)*.

WP3 – Envisioning and prioritising interventions
Work here will build on WP1, using stakeholder workshops to identify potential interventions (months 7-15)*(MS9, M15)*, developing theories of change (months 7-18)*(MS10, M18)*, assessing deliverability and evaluability of interventions (months 10-18)*(MS11, M18)*, undertaking in principle economic assessments (months 10-23)*(MS12, M18)* and prioritisation of interventions using deliberative methods (months 13-24)*(MS13, M24)*.

WP4 – Evaluation
Evaluation of overall system change will commence with baseline assessments in months 6-15 *(MS14, M15)*, drawing on our system cohort and food system data curated in WP2. Development and evaluation of specific interventions will commence in month 16. Support for co-development of interventions is likely to be intensive from months 16-30 *(MS15, M30)*, after which evaluations will likely demand most effort in WP4, continuing to month 57 *(MS16, M57 – 4 major evaluations of interventions completed).*

WP5 – Modelling
WP5 will work closely with WPs 1 and 3 to generate a map of the food system and undertake group model building to refine this conceptually(months 4-15), as well as build a dynamic model of the food system, and impact models focused on economic, health and environmental outcomes (months 7 to 27)*(MS17, M27)*. These models will be further refined as they are increasing applied from month 10 to month 57. Modelling of wider and longer term impacts will commence in month 19 and continue to month 57 *(MS18, M57)*. This will be accompanied by a process of engaging stakeholders and determining the best ways to present models, including the use of computer visualisations *(MS19, M57)*.

WP6 – Synthesis and impact
Knowledge exchange and impact work will commence in month 7 and continue to the end of the programme *(MS20, M57 – Impactful outputs achieved from each study and WP; final report completed)*. Work to synthesise findings from WP4 and WP5 will commence in month 28 and continue to month 57 (*MS21, M57 – Substantive synthesis of findings completed and implications for wider system change documented).*

Gantt Chart

	Month (start of quarter)																				
Activity	1	4	7	10	13	16	19	22	25	28	31	34	37	40	43	46	49	52	55	58	
WP1 –Engagement and system mapping																					
System stakeholder engagement																					
Citizen engagement																					
System map/group model building																					
Identifying leverage points, developing case studies/use cases																					
WP2 – Evidence and data resources																					
Evidence synthesis																					
Data curation																					
Population panel study																					
Citizen science study & system cohort																					
Data presentation																					
WP3 – Envisioning and prioritising																					
Identifying interventions for leverage points																					
Developing theories of change																					
Assessing deliverability/evaluability																					
In principle economic assessments																					
Prioritisation																					
WP4 – Evaluation																					
Supporting intervention development (multiple interventions)																					
Evaluation of prioritised intervention (X4)																					
Evaluation of system change																					
WP5 – Modelling																					
Building model of food system. Develop models for environment, health, economic and equity outcomes																					
Modelling impacts on environment, health, economy and equity																					
Modelling impacts in long term & on wider populations																					
Stakeholder engagement in modelling, visualisations, etc.																					
WP6 – Synthesis and impact																					
Synthesis of findings																					
KE/Impact/Reporting																					
Consortium Management																					
Strategic Management Group (SMG)(quarterly meetings, alternate meetings with partner representatives)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
International Scientific Advisory Group (ISAG)		●		●		●		●		●		●		●		●		●		●	
Stakeholder Advisory Board (SAB)				●				●				●				●				●	
Annual consortium conference				●				●				●				●				●	