Design of an Architectural Framework for a Health Assessment Information System for Urban Agriculture Interventions in Low-Resource Settings Using a Soft Systems Approach to Information System Design

by

Leanne Idzerda

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Supervisor: Dr Milla McLachlan

Co-supervisor: Dr Wojtek Michalowski

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Abstract

Introduction: Urban agriculture interventions in low-resource settings have not demonstrated the expected improvements to nutrition outcomes. Urban agriculture interventions also pose a number of potential risks to population health. The purpose of this research is to design the architectural framework for a technology-supported information system that can *support* program managers in developing strategies that aim to improve nutrition outcomes and mitigate the risks to population health. This tool is called the Health Assessment Information System for Urban Agriculture Interventions in Low-Resource Settings (HAIS).

Methods: The architectural framework was developed by identifying and capturing the technical and soft elements of the health impact assessment (HIA) approach. Soft systems methodology (SSM) was used in three phases of research to design the architectural framework of the HAIS. Each phase corresponds to a research question and determines (1) what activities need to be supported, (2) what information is required to support these activities, and (3) how to structure that information.

Results: Five activities where program managers require support were identified, and the information required to support these activities was defined. The architectural framework of the HAIS, which consists of several components that function together, was developed around these activities. This architectural framework builds the theoretical foundation for the development of a future technology-supported information system that can be used to support program managers to develop their own strategies within a complex organizational context.

Conclusion: The HAIS represents the first step towards developing a decision tool that can support program managers in complex low-resource organizational settings to develop strategies to improve nutrition outcomes and mitigate population health risks. This research represents the first attempt to use SSM to identify and capture the technical and soft elements of the HIA approach into an architectural framework for an information system that, when developed, may be used by non-experts to design urban agriculture interventions.

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Opsomming

Inleiding: Die evaluering van intervensies by stedelike landbou in gebiede met min hulpbronne dui daarop dat hierdie intervensies nie die verwagte verbetering in gemeenskapsvoeding behaal het nie. Boonop hou stedelike landbou ’n aantal potensiële risiko’s in vir gemeenskapsgesondheid. Die doel van hierdie studie is om die argitektoniese raamwerk vir ’n tegnologie-ondersteunde inligtingstelsel te skep wat programbestuurders kan *ondersteun* in die ontwikkeling van strategieë wat gemik is op die verbetering van voedingsuitkomstes en die vermindering van risiko’s vir gemeenskapsgesondheid. Hierdie instrument staan bekend as die gesondheidsassessering-inligtingstelsel (‘health assessment information system’; HAIS) vir stedelikelandbou-intervensies in laehulpbrongebiede. Die instrument se argitektoniese raamwerk is ontwikkel deur die tegniese en sagte elemente van die gesondheidsimpakassesseringsbenadering (‘health impact assessment’; HIA) te identifiseer en weer te gee.

Metodiek: Die kernkonsep onderliggend aan hierdie studie is dat kundigheid in so ’n formaat verpak moet word dat diegene wat nie deskundiges is nie dit ook kan gebruik om strategieë te ontwikkel. Hierdie omskakeling word bewerkstellig deur ’n sagtestelselbenadering tot die ontwerp van inligtingstelsels te gebruik. Dié benadering is gevolg omdat dit die tegniese sowel as die sagte elemente van die HIA-benadering kan weergee. Sagtestelselmetodologie (SSM) is in drie navorsingsfases gebruik om die HAIS se argitektoniese raamwerk te skep. Elkeen van hierdie fases stem ooreen met ’n navorsingsvraag om te bepaal (1) watter aktiwiteite ondersteun moet word, (2) watter inligting nodig is om hierdie aktiwiteite te ondersteun en (3) hoe daardie inligting gestruktureer moet word.

Resultate: Met die eerste navorsingsvraag is vyf aktiwiteite waar programbestuurders ondersteuning nodig het, geïdentifiseer. In reaksie op die tweede navorsingsvraag is die inligting wat nodig is om hierdie aktiwiteite te ondersteun, gedefinieer. En in reaksie op die derde navorsingsvraag is die HAIS se argitektoniese raamwerk, wat uit verskeie komponente bestaan wat saam funksioneer, óm hierdie aktiwiteite ontwikkel. Hierdie argitektoniese raamwerk vorm die teoretiese onderbou van ’n tegnologie-ondersteunde inligtingstelsel wat in die toekoms gebruik kan word om programbestuurders in ’n komplekse organisatoriese konteks met strategie-ontwikkeling by te staan.

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Gevolgtrekking: Die nuwe argitektoniese raamwerk vir die HAIS is hierdie studie se vernaamste kennisbydrae. Dit verteenwoordig die eerste tree in die ontwikkeling van ’n instrument wat programbestuurders van stedelikelandbou-intervensies kan bystaan om strategieë te ontwikkel in komplekse organisatoriese omstandighede waar daar min hulpbronne beskikbaar is. Die studie is uniek omdat dit die eerste poging verteenwoordig om SSM te gebruik om die tegniese en sagte elemente van die HIA-benadering te identifiseer en weer te gee in die argitektoniese raamwerk van ’n inligtingstelsel wat, wanneer dit ontwikkel is, deur programbestuurders van stedelikelandbou-intervensies gebruik kan word om strategieë te ontwikkel wat voedingsuitkomstes kan verbeter en die risiko’s vir gemeenskapsgesondheid kan bekamp.

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1.0 Introduction

If you have a garden and a library, you have everything you need.

— Marcus Tullius Cicero, Roman Philosopher ~63 BC

1.1 Background

Populations in most developing countries have been urbanizing at exceptional rates [1]. This has affected urban household food consumption in the following ways: (1) households, for the most part, must purchase food through a market system [2]; (2) households need to have access to a monetary income in order to purchase food through the market [1]; and (3) the foods purchased tend to be ultra-processed and low in fruits, vegetables, and fibre, and high in fat, salt and sugar [2]. Thus, both diet composition and food acquisition are changing rapidly with urbanization. This has led to an increase in all forms of malnutrition (undernutrition, obesity, and micronutrient deficiencies), particularly in low-resource settings. Low-resource settings are defined as settings in which the available resources do not cover population needs. These settings are typically found in low-income countries, but can also include underserved populations in middle- or high-income countries.

Urban agriculture, in its most favourable light, is regarded as a way to improve a population's nutritional status by increasing the availability of fresh, nutritious foods in urban areas. Urban agriculture can be defined as the formal or informal production of crops and animals in an urban environment using locally available resources. Urban agriculture includes all food production mechanisms such as animal rearing and fruit and vegetable production in community owned and operated spaces, home farms, and individual households [3]. This research focuses specifically on formal urban agriculture interventions put in place by an organization (government, non-governmental organization, or community-based organization) with the explicit purpose of improving nutrition within the target community. Community organized agriculture that brings people together organically without formal management arrangements or clearly defined health goals is excluded.

Program managers within these organizations generally undertake the design, implementation, and maintenance of these urban agriculture intervention sites with the

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intention of improving the community's well-being [4, 5, 6]. Because of the intuitive link between urban agriculture and nutrition, urban agriculture as a means for improving nutrition in low-resource settings has become increasingly popular in the past few years. A number of organizations are beginning to implement or are scaling-up implementation of small-scale agricultural interventions, including those in urban areas [7]. These organizations include local governments (e.g. the implementation of the Urban Agricultural Policy by the City of Cape Town [3]), international non-governmental organizations (e.g. Helen Keller International, The Red Cross or Action Against Hunger), and community-based organizations (e.g. in South Africa, there are more than a hundred churches, schools, and local non-governmental organizations that support a variety of urban agriculture activities in and around Cape Town [8]). Urban agriculture interventions are attractive to many organizations, funders, and politicians because (1) it is generally believed that a community that is able to produce its own food will be food secure; (2) vegetable gardening is regarded as a skill that increases the resilience of a community over time [9]; (3) organizations and funders regard it as an intervention that is self-sustaining [9]; and (4) it is viewed as a holistic intervention that has a number of perceived economic, social, environmental, and health benefits [8]. Of particular importance to this research are the perceived health benefits. The benefit of urban agriculture to health, and specifically nutrition, is generally conceptualized as a result of increasing the availability of fresh nutritious foods accessible to low-income households [10, 11].

1.2 Statement of the Problem Situation

Notwithstanding the fact that urban agriculture interventions are perceived as an important food-based initiative to improve nutrition, the actual benefits to health and nutrition outcomes have not been demonstrated through rigorous academic studies [12]. In addition, urban agriculture poses a number of potential risks to population health that are often not considered. For example, standing water around urban agriculture sites may attract mosquitoes which carry malaria, or the use of wastewater to water vegetable gardens may result in disease [13]. As will be shown in Chapter 2, the lack of demonstrable benefit to nutrition is likely not due to the lack of efficacy of the intervention, but rather due to the fact that program managers of these interventions do not consider the complex impact pathway between agricultural interventions and nutrition outcomes. Similarly, the fact that health risks are not assessed is likely

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not due to a lack of evidence, but rather due to a lack of knowledge on the part of program managers.

This research hypothesizes that if program managers of urban agriculture interventions are supported to assess a broad range of potential health impacts of the proposed intervention, then they could develop strategies that would strengthen the impact pathways to nutrition and mitigate the risks to population health [14]. Thus, this research seeks to discover how to support program managers in low-resource settings to develop these strategies. Although there is high-level recognition that supporting program managers of urban agriculture interventions to develop these strategies is important, there is currently no tool for doing this [15]. Thus, the gap in knowledge identified by this research is regarding ***how to support*** program managers of urban agriculture interventions ***to develop strategies*** that strengthen the impact pathways to nutrition and mitigate the risks to population health.

1.3 Rationale

In order to gain insight into how to support program managers of urban agriculture interventions, a review of the literature was conducted to determine whether there were any approaches that could be used by program managers in low-resource settings to assess the health effects of urban agriculture interventions prospectively. The health impact assessment (HIA) was viewed as one approach that could support program managers in developing strategies, particularly as it includes a technical process underpinned by a set of values and related soft elements (such as stakeholder engagement and trading-off evidence with values and preferences). These soft elements play a crucial role in assessing the potential impacts within the context of urban agriculture interventions. Thus, the HIA was deemed an appropriate approach to support program managers to develop strategies.

Although the health impact assessment (HIA) approach was deemed appropriate for supporting program managers to develop strategies, an analysis of this approach found that HIAs are time-consuming, require expert input and large amounts of data, and are expensive to conduct. Therefore, it was determined that although the HIA approach was desirable, it was not considered feasible for use by program managers in low-resource settings. This research therefore sought to capture the HIA approach into a decision support tool that could be used by non-expert program managers of urban agriculture interventions to develop strategies. The core

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concept underlying this research is the transformation and transfer of expert knowledge into a form that can be used use by non-experts to develop strategies.

A technology-supported information system, termed the Health Assessment Information System for Urban Agriculture Interventions in Low-Resource Settings (HAIS), was envisioned as an appropriate vehicle for this decision support tool. The long-term vision of this research is to design and develop the HAIS, which would support program managers of urban agriculture interventions in low-resource settings to develop strategies that would strengthen the impact pathways to nutrition and mitigate the risks to population health. The development of an information system is an extremely involved process composed of several steps and requiring a range of expertise. First the architectural framework of the information system needs to be created, based on inductive theoretical research. The architectural framework provides a layered structure indicating the parts of the HAIS and how they interrelate. Second, this architectural framework needs to be populated with the required data and tested with potential users. This is the purview of software engineers. Finally, the fully functioning information system needs to be implemented and evaluated within the context it will be used.

The **scope** of this research is limited to the first of these steps, namely the design of the architectural framework. This architectural framework then builds the theoretical foundation for the development of a future technology-supported information system. This research is inductive in nature and focuses on the creation of original theoretical knowledge.

1.4 Purpose of the Study

The **purpose of this research** is to design the architectural framework for the HAIS, based on the expert-driven HIA approach. This will provide the theoretical foundations on which to develop the fully functional HAIS in the future, which can then be used by non-expert program managers to develop strategies.

The theoretical foundations for designing the architectural framework for the HAIS were explored. Information system design is generally based on one of two underlying theoretical positions, hard systems theory or soft systems theory. The approach based on soft systems theory was deemed more appropriate as it is able to capture both the technical process of the HIA and the soft elements of the HIA such as stakeholder engagement, accommodation of others'

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intentions and needs, and the ability to make trade-offs between evidence and values. For these reasons, the conceptual framework of the soft systems approach to information system design was used to conceptualize the research questions and link the research questions to the research design.

1.5 Research Questions

Three research questions emerged from the conceptual framework of the soft systems approach to information system design. These are:

1. **What activities need to be supported so that program managers can develop strategies?**
2. **What information is required to support these activities?**
3. **How can this information be structured?**

The outcome of answering these research questions is an architectural framework that can be used as the basis for the future development of the HAIS.

1.6 Research Design

This research uses soft systems methodology (SSM) to guide the research process. SSM was selected as the most appropriate methodology because (1) it is based in soft systems theory, thus providing a conceptual link from the theoretical foundations to the research methodology, (2) it provides a systematic, well-documented process for designing an architectural framework, and (3) it offers a series of methods that can be used to identify and capture both the technical process and soft elements of the HIA process.

This research consists of three phases, with each phase corresponding to a research question. Each phase builds on the previous one and culminates in the architectural framework for the HAIS.

1.7 Significance of this Study

This research is about identifying and capturing the expert-driven HIA process (both the technical and soft elements of this process), using SSM, into an architectural framework for an

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information system, which, when fully developed, can be used by non-experts to develop strategies in complex organizational settings in low-resource areas.

The main contribution that this research makes to knowledge is a novel architectural framework for the HAIS. This represents the crucial first step towards developing a decision support tool that could support program managers of urban agriculture interventions in low-resource organizational settings to develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health. In addition, this research contributes to knowledge through the demonstration of a methodology for designing an architectural framework for an information system that focuses on more than just the technical step-by-step process by also considering the soft elements of the HIA process. This lays the methodological foundations for designing other information systems in related areas.

This research is unique as it represents the first known attempt to use SSM to identify and capture the technical and soft elements of the HIA approach into an architectural framework for an information system that can be used by non-experts to develop strategies.

1.8 Organization of the Study

This research report has the following structure: Introduction, Literature Reviews, Theoretical Foundations, Research Design, Methods and Results of Phases 1, 2, and 3, Discussion, and Conclusion.

Chapter 1 introduces the topic and establishes the importance of this research as well as the proposed contribution to knowledge.

Chapter 2 conceptualizes urban agriculture, health, and nutrition, with emphasis placed on the relationship between these three concepts. This chapter provides the context of the problem situation and gap in knowledge and identifies the research issue as **how to support** program managers to develop strategies

Chapter 3 reviews the literature to determine whether there are any approaches that could support program managers to develop strategies. This review found that the HIA approach could be useful in this situation. However, because it is an expert-driven approach, it is not feasible for program managers to use in low-resource settings.

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Chapter 4 provides a conceptual structure for thinking about how to identify and capture the expert knowledge contained within the HIA. This structure delimits the scope of this study as the design of an architectural framework for the HAIS. This architectural framework lays the theoretical foundations for the later development of this information system (this is outside the scope of this work).

Chapter 5 explores the theoretical foundations on which the research is designed. The rationale for using soft systems theory to guide the information system design is laid out and the conceptual framework describing the soft systems approach to information system design is used to structure the research questions and methods. In this way the theoretical foundations are used to link the research questions to the research design.

Chapter 6 outlines the research design of this study. This research study was designed under the action-research paradigm and uses soft systems methodology to design the architectural framework for the HAIS. This study is designed in three phases, with each phase answering a research question.

Chapter 7 presents Phase 1 of this research study and uses soft systems methodology to answer the first research question regarding what activities should be supported so that program managers can develop strategies. This chapter concludes with five activities that would require support if program managers were to develop strategies.

Chapter 8 presents Phase 2 of this research study and uses soft systems methodology to answer the second research question. This chapter concludes with five information requirements for the architectural framework.

Chapter 9 presents Phase 3 of this research study and uses the information system requirements to design the architectural framework for the HAIS. The architectural framework is presented along with four use-cases that aim to demonstrate its functionality.

Chapter 10 discusses the relevance of the architectural framework, the rigour of the research process, and next steps of this research.

Chapter 11 provides a brief summary of the research and the main contributions to knowledge as well as a discussion on the research limitations and areas of future research.

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2.0 Literature Review I: Context of the Problem Situation

The previous chapter presented urban agriculture as an intervention that benefits the nutritional status of a population by increasing the availability of whole unprocessed foods. The problem is that although urban agriculture interventions are theoretically efficacious, they have not demonstrated the expected results. The reasons that these results have not been demonstrated will be explored in detail in the first section of this chapter. In addition, there are a number of potential health risks associated with urban agriculture interventions. The potential negative effects of urban agriculture on health are reviewed in the second section of this chapter. This chapter concludes by summarizing the problem situation that led to the identification of the gap in knowledge and the related research issue.

This literature review covers a broad corpus of literature as it sits at the nexus of agriculture, health, and nutrition. This is a relatively new area of transdisciplinary research spearheaded by organizations such as Agriculture for Nutrition and Health (A4NH), the Leverhulme Centre for Integrative Research on Nutrition and Health (LCIRAH), and The International Development Research Centre (IDRC). This literature review focuses on the primary literature in each field in an attempt to cut through the broad and diverse literature base. The goal of this literature review is to conceptualize and contextualize the issues related to urban agriculture interventions with the intent of providing clarity and focus to the research topic.

2.1 Lack of Demonstrated Effect on Nutrition Outcomes

2.1.1 The Relationship between Urban Agriculture and Nutrition

In order to understand the reasons for the lack of demonstrable effect that urban agriculture interventions have had on nutrition, it is necessary to first understand the relationship between these two concepts. It is important to note that urban agriculture is a nutrition-sensitive intervention that may have an effect on nutrition through a variety of impact pathways [16]. In order to explore this relationship, a review of the conceptual models that have been developed to explain the linkages between urban agriculture and nutrition was conducted. This literature review broadened its search from urban agriculture to small-scale agriculture interventions as no conceptual models that specifically look at the linkages between urban agriculture and nutrition

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were found. Small-scale agriculture can be defined as the production of crops and livestock on a small piece of rural or urban land without using advanced and expensive technologies [17] and subsumes urban agriculture as one subset of interventions. Given the shortage of conceptual models for urban agriculture, much can be learned from models of peri-urban or rural small-scale agriculture that could be transferable to the urban agriculture situation.

This literature review found 17 published conceptual models that seek to explain the relationship between small-scale agriculture and nutrition. The details of the search strategy can be found in Appendix A. It is noteworthy that most of the conceptual models include very similar elements. This suggests that there is agreement on how small-scale agriculture impacts nutrition. One conceptual model will be presented here as an exemplar of the relationship between small-scale agriculture and nutrition. This conceptual model was first published in a 2012 report by the UK Department for International Development (DFID) [18]. It is an attempt to determine the various impact pathways between agricultural interventions and nutrition outcomes. The DFID model was developed by an expert panel and made use of well-established concepts to describe the interactions between small-scale agriculture and health. The process involved reviewing existing conceptual models, and then incorporating and simplifying the information. This model was selected as an exemplar as it is both explanatory of the relationship between small-scale agricultural and nutrition and can be operationalized in the research context. This conceptual model is graphically presented in Fig. 2.1 and is briefly summarized in the text below.

The **agricultural intervention** is described in the left-hand column of Fig. 2.1. **Agricultural inputs** refer to the resources required for the agricultural practice. These may include tangible resources such as crops, animals, or fertilizer and could include intangible resources such as knowledge (e.g. new breeding practices). **Agricultural practices** refer to the type of agricultural activity (e.g. horticultural practices or animal-rearing). These agricultural practices produce a variety of food supplies that are then transferred from the farmers to the community through a **food value chain** that may include storage, transformation, and marketing. This in turn directly affects the **food environment** by increasing the availability of food. This then affects individuals' **food consumption**, ultimately affecting their **nutritional status**. The described pathway from agriculture to nutrition traces the direct effects of small-scale agriculture on nutritional status; i.e. urban agriculture increases the availability of nutritious food in the food environment, which leads to increased consumption of these foods, which in turn has a positive impact on nutrition.

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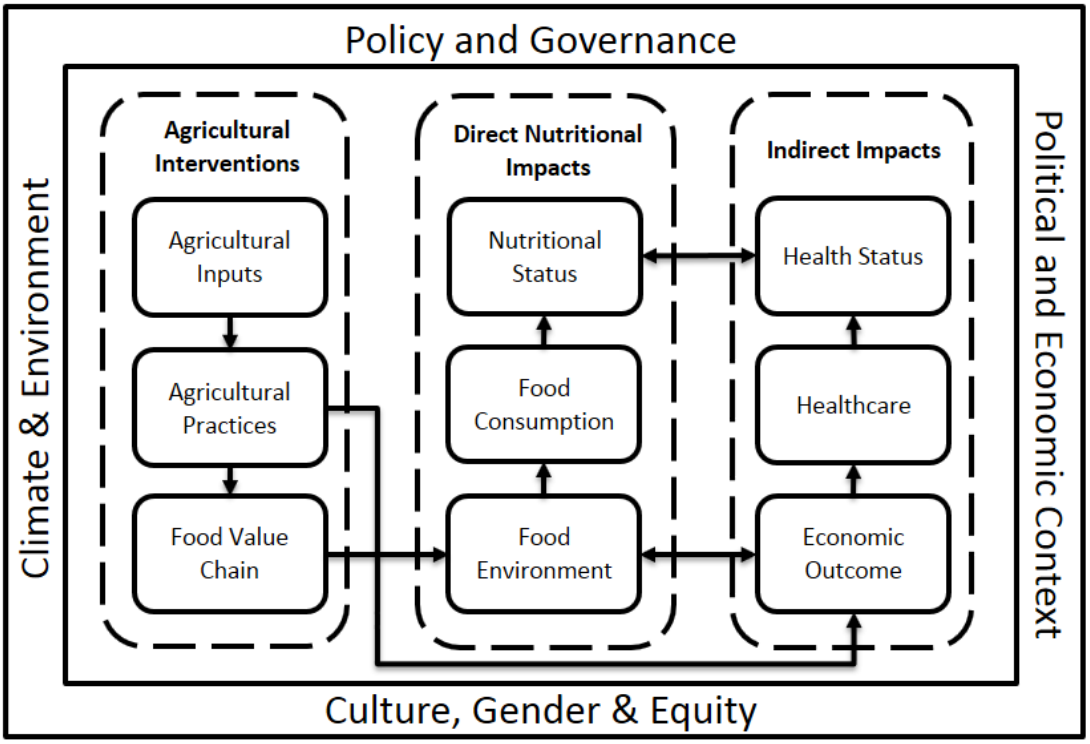

Figure 2.1 The conceptual model of the impact pathway between agricultural interventions and nutrition outcomes.

The agricultural intervention may also indirectly affect nutritional status through a series of intervening factors. For example, an increase in agricultural produce may affect **economic outcomes** by creating increased wealth through the sale of produce or by freeing up cash as the money that was being spent of food can be spent elsewhere [19]. Improved **economic outcomes** at the household level may lead to families (1) investing in a greater variety of foods, thus improving their food environment; (2) investing in better living conditions such as sanitation or electricity, thus improving quality of life; and (3) investing in **healthcare**, thus improving well-being. All of these improvements may lead to improved **health status**, which in turn improves **nutritional status**. It is important to note that health and nutrition are intimately connected in a bi-directional, cyclical relationship where nutrition is both a determinant and an outcome of health status.

This research takes a broad view of health and considers it as more than just the absence of disease. Health can be defined as a capacity or resource that allows one to pursue one's goals, to acquire skills and education, and to grow [20]. This definition of health is necessarily broad and includes the

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physical, mental, and social outcomes at both the individual and population health levels. This broad view of health is necessary, as urban agriculture largely affects population health indirectly through effects on the environmental, economic, or social conditions of the population. Examples of health determinants may include dietary diversity, food safety, soil quality, and social cohesion. Figure 2.2 illustrates that these health determinants can be categorized into individual factors (age, genetics, gender), individual behaviours (dietary diversity, physical activity), public services and infrastructure (healthcare, fresh foods market), living and working conditions (access to food, employment, soil quality), and social and political factors (social cohesion, poverty, inequality) [21]. It is important to note that each of these determinants has an equity component where certain factors, such as poverty, gender, or race may affect the social determinants of health [22].

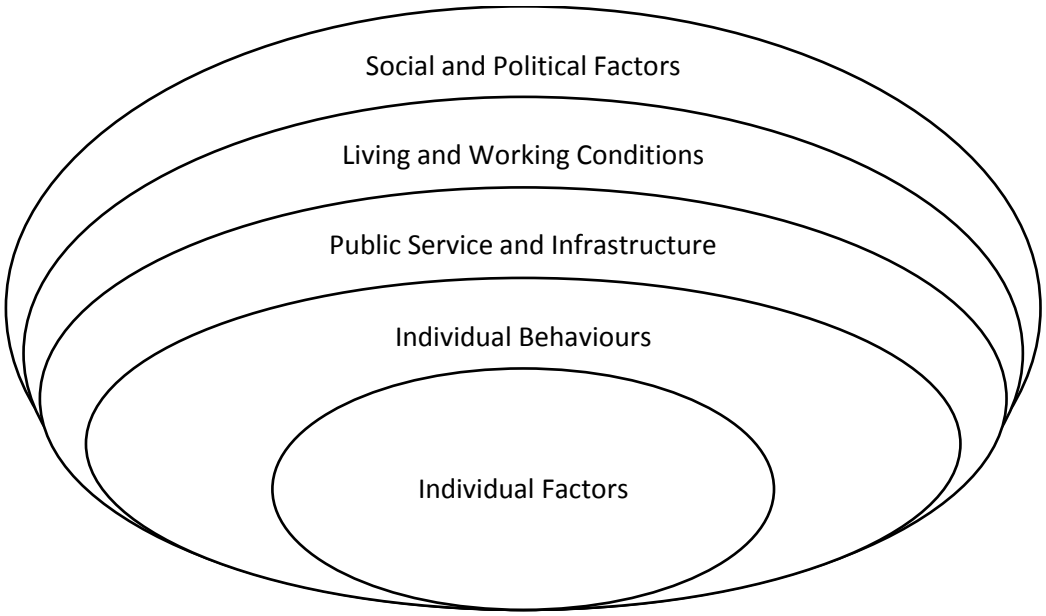

Figure 2.2 The social determinants of health.

Taking a step back to the larger view, each of these direct and indirect impact pathways occur within a larger context that includes gender, culture and equity; policy and governance; climate and environment; and politics and economics. It is important to note that all components of this model are intertwined. It is thus expected that a change at one level would affect the other areas of the model. For example, the introduction of a technology that improves the yield of an urban garden may lead to increased food availability for the urban farmer. Were she to sell some of the excess produce, she would then need to find a way to store, transport, and market it. If she were successful, the increase in income could allow her to buy a greater diversity of

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foods as well as improve the living conditions of her family (e.g. she might install a latrine). The health status of her family members would likely improve, potentially leading to an improvement in their nutritional status. These results would only be known if indicators were measured at each step in the model to determine how the intervention was working in the population. It is therefore imperative that small-scale agriculture interventions, particularly urban agriculture interventions, have a "good theoretical understanding of how the intervention causes change, so that weak links in the causal chain can be identified and strengthened" [23].

2.1.2 Urban Agriculture as a Complex (Multifaceted) Intervention

This exploration of the linkages between small-scale agriculture and nutrition has demonstrated the complexity of the relationship between agriculture, health and nutrition. Looking at the Medical Research Council's (MRC) definition of complex interventions, one can see that urban agriculture interventions that aim to improve nutrition fulfil all five characteristics of a complex intervention [23]. These characteristics are as follows:

1. There are a number of interacting components within the intervention.
2. There are a number of behaviours required by those delivering or receiving the intervention, or the behaviours are difficult to implement in a standardized manner.
3. There are a large number of groups or organisational levels targeted by the intervention.
4. There are a number of outcomes or high variability among the outcomes.
5. There is a lot of flexibility or tailoring of the intervention permitted.

This more nuanced understanding of urban agriculture interventions as complex multifaceted interventions allows a deeper discussion on the lack of demonstrable effectiveness that small-scale agricultural interventions have had on nutrition. One of the findings that the MRC's report on evaluating complex interventions has presented, in relation to a lack of measurable effectiveness of complex interventions, is that "the lack of effect may reflect implementation failure rather than genuine ineffectiveness" [23]. In support of this claim, leading researchers in the area of agriculture and nutrition [1, 18, 24] postulate that the lack of demonstrated effectiveness is not due to a lack of positive relationships between small-scale agriculture and nutrition, but rather is due to a lack of understanding of the complex impact

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pathway between the two. This view was also supported by a review [18] of the gaps in current and planned research of agricultural interventions for improved nutrition. This review revealed the existence of the widely held belief among researchers that small-scale agriculture interventions are efficacious at improving nutrition, but that they are too complex to be adequately implemented and measured. Thus, demonstrable results are in part lacking due to poorly designed and evaluated interventions arising from a lack of understanding of the complex multifaceted impact pathway between agriculture, health, and nutrition [18].

This literature review led to the following hypothesis: The failure of urban agriculture to demonstrate an effect on nutrition is likely not due to the lack of efficacy of the intervention, but rather to the ways in which these interventions are designed and implemented.

2.1.3 An Analysis of Evaluation Studies

In order to test this hypothesis, an analysis of 21 evaluations of small-scale agricultural interventions that aimed to improve nutrition outcomes was conducted. Small-scale agricultural interventions were searched in lieu of urban agriculture interventions as there were very few studies that specifically assessed the nutritional outcomes associated with urban agriculture interventions. The full details of this analytical study can be found in Appendix B. Data from each study`s intervention pathway was extracted and mapped onto the conceptual model of the impact pathways between agricultural interventions and nutrition outcomes (Fig. 2.1). The intent was to elucidate the impact pathway between agriculture and nutrition that each evaluation study assessed. This analysis found that the majority of these evaluations measured only a small portion of the impact pathway and no study assessed the full impact pathway. Although the full **direct** pathway between agriculture interventions and nutrition outcomes were seldom considered, most studies did measure at least one indicator along this pathway, most frequently in the food consumption category (usually measured as dietary diversity). On the other hand, it was rare that a study measured the **indirect** impact pathways to nutrition and health through the social determinants of health, even though this pathway may have a greater impact on health and nutrition outcomes.

Interestingly, although perhaps not surprisingly, it was found that studies that clearly laid out an impact pathway measured a wider variety of intermediate outcomes [25]. In these studies, researchers were able to be responsive and to tweak the intervention between

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intervention cycles as they had data on how the intervention was working. These same studies typically exhibited an increased positive effect on the measured outcomes. These results provide support for the importance of understanding the full intervention pathway between agricultural intervention and nutrition outcomes. Without this knowledge it is difficult to design, implement, or monitor agricultural interventions as one does not know how or why an intervention is working or not working. For these reasons, it is crucial that implementers of small-scale agricultural interventions, including urban agriculture, understand the full intervention pathway and design interventions that measure at least some indicators along this pathway.

2.1.4 Designing and Implementing Multi-Faceted Interventions

Experience and research [26] in the area show that it is not enough to just understand the intervention pathway. There are a number of other factors that need to be considered when designing and implementing these types of complex interventions. First, because no organization can solve an issue like malnutrition on its own, the capacity and responsibility for doing so must be shared amongst the various actors in the system [27]. Thus, organizations need to actively work with these other actors to develop and implement solutions. Second, implementing an intervention will not create a new insular system. Organizations need to accept that they must work within the existing system and that they can only influence outcomes, not create outcomes [26]. Third, because complex problems are non-linear, it may be difficult to predict outcomes and small inputs may have large effects, and vice versa [26]. Thus, careful thought needs to be placed into how to measure the effects of the intervention. Fourth, program managers have to recognize the political and economic context where the intervention is taking place. In this context, solutions are a continual negotiation between stakeholders with competing priorities [27]. Finally, there are always multiple strategies that could be used to solve a complex problem situation and often many strategies aimed at various levels and stakeholders are needed at the same time [27]. Thus, it is not easy to design and implement these types of complex interventions and program managers will need to take these other **soft** elements into account. It should be noted that the use of soft here does not mean that these elements are somehow unimportant, but rather that these elements are difficult to define and capture with traditional methodologies.

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In summary, the goal of this section was to assess the complex relationship between agriculture and nutrition in order to better understand how urban agriculture interventions affect nutrition outcomes. An exploration into the conceptual models that define and describe this relationship revealed that small-scale agriculture, of which urban agriculture is a subset, is a complex intervention with multiple direct and indirect pathways to improving nutrition outcomes. The literature review and 21-study analysis found that it is generally accepted by experts in this field that urban agriculture is in fact an efficacious intervention, however its effectiveness has not been demonstrated through rigorous academic studies, likely because it is a complex intervention acting on a number of different impact pathways. Thus, it is imperative that the complex web of activities is considered when small-scale agriculture interventions are designed, implemented, and evaluated. This is, however, not easily done, as complex interventions present a number of challenges to program managers.

2.2 Assessing the Risks to Population Health

The discussion to date has focused on the positive impacts of urban agriculture on nutrition and health. It is important to note that the impact of urban agriculture on nutrition and health could also be negative. A number of potential risks to population health have been identified in the literature, with more than 50 different real and perceived risks of urban agriculture to health reported in research papers on this topic [13]. These health risks may be classified as risks resulting in communicable disease, non-communicable disease, injury, and psychosocial health risks. Examples of the impacts of urban agriculture on:

1. **Communicable disease** includes:
    a. The use of wastewater to water vegetables, e.g. diarrhoea, cholera or salmonellosis.
    b. Zoonotic disease from improperly managed livestock.
2. **Non-communicable disease** includes:
    a. Exposure to chemicals (e.g. pesticides).
    b. Contamination of soil used to grow food.
3. The prevalence of **injuries** includes:
    a. Accidents caused by straying animals.
    b. Farm work related injuries.

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4. **Psychosocial health** risks include:
    a. Stress caused by seasonal variability, theft, and market price variations.
    b. Long working hours, particularly for livestock farmers.

In order to determine whether studies regularly assess the potential health risks of urban agriculture interventions, the same 21 evaluation studies described in Section 2.1 and Appendix B were assessed. This analysis found that no study reported either real or perceived health risks of agricultural interventions. Given the types of interventions described, including studies on livestock, it is unlikely that the interventions carried no health risks. The studies may not have taken the health risks into account and therefore no data was collected on them, or the health risks were considered, but not reported. It is important to measure and report health risks as they may 'cancel out' the health and nutrition benefits of the agricultural intervention. Or they may be causing detrimental effects to population health that are not captured by the instruments used or the population sampled, particularly if the health effects are outside the population of study. Thus, it is critical that the potential health risks are assessed during the design, implementation, and evaluation of urban agriculture interventions so that these risks can be mitigated prior to implementation.

2.3 Conclusion

This chapter has conceptualized and contextualized the **problem situation.** This problem situation can be summarized as follows. A number of organizations are putting in place urban agriculture interventions with the intent of improving nutrition. These interventions, however, have not demonstrated the improvements in nutrition that were anticipated. Through a review and analysis of the literature, it was found that the failure of urban agriculture to demonstrate an effect on nutrition is likely not due to the lack of efficacy of the intervention, but rather to the ways in which these interventions are designed and implemented. It is, therefore, important that these interventions are based on a good theoretical understanding of the complex impact pathways between urban agriculture and nutrition, so that weak links in the impact pathway can be identified and strengthened during the design and implementation of the intervention. In addition, urban agriculture poses a number of potential risks to population health. It is important that these health risks are considered prior to implementation of the intervention so that strategies can be developed to mitigate the risks to population health.

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In summary, this literature review revealed that if program managers were to strengthen the impact pathways to nutrition and mitigate the health risks, they would require support to undertake the following activities:

1. Assess the potential health impacts of their proposed intervention, prior to implementation of the intervention,
2. Assess a broad range of potential health and nutrition outcomes, based on the social determinants of health,
3. Identify the potential risks to population health,
4. Develop strategies to mitigate those risks,
5. Identify the various impact pathways between the intervention and nutrition outcomes, and
6. Develop strategies to improve nutrition outcomes, based on the identified impact pathways.

The term 'develop strategies' is used throughout this research as a shorthand for these six activities. It is important to note that these six activities are not linear and mutually exclusive, but rather that together they represent an integrated approach that can support program managers to assess and mitigate the risks to population health as well as assess and improve on the impact pathway between urban agriculture interventions and nutrition outcomes.

This research postulates that this problem situation is emerging because the widespread use of urban agriculture as a food-based response to malnutrition is a fairly new area of intervention. The 'honeymoon' period of urban agriculture as a solution to malnutrition is coming to an end, and both the academic and practice communities are becoming more critical of the lack of impact that this intervention has had on nutrition and also the potential health risks that have not been addressed. In the last few years there have been some important publications calling for the assessment of potential health risks and the need for demonstration of the nutritional benefits of urban agriculture interventions [15]. There is, however, no generally accepted means for program managers to do this. This research intends to address this gap in knowledge.

The **gap in knowledge** emerged following reflection on the problem situation, immersion into practice through volunteering in urban agriculture projects, and informal discussions with

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members of organizations implementing urban agriculture interventions. The gap in knowledge, and conversely the research issue, is regarding **how to support** program managers to develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health.

The next chapter reviews the literature to determine whether any approach that could support program managers of urban agriculture interventions to develop strategies currently exists.

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3.0 Literature Review II: Approaches to Prospectively Assess the Health Effects of Urban Agriculture Interventions

This chapter reviews the literature to determine whether there are any approaches that could support program managers to develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health. This literature review finds that the health impact assessment (HIA) approach could be appropriate. This approach is therefore assessed to determine whether it is suitable to use in the context of a complex intervention like urban agriculture and whether it is feasible to use in low-resource settings.

3.1 Review of Impact Assessment Approaches

A scoping review, which included searching for academic papers through Scopus and Google Scholar as well as a grey literature search, was conducted to determine whether there were any health assessment approaches that could support program managers to develop strategies. No approaches that were specifically designed for urban agriculture were found, however, four approaches that aim to measure the potential effects of interventions on health more broadly were found. These are community health assessments, environmental health impact assessments, human health risk assessments, and health impact assessments. These four health assessment approaches were analysed to determine whether they addressed the six areas where program managers would require support to develop strategies as outlined in Section 2.3. The results are summarized in Table 3.1.

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Table 3.1 Comparison of four health assessment approaches.

Does this strategy:	Community Health Assessment	Environmental Health Impact Assessment	Human Health Risk Assessment	Health Impact Assessment
Assess the potential health impacts?	Y	Y	Y	Y
Assess a broad range of health and nutrition outcomes?	Y	N	N	Y
Identify the potential health risks?	N	Y	Y	Y
Provide a means of developing risk mitigation strategies?	N	Y	Y	Y
Identify various impact pathways?	N	N	N	Y
Provide a means of developing strategies to maximize impact pathways?	N	N	N	Y

Community Health Assessments (CHA) aim to identify the key health needs and issues of a community through systematic, comprehensive data collection and analysis prior to the design of an intervention. The goal of a CHA is to identify the health priorities of the population and facilitate collaborative action planning directed at improving community health status [28]. This type of assessment does not specifically aim to determine the health risks and benefits of a proposed project, but rather to develop strategies to address the community's health needs, although these two goals may intersect. The CHA employs a broad definition of health and may include assessment of both biological health factors and social health factors [28]. This assessment methodology does not specifically support the development of risk mitigation strategies or strategies to improve on the outcomes along the impact pathway intervention and outcome.

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Environmental Health Impact Assessments (EHIA) are conducted prospectively to identify the benefits and risks of a proposed project in order to mitigate the risks and maximize the benefits. This assessment method is focused on the environmental impacts and health is only included as one component among many. The EHIA usually does not employ a broad definition of health and focuses mainly on a biological definition of health. Health issues that are taken into account are generally those that can be measured using quantitative methods, such as chemical and pollution exposure [29]. There is limited emphasis placed on assessing the impact pathways between intervention and health outcomes.

Human Health Risk Assessment (HHRA) is an approach to quantifying the burden of disease resulting from risk factors associated with exposure to specific chemical contaminants or other hazards in the environment. Such assessments may be conducted on current or prospective risks and is mostly focus on the risks as opposed to the potential benefits of the intervention. HHRAs do not employ a broad definition of health and tend to focus on biophysical risks from exposure to hazardous substances. Finally, HHRAs measure a simple dose-response relationship and are not designed to measure the impact pathways between intervention and outcomes [29].

Health Impact Assessments (HIA) are used to study the likely impacts of a proposed policy, program, or project before it is put into place [30]. HIAs use a population health lens to assess the physical, mental, and social health outcomes, both directly and indirectly, through effects on the environmental, economic, or social conditions of the population [20]. HIAs use a combination of procedures, methods, and tools to systematically identify potential risks to population health and as well as to identify the potential benefits to health and nutrition. Their purpose is to recommend strategies to mitigate the identified risks and enhance the identified benefits [31]. Thus, the HIA approach is useful for assessing the health effects of urban agriculture.

HIAs were the best fit as they were the only health assessment approach that addressed the six areas outlined in Table 3.1. The health impact assessment approach will be explored in more detail in Section 3.2.

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3.2 Description of the Health Impact Assessment Approach

The HIA approach embodies both a core set of values and a step-by-step process. The values of the HIA approach were first described in the WHO's 1999 Gothenburg Consensus Paper on HIA [32]. The four values underlying the HIA approach are democracy, equity, sustainable development, and the ethical use of evidence. **Democracy** emphasizes people's right to participate in a transparent process for the formulation, implementation and evaluation of interventions that affect their lives. **Equity** emphasizes that HIAs should not only assess the aggregate impact of the proposed intervention on the health of a population but also on the distribution of the impact within the population (in terms of place of residence, gender, occupation, age, race, social capital, etc). **Sustainable development** emphasizes that the HIA should take into consideration both the short- and long-term impacts of the proposed intervention. Finally, the **ethical use of evidence** emphasizes that the use of quantitative and qualitative evidence must be rigorous, and based on different scientific disciplines and methodologies to get a comprehensive assessment of the expected impact.

These four core values form the basis for the process of conducting an HIA. In 2014, the North American HIA Practice Standards Working Group published the latest version of the Minimum Elements and Practice Standards for Health Impact Assessment [33]. This document provides guidance on what is required for a study to be considered an HIA (Minimum Elements) and some benchmarks for effective practice (Practice Standards). This document outlines a six-step process for implementing a health impact assessment:

1. **Screening** determines whether an HIA is feasible, timely, and would add value to the decision-making process.
2. **Scoping** is a research management step with the goals of defining priority issues, creating a timeline, and identifying participating roles. This step includes establishing the steering committee, developing terms of reference, developing a work plan, and establishing goals.
3. **Assessment** aims to provide a profile of existing conditions and an evaluation of potential health impacts. The goal of this step is to determine the potential impacts on health (positive and negative) that may arise from the implementation of the project. In addition, an HIA attempts to determine whether these health impacts are evenly distributed across the population.

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4. **Recommendations** outlining evidence-based strategies to mitigate negative and maximize positive health impacts are presented based on the identified risks and benefits.
5. **Reporting** of the HIA process, evidence, and recommendations to the necessary stakeholders is an important step in translating the gathered evidence into action.
6. **Monitoring** is important to track the impacts of the HIA on the decision-making process of the project, the implementation of those decisions, and the impacts of those decisions on the determinants of health.

The four core values, when taken with the six-step process, form the basis of every HIA application.

Although the HIA approach does not formally integrate complexity thinking into the approach, it does appear that HIAs are able to respond to some of the challenges inherent in designing a complex intervention that were outlined in Section 2.1.4. Table 3.2 summarizes how the HIA approach may be able to respond to some of these challenges. The first column outlines five challenges, based on the literature [26], that should be addressed during the design and implementation of a complex intervention like urban agriculture. The second column outlines how the HIA approach may be able to respond to these challenges.

As seen in Table 3.2, the HIA approach may respond to the challenges of designing and implementing complex interventions as this approach (1) emphasizes the importance of multi-stakeholder engagement, (2) focuses on working within the current system by making accommodations for others intentions, priorities, and needs, (3) employing a wide variety of methods, (4) negotiating solutions by making trade-offs between evidence and stakeholder`s values and preferences, and (5) allowing for the use of multi-pronged, multi-level strategies targeted at a variety of levels. Thus, the HIA approach appears to embody a number of soft elements that could help address some of the challenges in designing and implementing a complex intervention like urban agriculture. It is of note that these soft elements, and the values underlying these elements, are not trivial. Rather these soft elements are likely more valuable than the technical six-step process as they allow the HIA to be useful in real-life settings.

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Table 3.2 How an HIA may be able to address five features of a complex social program.

Challenges in designing complex interventions	**How an HIA may be able to respond to these challenges**
1. No organization can solve an issue, such as malnutrition, on its own. The capacity to tackle complex problems must be shared amongst actors and stakeholders.	HIA emphasizes the importance of *multi-stakeholder involvement*. By its very nature it requires that cross-sectoral action is taken on policies and programs.
2. Organizations or networks can only influence change in a system, they cannot create a new system.	The recommendations of an HIA focus on how to work within the current system, not how to create a new system. Program managers thus need to make *accommodations for others intentions, priorities, and needs* during the design and implementation of an intervention.
3. Because complex problems are non-linear, it is difficult to predict their outcomes and small inputs may have large effects.	The HIA attempts to predict outcomes. Although many HIAs to date have used traditional epidemiological or toxicological data, it does not necessarily need to be the case. The HIA can accommodate a *wide variety of methods* to make predictions, including systems methods such as systems dynamics or soft systems methodology.
4. Possible strategies have to recognize the political and economic context of the program. In this context, solutions are a continual negotiation between stakeholders with competing priorities.	This is the very nature of an HIA. HIAs by definition have to consider the political and economic context of the program or policy under assessment. It is critical that negotiation between stakeholders occurs in order to develop meaningful and implementable recommendations. These negotiations need to include a *trade-off between the academic evidence and the values and preferences of stakeholders*.
5. There are always multiple strategies that can be utilized to solve a complex problem and often many of the strategies are needed at the same time.	The HIA is not limited in scope to just one field or solution. This allows for the use of a *multi-pronged, multi-level strategy approach* that includes wide variety of strategies across various sectors, targeted at a variety of levels.

This section has summarized the HIA approach and discussed this approach's utility in supporting program managers to develop strategies. It is not clear, however, whether it is feasible for program managers to use this approach in low-resource settings. This issue will be explored in the next section.

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3.3 Feasibility of the HIA Approach for Program Managers in Low-Resource Settings

A search for HIAs of urban agriculture policies and programs was undertaken to determine whether these are commonly conducted in low-resource settings. The methodological details of this search can be found in Appendix C. This search revealed eleven HIAs of urban agriculture interventions. Of these published HIAs, eight were conducted in the United States, one was conducted in Argentina, one was conducted in South Africa, and one was conducted in Uganda. From this geographical spread of HIAs, one can see that although it is feasible to conduct an HIA of urban agriculture in both high- and low-resource settings, it is not common practice to undertake HIAs on this topic outside of the United States. This research sought to determine why this might be the case by reviewing the literature to assess the barriers to conducting HIAs in low-resource settings.

A review of the literature identified four interrelated barriers to conducting HIAs in low-resource settings:

(1) **Availability of data:** HIAs require a great deal of data, both from academic evidence bases and local data sources. Academic evidence is often difficult and time consuming to access, and may not address specific questions that a program manager is interested in. Data at the local level may come from primary or secondary sources. Primary data may be time-consuming and expensive to gather and secondary data might not be available at the level at which it is required [38].

(2) **Expertise:** Some HIA practitioners have argued that it is not desirable for people who are not experts on the HIA approach to conduct their own HIAs. These HIA practitioners maintain that HIAs require a strong grasp of a wide range of methodologies and an in-depth understanding of the social factors impacting health [34]. They posit that those implementing HIAs should have extensive experience conducting HIAs and sound knowledge of both qualitative and quantitative methodologies [34]. Program managers of urban agriculture projects do not generally possess this knowledge or skill set [35, 36]. Therefore, experts need to be brought in from outside the organization. This may be difficult for organizations in low-resource settings due to the high financial and time costs associated with contracting external expertise.

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(3) **Timeliness:** In order for an HIA to be most effective in affecting the decision-making process it needs to be timely. Program managers and other decision-makers are often not willing to wait for a lengthy HIA process as they need to implement projects on short timelines. HIAs therefore need to occur within a matter of days or weeks [35, 38, 39]. HIAs are, however, more likely to take several weeks or months [40]. Although this issue is not specific to low-resource settings, it may have a more pronounced effect in these settings as resources are scarce and program managers may not be able to wait extended periods of time for a HIA to be completed.

(4) **Financial costs:** As noted above, the financial costs of accessing data and bringing in external expertise to conduct an HIA can be very high. The average cost of conducting an HIA varies between $10,000 and $100,000 USD per HIA [36, 38, 39]. This may be a major impediment to organizations, especially in low-resource settings.

This analysis of the barriers to conducting HIAs in low-resource settings identified that HIAs are an expensive, time-consuming, expert-driven process that require large amounts of data. Therefore, although HIAs do provide a means of assessing the health effects of urban agricultural interventions, it appears that they are not feasible for program managers to use in low-resource settings.

3.4 Conclusion

The goal of this chapter was to review the literature to determine whether there were any approaches that could be used to support program managers in low-resource settings to develop strategies. Of the four approaches identified, the HIA approach was deemed the most appropriate because it can measure a broad range of potential health outcomes and it can be used to identify both the risks to population health and the various impact pathways to nutrition. The HIA approach was assessed to determine whether it was applicable in the context of a complex intervention like urban agriculture. Upon assessment of this approach, it became clear that the HIA is more than just a technical six-step process. Rather the step-by-step process is underpinned by a set of values and related soft elements. These soft elements include multi-stakeholder engagement; the ability to make accommodations for others' intentions, priorities, and needs; making trade-offs between evidence, values and preferences; creatively developing a set of evidence-based strategies aimed at a variety of levels; and utilizing a wide variety of methods. It is these soft elements that make the HIA a desirable approach in this context.

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The feasibility of program managers utilizing this approach in low-resource settings was then assessed. This assessment found that HIAs are an expensive, expert-driven process requiring access to a variety of expert knowledge and skills. Thus, HIAs are unlikely to be feasible in low-resource settings. However, because the HIA approach was clearly desirable in this context, it was postulated that if the expert-driven HIA could be captured into a decision support tool for use by non-experts, then program managers could use that tool to develop their own strategies. This idea will be conceptualized in the next chapter.

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4.0 Conceptualizing the Transfer of Knowledge from an Expert to a Non-Expert

The previous chapter proposed that if the expert-driven HIA approach could be captured into a decision support tool for use by non-expert program managers, then they could use that tool to develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health. The goal of this chapter is to conceptualize the transformation and transfer of the HIA approach into a decision support tool that can be utilized by non-experts. This chapter is structured as follows: First, a conceptual model for thinking about the transfer of knowledge from experts to non-experts is discussed along with the long-term vision of this research project. Next, an information systems approach to developing a decision support tool is explored. Finally, various approaches for developing a technology-supported information system are reviewed to determine which approach best fits the goals of this research project. This chapter concludes with a definition of the scope of this research.

4.1 Knowledge Transfer

The core concept underlying this research is the identification and capture of expert knowledge for use by non-experts. In the field of population health, this is called knowledge transfer. In order to gain insight into how to transform expert knowledge into a form that can be used by non-experts, a scoping review of conceptual models of knowledge transfer was conducted. This review found more than 30 conceptual models that are pertinent for transforming expert knowledge so that it can be used by non-experts. Three of the most commonly used models include: The Promoting Action on Research Implementation in Health Services, the Consolidated Framework for Implementation Research, and the Knowledge to Action (KTA) model [41]. The KTA model was selected as the guiding conceptual model in this research as (1) the content of the KTA model encompasses many previous models and is based on an extensive systematic review and synthesis of 31 planned action theories. (2) The KTA model integrates knowledge creation with the implementation of the created knowledge, whereas the other models do not explicitly focus on knowledge creation. (3) The KTA model is widely used and cited [41]. (4) The KTA model emphasizes the context where the resulting information system will be used. (5) The purpose of the KTA model is to transfer knowledge so that this knowledge can be used to inform decision-making [42].

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The KTA model was developed by the Canadian Institutes of Health Research with the intent of providing guidance on the process of transforming and transferring expert knowledge into knowledge that can be used by non-experts to take action or decisions. The KTA process embodied in the model is divided into two separate phases: the knowledge creation funnel and the action cycle (Fig. 4.1).

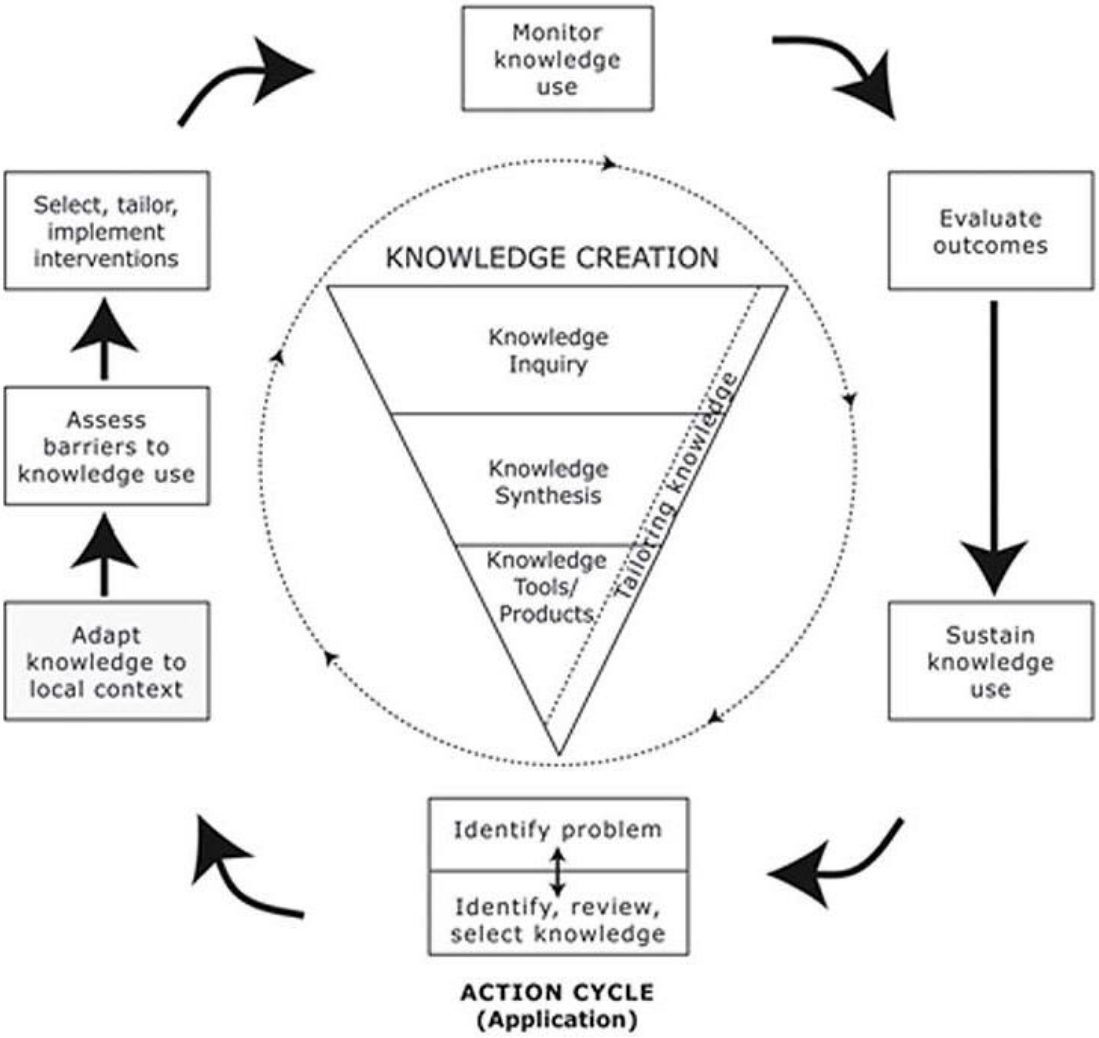

Figure 4.1 Knowledge to Action Model (Source: [43]).

4.1.1 Knowledge Creation

The knowledge creation phase of the KTA model is represented by the knowledge funnel and has as its goal the production of contextualized knowledge bases that can aid in decision-making or otherwise taking action [43]. The knowledge funnel consists of three distinct levels of

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knowledge production: knowledge inquiry, knowledge synthesis, and decision support tools. As knowledge moves through the funnel, it becomes more synthesized and presumably more useful to the end user. The first level of knowledge inquiry can be described as knowledge that is in its natural state (i.e. original research studies or experiential knowledge held by a single person). Second-level knowledge is that knowledge which has undergone some form of synthesis and represents an aggregation of existing knowledge. This knowledge may take the form of a systematic review or a 'good practice' summary. Third-level knowledge consists of decision support tools [43]. The purpose of a decision support tool is to present knowledge in a clear, concise, user-friendly manner with the intent of supporting practitioners in decision-making. Examples of decision support tools include practice guidelines, decision aids and rules, and care pathways [43]. Decision support tools can theoretically take any form, however are usually paper-based or electronic.

4.1.2 The Action Cycle

The action phase of the knowledge to action model takes the knowledge generated in the knowledge creation phase through to implementation. Once a problem has been identified and the knowledge to solve that problem is captured into a decision support tool, the following steps need to take place:

1. the decision support tool should be adapted to the local context,
2. the barriers to the uptake of the decision support tool should be addressed,
3. the decision support tool should be tailored and implemented appropriately,
4. the uptake of the decision support tool should be monitored,
5. the decision support tool should be evaluated within the context that it is being used to determine whether it is leading to improved outcomes, and
6. the use of the decision support tool should be sustained through regular monitoring and updated as appropriate.

Later iterations and writings on the KTA model noted that these steps are dynamic and that the process of translating knowledge into action is complex and not necessarily linear as presented in this model [42]. The outcomes of the various steps of the action cycle may influence the design and form of the decision support tool. And vice versa, the knowledge creation phase may influence the steps in the action phase.

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4.1.3 The Long-Term Vision

The long-term goal of this research is to encode the knowledge contained in the expert-driven HIA into a decision support tool that can be used by program managers in low-resource settings to develop strategies. In order to bring this decision support tool to fruition, it first needs to be designed (the knowledge creation funnel) and then implemented (the action cycle) as described above. The design and implementation of a decision support tool is a long and involved process requiring many different skills, people, and time. This dissertation contributes to that long-term goal by focusing on the first of these steps, which is the **design** of the decision support tool. The implementation of the resulting tool through the steps in the action cycle is beyond the scope of this work. However, it will be necessary to follow through on this cycle once the decision support tool has been developed. The next section discusses the process of designing the decision support tool.

4.2 Designing a Decision Support Tool using an Information Systems Approach

This research is concerned with the design of a decision support tool that can be used by program managers to develop strategies in low-resource settings. A review of the decision support tool design methods most often utilized within the KTA model revealed that although the potential number of formats for a decision support tool is endless, most that have been developed are either simple decision aids or practice guidelines. The main criticism of the KTA model by this research is that it lacks guidance on how to develop the more complicated decision support tool that the HIA necessitates. This research found that the leap from second level knowledge (knowledge synthesis) to third level knowledge (a decision support tool) is too large. In addition, the KTA model has historically been used to transfer content knowledge that can easily be captured (for example, a list of health effects). In order to make the HIA approach accessible to non-experts, it will be necessary to not only capture the content knowledge related to the health effects of urban agriculture, but also capture the methods or means of acquiring that knowledge. Due to the complexity of transferring this type of expert knowledge, more specific guidance on developing decision support tools was deemed necessary.

In order to learn more about decision support tool development, a review of the literature outside of the population health field was performed to determine whether there were

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guiding principles in other fields that could be useful. The field of information systems was found to have an abundance of theories in this area, including theories on knowledge management, knowledge representation, and artefact design. The idea of transforming and transferring expert knowledge into something that can be used by non-experts is a basic tenet of an information system, which can be defined as a system that provides "information to support the operations, management, and decision-making functions of an organization" [44: p42]. In other words, information systems serve to help people take action or decisions in real-world problem situations. Viewed from this paradigm, a decision support tool can also be viewed as an information system.

Information systems are often equated with information technology (IT) and so it is useful to differentiate the two concepts here. As defined above, information systems are a means of organizing the collection, storage, and communication of information. IT is a computer-based system that can be used to support information systems, but is not a necessary precondition of an information system. Although information systems do not necessarily need to include a technological component, the reality in our current society is that they usually do include some form of IT. Due to the complexity inherent in designing urban agriculture interventions and the amount of information that would need to be captured for reuse, it is probably most feasible to think about the organization of an information system resulting from this research as an information technology, such as a software application.

Some researchers [45, 46] have been very vocal about the importance of harnessing the latest technologies in the development of decision support tools. They argue that because technology can help to deliver results faster than humans and at a lower cost, it should be used more extensively. Other benefits of using IT include faster decisions, better outcomes, greater efficiency, lower costs, greater scale, and service innovation [47]. Technologies are already widely used, for example in banking (fraud detection systems), health care (analysis of medical images, decision aids for diagnosis), and the public sector (surveillance, compliance, and automation of services). With the rapid development of IT and the internet, even in the most low-resource of settings, it is now feasible to imagine the widespread use of IT, particularly on smartphones [48]. In fact, some researchers are critical of *not* using IT in these settings as much research in the last 10 years has shown the advantages that information technologies can have on health outcomes in low-resource settings [47]. Two recent examples of technology-supported information systems

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that are currently being used in low-resource settings include (1) the Nutrition Information System in Ethiopia [49], which collects routine data for use in decision-making at local levels by governments and international NGO's and (2) the Academic Model Providing Access to Healthcare (AMPATH) Nutritional Information System, which was designed as a comprehensive electronic system to record and assist in effective food distribution in a region with poor infrastructure in Kenya [50]. The issue in these low-resource settings is usually not the use of the technology itself, but rather the uptake of that technology by the end users. Thus, the action cycle of the KTA model is an important component for theorizing the implementation of any resulting technology. Although IT can have many benefits, it is important that it is not viewed as a catch-all solution. It is an enabler that can help organize, store, and access knowledge, but it is not a solution in and of its own [51].

In summary, information systems provide the 'right' information, at the 'right' time, in the 'right' place, in the 'right' way, to the 'right' person [52]. An information system was deemed an appropriate solution by this research because it could provide the right information (information on how to assess and mitigate the health risks as well we assess and maximize the critical impact pathways of nutrition) to the right people (program managers designing and implementing urban agricultural interventions) in the right place (low-resource settings) at the right time (prior to implementation of the intervention) in the right way (in a readily available and easily contextualizable manner). The information system developed in this research is termed the Health Assessment Information System for Urban Agriculture Interventions in Low-Resource Settings (HAIS).

4.3 Information System Development Approaches

A broad introduction to developing information systems is presented with the goal of defining the scope of the research. The field of information systems incorporates a variety of approaches for developing technology-based solutions. Each of these approaches proposes a structure for planning and undertaking the development process. These include the waterfall approach, prototyping, rapid application development, and the spiral approach. Each of these approaches is best suited to specific kinds of information system development projects and one system development approach is not necessarily suitable for use in all projects. These approaches

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were therefore compared to determine which is most suitable within the context of this research. A very brief summary is included below:

The **waterfall approach** is the conventional approach to information system development and consists of a sequential multi-stage process, where each stage is completed prior to moving onto the next stage [53]. Each stage in this process requires a different set of skills, methods, and techniques. As depicted in Fig. 4.2, these stages are as follows:

1. **Initial investigation** - the goal of this stage is to gain an in depth understanding of the problem situation. This forms the basis of all other stages in the process.
2. **Requirements definition** - this involves defining the requirements of the information system to be developed.
3. **Systems design** - in this stage, the information requirements are converted into detailed specifications for an architectural framework. An architectural framework is defined as a layered structure that indicates the parts of the information system and how they interrelate.
4. **Coding and testing** - the architectural framework is translated into a functioning technology-based solution. The information system is created and the underlying software is developed and tested for errors and robustness.
5. **Implementation** - the information system is deployed with feedback mechanisms in place that would inform the system's improvement as described in the action cycle of the KTA model.
6. **Operation and support** - this stage occurs once the information system has been deployed and refers to the ongoing support and maintenance that may be required to keep it functional and up-to-date.

Control of the development process is maintained through formal reviews and extensive written documentation.

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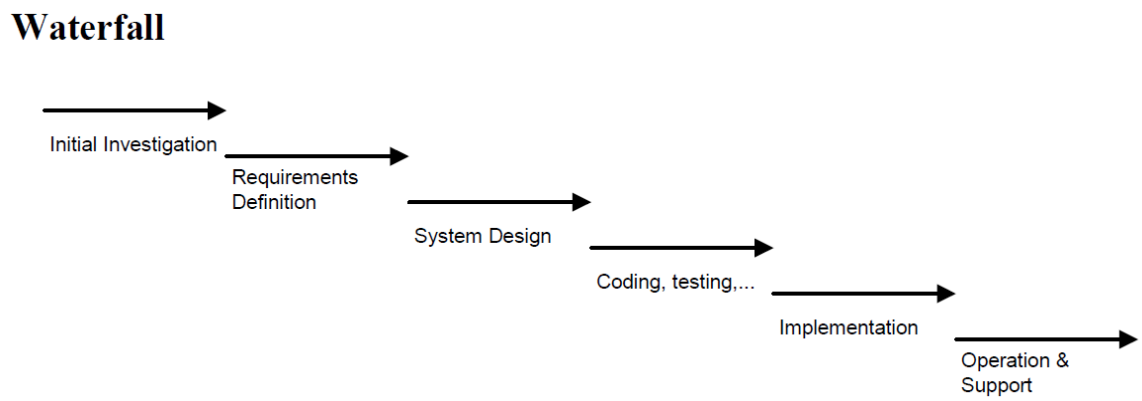

Figure 4.2 The waterfall approach to information system development [53]

The waterfall approach is used in situations where there are clear objectives, the requirements are stable and unchanging, the information system does not need to be immediately implemented, and there are strict requirements for formal approvals at designated milestones. Within the context of this research, all of these issues hold true for the development of the HAIS.

Some of the weaknesses of the waterfall methodology include [53]:

1. It is inflexible, slow, costly and cumbersome due to significant front-end structures and tight controls.
2. Since this is a sequential process where the design is fully completed before the population and implementation stages, there is limited flexibility and any changes in later stages could prove difficult or costly.
3. Similarly, because testing can only occur once the system is almost fully coded, problems or issues of under-capacity will only be discovered very late in the process.
4. This approach produces excessive documentation and keeping it updated as the project progresses may be time-consuming.

The waterfall approach is the classic approach to information system development and the other approaches, described below, were created to partially address some of these weaknesses.

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Prototyping refers to a cycle of developing and deploying small-scale mock-ups of an information system. This process continues until the prototype evolves to meet the users' requirements. Prototyping assumes that the end user and software engineer are intimately involved in the system development. Prototypes are often used in addition to, or sometimes in place of, having detailed design specifications. This design methodology is most useful in situations where the objectives of the information system are unclear.

Rapid-application development (**RAD**) refers to an adaptive information system-development approach that places less emphasis on planning and more emphasis on an adaptive process of developing working prototypes. Similar to prototyping, this approach relies on the intimate involvement of a software engineer and the end users in system development process. RAD is especially well suited for projects where the functionality and technical architecture are clearly defined.

The **spiral approach** is an iterative process wherein the project is broken down into almost autonomous components and each component is developed and tested separately. The benefits of this approach are that it can incorporate the other design methodologies (prototyping, waterfall, RAD) on an as needed basis. The downside of this approach is that it requires an extensive knowledge of the technicalities of information system design.

The waterfall approach was selected as this is the only approach that does not require the intimate involvement of a software engineer at the outset of the process. In addition, it follows a clearly delineated step-by-step process with very well-defined boundaries and activities comprising each stage. Thus, progress through the system development process is measurable. Finally, the orderly progression through steps and strict controls for ensuring the adequacy of documentation and design reviews help ensure that quality and accountability are maintained through detailed documentation. This was an important consideration in the context of this doctoral research project.

4.4 Conclusion

This chapter has outlined the general steps that would need to be undertaken to design, develop, and implement the HAIS. Through this discussion, one can see that the development

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and implementation of an information system is a highly involved process that cannot be achieved within the lifetime of a doctoral research project.

Although the long-term intent is to engage computer scientists and implementation researchers in the development and implementation of a technology-based information system, this is beyond the scope of this doctoral research project. Time and resource constraints inherent in a doctoral research project as well as a lack of expertise in software programming helped limit the scope of this study. The **scope** of this research is limited to the first three stages of the waterfall approach namely, the initial investigation, the requirements definition, and the system design. These three stages were selected as they require original, inductive, theoretical research. The outcome of this research is an architectural framework that lays the theoretical foundation for the next stage in the development process, namely the coding and testing of the information system.

The next chapter will discuss the theoretical underpinnings of information system design as it applies to the development of this architectural framework.

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5.0 Theoretical Foundations for the Design of an Architectural Framework

The previous chapter defined the scope of this research as the design of an architectural framework for the HAIS. The design of an architectural framework is generally based on one of two underlying theoretical foundations, hard systems theory or soft systems theory. These two theoretical foundations are compared in this chapter with regards to their philosophical and sociological underpinnings, the role of models, the organizational context, the role of the information system, and implications of these for the design of an architectural framework. Soft systems theory is selected as more appropriate and is used to provide a theoretical basis for the research design, which will be discussed in Chapter 6. Thus, the theoretical perspectives are used to link the research questions to the research design.

Discussion of the underlying theoretical perspectives is based on literature resulting from an ongoing forty-year-old action-research program at the University of Lancaster in the United Kingdom under the leadership of Peter Checkland. This review focuses on the primary literature in this field as it is presented in the following seminal textbooks: Systems Thinking, Systems Practice (1981) [54]; Soft Systems Methodology in Action (1990) [55]; Information, Systems and Information Systems (1998) [44]; and A Thirty-Year Retrospective (1999) [56]. These primary sources were supplemented by a number of original articles published by Checkland and colleagues on information system development.

5.1 Hard vs Soft Systems Theory

Two approaches to designing an architectural framework, one based on hard systems theory and the other based on soft systems theory, are compared to determine which approach is more appropriate in the context of a complex intervention like urban agriculture. A summary of this comparison is presented in Table 5.1. Hard systems theory will be discussed in Section 5.2, followed by a discussion of soft systems theory in Section 5.3.

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Table 5.1 Differences between hard systems and soft systems theory (Adapted with permission from: [44]).

	Hard Systems Theory	**Soft Systems Theory**
Philosophical underpinnings	Positivism	Phenomenology and hermeneutics
Sociological underpinnings	Positivist sociology	Interpretivist sociology
Role of models	Assumes the world contains systems that can be modelled	Mental models are relevant to the real-world, but do not represent any real-world structures. They can be used to interpret the 'messy' real-world.
Organizational context	Managers seek to achieve declared organizational goals	Managers seek to manage relationships by making trade-offs between organizational goals and others' values, preferences, and goals
Role of the information system	Provides technical information based on the best available evidence to support decision-making	Supports purposeful action by helping individuals to conceptualize their world, find accommodations, form intentions and take action

5.2 Hard Systems Theory for Information System Design

Hard systems theory is philosophically based in positivism and derives its view of a single social reality from the positivist sociology of Durkheim [44]. As seen in Fig. 5.1, hard systems theory views the world as comprising of observable systems; for them the world is systemic. Hard systems theory assumes that the world contains systems that can be modelled, with models representing a shared vision of an objective reality and generally corresponding to structures.

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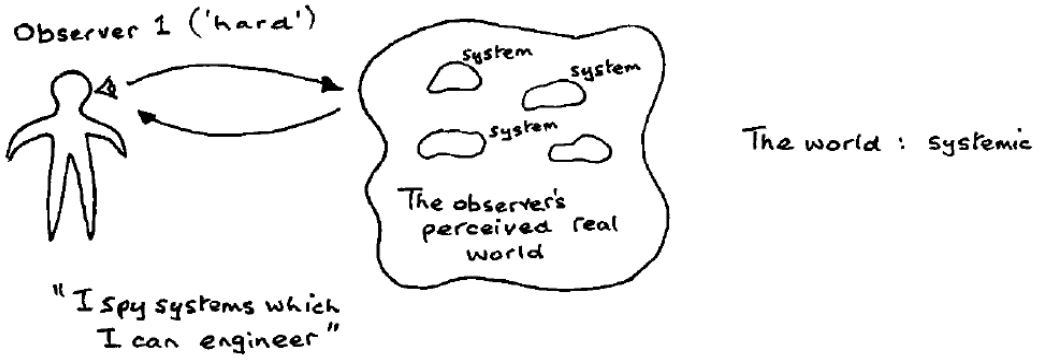

Figure 5.1 A hard systems view of the role of models (Reprinted with Permission from Wiley & Sons [56: Fig. A2]).

An example of this kind of systems model might be a model of the organizational structure representing the various departments within an organization. Hard systems theory is based on the unquestioned assumption that organizations are goal-seeking entities and that management is synonymous with maximizing efficiency through decision-making [44]. According to this view, managers exhibit a limited or bounded rationality, searching for decisions which are good enough, given the circumstances, even if they are not optimal. In this way, the manager moves towards his or her goal by making incremental adjustments based on the best decisions possible at that time [44]. This view of management proposes a three-stage process of decision-making. In the first stage, problems are identified and data is collected. In the second stage, a range of possible solutions are explored. In the third stage, a choice which is 'good-enough' is selected and its implementation is monitored [55].

The role of an information system in this type of organizational context would be the provision of technical data on the health risks and benefits to support decision-making. For example, the information system might supply program managers with a list of health risks and some important impact pathways based on the best available evidence and then help them apply this within their context to come up with a set of recommendations on how to reduce the risks and maximise the nutritional benefits. This type of information system is based on the assumption of hard systems theorists that if program managers implementing urban agricultural interventions in low-resource settings had support to identify the health risks of urban agriculture as well as identify the critical impact pathways to nutrition before the intervention is

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put into place, they would be able to mitigate the associated health risks and maximize the nutritional benefits. This is based on the deeper assumption that program managers are primarily seeking to maximize the efficacy and efficiency of their interventions and that if they were supplied with information on how to achieve this, they would design and implement more effective and efficient interventions. This type of information system does not, however, consider the complexity within the organizational context. Nor does it consider the values of the people involved nor the relationships between them. An information system based on hard systems theory is not sufficient because the view of an organization as a purely goal-seeking entity is not representative of the complex context wherein a health assessment of urban agriculture intervention takes place.

5.3 Soft Systems Theory for Information System Design

Soft systems theory emerged out of the challenges of the functionalist approaches of hard systems theory. Researchers (Checkland and colleagues) seeking to model complex management issues within the increasingly complex organizational settings of the 1970's encountered difficulty when attempting to answer such apparently simple questions as 'What is the system we are concerned with?' and 'What are the system's objectives?' [56]. These academics concluded that in the complexity of human organizations, the unequivocal pursuit of defined goals is an occasional special case and is certainly not the norm [56]. As a result, they developed an alternative theory to the traditional hard systems perspective, terming it soft systems theory. Soft systems theory is philosophically part of the tradition of phenomenology and hermeneutics. It is sociologically linked to the interpretive approach of Max Weber, rather than the positivist sociology deriving from Durkheim that underlies hard systems theory. Thus, soft systems theory is based on a tradition that emphasizes the subjective nature of the real-world. In line with this underlying philosophy, soft systems theory views the organizational context as a socially constructed entity wherein meanings are created by people within the organization.

Soft systems theory, in contrast to hard systems theory, views models as intellectual devices whose role is to help structure the exploration of the problem situation being addressed. As can be seen in Fig. 5.2, the models developed by soft systems theorists do not exist in reality, they are however relevant to reality and can be used to systemically structure the process of

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inquiry into reality [44]. Soft systems theorists believe that the world can be 'systemically' interpreted using mental models.

> Thus, the use of the word system is no longer applied to the world, it is instead applied to the process of dealing with the world. It is this shift of systemicity from the world to the process of inquiry into the world which is the crucial intellectual distinction between the two fundamental forms of systems thinking [56: p.10].

According to soft systems theory, these models are based on the idea that all problem situations have in common the fact that they contain humans interested in taking purposeful action [44]. Purposeful action can be defined as those activities that are undertaken by humans (i.e. program managers) to achieve a specific purpose (i.e. develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health). The six activities defined in Section 2.3 can therefore be viewed as purposeful actions. The models related to these purposeful actions are termed 'purposeful human activity system' models.

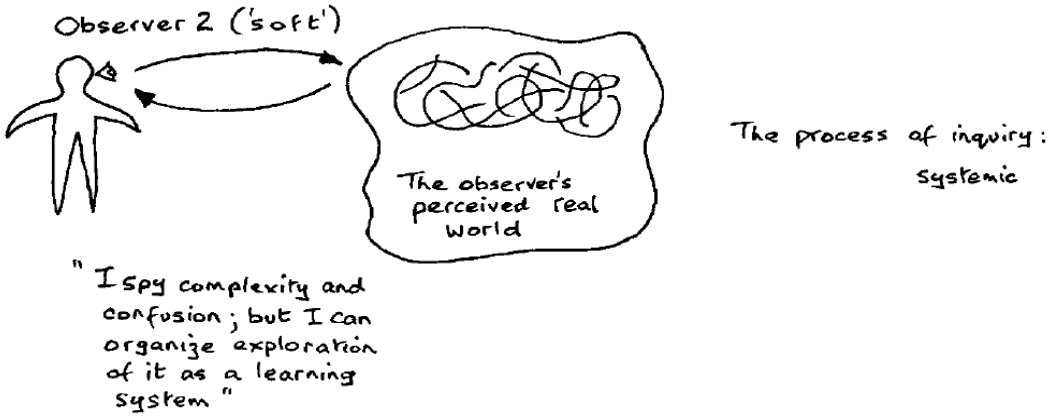

Figure 5.2 A soft systems view of the role of models (Reprinted with Permission from Wiley & Sons [56: Fig. A2]).

It is important to reiterate that this 'system' is not some system existing out there in the real-world, but is rather a mental model of hypothetical activities that could be undertaken in the real-world. Thus, human activity system models are never models **of** real-world action, they are models **relevant to discourse** about real-world action. They are thought devices that could be used to structure debate about different ways of seeing a situation [55].

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5.3.1 Soft Systems View of Organizational Context

Soft systems theory's view of management within organizations is based on Sir Geoffrey Vickers' theory of appreciative systems [56]. Vickers proposes a view of organizations as social entities wherein managers seek to manage relationships, not merely achieve goals. Managers act based on their perceptions of the situation, their envisaged desired relationships, and their judgements of the facts and values [55]. These judgements are based on a set of standards that they hold as a result of their history with the organization. Managers in organizations implementing urban agriculture interventions do not necessarily make decisions based on the best available research evidence with the intent to optimize the efficiency of an intervention. Instead, managers may make decisions based on their perception of the situation (this may include perceived or real pressure from interest groups or perceptions about the local context), their envisaged relationships (e.g. they may implement the project in a certain way or in a certain time frame in order to maintain their relationship with the funding agency or local authorities), and their judgment of standards based on the history of the system (e.g. doing something in a certain way because 'that's how it has always been done'). These examples illustrate that managers in organizations do not necessarily make decisions to optimize the efficiency of the intervention, but rather work to maintain relationships over time [44]. Progress is achieved by reaching accommodations between the various actors concerning which changes are desirable and feasible within the local context. This theoretical exploration into the organizational context has shown that organizations are not purely goal-seeking entities; they are in fact social entities, made up of multiple people with multiple agendas. This view of organizations is a more accurate description of the organizational context in which HIAs are conducted. As discussed in Section 3.2, the HIA approach consists of both a technical 6-step process and also a number of underlying soft elements to include: the need for multi-stakeholder engagement; the ability to make accommodations for other people's intentions, priorities, and needs; making trade-offs between evidence, values and preferences; creatively developing a set of evidence-based strategies aimed at a variety of levels; and utilizing a wide variety of methods. These soft elements are better captured by soft systems theory than by hard systems theory.

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5.3.2 The Role of Information Systems According to Soft Systems Theory

The role of an information system in this type of organizational context is to support humans who are trying to take action. Fig. 5.3 provides a graphic depiction of the role of an information system in the type of organizational context described by Vickers.

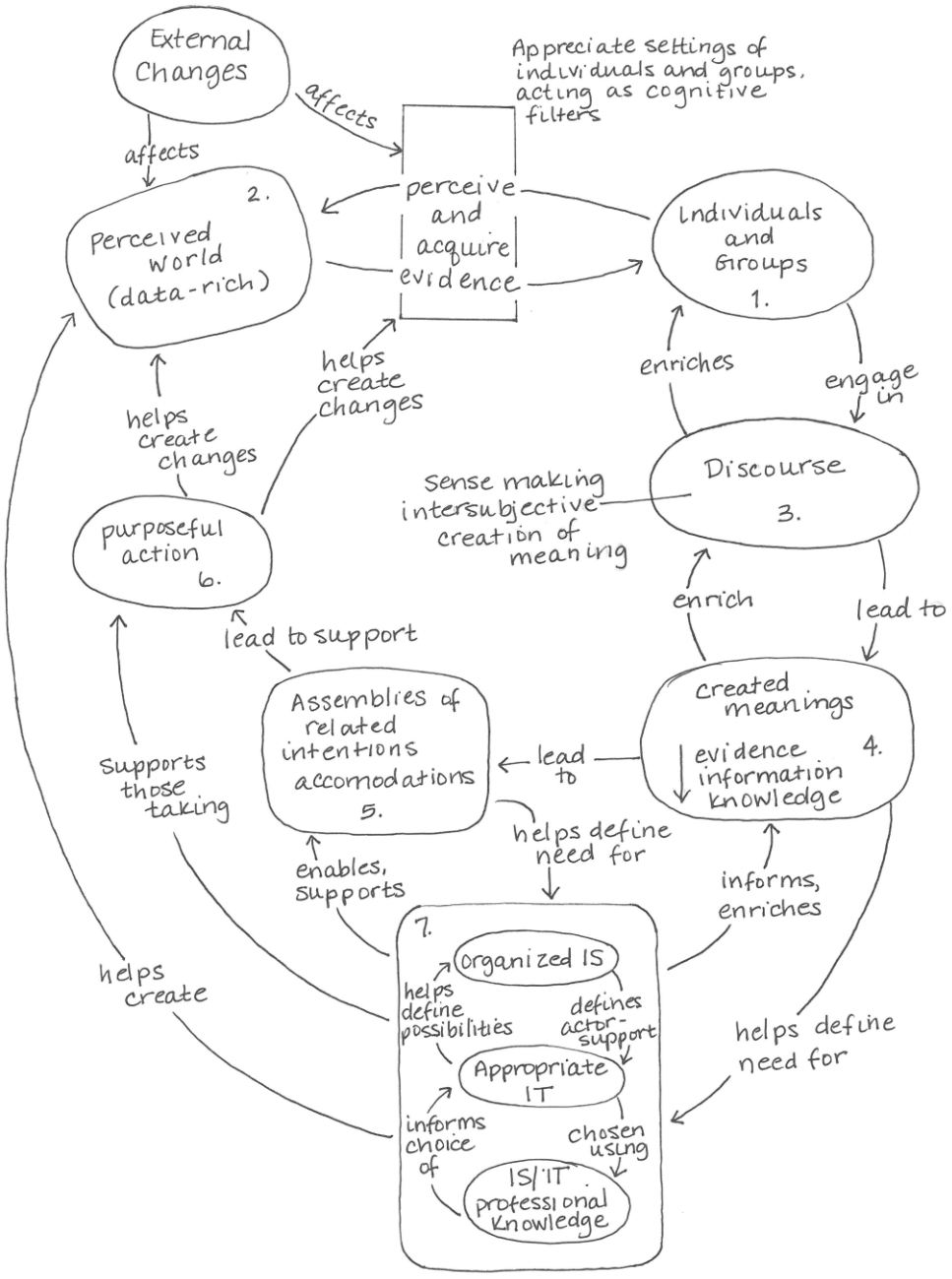

Figure 5.3 The role of information systems in organizations according to soft systems theory (Reprinted with permission from Wiley & Sons [44: Fig. 7.7]

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It is important to note that Fig. 5.3 is not a model of any specific organizational context, but is rather a conceptual tool designed to stimulate thought about the various activities within an organization that are relevant to the role of information systems. As shown in Fig. 5.3, program managers within the organization perceive the real-world through their own cognitive filters (1-2). These individuals then create meaning about that real-world through discourse with other stakeholders (1,3,4). This discourse includes both the complex social processes that occur between individuals, such as discussion, persuasion, and coercion, as well as rational decision-making. This internal and external debate leads to program managers forming intentions based on their own preferences and by making accommodations for others' preferences (5). These intentions then lead to purposeful action being taken in the real-world (6). This action is based on the premise of managing relationships, not only on structured decision-making. This purposeful action in turn helps to create the real-world and also simultaneously changes perceptions of the real-world (2). According to this model, information systems (7) serve to support program managers is taking purposeful action.

A simplified version of Fig. 5.3 is presented in Fig. 5.4. This figure makes clear that information systems do not exist for their own sake, rather any information system needs to support managers working within an organizational context to take purposeful action.

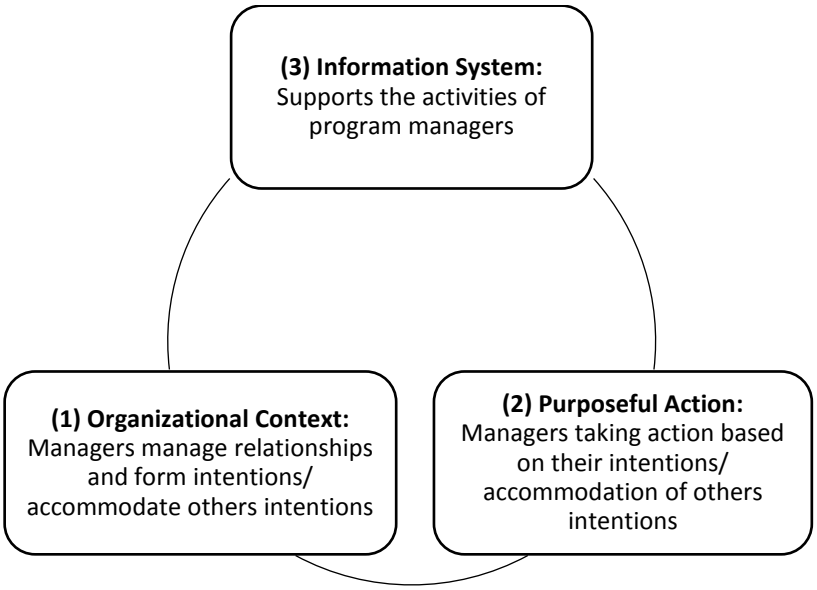

Figure 5.4 Role of the information system in soft systems theory [Adapted with permission from Wiley & Sons [44: Fig. 4.6]).

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The first element depicts the *organizational context,* wherein program managers manage relationships and form intentions based on their own values and/or preferences as well as accommodations of others' intentions (this subsumes elements 1-5 of Fig. 5.3). The second element depicts managers acting on these intentions to take *purposeful action* in the real-world (this includes elements 2, 5, 6 in Fig. 5.3). The third element provides the necessary *informational support* to managers acting on their intentions to take purposeful action (this corresponds to element 7 in Fig. 5.3). Thus, the role of the information system is to support humans within an organizational context to take purposeful action (i.e. develop strategies) based on their intentions as well as accommodate others' intentions [44].

5.3.3 Applying Soft Systems Theory to the Design of an Architectural Framework for an Information System

From the discussion above, it is clear that the role of the HAIS under soft systems theory is to support program managers to develop strategies that aim to improve nutrition outcomes as well as mitigate the risks to population health. The conceptual basis for this role is captured by the conceptual framework of the soft systems approach to information system design. Under this conceptual framework there are two systems. The first is the system which is served (depicted in the right-hand box of Fig. 5.5). This system consists of humans taking purposeful action within a complex organizational context. The second system is a system that serves this first system (depicted in the left-hand box of Fig. 5.5). This second system provides information that is relevant to people taking action in the first system.

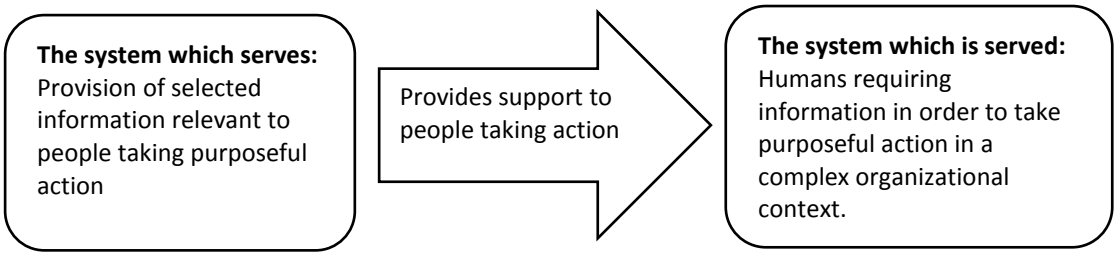

Figure 5.5 Conceptual framework of the soft systems approach to information system design (Adapted with permission from Wiley & Sons [44: Fig 4.7]).

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The implication of this insight for information system design is best described by Checkland in his seminal book on the subject,

> Whenever one system serves or supports another, it is a very basic principle of systems thinking that the necessary features of the system which serves can be worked out only on the basis of a prior account of the system served. This must be so because the nature of the system served - and the way it is thought about - will dictate what counts as 'service', and hence what functions the system which provides that service must contain [44: p.111].

Based on the conceptual framework, there are three steps that should be undertaken to design an architectural framework:

1. Define the activities that are to be supported (the system which is served).
2. Explore what information is necessary to support the identified activities (the system that serves).
3. Structure that information appropriately (the architectural framework).

Each step in this conceptual framework builds on the previous one. Therefore, a research approach that is cyclical and allows space for reflection upon the process and outcomes is required so that the next phase of the research can build on the previous one. In addition, the approach and methodology should be qualitative in nature as this inductive research is dealing with perceptions of reality.

Three research questions emerge from this conceptual framework. Since it is necessary to first discern what specific activities require support [44], the **first research question** asks:

1. **What activities need to be supported so that program managers can take purposeful action (i.e. develop strategies)?**

In order to answer the first research question, soft systems theory posits that the system which is served needs to first be explored and made explicit. This can be achieved by developing purposeful human activity system models of the hypothetical activities that would need to be undertaken by program managers in low-resource settings if they were to develop strategies. These models can then be systemically interrogated to determine which activities are feasible and desirable for an information system to support in the context of this research.

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Once the activities that require support are defined, it is necessary to determine what information is required to support these activities. This leads to the **second research question:**

2. What information is required to support these activities?

Purposeful human activity system models can once again be used to structure the enquiry to determine what information would be required to support the activities identified by research question 1. This will result in a list of information system requirements that can be used to design the HAIS. This leads to the **third research question**:

3. How can this information be structured?

The information system requirements identified by the second research question can then be organized in an architectural framework that can be used as the basis for the design of an information system. This architectural framework should include the various parts of the information system as well as how they interrelate.

The **outcome** of answering these research questions will be an architectural framework that can be used as the basis for the development of the HAIS.

This research is **original** because it seeks to identify and capture both the technical process and also the soft elements of the HIA process. The use of soft system theory is particularly important in this contextual setting where an HIA of a complex intervention like urban agriculture cannot just be about selecting the best available evidence. Rather, the evidence needs to be balanced with the values and preferences of stakeholders as well as the priorities of the program managers. Basing the information system design on soft systems theory will result in an architectural framework for an information system that is able to take into account program managers' intentions, as well as make accommodations for others' intentions, within a complex organizational context where evidence and stakeholder's values and preferences need to be traded-off.

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5.4 Conclusion

The goal of this chapter was to present the theoretical foundations related to designing an architectural framework for an information system. These theoretical perspectives performed two important functions. First, the theoretical perspectives aimed to **clarify the research topic** by:

1. defining the major constructs used in this research,
2. providing a discussion of hard systems theory and soft systems theory in order to define the implications of each of these theoretical perspectives on information system design,
3. using a conceptual framework based on soft systems theory to provide specification on what this research intends to achieve, and
4. defining the originality and proposed contribution to knowledge of this research.

Second, the theoretical perspectives **influence research design** by providing a conceptual grounding for the research approach and methodology selected. These research design considerations will be discussed in Chapter 6.

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6.0 Research Design

The previous chapter presented the theoretical foundations of this research, the research questions, and a conceptual framework to guide the design of the architectural framework of the HAIS. This chapter presents the paradigm, methodology, and overall research design of this study based on the following considerations, which emerged out of the theoretical perspectives:

1. The philosophical underpinnings of this research are essentially inductive as this research aims to generate theory on what should be included in the architectural framework of the HAIS.
2. A qualitative approach was needed as this theory is generated based on perceptions of reality.
3. A paradigm that focused on the generation of theory, but also appreciated the design of practical solutions was seen as an important feature.
4. An overall research approach that was appropriate within the context of designing an architectural framework for an information system was needed.
5. A methodology based in soft systems theory was preferred.

6.1 The Action-Research Paradigm

It is useful to present the paradigm under which this research is conceived and conducted as it provides a structure with which to assess the rigour and merits of this research. Action-research is a well-established research paradigm that has been in use in the social and medical sciences since the mid-twentieth century [57]. Action research has a specific focus on practical problems that have theoretical relevance [58]. The action-research paradigm was selected as the guiding paradigm in this research because while it prioritizes the development of theory, it also recognizes the importance of reaching practical solutions to the problem at hand. In addition, the action-research paradigm is cyclical and allows space for critical inquiry and reflection at each stage to encourage learning.

The action-research paradigm can be characterized according to its ontology, epistemology, and axiology [59]. This paradigm will be compared to the positivist paradigm, not because either paradigm is superior to the other, but rather because the positivist paradigm has been the dominant scientific paradigm since around the 6th Century BC when Greek

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philosophers began conducting scientific experiments [44]. This positivist paradigm is so pervasive in the health sciences that any deviation deserves discussion.

Ontology (How does this paradigm view reality?): A critical-realist stance forms the philosophical underpinnings of the action-research paradigm. Like the positivist paradigm, the action-research paradigm believes that reality is objective. Whereas the positivist paradigm believes that reality can be objectively studied and `discovered`, the action-research paradigm holds the view that reality is always socially constructed based on the perceiver's values, preferences, and experiences. Finally, the positivist paradigm believes that researchers can objectively study a phenomenon without influencing the outcomes of their study. In contrast, the action-research paradigm posits that researchers are not outside the influence of the research study and can both influence and be influenced by the study [57]. The implication of the ontological stance for this study is that action-research is always informed by a dialectic as it requires multiple viewpoints to construct an accurate view of social reality. Dialectic refers to two or more viewpoints debating an issue until a 'truth' is reached. Researching social reality is therefore an organized excursion into how humans make sense of their perceived worlds rather than an objective exercise in fact-finding [44].

Axiology (What values underlie this program?): The positivist paradigm believes that phenomena should be reduced to the simplest elements so that they can be tested. In contrast, the action-research paradigm assumes that complex social systems cannot be reduced and must be taken as a whole for meaningful study [58]. Whereas the goal of the positivist paradigm is to determine causality, the goal of the action-research paradigm is to improve understanding of the general situation so that practical solutions may be developed [57].

Epistemology (How does this paradigm know something to be true?): The positivist paradigm believes that knowledge is 'discovered' by the researcher dispassionately manipulating and observing phenomena of interest through endless hypothesis testing and refutation [44]. These researchers believe that confidence in knowledge can be strengthened to the extent that a method or procedure gives the same answer whenever it is carried out. In contrast, the action-research paradigm believes that knowledge is acquired through an iterative cyclical process of action, critical enquiry (research), and reflection (learning). This paradigm believes that confidence in knowledge can be strengthened by seeking multiple perspectives or information

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sources on the topic [57]. The convergence of ideas through iterative cycles of disparate views produces knowledge.

From this discussion it is clear that the positivist paradigm and the action-research paradigm have very different ways of viewing research and scholarship. It therefore follows that the two paradigms have very different ways of measuring scholarship. The positivist approach can be characterized by three principles that give it power: reductionism, repeatability, and refutation. This paradigm generally assesses the scholarship of research based on the level of reliability and validity of a study. This paradigm holds that if a study is able to get the same results using the same methods over time, then this study is of high scholarship. For example, sulfuric acid added to a barium chloride solution will always produce a white precipitate no matter who is doing it, where they are doing it, or why they are doing it. The same measures cannot be used in research of social situations because social situations, such as those found in complex organizational settings, are continuously changing. In the example given above, the sulfuric acid and barium chloride solution never changes, regardless of time, place, or whether or not someone is studying it. However, in a social situation, not only is the reality of that situation continuously changing, but it is also changed by the fact that someone is studying it [44].

Although reliability and validity, as they are measured under the positivist paradigm, are not achievable or desirable goals under the action-research paradigm, that does not mean that action-research should not be subjected to high standards of scholarship [44]. The action research paradigm measures scholarship in terms of coherence, credibility, and consensus [60]. This paradigm claims that if the methodology is appropriate, the research process is transparent and recoverable, and the results are arrived at through a dialectic, then one can be confident in the results. These criteria for rigour will be expanded upon in Section 6.4 in relation to the specific methodology that is used to guide this research.

6.2 Soft Systems Methodology

The action-research paradigm encompasses a variety of methodologies and subscribes to a pragmatic approach in selecting the most appropriate methodology. This research study selected Soft Systems Methodology (SSM). SSM has been developed and refined through a forty-year action research program at the University of Lancaster in the United Kingdom under the

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leadership of Peter Checkland. The methodology as it is applied in this study has been described in several seminal books and articles written by Checkland and colleagues [44, 54-56, 60].

Although SSM is used to guide the fieldwork, this research acknowledges that a number of other systems-based methods could have been used. Other systems-based methodologies that were considered include the Strategic Option Development and Analysis (SODA) [61], concept mapping [62], and group model building [63]. SSM was selected as the most appropriate methodology because it provides a logical, structured way for thinking through the main activities that program managers would hypothetically need to undertake if they were to design their own strategies, what information is required to support these activities, and how to structure that information into an architectural framework. Specifically, SSM addressed the research design considerations resulting from the discussion of the theoretical foundations (Chapter 5) in the following ways:

1. SSM is based in soft systems theory, thus providing a conceptual link from the theoretical foundations to the research methodology.
2. SSM provides an inductive research approach that aids in the generation of theory.
3. SSM allows users to create hypothetical models of issues without the constraints of the real-world, thus maximizing creativity in the generation of solutions.
4. SSM is a very well-developed methodology with a long history of success and a well validated set of methods and data collection techniques [44]. There are many documented examples of the successful use of SSM to design architectural frameworks for information systems in a variety of fields including sustainable development [64], health [65], and agriculture [66]. A well-tested methodology provides confidence that the methods achieve what they are supposed to achieve.
5. SSM maintains that the development of an information system should be based on sound logic, however SSM also recognizes that the organizations in which the information systems will be used are not purely logical entities and come with a particular history, culture, and power structure. Therefore, in order to define the activities that are to be supported and their related information system requirements, SSM goes beyond just a logical solution to one that considers the

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full context of the situation. This provides for a more realistic definition of the information system requirements and related architectural framework.

SSM was therefore selected to guide the design of the architectural framework of the HAIS.

6.3 Critiques of SSM

This study proposes three main criticisms of SSM. The first critique is regarding the lack of reflexivity in the primary SSM literature. The second critique is regarding potential sources of subjectivity in the application of SSM. The final critique is regarding the perceived lack of rigour of this approach. Each of these will be discussed in detail below.

The first main critique by this research is the lack of reflexivity of the SSM approach. The primary SSM literature and advocates of SSM seldom discuss the limitations of the methodology. In addition, it is difficult to garner critiques of SSM from the secondary literature as SSM is not well understood and so is not well presented in the secondary literature. SSM proponent, Sue Holwell, in her review of the secondary literature relating to SSM concludes that, “For anyone interested in critical use of the ideas [of soft systems methodology], then these contradictions, gaps, and poor understanding make general use of the secondary literature something of a dubious undertaking” [67: p.792]. Despite the fact that SSM has been applied to information system design for at least the last 20 years, it is not widely used and is only occasionally cited in information system design textbooks, usually superficially as an alternative to the hard systems approach. This is likely because, compared with hard information system design approaches, the concepts within SSM are more complex and difficult to explain and use [67]. In addition, SSM is far more time-consuming and labour-intensive than the hard systems alternatives [68].

The second criticism of SSM is regarding the potential subjectivity that may arise in the application of SSM. Three related issues are explored below. Firstly, SSM relies on perceptions of the situation to build the human activity system models. It is therefore important to note that the results of this study are based on a particular group’s point of view at a particular point in time [69]. This issue was mitigated in this research by triangulating participant responses with data from a document analysis and literature review. Secondly, SSM requires some level of consensus to define the activities that require support [70]. In this study, participants were not diametrically

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opposed in their views and there was considerable consensus between the participants and the results of the document analysis. Had there been substantial disagreement, it would have been necessary to first reach consensus (for example through a nominal group technique) before being able to develop the human activity system models. Thirdly, the accuracy of an SSM application is highly dependent on the person applying SSM as it relies on the logical, though subjective, progression of a researcher through a set of steps. In order to mitigate this issue, this research has documented all the steps, decisions, and reasons for taking these particular decisions in an attempt to increase transparency in the research process.

The third criticism of SSM, and of the action-research paradigm more broadly, is the perceived lack of rigour of this approach. This perception is likely due to the very different way that scholarship is viewed in the positivist paradigm. It is therefore imperative that this research clearly define and apply criteria for assessing the rigour of this type of research. These criteria will be outlined in the next section.

6.4 Assessing the Research Rigour

Lincoln and Guba [71] published an influential book in 1985 that outlines the criteria of a rigorous research design. They argue that criteria for assessing the rigour in positivist research, such as validity, reliability and generalizability, have dominated the research world, but that they are not applicable in other paradigms, such as the action-research paradigm. They present four ways in which the rigour of a research project can be assessed: truth value, applicability, consistency, and neutrality. Each of these will be explored in detail below.

6.4.1 Truth Value

Truth value refers to the level of confidence that the researcher has in whether the research is an accurate reflection of the situation studied. In the action-research paradigm, confidence in the accuracy of the research resulting from the use of SSM can be increased by using multiple sources of information, which creates a dialectic. Examples of how a dialectic might be used is through the engagement of multiple informants, different research settings, the same informant responding to questions on the same topic from various points of view, or different methods to measure the same phenomenon (also known as triangulation). A dialectic

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increases the rigour of the research by creating opportunities for debate and consensus with a goal of convergence on the truth.

6.4.2 Applicability

Applicability refers to the degree to which the findings can be applied in other contexts. There are three ways in which this principle might be applied. Firstly, applicability may refer to the degree to which research findings can be generalized to other contexts. SSM is often criticized for the lack of universal generalizability of findings. This criticism however, misses the goal of SSM, which is not to discover generalizable laws, but rather to achieve understanding in a particular situation in order to improve that specific situation. SSM is primarily a method for developing theory that can be used to bring about improvement in a specific problem situation [57]. In this research study, SSM is used to design the architectural framework for the HAIS. Therefore, generalizing findings from this research context to another context is neither feasible nor desirable. The second way in which this principle might be applied is through the construct of transferability. Transferability refers to how well the current research findings might 'fit' another similar problem situation. In order to transfer the research findings to another similar situation, the research process needs to be recoverable [44]. In other words, enough information, data, and process information need to be included so that future researchers can judge whether the findings are transferable to their situation. Finally, relevance refers to the extent to which the architectural framework for the HAIS is useful to real-life settings [72]. In order for an SSM study to be valid, it needs to culminate in action that is useful in improving the problem situation.

6.4.3 Consistency

Consistency under the action-research paradigm refers to whether a study would reach the same conclusions if it were conducted again. In order to achieve this aim, variability in the study implementation and results should be tracked and appropriately attributed. Consistency can be maintained in a study by presenting in advance the research themes to be investigated [44]. Having a declared-in-advance conceptual structure that can be used to interpret the results allows findings to be arrived at openly and not based on hidden hunches and intuition. This transparent reasoning and reporting increase the likelihood that a study could be repeated with similar results and thus increases the rigour of the research study.

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6.4.4 Neutrality

Neutrality refers to the degree to which findings are purely a function of the informants and conditions, and not of other biases, motivations, or perspectives [73]. Within SSM the neutrality of the researcher cannot be established as the researcher is an intricate integral part of the study. As Checkland succinctly writes, SSM "involves the researcher immersing himself or herself in a human problem situation and following it along whatever path it takes as it unfolds through time" [74: p.13]. The emphasis is therefore on the neutrality of the data as opposed to the researcher. One way to improve the neutrality of the research is to declare in advance the structures and models that will be used to interpret the data. Checkland is very critical of action-research that is conducted without such a structure [44]. He states that "without a declared-in-advance epistemological framework it is sometimes difficult to distinguish researching from novel writing" [44: p.23]. Presenting a structure in which to interpret the results in advance allows researchers to interpret their findings using theory as opposed to their own hunches, thus improving the neutrality and rigour of the research.

This discussion has identified four criteria for assessing the rigour of an SSM research project. The rigour of this dissertation will be assessed using these criteria and a discussion on the academic scholarship of this research will be presented in Chapter 10.

6.5 Overview of the Research Design

Figure 6.1 outlines how the theoretical models that have been used to date combine to deliver the research design. Firstly, the knowledge to action model was used to conceptualize the transformation and transfer of expert knowledge to non-experts. This model delimited the scope of the research to the creation of a knowledge tool. Next, the waterfall approach was used to conceptualize the design of this knowledge tool (or more specifically this technology-supported information system). The scope of this research was further delimited to the first three steps of the waterfall approach, which lays the theoretical foundation for software engineers to develop a fully-functioning information system, based on the architectural framework. Each step in the waterfall approach corresponds to a phase in the conceptual framework of the soft systems approach to information system design as well as a research question.

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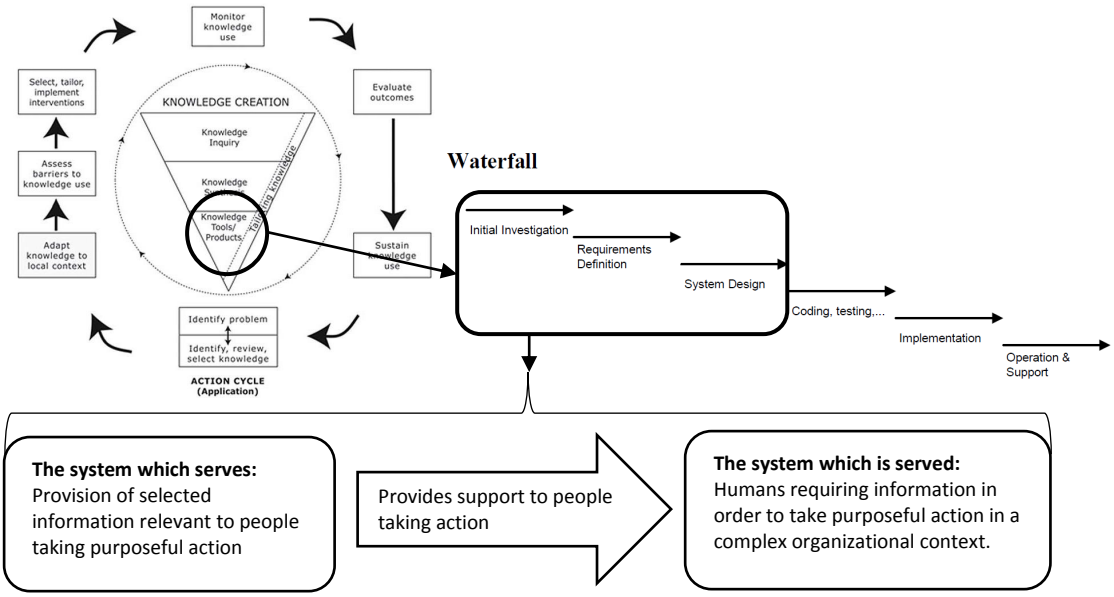

Figure 6.1 Relationship between the theoretical frameworks

This research has three phases, as depicted in Fig. 6.2. Each phase of this research corresponds to a research question and culminates in an outcome that addresses the research question. The first phase addresses research question 1 and aims to make explicit the system that is served. This phase corresponds to the 'initial investigation' of the waterfall approach. The second phase addresses research question 2 and aims to explore the information necessary to support the identified activities. This phase corresponds to the 'requirements definition' of the waterfall approach. The outcome of this phase is a set of information system requirements. The third phase addresses research question 3 and uses the definition of the information system requirements to develop the architectural framework for the HAIS. This phase corresponds to the 'system design' of the waterfall approach.

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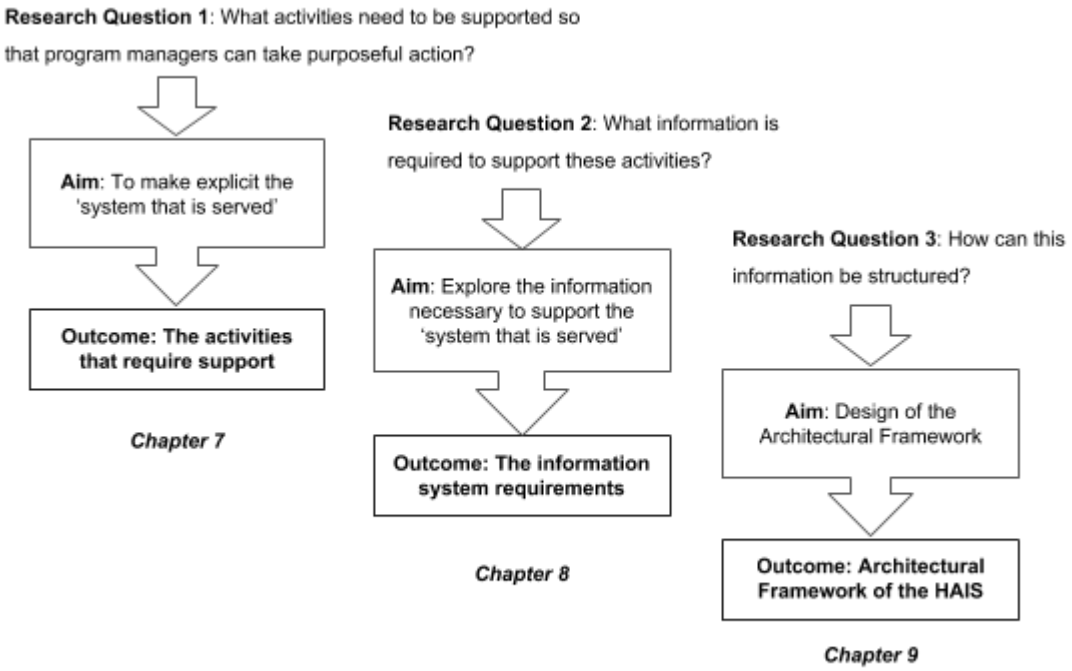

Figure 6.2 Overall Research Design.

6.5.1 Steps in the Research Process

This research was guided by SSM and was conducted in a number of consecutive steps. As depicted in Figure 6.3, the first step was to enter into the problem situation. Entering into the problem situation allows for an immersion into practice and thus a greater understanding of the issues involved.

The goal of step 2 is to express the problem situation. This step makes explicit the system that is served by graphically depicting that system.

Steps 3 and 4 involve entering into the ideal world to creatively explore the activities that program managers should undertake if they wish to take purposeful action (develop strategies). This was done by building a purposeful human activity system model to make explicit the activities that should be supported by the HAIS. The outcome of this model was a list of activities that would require support should program managers wish to take purposeful action. These activities comprise the answer to research question 1.

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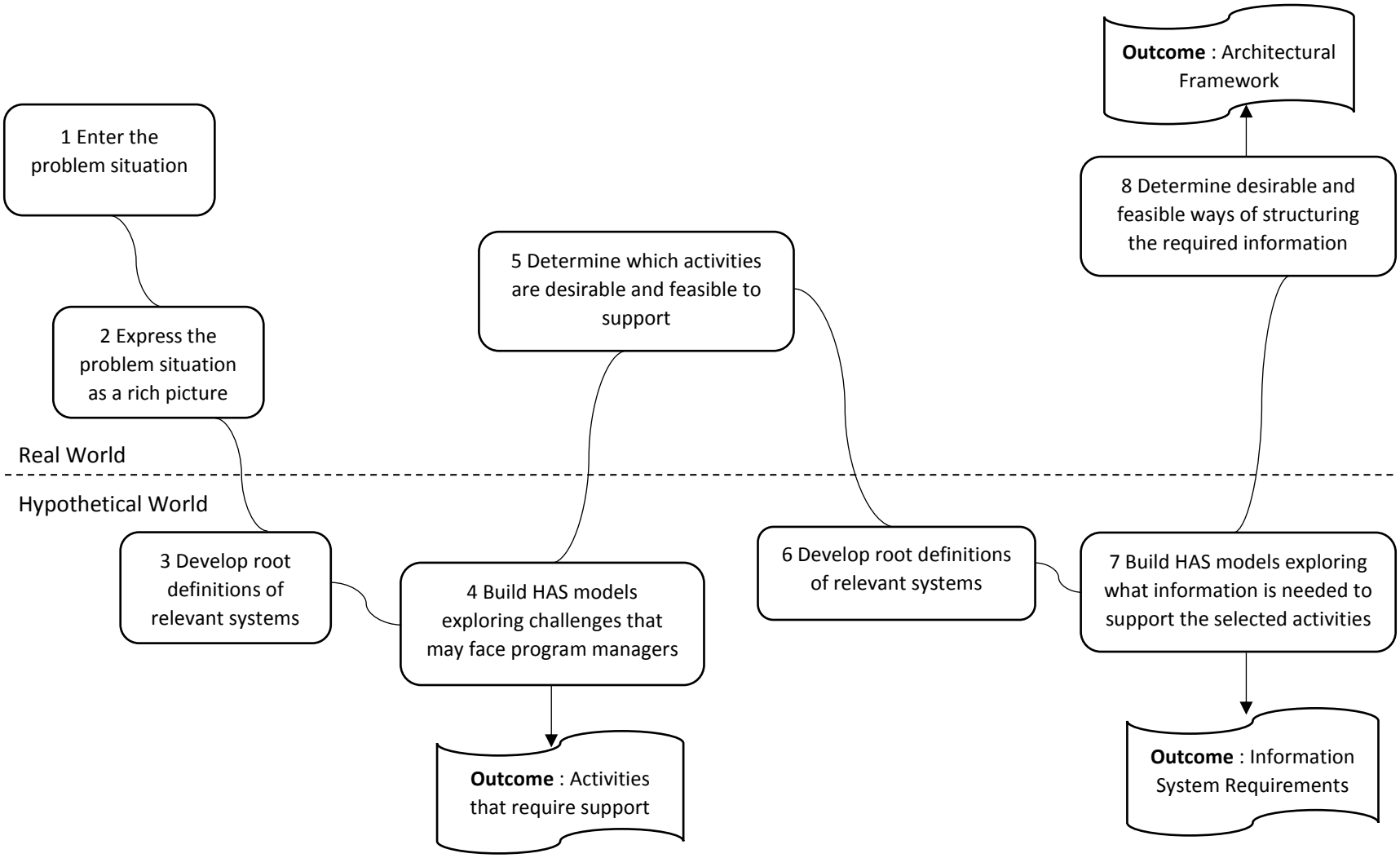

Figure 6.3 Overview of the research process (SSM).

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Step 5 involves undergoing a formal questioning process to determine which of these identified activities are desirable and feasible for an information system to address within the context of this research.

Steps 6 and 7 once again entered the hypothetical world to creatively explore what information program managers would theoretically require to undertake the activities identified in step 5. A human activity system model is once again utilized. The result of this systemic exploration is a list of information system requirements. These information system requirements comprise the response to research question 2.

In step 8, these information system requirements are assessed using a formal questioning process to determine how to structure the architectural framework of the HAIS. This constitutes the answer to research question 3.

Due to the large number of steps in this process and the fact that each step builds upon the previous one, it was determined that for ease of presentation, the data sources and data analysis methods that were utilized at each step will be presented along with the results and the analysis and interpretation of those results in the relevant chapter. Phase 1 is described in Chapter 7, Phase 2 is described in Chapter 8, and Phase 3 is described in Chapter 9.

6.5.2 Overview of Data Sources

SSM allows for a wide variety of data sources. In early steps of SSM, the data collected is usually qualitative data based on perceptions of the problem situation. In later steps of SSM, the primary data collected is supplemented with the data generated by the methodology from previous steps, so that each step of SSM builds on preceding steps.

As discussed in Chapter 5 and considering that SSM is based on an interpretive paradigm and intends to measure perceptions of reality, this research took a qualitative approach. The data sources utilized by this research reflect the type of knowledge that was needed. Therefore, five separate data sources were used:

1. An HIA of an urban agriculture intervention conducted in a low-resource setting in South Africa.
2. Learnings from a structured reflection on practice.
3. An expert consultative survey.
4. Procedural document analysis.

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5. SSM generated data - as SSM builds upon itself through the steps, the data used in one step is often the result of a previous step.

Each of these data sources will be described in detail in the step where they are utilized.

6.5.3 Design Team

A design team was assembled to represent the expertise of those involved in a traditional health impact assessment as well as methodological expertise in SSM. These experts were accessed for their expertise on an ad-hoc basis at various points throughout this research project:

Small-Scale Agriculture and Nutrition: Milla McLachlan, PhD (supervisor)
Soft Systems Methodology: Wojtek Michalowski, PhD (co-supervisor)
Health Impact Assessment: Maria Benkhalti, PhD (advisor)

6.6 Ethical Considerations

Ethics approval for this dissertation has been granted by the Health Research Ethics Committee (HREC) at the University of Stellenbosch. This research was approved under Ethics Reference Number S13/07/134 (Appendix .

The following ethical considerations have been considered:

1. **Respect for persons**: Written informed consent has been obtained from all participants for all activities, specifically for interviews, focus groups, and surveys. Importantly, the privacy, confidentiality, and anonymity of all participants was respected by offering informed consent as well as rendering the data anonymous.
    a. **Privacy**: The information that was collected through the course of this study will remain confidential and protected. All comments were rendered anonymous before going back to the participant group. The identity of all participants will continue to remain anonymous.
    b. **Data storage:** All personal information (names, contact details) has been stored separately from responses in an excel spreadsheet on a personal computer hard drive. This data will be stored for up to 5 years following the completion of this research study, at which point it will be irreversibly deleted.

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2. **Academic Freedom:** As a researcher, one has an obligation to report research results accurately and transparently in both the public domain and to the target group of the study. Neither funders nor other stakeholders were or will be allowed to influence any research publications. Data has been represented fairly in all communications and transparency of all methodologies and analyses have been maintained.
3. **Justice**: Every effort was made to treat all participants fairly, equitably, and with dignity and any accommodations that were required in order for stakeholders to participate was sought. Informed consent forms were available in English, Afrikaans, or Xhosa as requested; other languages were available upon request. A translator would have been provided had participants chosen to conduct any portion of this research in another official South African language.
4. **Integrity:** Data has been fairly represented in all communications and transparency of all methodologies and analyses were maintained.
5. **Beneficence:** Beneficence is the obligation to do good. As a researcher, one has an obligation to first do no harm and then to ensure that the research aims to accomplish some overall good. This study contributes to beneficence by laying the theoretical foundations for a tool that can be used by program managers to develop strategies that would strengthen the impact pathways to nutrition and mitigate the risks to population health.
6. **Scientific validity**: Engaging in research which has fundamental flaws in methodology and design is a waste of human, monetary and other resources and is thus unethical. Therefore, this research underwent appropriate peer review processes to ensure that it is timely, relevant, and methodologically sound. In addition, a self-audit was conducted to ensure that this research was rigorous.

6.7 Conclusion

The rationale for the selection of the action-research paradigm was based on the research design considerations that emerged from the discussion on the theoretical foundations in Chapter 5. The action-research paradigm was selected as it prioritizes the generation of theory, but also recognizes the importance of reaching practical solutions to the problem at hand. SSM was selected as the most appropriate methodology and an overview of this methodology along

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with how it addresses the design considerations was presented. The critiques of SSM were discussed, one of the main ones being the perceived lack of rigour. Criteria that could be used to assess the rigour of this research were therefore discussed. Finally, the ethical considerations that were considered by this research were presented.

The next three chapters present the three phases of research. Chapter 7 presents Phase 1, Chapter 8 presents Phase 2, and Chapter 9 presents Phase 3 of this research. The specific methods and data sources utilized, the analyses, the results, and interpretations relevant to each phase of this research are summarized in each chapter.

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7.0 Phase 1: Define the Activities that Require Support

This chapter summarizes Phase 1 of this research. The goal of this phase is to define what activities need to be supported in order for program managers to take purposeful action (i.e. develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health). This goal is achieved by using SSM to answer research question 1:

> **What activities need to be supported so that program managers can take purposeful action?**

This question will be answered in four steps (Steps 1- 4) as depicted in Fig. 6.3. In the first step, the problem situation is entered. In the second step, the problem situation is expressed. In the third and fourth step, the hypothetical activities that program managers would require support to undertake if they were to take purposeful action are explored. The outcome of this phase of research is a list of activities that would need to be supported if program managers were to take purposeful action.

7.1 Step 1: Enter the Problem Situation

In order to enter into the problem situation, an HIA of an urban agriculture intervention in a low-resource area in South Africa was conducted. This immersion into practice was conducted in order to experientially understand the process of conducting an HIA in a low-resource setting as well as to gain first-hand knowledge of the types of challenges inherent in these settings. Reflection on this immersion into practice was later corroborated by a review of literature on the process and challenges of conducting HIAs of urban agriculture in low-resource settings. The data source, related methods, and results are described in detail below.

7.1.1 Data Source: A HIA of Urban Agriculture in a Low-Resource Setting in South Africa

SSM recommends that an initial understanding of the problem situation is gained through observation and participation in regular activities. An HIA of the health impacts of an urban agricultural intervention in a low-resource setting in Ocean View (Cape Town), South Africa was therefore undertaken to gain a deeper understanding of the problem situation. This HIA implicated local stakeholders including: a local non-profit organization (NPO) (Green Earth Culture), the Municipality of Cape Town, and individual urban farmers. The purpose was to elicit

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the perceived health risks and benefits of three food garden interventions that were being implemented by the NPO with support from local government through the City of Cape Town's Urban Agricultural Policy. The goal of this HIA was to recommend strategies that could mitigate the perceived health risks as well as strategies that could improve nutrition and health through the complex impact pathways.

This HIA was conducted in five steps:

1. Literature review and document analysis of previous HIAs, policy documents, and academic literature,
2. Interviews with the municipality to gain insight into the implementation of the food gardens policy,
3. Interviews with the NPO to understand the meaning, reality, and the challenges faced by the NPO in implementing this policy,
4. Workshops with the urban farmers to determine firstly, their perception of the food gardens implementation and secondly, the perceived health risks and benefits of the food gardens, and
5. Follow-up exchanges with the municipality and NPO to validate data obtained from the interviews and workshops as well as develop the set of recommendations.

This part of research was approved under Ethics Reference Number S13/07/134 on June 24, 2015.

A final report on this HIA has been published [20]. The full results of this study are not included in the body of this dissertation as the specific results and recommendations that emerged from this HIA, although interesting, are not considered directly relevant to this research. Rather a reflection on the *process* and *challenges* of conducting the health assessment was deemed important for this research. The process of conducting this health assessment was used as the data source and structured reflection on practice was used as the data analysis method.

7.1.2 Data Analysis Method: Structured Reflection on Practice

Structured reflection on practice, or reflective practice, is a well-established technique in qualitative research. It is defined as the ability to reflect on one's actions so as to engage in a

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process of continuous learning [75]. Reflective practice is based on the theoretical model of experiential learning, which posits that experience alone does not necessarily lead to learning; deliberate reflection on experience is essential [76]. The specific technique used by this research was Bolton's reflective practice writing technique, as described in the book Reflective Practice: Writing and Professional Development [77]. This structured reflection on practice used the HIA of urban agriculture in Ocean View, South Africa as the data source.

7.1.3 Results

The results of the reflection on practice are summarized in Fig. 7.1.

Researcher: Leanne Idzerda.
Location: Ocean View, South Africa.
Intervention: Three community gardens implemented by a local NPO, with support from the Municipality of Cape Town.
Summary of Learnings:
Resource Intensive: Despite the pro-bono involvement of an HIA practitioner, my knowledge of urban agriculture and nutrition, as well as a research budget of $10,000 CDN (~R100,000), this HIA took a year to complete and required a lot of time and energy searching the evidence base as well as collecting the necessary primary and secondary data.

Skills in HIA Process: Although the HIA process is a structured process that is generally conducted following the same sequential steps, every HIA guide is slightly different and therefore if one is not familiar with the process (or does not have an HIA practitioner on the team) conducting an HIA or even knowing where to start can be very challenging.

Knowledge on the Health Effects*:* Scientific evidence of the health risks and benefits of urban agriculture, is vast, ranging from toxicological health risks to the building of social networks. It thus requires the involvement of an expert knowledgeable about the risks and benefits of urban agriculture or someone that is able to access the evidence base. Even in these ideal situations, accessing the evidence is still a time-consuming and complicated endeavour due to the variety of evidence required.

Importance: Despite these challenges, the HIA was extremely important and identified a number of health risk factors that were previously unknown including injury to urban farmers, community perceptions of persons with tuberculosis growing food, and high levels of stress among urban farmers [20]. In addition, the recommendations were taken up the Municipality of Cape Town during the scale-up of the implementation of the food gardens program, thus demonstrating both the need and importance of conducting HIAs of urban agriculture interventions in low-resource settings.

Figure 7.1 Summary of learnings from the structured reflection on practice.

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The goal of this step was to enter into the problem situation. Entering into the problem situation experientially added value to the research process by providing a physical immersion into the problem situation, thus adding another dimension to what can be gained from the literature and the guidelines. This allowed a much greater understanding of the problem situation and a strong basis on which to precisely express the problem situation.

7.2 Step 2: Express the Problem Situation

The goal of this second step is to make explicit the problem situation. This was done by conducting a cultural analysis of the problem situation (methodology described in Section 7.2.2) to find out more about the intervention, as well as the social and political systems that surround the intervention. This analysis was then used to draw a picture of the problem situation. Drawings of the problem situation to indicate the many elements and complexity is invaluable - as the old saying goes, a picture paints a thousand words. The rationale of drawing pictures lies in the fact that the complexity of human affairs is always a complexity of multiple interacting relationships, structures and processes, and pictures are a better medium than text for expressing these relationships. Pictures can be taken as a whole and encourage holistic thinking rather than reductionist thinking about a situation [56]. Expressing the problem situation in this way allows for greater clarity and transparency of the situation, the people involved, and the main issues. In SSM, these pictures are termed rich pictures.

7.2.1 Data Source: Learnings from the Structured Reflection on Practice

The data source for the cultural analysis was the learnings that came out of the structured reflection on practice (see section 7.1). Thus, the cultural analysis and subsequent rich picture were drawn based on the problem situation as it was perceived in one specific instance. A potential criticism of this study is that the rich picture is based on a single example of an urban agriculture intervention and may not consider all the possible configurations of this type of intervention. This criticism, however, misses the goal of the rich picture, which is to deepen understanding of the issue. The goal is not to present a comprehensive model of every reality, but rather to represent an example based on a real situation, which allows one to practically assess the cultural context.

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7.2.2 Data Analysis Method: Cultural Analysis

The cultural analysis proposed by SSM involves three separate analyses (Analysis One, Analysis Two, and Analysis Three). Each analysis follows a slightly different data analysis method. In Analysis One the intervention itself is analysed. In Analysis Two the social situation is analysed. In Analysis Three the power dynamics in the situation are analysed [54]. Each of these data analysis methods will be explored in more detail below.

Analysis One is an examination of the intervention itself. Analysis One entails making a list of stakeholders according to whether they are the:

1. Client, defined as the person(s) that caused the intervention to be implemented.
2. Problem Solver, defined as the person that wishes to do something about the problem situation; or
3. Problem Owner, defined as those people that have an influence on the problem situation, regardless of whether they accept responsibility for the problem.

The specific questions to be asked in this analysis include:

1. Who are the clients and what are their aspirations?
2. Who are the problem solvers and what resources, or resource constraints, are present?
3. Who are the problem owners and why do they regard the problem as a problem?

Analysis Two studies the problem situation as a 'social system'. In SSM it is assumed that the 'social system' is the continually changing interaction between norms, values, and roles of the various stakeholders.

Roles: are defined as social positions recognized as significant by the people in the problem situation. Roles may be institutionally defined (e.g. urban farmer or program manager) or may be defined behaviourally (e.g. gardener).

Norms: refer to the expected or normal behaviours of those in the various roles.

Values: refer to what constitutes good or bad behaviour. Performance in the role is judged according to local standards or values. For example, an urban farmer may be valued if they develop a successful business model.

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It is important to note that the 'social system', as defined here, is never complete or static, but rather is continuously changing in response to emerging roles, norms and values.

This analysis answers the following questions:

1. What is the role of each of the stakeholders involved in conducting an HIA of urban agriculture interventions?
2. What are the expected norms associated with each role?
3. How are the people in these roles valued?

Analysis Three is concerned with the distribution of power in a social situation. Power in a relationship is assumed to always exist, and so there is no discussion on whether power exists, but rather a discussion on how power is expressed in the relationships between stakeholders. As power is usually hidden, it is important to read between the lines for the organizational jokes or undertones. This analysis answers the following two questions:

1. How is power expressed in this situation?
2. How is power protected, preserved, passed on, or relinquished?

The results of these three cultural analyses were used to draw the rich picture of the problem situation. This step of expressing the problem situation was an iterative step wherein the rich picture and the cultural analysis were continuously updated to ensure that they were reflective of the current understanding of the situation. The rich picture and cultural analysis as presented in the results section below are the final iterations of this process.

7.2.3 Results

The full results of the cultural analysis are included in Appendix E. These analyses were used to draw the rich picture presented in Fig. 7.2. The goal of the rich picture is to graphically *express* a high-level overview of the problem situation

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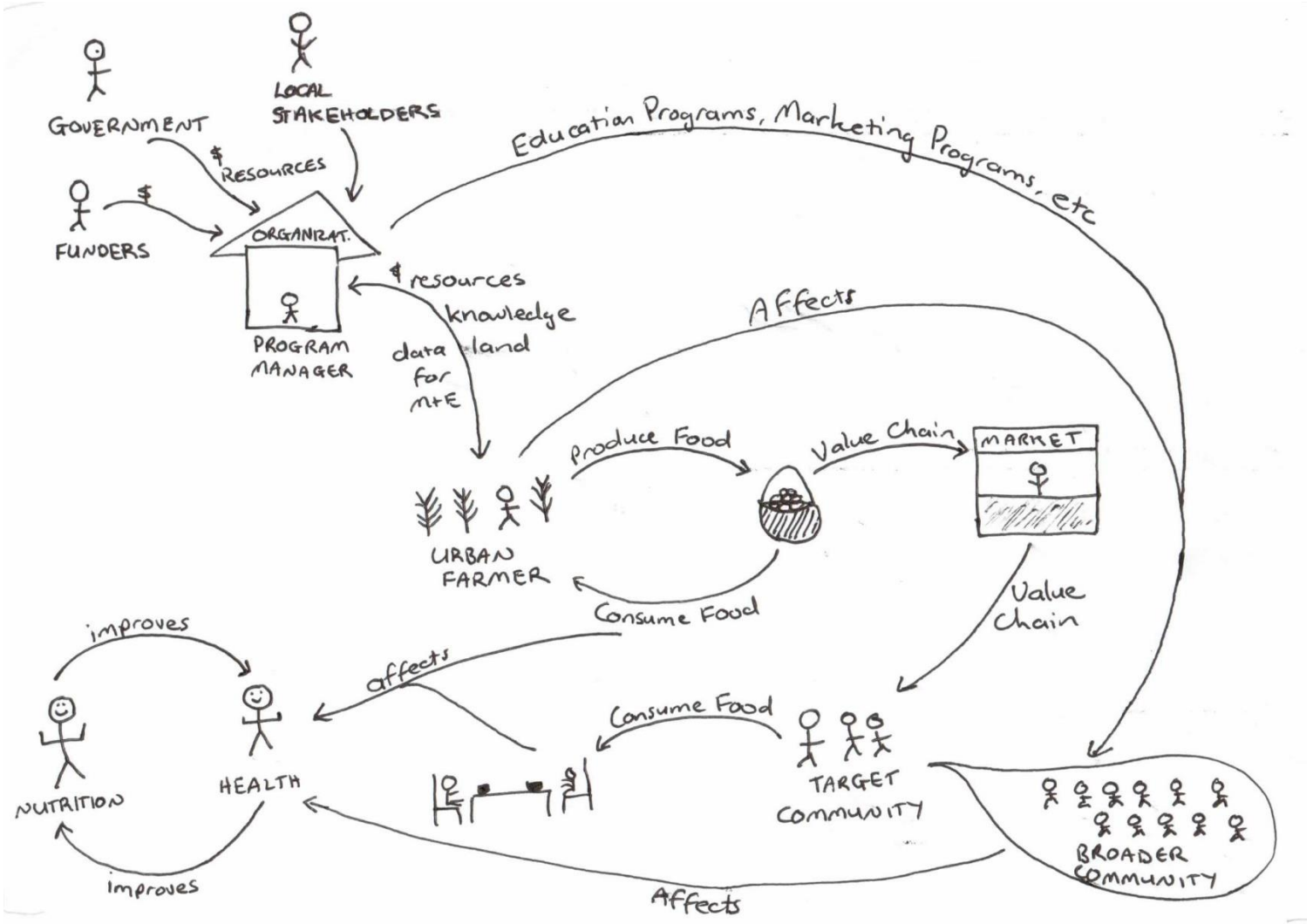

Figure 7.2 Rich picture of the problem situation

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As can be seen in Fig. 7.2, the implementing organization houses a person or persons responsible for the design and implementation of the urban agriculture intervention. This person is termed program manager by this research as they manage the resources of the urban agriculture intervention. The intended purpose of this intervention is to improve nutrition among urban farmers and/or the target community. This improvement in nutrition is theoretically achieved through access to whole fresh foods. The role of the program manager is to work with urban farmers, and possibly other local stakeholders, to design and put in place the urban agriculture intervention (which may be a garden, greenhouse, small livestock initiative, etc.). In addition to the program manager, the people involved in an urban agriculture intervention may include local government representatives, funders, local community leaders, urban farmers, the target community, and the broader community where the intervention is implemented. The role of local government may be to provide funding, in-kind support, or resources. They may also enforce local laws and bureaucracy, and approval may need to be sought from them for various agricultural activities. The role of the funders is generally to supply cash, in-kind support, or resources. They may place constraints on the organization by requiring that certain conditions are fulfilled during implementation of the intervention (for instance that results are demonstrated on short timelines). The organization also generally needs to show some level of improvement in the outcomes (e.g. nutrition). Failure to do so could result in funding cuts for future years or phases of the intervention, as well as loss of confidence in the abilities of the implementing organization.

The role of urban farmers is to produce food with the resource inputs that may come from the implementing organization or from other sources. These resource inputs may include: (1) farming resources such as seeds, livestock, tools, feed, compost, water, or infrastructure; (2) land, which may be given, rented, or bought from the implementing organization, local government, a local organization, or local citizens; (3) money, in the form of cash grants or micro-lending, that may come from the organization's internal funding or from another source, such as local government grants or external funders; (4) knowledge on farming practices or innovations; and (5) small business skills to aid urban farmers in setting up a market base or micro-enterprise. Cutting these resources to urban farmers (e.g. cutting funding or the supply of seeds and compost) may result in a lack of confidence in the organization and therefore a lack of community support for the organization.

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The organization may also work with the target community, who are part of a broader community, to build a market for the produce. They may do this through marketing or education campaigns that create a need for fresh, locally produced food within the target community. Urban farmers may sell their produce through local formal or informal markets to individuals or community-based organizations such as school or community feeding programs. These clients are generally malnourished communities that do not currently have access to healthy, fresh foods. The increased access to healthy fresh food theoretically improves population health and nutrition through a number of direct and indirect pathways.

In summary, the cultural analysis highlighted the fact that the urban agriculture intervention needs to show improvement in the intended outcome of nutrition, or at least a logical argument for improvement in nutrition outcomes, otherwise the target community, urban farmers, and funders may withdraw their support for the project. In addition, if the urban agriculture intervention has unintended negative consequences on health, the project could be stopped by the community, urban farmers, local government, and funders. Therefore, it is important to assess the health effects for both the efficacy of the intervention and the survival of the project. This analysis also showed that assessing the health effects is valuable as it would increase the confidence of the target groups, broader community, funders, and government; not only with regards to the intervention, but also with regards to the credibility of the implementing organization. This is very valuable to the organization and could result in more projects/ collaborations/ funding and thus more organizational impact. Prospective assessment of the health effects was seen as important so that negative effects could be mitigated and positive effects could be enhanced. This would allow interventions to demonstrate their value from the beginning.

In conclusion, SSM was used in this step of the research to *express* the problem situation through the cultural analysis and subsequent depiction of that situation as a rich picture. The cultural analysis added value by creating a deeper understanding of the social structures and power relations within the intervention context. Conveying the problem situation as a rich picture added value to the research process by providing a holistic overview of the structures, processes, and people involved in an urban agriculture intervention that aims to improve nutrition in low-resource settings. This rich picture illuminated the fact that urban agriculture interventions are a complex activity involving multiple actors with differing goals, values, and

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norms. This step is important as it provides an overview of the context in which the requirements for the architectural framework of the HAIS will be defined.

7.3 Step 3: Develop Root Definitions

This study utilizes purposeful human activity system models to systematically explore the areas where program managers would require support if they were to take purposeful action. In order to build these models, it was necessary to first succinctly define the system that is to be modelled. This is termed the root definition by SSM. These root definitions help to identify the main elements, the assumptions, and the stakeholders in the system to be modelled. Step 3 outlines the methods that were used to develop the root definition. Step 4 outlines the methods that were used to construct the human activity system model.

7.3.1 Data Sources: The Cultural Analysis, Rich Picture, and Learnings from the Structured Reflection on Practice

SSM follows an iterative cycle and builds on itself through the various steps. This step (step 3) builds on the first two steps of entering (step 1) and expressing (step 2) the problem situation. It uses the cultural analysis and rich picture developed in step 2 as the foundation on which to imagine the ideal functions of an information system that could support program managers to take purposeful action.

7.3.2 Data Analysis Method: Developing Root Definitions

The root definition expresses the core purpose of the ideal hypothetical information system. The goal of the root definition is to express the purpose of the intended information system in one sentence. In the next step (step 4), this root definition will be used as the basis on which to draw the purposeful human activity system models. Checkland [54] suggests that well-formulated root definitions should be prepared by consciously considering the elements of the mnemonic CATWOE. CATWOE is a useful tool to identify the main elements, assumptions, and stakeholders involved in a problem situation. CATWOE stands for:

(C) Customers - the victims or beneficiaries of the transformation.

(A) Actors - those who would do the transformation.

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(T) Transformation - from a situation of little or no support to one wherein customers receive the support that they require.

(W) *Weltanschauung* - the worldview which makes the transformation meaningful in context.

(O) Owners - those who could stop the transformation process.

(E) Environmental Constraints - elements outside the system which it takes as given.

At the core of CATWOE is the pairing of the transformation process (T) with the declared worldview (W) that makes the transformation meaningful. The transformation (T) represents the hypothetical transformation from a situation of little or no support to one wherein program managers receive the support that they require. The other elements of CATWOE add the ideas that someone must undertake the transformation, someone could stop it, someone will be its beneficiary or victim, and that this system will be operating within environmental constraints.

Checkland [54] recommends using the PQR method to develop root definitions from the elements of CATWOE. The PQR method can be demonstrated as follows: Do P by Q in order to contribute to achieving R. Creating root definitions in this way answers three questions: What to do (P), How to do it (Q), and Why do it (R)? SSM posits that root definitions constructed with these elements are rich enough to be modelled.

7.3.3 Results

In order to develop the root definition, CATWOE was used to structure thinking on the elements that should be included. A summary of the CATWOE can be found in Fig. 7.3.

Customers: Urban agriculture program managers, target community, broader community.
Actors: Primary researcher, HIA practitioners.
Transformation: Program managers cannot take purposeful action → Program managers can, with the necessary support, take purposeful action.
Weltanschauung: Program managers that are able to take purposeful action can mitigate the health risks and maximize the nutritional benefits prior to implementing the intervention.
Owners: Primary researchers, supervisors, academic committee.
Environmental constraints: Resources to conduct research, lack of access to necessary expertise.

Figure 7.3 CATWOE for activity model 1.

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The root definition was constructed using the elements contained in the CATWOE analysis. This root definition describes the architectural framework of the HAIS as:

> A system that enables program managers to mitigate risks to population health and maximize nutritional impact pathways for the target population by supporting program managers to take purposeful action during the design phase of a planned urban agriculture intervention, prior to implementation.

This root definition was used as the basis for the human activity system model built in the next step.

7.4 Step 4: Build a Purposeful Human Activity System Model

The goal of this step is to explore what activities would ideally require support if program managers were to take purposeful action. This was done using a human activity system model. These models are not intended to represent or predict anything in the real-world, rather they are intellectual devices whose role it is to explore the hypothetical activities that program managers would need to undertake if they were to take purposeful action. The data source for this model was taken from a consultative survey of HIA practitioners (described in Section 7.4.1). The outcome of this model is a list of activities that would require support if program managers were to take purposeful action. These activities comprise the answer to research question 1.

7.4.1 Data Source: Expert Consultative Survey

Six out of ten HIA practitioners voluntarily responded to an email survey consisting of seven questions that garnered their opinions on the challenges and opportunities of assessing the health effects of urban agriculture interventions in low-resource settings. These questions were based on the CATWOE analysis and root definition developed in step 3. Participants were selected using a snowball sampling method. Only participants who were familiar with conducting HIAs in low-resource settings were included in this survey. Informed consent was obtained from all participants. The full consultative survey guide is included in Appendix F.

This part of research was approved under Ethics Reference Number S13/07/134 (24 April 2015).

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The consultative survey sought to determine what challenges program managers may face if they were to undertake their own HIAs in a low-resource setting. In order to do this, HIA practitioners were provided with a short scenario to focus their thinking. Subsequently, a series of questions garnered their opinions on the challenges facing program managers in low-resource settings. HIA practitioners were recruited as opposed to program managers as it was thought that they were able to better understand and articulate the potential challenges of conducting and HIA in low-resource settings. Program managers were not recruited as it was believed that they did not have experience with conducting HIAs and so they would not have been able to articulate the challenges of implementing an HIA in their setting. It will be important to involve them at a later stage in the validation of the resulting information system. The small number of experts consulted was a possible threat to the validity of this part of the research. It was, however, felt by the design team that because this research is in the conceptual development stage, a smaller group was sufficient. Future work on the deployment and testing of the resulting information system should engage a larger and more diverse group.

7.4.2 Data Analysis Method 4: Building Purposeful Human Activity System Models

The challenges identified by the HIA practitioners in the consultative survey were reviewed and grouped by theme. Many challenges were identified using different words (for example, financial resource constraints and lack of funding). In these cases, phrases were grouped together as one challenge. These challenges were then rephrased as activities that require support within the purposeful human activity system model. Links were made between each of the activities in the model based on which activities are contingent upon which other activities. The activities were arranged in logical progression and modelled accordingly.

SSM suggests that every model include some measure of its' performance. Therefore, once the activities for the root definition were modelled, performance in the model was measured using three separate criteria, termed the 3 E's in SSM:

1. Efficacy - Do the activities actually produce the desired transformation?
2. Efficiency - Is the transformation being carried out with the minimal amount of resources?
3. Effectiveness - Is the transformation meeting the longer-term aim?

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The measures of performance developed during this model building exercise were used during formal questioning (step 5) to evaluate the potential solutions.

7.4.3 Results

The goal of this consultation was to brainstorm the challenges that program managers would face if they attempted to assess the health effects of their interventions. The results of this consultation are presented in Fig. 7.4. Each phrase in this figure represents a challenge that was identified by at least one person during the consultative survey with HIA practitioners. Similar phrases were grouped together.

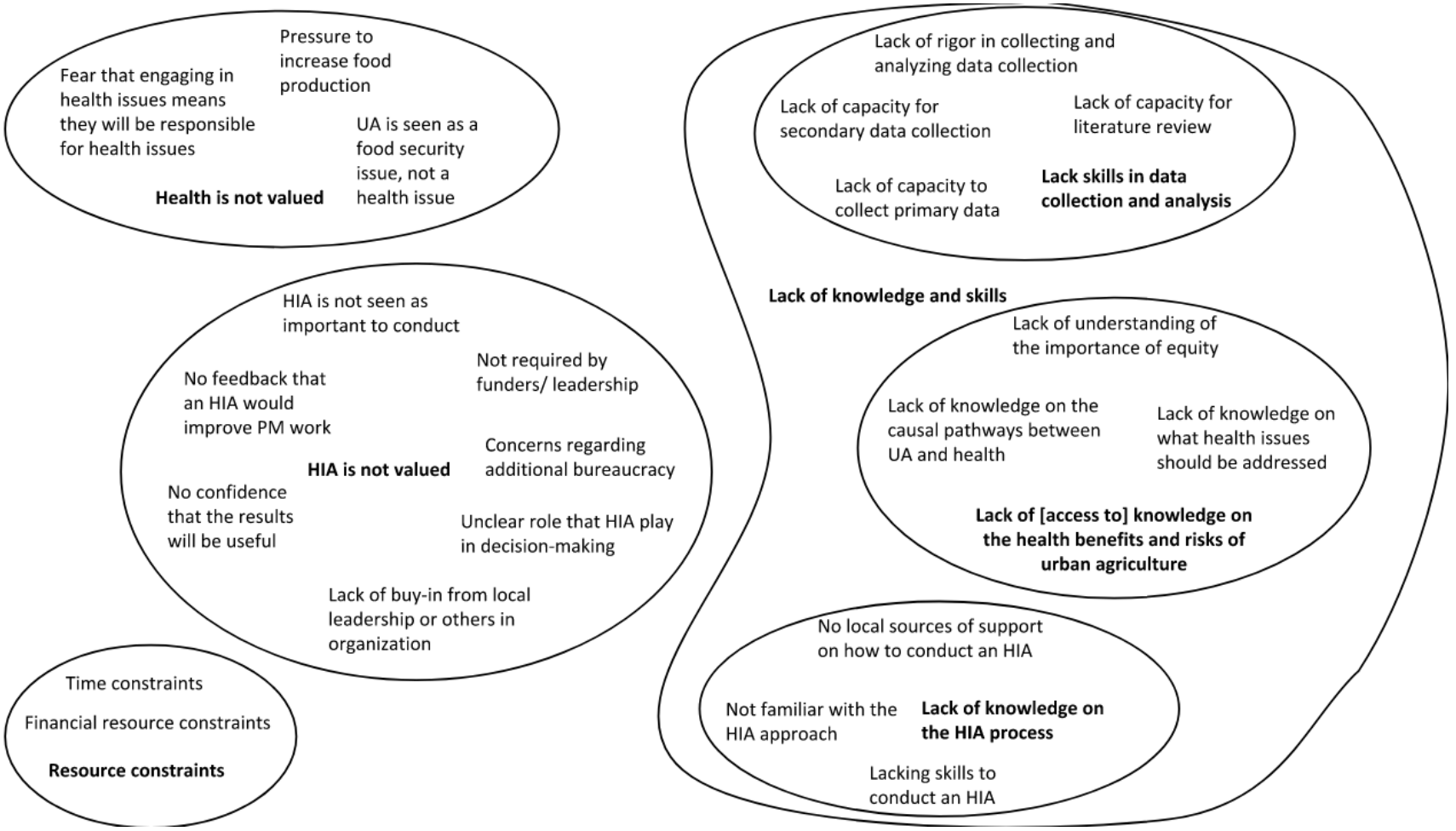

Figure 7.4 Results of the expert consultative survey with HIA practitioners on the challenges of conducting health assessments in low-resource settings

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During the analysis, six separate themes emerged:

1. Lack of resources to conduct an HIA.
2. Lack of knowledge of the HIA process.
3. Lack of (or lack of access to) knowledge on the health benefits and risks of urban agriculture.
4. Lack of capacity for data collection and analysis.
5. Health not valued as an important component of urban agriculture interventions.
6. HIAs not seen important to conduct in these settings.

These six themes were organized into a purposeful human activity system model and activities that were contingent on one another were modelled according to the method described above. The resulting Activity Model is presented in Fig. 7.5. The first three issues were all related to a lack of knowledge or skills and so these were grouped together into one activity in the human activity system model (Activity 3). In addition, the purpose of the system is to allow program managers to take purposeful action and so this was also included in the human activity system model (Activity 5).

It should be noted that the building of this model was a cyclical iterative process and the model presented here is the final version of this process.

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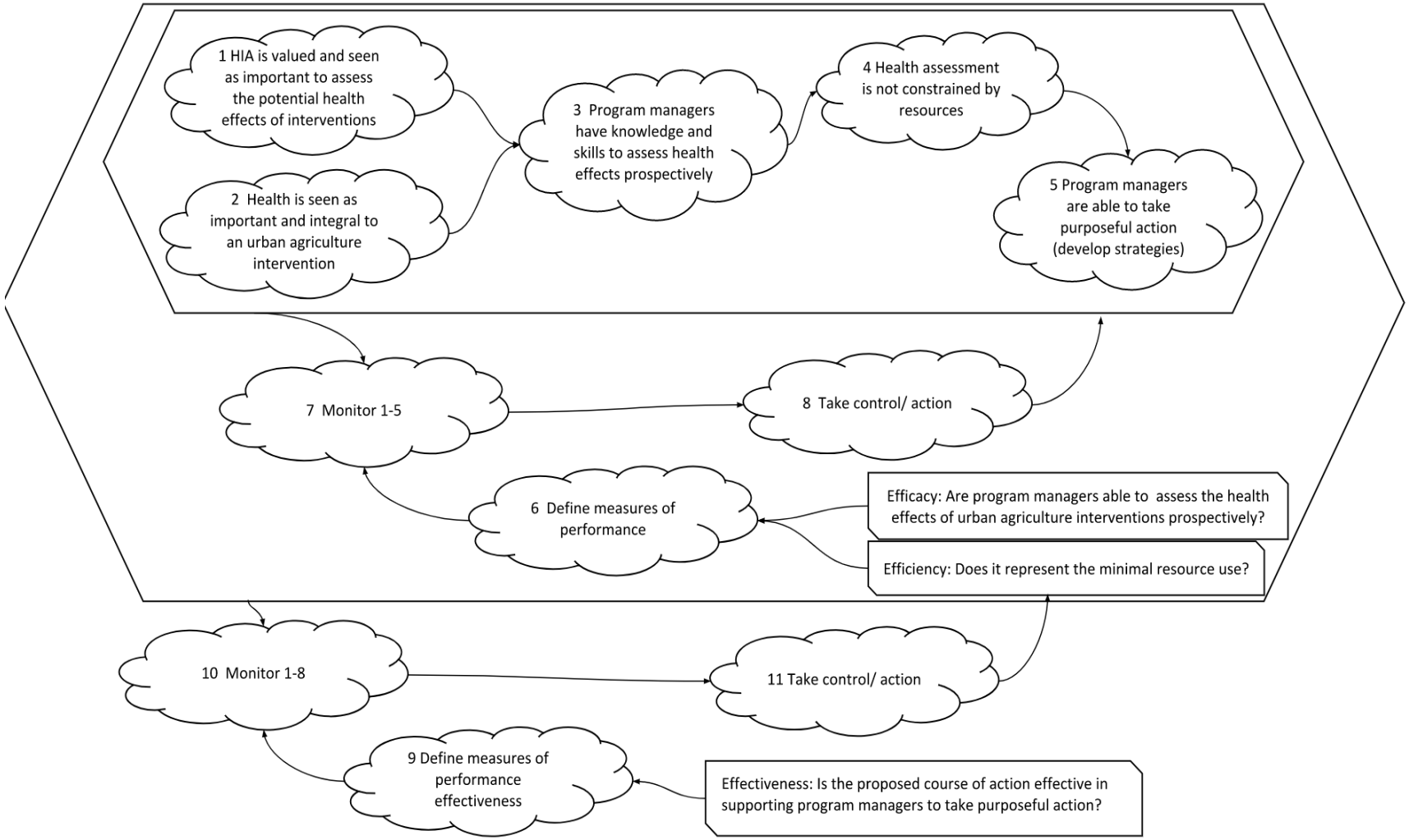

Figure 7.5 Activity model 1 – The challenges of conducting an HIA in a low-resource setting

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This activity model added value to the research process as it made two issues clear. First, it made clear that the reasons program managers do not conduct HIAs of their own projects falls into two main categories – either they *do not want to* conduct an HIA (because health is not valued or the HIA process is not valued) or they *cannot* conduct an HIA (because they do not have the capacity or resources). Second, the model made clear that before any capacity strengthening can be done, it is necessary that health and health assessments are valued as an important component of urban agriculture interventions.

Measures of performance were also included in this activity model. These measures of performance (efficacy, effectiveness, and efficiency) are in place to ensure that the activities in the model are in fact achieving their intended purpose. Three performance questions were established as follows:

1. Efficacy: Are program managers able to assess the health effects of their own urban agriculture interventions prospectively?
2. Efficiency: Does this represent the minimal resource use?
3. Effectiveness: Is the proposed course of action effective in supporting program managers to take purposeful action?

These performance questions were used in the next phase of research to evaluate potential solutions.

7.5 Conclusion

This chapter sought to answer research question 1:

> **What activities need to be supported so that program managers can take purposeful action?**

The human activity system model revealed five activities that ideally should be supported so that program managers can take purposeful action:

1. HIA should be valued and seen as important to assess the potential health effects of interventions.
2. Health should be seen as important and integral to an urban agriculture intervention.

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3. Program managers should have knowledge and skills to assess the health effects prospectively.
4. The health assessment should not be constrained by resources.
5. Program managers should be able to develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health.

These five activities comprise the answer to research question 1.

Answering this research question was done by following the first four steps outlined in Fig. 6.2. In the first two steps, the problem situation was entered and graphically expressed. Entering into the problem situation experientially added value as it allowed a deeper understanding of the problem situation and created a strong foundation on which to precisely express the problem situation. SSM's cultural analysis added value as it allowed an analysis of the social structures and power relations within the intervention context. This understanding could then be used to draw a much richer picture of the problem situation. This rich picture provided a holistic overview of the structures, processes, and people involved in an urban agriculture intervention. The third and fourth steps entered the ideal world to hypothetically explore the areas where program managers would require support if they were to take purposeful action. SSM added value in these steps of the research as it provided a means of systemically identifying the areas where program managers may require support.

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8.0 Phase 2: Define the Information System Requirements

The previous chapter defined the five activities that need to be supported in order for program managers to take purposeful action. The goal of this chapter is to determine what information is needed to support the identified activities. SSM was used to answer research question 2:

What information is required to support these activities?

This research question will be answered in three steps (steps 5-7) as depicted in Fig. 6.2. First, the five activities identified by the first research question will be assessed to determine which among them are desirable and feasible to support within the scope of this research project. Next, how to support the selected activities will be explored in steps 6 and 7 by once again developing root definitions and human activity system models. The outcome of this phase of the research is a list of information system requirements for the architectural framework of the HAIS.

8.1 Step 5: Determine Which Activities are Desirable and Feasible to Support

The human activity system models developed in step 4 identified five activities that would ideally require support if program managers were to take purposeful action. In this step, those five activities are reviewed to determine which of them are possible to support given the scope of this research. In order to do this, each of the five identified activities underwent an SSM formal questioning process (methods described in Section 8.1.2) to determine what support is needed, whether it is desirable to support this activity, and whether it is feasible to support this activity in the context of this research.

8.1.1 Data Source: Human Activity System Model 1

This step uses the human activity system models developed in step 4 as the main data source. This is supplemented with academic literature as required.

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8.1.2 Data Analysis Method: Formal Questioning

SSM recommends a variety of ways in which the activities included in the human activity system models could be analysed to determine which are possible to support in the real-world. Formal questioning has emerged as the most common method for doing this and is the method used by this research. The formal questioning process involves developing a matrix of questions and systematically interrogating each of the activities identified in the human activity system model. This method allows one to logically progress towards a solution. The formal questioning process was conducted twice in this step. The first formal questioning assessed the activities included in activity model 1 to determine what support would be required and whether providing that support through an information system solution was both desirable and feasible. The second formal questioning assessed three possible courses of action according to the three performance measures developed as part of activity model 1 (Section 7.4.3).

8.1.3 Results

The results of this formal questioning process are summarized in Table 8.1. The formal questioning process found that it was desirable to support the first two activities (1) health assessment is valued and (2) health is valued. However, such support was outside the scope of this research for the following reasons: these two activities are related to the attitudes of the program managers and other decision-makers towards health and health assessments. The scope of this research is limited to the establishment of the foundations for an architectural framework for the HAIS and therefore changing attitudes is not part of such foundations. There is, however, a significant body of literature on changing attitudes that could be accessed for further research on this topic. It will be important to return to this issue during the eventual implementation of the HAIS.

As shown in Table 8.1, the third activity, supporting program managers with the skills and knowledge to conduct their own health assessment, was deemed desirable. Since the goal of HAIS is to provide the right information to the right people at the right time in the right place, it was also deemed feasible. Possible courses of action regarding how to do this will be explored in more detail below in a second formal questioning process.

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Table 8.1 Results of the formal questioning process of activity model 1.

Activity in model 1	What support is needed?	Is it desirable to support this activity?	Is it feasible to support this activity?
1. HIA is valued and seen as important to assess the potential health effects of interventions	Program managers need support to change their attitudes and the attitudes of other decision-makers regarding the value of conducting a health assessment prospectively	Yes	Yes, but not in the scope of this research
2. Health is seen as important and integral to an urban agriculture intervention	Program managers need support to change their attitudes and the attitudes of other decision-makers regarding health as an integral part of an urban agricultural intervention	Yes	Yes, but not in the scope of this research
3. Program managers have knowledge and skills to take purposeful action	Program managers need support of their capacity to conduct health assessments	Yes	Yes, within scope of this research
4. Health assessment is not constrained by resources	Program managers need resources to conduct health assessments	Yes	No, not feasible to supply resources to program managers
5. Program managers are able to take purposeful action	Program managers need support to make decisions that will mitigate the health risks and maximize on the impact pathways to nutrition	Yes	Yes, within scope of this research

The fourth activity, which is to supply the program managers with the resources to conduct their own health assessments, was deemed desirable, but is only feasible under certain conditions. It is not feasible to supply program managers with unlimited funding to conduct unlimited health assessments. It is desirable and feasible to make the health assessment process cheaper and less time consuming so that it becomes an acceptable and useful activity when program managers are planning urban agriculture interventions. Any solution needs to take resource constraint into careful consideration.

The final activity, which is to support program managers in decision-making, was considered both desirable and feasible. The strategies taken to assist program managers in making their own decisions varies widely from direct counselling (which is highly resource

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intensive) to guidance through information systems (which requires minimal resources but may not provide the direct one-on-one guidance required). Any proposed solution would need to consider the resource challenges and therefore should require minimal resource usage.

With these factors in mind, the third activity will now be returned to. In order to provide program managers with the skills and knowledge they require to take purposeful action, three possible courses of action for the HAIS were considered:

1. **Capacity building**, which includes activities such as education and training. A capacity building HAIS would, for example, provide an information system that trains program managers through workshops, continuing education, online courses, or coaching to conduct their own health assessments.
2. **Business as usual** refers to the current situation where experts are brought in from outside to assess the health effects of interventions. The role of the HAIS in this situation would be to locate and contact expertise. Continuing with this practice would require that experts be brought into low-resource settings to assess the health effects in conjunction with program managers.
3. **Knowledge management,** which is the process of capturing, distributing, and effectively using knowledge [78]. Knowledge management refers to getting the right knowledge to the right people at the right time. A knowledge management solution would entail guiding the program manager through a step-by-step process to assess the potential health effects of their own interventions.

Each of these courses of action was assessed using the performance measures developed as part of activity model 1 (Fig. 7.3). Table 8.2 summarizes the second formal questioning process. Efficiency in particular was seen as an important indicator of performance as resource constraints (particularly financial and time constraints) pose a significant challenge to conducting health assessments in low-resource settings.

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Table 8.2 Evaluation of potential strategies to provide program managers with the knowledge and skills to assess the health effects of urban agricultural interventions.

	Effectiveness: Is the proposed course of action effective in supporting program managers to take purposeful action?	Efficacy: Are program managers able to assess the health effects of urban agriculture interventions prospectively?	Efficiency: Does it represent minimal resource use?
Capacity Building	Yes	Yes	No
Business as Usual	Yes	No	No
Knowledge Management	Yes	Yes	Yes

As seen in Table 8.2, this formal questioning process found that all three proposed courses of action would be effective in supporting program managers to take purposeful action. With regards to whether program managers can assess their own interventions, it was found that capacity building and knowledge management were the only two courses of action that would allow program managers to conduct their own health assessments (as continuing with business as usual requires experts be brought in to the situation). Lastly, regarding resource-use, it was determined that capacity building was highly time-consuming for program managers to take part in and would require a lot of front-end investment on their part to train in health assessments methods that they would rarely use. Similarly, continuing business as usual was also highly resource intensive given the need to bring in expensive experts. Finally, the knowledge management solution was also viewed as a resource intensive. However, in this case, the investment is not part of the program managers' costs but rather is borne by researchers and developers in the design and development stage of the information system. Knowledge management was therefore considered as a low resource solution from a program managers' point of view.

In conclusion, knowledge management was the only course of action to address all three performance measures. Within the context of the HAIS, a knowledge management solution would provide a mechanism to capture, retain, and distribute the knowledge and skills to those who need it.

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This formal questioning process added value as it provided a structured logical method for evaluating the potential solutions. The next step in this study was to determine what knowledge and skills included in the HIA process should be captured and made available to program managers so that they could take purposeful action. This will form the basis for the definition of the information system requirements for the architectural framework of the HAIS.

8.2 Step 6: Develop Root Definitions of Relevant Systems

A purposeful human activity system model was once again built to structure thinking on the specific knowledge and skills that would require support if program managers were to take purposeful action. In order to build this model, a root definition was first developed to define the system to be modelled.

8.2.1 Data Source: Outcomes of Formal Questioning

The outcomes of the formal questioning process in step 5 are used as the data source for the development of the root definition for this second purposeful human activity system model.

8.2.2 Data Analysis Method: Developing Root Definitions

The development of the root definitions follows the same data analysis methods as were outlined in step 3 (Section 7.3.2).

8.2.3 Results

CATWOE was used to structure thinking on the elements that should be included in the root definition. A summary of CATWOE is included in Fig. 8.1.

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Customers: Program managers of urban agriculture interventions.

Actors: HIA practitioners, designers of the architectural framework for the HAIS.

Transformation: Program managers do not have the knowledge and skills to take purposeful action → Program managers have the knowledge and skills to take purposeful action.

Weltanschauung: Program managers that can access the right knowledge in the right place at the right time will be able to assess the health effects of their prospective projects with minimal resource input.

Owner: Developers of the architectural framework for the HAIS, supervisors, academic committee.

Environmental constraints: Access to HIA practitioner expertise, access to knowledge on the HIA process and the health effects of urban agriculture, resources to design an information system.

Figure 8.1 CATWOE for activity model 2.

The root definition was constructed using the elements contained in the CATWOE analysis. This root definition describes the architectural framework of the HAIS as:

> A system that equips program managers with the right knowledge and skills in the right place at the right time to take purposeful action regarding their planned interventions by identifying what components of the HIA approach should be captured and structured as part of a knowledge management solution, so that program managers can develop their own evidence-based strategies to mitigate the health risks and maximize the nutritional impact pathways with minimal resource input.

This root definition was used as the basis for the human activity system model built in the next step.

8.3 Step 7: Build a Purposeful Human Activity System Model

The goal of this activity model was to explore the knowledge and skills that program managers would need if they were to take purposeful action. The outcome of this activity model is the information system requirements for the architectural framework of the HAIS. Using models to hypothetically explore the information system requirements "lifts the thinking in the situation out of its normal, unnoticed, comfortable grooves" [56: p.21] and allows one to think

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creatively about solutions. Activity model 2 (Fig. 8.2) was built based on the CATWOE and root definition described in step 6.

8.3.1 Data Sources: Consultative Survey and Procedural Document Analysis

The data for this model came from the consultative survey of HIA practitioners (described in Section 7.4.1) and a procedural document analysis that included a review of both the technical and soft elements of the HIA process (described below).

Procedural document analysis: A review of the numerous HIA practitioner guides was conducted to determine what structures, processes, and stakeholders are involved in the typical HIA process. A full list of HIA guides was obtained from the HIA expert advisor. These guides were reviewed for their utility and the most comprehensive of these guides were selected as the basis for this analysis. Namely, the Human Impact Partners HIA guide [14] and the Minimum Elements and Practice Standards [33]. The importance of these guides was later triangulated at the Society of Practitioners of Health Impact Assessment (SOPHIA) biennial conference (2016), where an informal survey of HIA practitioners confirmed that these were the most critical resources for HIA practitioners. The data extracted from these guides incorporated both the technical elements of the HIA process and also the soft elements of the HIA process. This ensured that the architectural framework for the HAIS not only reflected the technical six-step HIA process, but also gave significance to multi-stakeholder engagement; the ability to make accommodations for other's intentions, priorities, and needs; making trade-offs between evidence, values and preferences; creatively developing a set of evidence-based strategies aimed at a variety of levels; and utilizing a wide variety of methods.

8.3.2 Data Analysis Method: Building Purposeful Human Activity System Models

The development of the activity models follows the same data analysis methods as were outlined in step 4 (Section 7.4.2).

8.3.3 Results

The goal of this model was to explore what knowledge and skills program managers would ideally need to be equipped with in order for them to take purposeful action. It should be noted that the building of this model was a cyclical iterative process and the model presented in Fig. 8.2 is the final version of this process.

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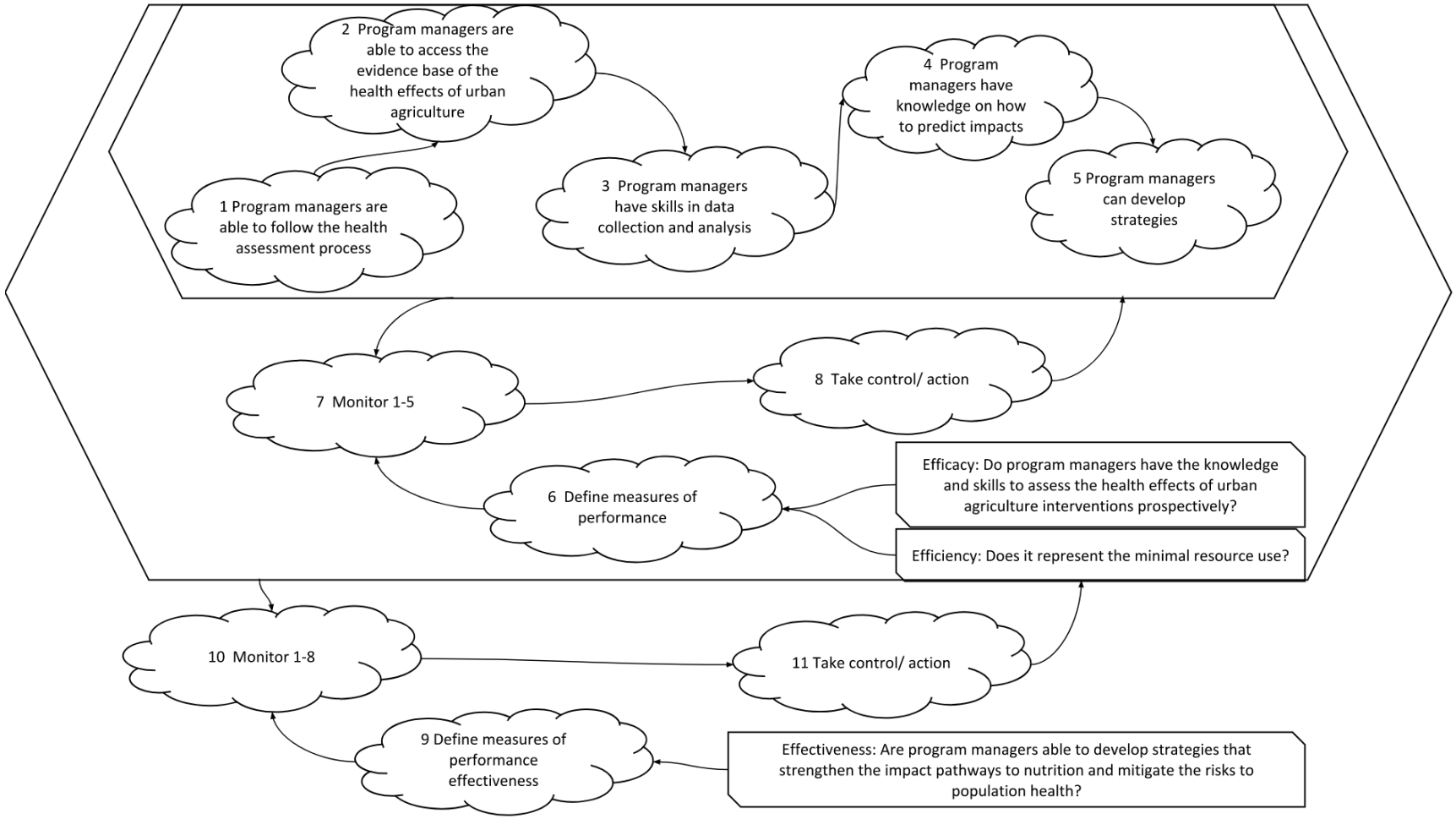

Figure 8.2 Activity model 2 - Defining the information system requirements.

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The consultative survey with health assessment experts revealed that program managers require support in the following three distinct areas:

1. They require support on the process of conducting a health assessment prospectively (Fig. 8.2, item 1).
2. They require support to access an evidence base on the health benefits and risks of urban agriculture (Fig. 8.2, item 2).
3. They require support on data collection and analysis skills (Fig. 8.2, item 3).

The procedural document analysis was used to supplement this expert consultation in order to ensure that all activities were captured. This procedural document analysis revealed that understanding how to predict potential outcomes based on the available data is an important skill that should be included in the HAIS (Fig. 8.2, item 4). The outcome of supporting these activities is that program managers would be able to develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health (Fig. 8.2, item 5). Thus, program managers need support in five areas of activity, as depicted in activity model 2.

Table 8.3 identifies the knowledge and skills that program managers would require support of if they were to undertake purposeful action.

Table 8.3 Overview of the knowledge and skills that program managers would require.

Activities that program managers require support to undertake:	**What knowledge or skills are required to support these activities?**
Support on the process of conducting health assessments prospectively	Knowledge on the health assessment process
Support to access the evidence base on the health benefits and risks of urban agriculture	Knowledge of (or access to) the evidence base
Support of data collection and analysis skills	Skills in data collection and analysis
Support to predict potential outcomes, based on available data	Knowledge and skills on how to predict the potential outcomes of an intervention
Support for developing evidence-based strategies to mitigate/ improve potential health effects	Skills in developing mitigation and improvement strategies

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In summary, program managers require support in the form of the following knowledge and skills:

1. Knowledge on the health assessment process.
2. Knowledge of (or access to) the evidence base.
3. Skills in data collection and analysis.
4. Knowledge on how to predict the potential outcomes.
5. Skills in developing mitigation and improvement strategies.

These five knowledge and skills requirements comprise the requirements for the architectural framework of the HAIS.

In order to ensure that the soft elements, described in Section 3.2, were not lost in the design of the architectural framework, the procedural document analysis specifically sought out the soft elements that are related to each of the knowledge and skills identified. These elements are grouped according to the five information system requirements and explicate the functions that the HAIS should possess.

The soft elements that should to be considered during the design of the architectural framework for the HAIS are outlined in Table 8.4:

Table 8.4 The soft elements to be taken in account during the design of the architectural framework.

Knowledge on the health assessment process
a. Stakeholders, including minority or disadvantaged groups, should be engaged from early on in the process. This will help ensure that their needs, values, preferences, and priorities are considered [14, 34].
b. The resources for a health assessment should only be expended if the results of the health assessment are likely to be considered. Therefore, there should be some mechanism for program managers to assess the likelihood of uptake prior to commencing the health assessment.
c. Guiding users through a declared step-by-step process may help to ensure that unforeseen consequences are identified ahead of time and program managers can therefore think through a multi-level strategy that addresses concerns at all levels [14].
d. HIAs have been criticized for not always providing transparent reporting of the linkages between the evidence and the recommended strategies [79-81]. The HAIS should therefore have a

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component that makes the linkages between evidence and recommendations clear, thus increasing the transparency and confidence in the resulting recommendations.

Knowledge of (or access to) the evidence base

a. Program managers require access to a vast evidence base. The HAIS would therefore benefit from having a database of proven interventions and mitigation measures for urban agriculture. The evidence contained in this database should be appropriately packaged and readily made available to program managers [34].

b. An important aspect of an HIA is knowledge on the impact pathways between the intervention and the health impacts. Many academics believe that an overall map of the impact pathways, which can be adapted to the local context, would be extremely useful [35, 37]. Offering program managers a mechanism for mapping the impact pathways, along with an indication of the major mediating factors along the pathway, could help practitioners think more carefully about the assumptions behind their predictions. As seen in Chapter 2, several models of impact pathway have already been developed. The best of these could be adapted for the HAIS as an impact pathway mapping tool.

Skills in data collection and analysis

a. HIAs require a great deal of data at the local level. Therefore, guidelines on selecting outcome measures, indicators, and data collection tools would be extremely useful to those trying to gather and assess both primary and secondary data [34].

b. The HAIS should recommend the collection of data from various disadvantaged and minority groups to ensure that the equity factors are considered [34].

c. A decision may positively affect the health of one subgroup, but negatively affect the health of another subgroup. Therefore, careful attention needs to be given to the distribution of the effects of the intervention within the population of interest [14]. Guidance on the process of subgroup analysis of various minority groups should be provided with emphasis placed on between-subgroup analyses.

Knowledge on how to predict the potential outcomes

a. The HAIS should provide a mechanism for easily allowing program managers with limited skills in prediction to qualitatively and quantitatively predict the likely impacts of their planned intervention.

b. The impact of the intervention should be measured not only for the target group, but unintended consequences for the health of other subgroups, particularly marginalized subgroups, should also be considered. Individuals from minority groups should be explicitly engaged in the process [34].

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Skills in developing mitigation and improvement strategies

a. The recommended strategies to mitigate the risks and strengthen the impact pathways to nutrition should be evidence-based. This not only increases the effectiveness of the resulting strategies, but also may increase the confidence of decision-makers in the proposed strategies.

b. On the other hand, it should be recognized that those implementing the recommended strategies are not merely seeking to maximize outcomes, but rather function within an environment where politics and relationships influence their decisions. Thus, the HAIS needs to include guidance on how to manage trade-offs between the evidence and stakeholders' values and preferences [14].

c. Strategies to increase the uptake of the recommendations should be included. For example, engaging decision-makers and other stakeholders, including those with local knowledge, early on in the assessment process increases the likelihood that the recommendations resulting from the health assessment will be implemented [14].

d. Disadvantaged groups should be recognized up front to ensure that the recommendations explicitly take these groups into account. In addition, members of these groups should be included in the process from the beginning to ensure that the recommendations take their needs and priorities are also taken in account [34].

e. The results should be shared with relevant stakeholders in ways that are appropriate. This is particularly important for disadvantaged groups who may not be able to access traditional text-based feedback mechanisms. In this case an oral account or pictures for example may be more appropriate.

f. It is important to note that health assessments only provide information to inform decisions. There is no guarantee that the recommended strategies will be put into place. A range of strategies should therefore be provided to allow maximum flexibility to decision-makers so that they can decide which pieces of the intervention to implement or which mitigation or enhancement strategies to put in place [14].

g. Regardless of whether or not the recommendations are implemented, the HIA process provides a documented rationale for reference on future decisions. It provides an accountability mechanism by which the rationale behind previously implemented decisions can be traced backwards and decisions to implement future recommendations can be adequately supported by evidence.

In summary, Table 8.4 outlines a number of soft elements that should be considered during the development of the HAIS. Taking these elements into account will help ensure that the resulting information system is as robust as possible.

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8.4 Conclusion

This chapter summarized Phase 2 of this research and addressed research question 2, which asks:

What information is required to support these activities?

SSM was used to answer this research question. The following information is required to support program managers:

1. Knowledge on the health assessment process.
2. Knowledge of (or access to) the evidence base.
3. Skills in data collection and analysis.
4. Knowledge on how to predict the potential outcomes.
5. Skills in developing mitigation and improvement strategies.

These comprise the information system requirements for the architectural framework of the HAIS.

As this is a pivotal point in this research process, it is useful to walk through and summarize the process to show how all the previous steps of this research have culminated in the information system requirements for the architectural framework of the HAIS. It would not have been possible to define these information system requirements without the processes described in the previous eight chapters. Chapters 2-4 presented background in the form of in-depth literature reviews and analyses. Chapter 2 identified the importance of the problem situation and gap in knowledge that this research aims to address. Chapter 3 presented the HIA as a possible solution, but found it was not feasible due to the expert-driven nature of the assessment methods. Chapter 4 conceptualized the translation and transfer of expert knowledge for use by non-expert program managers and proposed the HAIS as one possible solution that could contribute to filling the gap in knowledge. One of the key findings of these early chapters is that the HIA is more than just a six-step process. It is rather a holistic approach that consists of a number of soft elements to include multi-stakeholder engagement; the ability to make accommodations for others' intentions, priorities, and needs; making trade-offs between evidence, values and preferences; creatively developing a set of evidence-based strategies aimed at a variety of levels; and utilizing a wide variety of methods. It was clear that any attempt to design an information system would need to take these soft elements into account. Chapter 5

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outlined the theoretical foundations for the design of an architectural framework for the HAIS. This chapter concluded with the research questions, which are based on the conceptual framework of the soft systems approach to information system design. Chapter 6 presented the rationale for the selection of the paradigm and methodology as well the overall research design. Chapter 7 answered the first research question and identified five activities that would need to be supported if program managers were to develop their own strategies. Chapter 8 determined what information is required to support program managers and concluded with the information system requirements for the architectural framework of the HAIS.

Each step in this research was necessary and built on the previous step. This research has culminated in a list of information system requirements that are based on a realistic view of the organizational setting. This is in contrast to the technical solutions that are usually offered by hard systems information system designers. It would not have been possible to define these requirements without the research contained in the previous 8 chapters. In addition, SSM was instrumental as it provided the use of a formal structured methodology to critically assess the hypothetical needs of the program managers operating within a complex organizational context. This methodology took the research beyond the simple translation of the six-step HIA process into an information system and facilitated taking into consideration the complex organizational setting that program managers are working in as well as the complex nature of the intervention itself.

The next chapter explores how these requirements can be structured into an architectural framework for the HAIS.

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9.0 Phase 3: The Architectural Framework of the HAIS

The previous chapter identified five information system requirements for the architectural framework of the HAIS:

1. Knowledge of the health assessment process.
2. Knowledge of (or access to) the evidence base.
3. Skills in data collection and analysis.
4. Knowledge on how to predict the potential outcomes.
5. Skills in developing mitigation and improvement strategies.

The goal of this chapter is to design an architectural framework for the HAIS that addresses these five information system requirements and their related soft elements. In doing so, research question 3 will be answered:

How can the architectural framework for the HAIS be structured?

This chapter is organized as follows: first the five information system requirements identified in the previous chapter are assessed using SSM's formal questioning process to determine how these requirements could be addressed by the HAIS. Next, the architectural framework for the HAIS is presented. Finally, the functionality of the HAIS is demonstrated by presenting an example of its use.

9.1 Step 8: Determine a Structure for the HAIS

The goal of this step of the research is to determine how the identified information system requirements could be incorporated into an architectural framework for the HAIS.

9.1.1 Data Source: Human Activity System Model 2

This step uses data from the human activity system model developed in step 7 (Section 8.3.3) as well as the analysis of the soft elements that should be included (Table 8.4) as the data sources for the formal questioning process.

9.1.2 Data Analysis Method: Formal Questioning

In order to determine the most effective way of structuring the architectural framework for the HAIS, each of the five requirements identified in human activity system model 2 (step 7)

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underwent SSM's formal questioning process. The goal was to determine how these requirements could be addressed by an information system, how this knowledge could be included in the HAIS, and where each component could be stored.

9.1.3 Results

The formal questioning process was conducted using an excel spreadsheet that outlined all the data points and then formally analysed each data point to establish the specific requirements, based on the HIA approach, for the information system. The data for this spreadsheet was taken from the expert consultations as well as an analysis of HIA practitioner guidelines. A summary of the results of this formal questioning process are presented in Table 9.1 and explicated in the text below. The formal questioning process assumes that the HAIS will be supported by an information technology.

The HAIS should support program managers to go through the health assessment process (item 1, Table 9.1) by providing guidance on the tasks that need to be completed, who should complete those tasks, and what additional resources are required to complete those tasks. There could be a component that guides users through the health assessment process and draws on the tools, evidence, or modules as required. Going through this process would provide a transparent link between the issues, evidence, and recommendations. Thus, this aspect of the HAIS requires a Health Assessment (HA) Process Executor.

With regards to knowledge of (or access to) the evidence base (item 2, Table 9.1), the HAIS could provide packaged information that aids program managers to make informed decisions. For example, the HAIS could provide a program manager who is planning on including compost heaps in the intervention with a list of the potential health risks of compost heaps. The program manager could then review the evidence and make an informed decision on which indicators to select that would ensure that the health effects of compost heaps are measured. Thus, the HAIS requires a Tool Library that would include all the relevant evidence packaged for each task.

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Table 9.1 Results of the formal questioning process of activity model 1.

Information system requirements:	**What knowledge or skills are required to support these activities?**	**How could these knowledge/ skills be included in the HAIS?**	**What component of the HAIS is it?**
1) Knowledge on the health assessment process	Guidance on the tasks that need to be completed, who should be assigned to the task, and what additional resources are required to complete the task	A component that guides users through the process by executing tasks and accessing evidence and tools as necessary	HA Process Executor
2) Knowledge of (or access to) the evidence base	Evidence related to the task at hand so that program managers can make informed decisions	Evidence could be packaged and stored appropriately	Tools Library
3) Skills in data collection and analysis	Guidance on data collection and analysis techniques so that program managers can collect and/ or analyse their own data Data analysis algorithms which would analyse the data entered into the system	Computerized tool that guides users through the data analysis/ collection for each indicator Data analytics routines	Tools Library Analytics Module
4) Knowledge and skills on how to predict the potential outcomes of an intervention	Algorithms that could predict the likely impact of the intervention on a selected indicator based on the data that has been entered	Dedicated predictive analytics capabilities that can predict likely impacts for selected indicators	Analytics Module
5) Skills in developing mitigation and improvement strategies	Appropriate strategies based on the data that has been entered	Association of the results of data analysis with the existing evidence	Report Generator Recommendation Repository

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With regards to skills in data collection and analysis (item 3, Table 9.1), two options exist. In option 1, the HAIS could provide guidance on data collection and analysis. This would allow users to collect and analyse the data themselves. In this instance, the HAIS needs to include a Tool Library with the relevant data acquisition tools. In option 2, the HAIS could provide data analysis algorithms that would allow users to enter data into a specific module designed for this purpose. The module would then run the appropriate data analytic routine and return the final numbers. In this instance, the HAIS would need to include a Data Analytics Module that holds the relevant data analysis algorithms.

With regards to knowledge and skills to predict the potential outcomes (item 4, table 9.1), the HAIS should support program managers to predict the likely impact of the intervention on a selected outcome. In order to make these predictions, the HAIS could draw on dedicated analytics module that uses data previously entered into the system to make predictions. Thus, the HAIS needs to include Data Analytics Modules for prediction purposes.

With regards to skills for developing mitigation and improvement strategies, the HAIS could select appropriate strategies based on the data that has been entered into the system. This could be done by comparing the data that has been entered with a list of possible strategies and selecting the most appropriate. Thus, the HAIS needs to include a component that can do this task (termed Report Generator) as well as a Recommendation Repository to store the evidence-based strategies.

The HAIS needs to possess functionality that will allow it to support the program managers in the activities described above. In order to do so, development of the HAIS should follow a blueprint established by the architectural framework as described in the next section.

9.2 The HAIS Architectural Framework

Figure 9.1 presents the architectural framework of the HAIS. The user (program manager) interacts with the HAIS through a front-end (user interface). The front-end relies on the HA Process Executor to walk through the tasks associated with a health assessment. In doing so, the HA Process Executor draws the information from the Tool Library and the Data Analytics Module. All information that is generated throughout the health assessment process is stored in a Temporary Storage Facility. Upon going through the entire cycle, the final task of the HA Process

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Executor is to generate a report with recommendations. This is done by the Report Generator, which retrieves relevant information from the Temporary Storage Facility and associates it with the Recommendation Repository in order to make recommendations to the program manager. Each component of this framework is described in detail below.

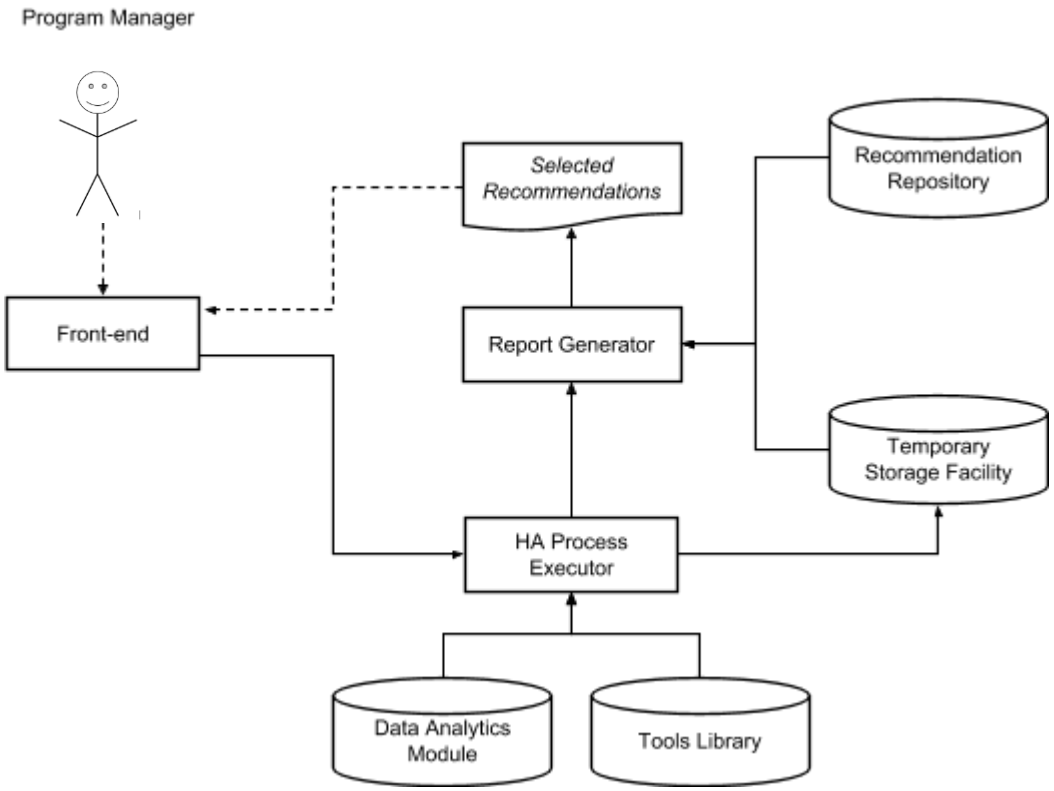

Figure 9.1 Architectural Framework of the HAIS.

9.2.1 Front-end

The HAIS could be a web-based system that can be accessed from different devices remotely, including mobile devices or desktop computers. In order for program managers to use the HAIS it needs to have a user-friendly interface that adapts to the access device that is being used. The final report, which is generated by the Report Generator, uses this front-end to present the final recommendations to the program manager.

9.2.2 HA Process Executor

A health assessment is a process with steps and tasks to be completed. Thus, what drives the entire system is execution of the Health Assessment process. In the proposed architectural framework for the HAIS, this is done by the 'HA Process Executor' component. This is where

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control of the HAIS behaviour takes place, where required tools are called for, and where generation of the reports is initiated. The HA Process Executor executes tasks by identifying what task should be completed, who should be assigned to this task, and what additional resources are required for the task to be completed.

9.2.3 Tools Library

Some of the process tasks can be very complicated and may require complex assessments that involve additional data collection and additional processing that cannot be accomplished by the Process Executor. If such a task is encountered, then the appropriate Tool to help with completing this task is retrieved by the HA Process Executor from Tools Library. Content of this library can be updated, however the process of doing this is beyond the scope of this research.

Examples of the tools included in this library are:

1. Stakeholder identification tools,
2. Prioritization tools,
3. Impact pathway development tools,
4. Data acquisition tools, and
5. Impact prediction guidance tools.

Since use of these tools may require information previously entered into the system, it is important that as information is entered into the system, it is stored and appropriately tagged in a Temporary Storage Facility so that it can subsequently be easily retrieved by the HA Process Executor.

9.2.4 Data Analytics Module

Completion of some tasks may require complex computations and analysis that are beyond the capabilities of the HA Process Executor. An example includes forecasting the potential effects of an urban agriculture intervention on a selected indicator. In these situations, dedicated analytics capabilities (i.e. for example a forecasting module) will need to be made available. These are retrieved from the Data Analytics Module.

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9.2.5 Report Generator

The Report Generator is invoked when the health assessment process is completed and recommendations need to be provided. Upon being invoked, it retrieves all relevant data that was collected during process execution (this data is stored in the Temporary Storage Facility). It has the capability to identify relevant risk mitigation and benefit enhancement strategies based on the data that was collected during the process. These strategies are stored in the Strategy Repository. All the relevant data is assembled into a report, which is produced by the HA Process Executor.

9.2.6 Strategy Repository

The purpose of using the HAIS is, for a given urban agriculture intervention, to generate a set of relevant strategies that can take into account all that is known about the intervention under consideration. Strategies are stored in this repository following an appropriate format that allows for easy tagging, indexing, and therefore retrieval. This repository could be updated with new strategies or failed ones can be removed. The process of doing this is, however, outside scope of this research.

9.2.7 Temporary Storage Facility

This is a technical component of the HAIS where all intermediate results and data are stored for use by different components, including the Report Generator. Once the assessment process is completed and the report is generated, content of this facility is erased for that particular intervention (in other words HAIS does not have a ‘memory’ of the past interventions).

9.3 Demonstration of the Functionality of the HAIS

The functionality of the HAIS will be demonstrated through the presentation of four use cases. These use cases provide a means of describing the sequence of steps that could be carried out by the HAIS [82]. This demonstration will be completed using a scenario as described below.

Scenario: A program manager working for an international NGO is responsible for designing an urban agriculture intervention that includes a vegetable garden and raising chickens for eggs in a poor urban area. The intervention site is called Greenbank Gardens. The target group are socially disadvantaged women, who are able to dedicate at least three hours per day

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to the intervention, and each has at least one child under 5 years old. The intervention will be implemented on a community site that has been designated by the local government for this purpose. The goal of the intervention is to improve the nutritional status of the women's children. The program manager is concerned with the potential health risks associated with the planned intervention site and she is uncertain how to maximize the nutritional outcomes for the target population. She decides to use the HAIS to help her assess the potential impacts of the planned urban agriculture intervention.

The program manager is assisted by the HAIS in her assessment. She starts by entering the name of the intervention. The HAIS then walks her through a series of steps. Four of these steps will be described below as separate use cases in order to demonstrate the functionality of the HAIS. Each use case begins with an explanation of the function that will be illustrated, next a mock-up interface is presented, this is followed by the actions of the program manager. Finally, the actions of the HAIS are described.

9.3.1 Use Case 1

This use case illustrates the first task of the HAIS, which is to determine whether it is desirable to conduct a health assessment in this setting.

The mock-up screen that the program manager sees is presented in Fig. 9.2.

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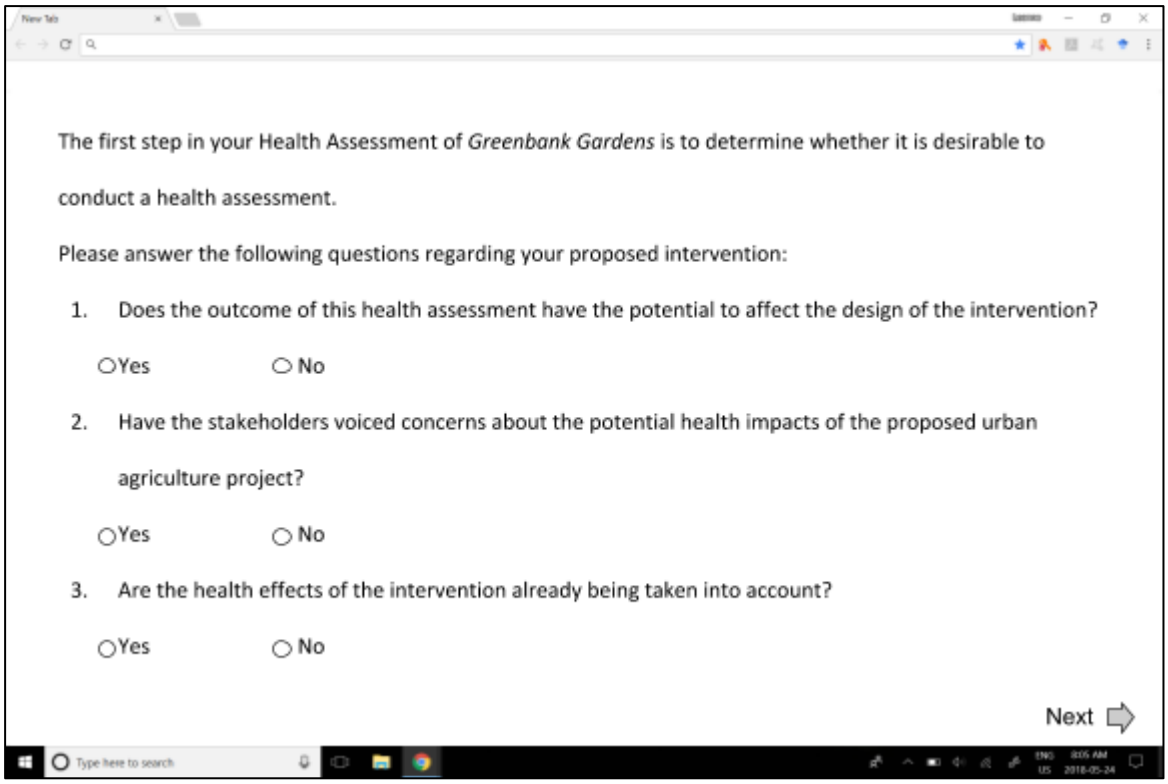

Figure 9.2 Mock-up interface for use case 1.

The program manager responds to these questions and clicks the next button.

In this step, the HAIS takes the following actions:

1. The HA Process Executor identifies that the task is 'Assess the desirability of conducting a health assessment'.
2. The HA Process Executor calls the 'Desirability Questionnaire' from the Tool Library.
3. The program manager enters data into the Desirability Questionnaire Tool.
4. The data is stored in the Temporary Storage Facility.
5. The HA Process Executor identifies that this step is complete when the program manager proceeds to the next task.

9.3.2 Use Case 2

This use case illustrates the second task of the HAIS, which is to determine the resources that are available for the health assessment. This information will be used in later stages when selecting the outcomes and data collection methods.

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The mock-up screen that the program manager sees is presented in Fig. 9.3.

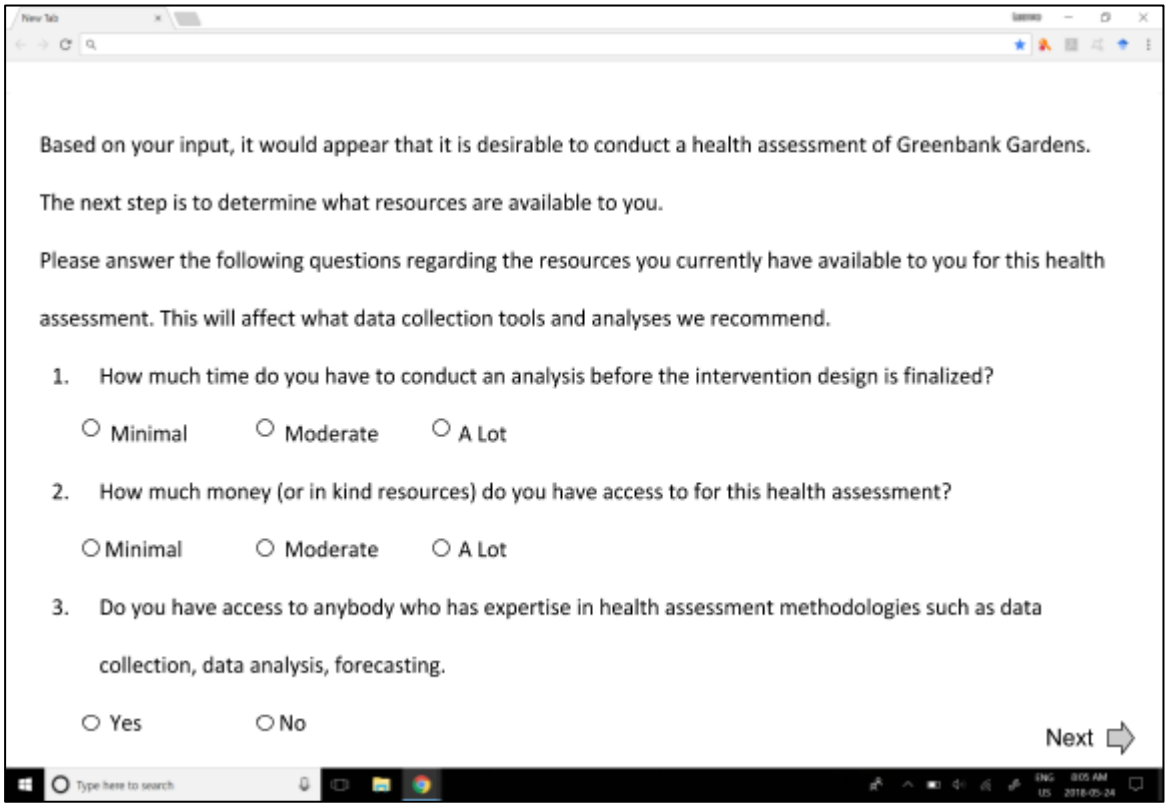

Figure 9.3 Mock-up interface for use case 2.

The program manager responds to these questions and clicks the next button.

In this step, the HAIS takes the following actions:

1. The HA Process Executor identifies that the task is 'Identify the Resources'.
2. The HA Process Executor calls the 'Resource Identification Questionnaire' from the Tool Library.
3. The program manager enters data into the Tool.
4. The data is stored in the Temporary Storage Facility.
5. The HA Process Executor identifies that this step is complete when the program manager proceeds to the next task.

9.3.3 Use Case 3

This use case illustrates a later task in the process, that of selecting the indicators and data collection tools.

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The mock-up screen that the program manager sees is presented in Fig. 9.4.

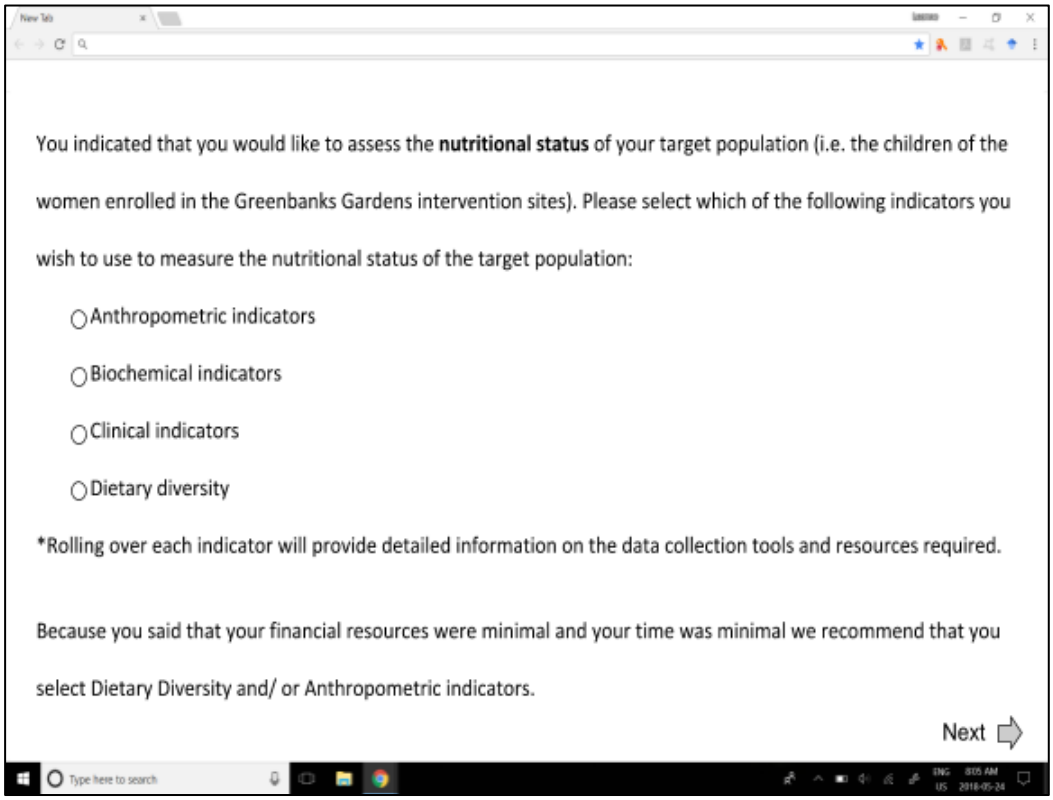

Figure 9.4 Mock-up interface for use case 3.

The program manager responds to these questions and clicks the next button.

In this step, the HAIS takes the following actions:

1. The HA Process Executor identifies that the task is ‘Select Indicators’.
2. The HA Process Executor identifies all possible indicators for a selected outcome (stored in the Tools Library).
3. The HA Process Executor recommends indicator(s) (stored in the Tools Library) based on the identified resources (stored in the Temporary Storage Facility).
4. The program manager selects an indicator(s).
5. The selection is stored in the Temporary Storage Facility.
6. The program manager signals completion of this task by pressing the next button.

9.3.4 Use Case 4

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This use case illustrates the final task in the process, which is recommending strategies to mitigate the health risks or maximize the nutritional benefits. The mock-up screen that the program manager sees is presented in Fig. 9.5.

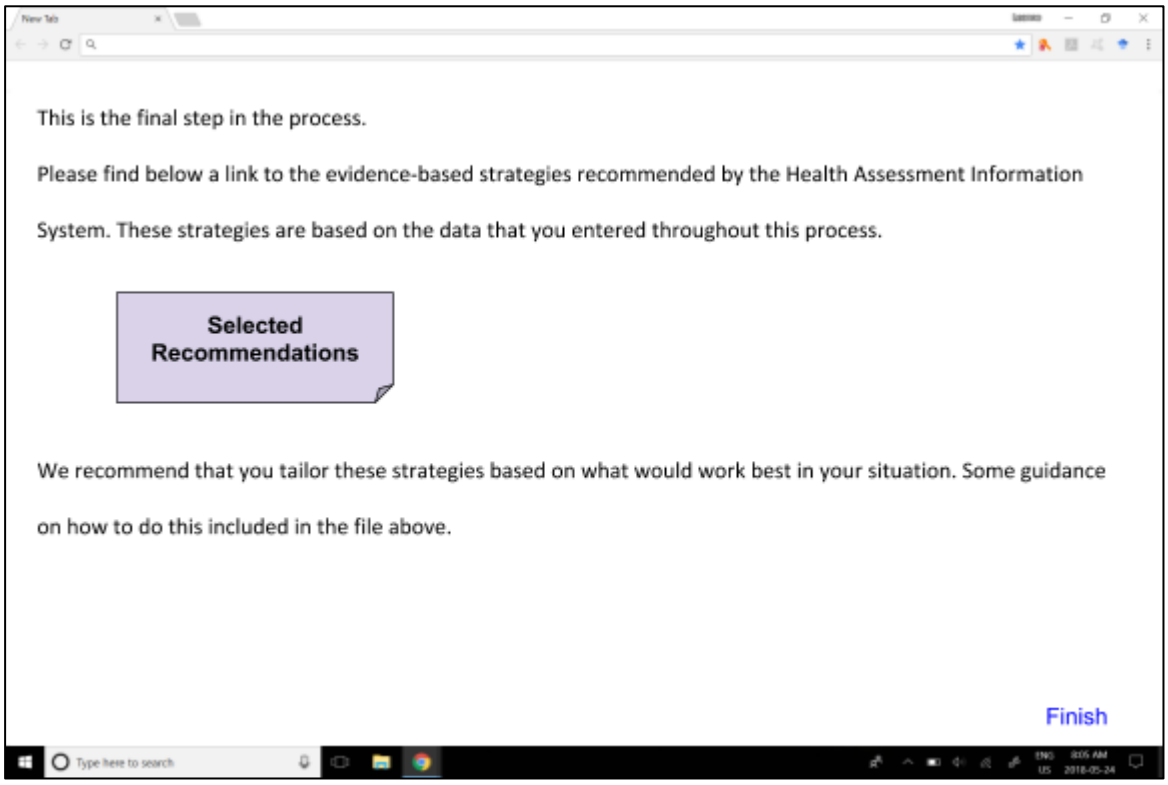

Figure 9.5 Mock-up interface for use case 4.

The program managers can print or save the recommendations for future reference. The recommendation document includes guidance on how to prioritize the proposed strategies based on the stakeholders` values and preferences.

In this step, the HAIS takes the following actions:

1. The HA Process Executor identifies that the task is 'Recommend Strategies'.
2. The Report Generator is invoked by the HA Process Executor.
3. The Report Generator retrieves all the relevant data stored in the Temporary Storage Facility.
4. The Report Generator compares this data with the Strategies contained in the Evidence-Based Strategy Repository.
5. Relevant strategies are selected and returned as a report to the program manager.

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6. This report also includes ‘prioritization strategies’ drawn from the Tools Library.
7. The HA Process Executor identifies that the process is complete when the program manager presses the Finish button

9.4 Conclusions

This chapter presented the overall design of the architectural framework of the HAIS. The functionality of the HAIS was then demonstrated by using an example that included four use cases. These use cases demonstrated a series of different tasks that could be undertaken by the program manager with support from the HAIS.

The next chapter discusses the relevance of the architectural framework, the rigour of the research process that was used to design the architectural framework, and the next steps for the development of the fully-functioning HAIS.

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10.0 Discussion

This chapter closes the research circle. This is first done by appraising the relevance of the resulting architectural framework to real-life settings. Next, the rigour of the research process is assessed based on the criteria that were outlined for this purpose in Section 6.4. Finally, the architectural framework for the HAIS is contextualized within the larger information system development process by referring back to the KTA model and waterfall approach in order to identify the next steps in this research process.

10.1 Assessment of the Relevance of the Architectural Framework

Relevance refers to the extent to which the findings of a research study are useful to real-life settings [72]. The relevance of this research can be interrogated through three avenues. The first avenue relates to whether the HAIS addresses the gap in knowledge outlined in Chapter 2. The second avenue is regarding the quality of the HAIS. The third avenue is regarding whether the HAIS takes into account the soft elements of the HIA that were outlined in Section 3.2. Each of these avenues will be explored in more detail below.

10.1.1 Does the HAIS Address the Gap in Knowledge?

The relevance of the HAIS can be established by ensuring that it meets the gap in knowledge identified by this research. The gap in knowledge outlined in Chapter 2 is regarding **how to support** program managers to take purposeful action, where purposeful action is defined as those activities that allow program managers to:

1. Assess the potential health impacts of their proposed intervention during the design phase of the intervention,
2. Assess a broad range of potential health and nutrition outcomes, based on the social determinants to health,
3. Identify the potential risks to population health,
4. Develop strategies to mitigate those risks,
5. Identify the various impact pathways between the intervention and nutrition (or health) outcomes, and
6. Develop strategies to improve nutrition outcomes, based on the identified impact pathways.

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This gap in knowledge has been filled by proposing a technology-supported information system that can support program managers in taking purposeful action. Table 10.1 outlines how the HAIS might support program managers in taking purposeful action by demonstrating which architectural components will be activated in order to achieve a desired result.

Table 10.1 How the HAIS support purposeful action.

Purposeful Action:	**The HAIS supports purposeful action in the following ways:**
Assess the potential health impacts of the proposed intervention, during the design phase of the intervention.	The HAIS is intended to be used during the design phase of the intervention. The HA Process Executor walks users through a step-by-step process. The HAIS provides methods for prospectively assessing and predicting the health impacts. These methods are part of the Prediction Tools and are stored in the Data Analytics Module.
Assess a broad range of potential health and nutrition outcomes, based on the social determinants to health.	The HAIS includes a broad range of health indicators, including indicators of both the direct and indirect effects of urban agriculture on nutrition and health, thus considering the social determinants of health. All the evidence related to the indicators is stored in the Tool Library and will be called by the HA Process Executor as required.
Identify the potential risks to population health.	The HAIS provides a function to identify the risks to population health. This function is stored in the Tools Library and will be called by the HA Process Executor as required.
Develop strategies to mitigate those risks.	The Report Generator considers all the data that has been entered on the health risks and compares this data with the possible strategies (stored in the Recommendation Repository) to mitigate those risks. It then provides a list of suitable strategies.
Identify the various impact pathways between the intervention and nutrition (or health) outcomes.	The HAIS includes a tool in the Tool Library that assists program managers to link the impact pathways with the intervention and nutrition outcomes.
Develop strategies to improve nutrition outcomes, based on the identified impact pathways.	The Report Generator considers all the data that has been entered on the nutrition outcomes and compares this data with the possible strategies to enhance the nutritional benefits (stored in the Recommendation Repository). It then provides a list of possible strategies to the program manager along with guidance on tailoring these strategies to their situation.

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Thus, the HAIS, once fully developed, will address the gap in knowledge outlined in Chapter 2 by supporting program managers to develop strategies that aim to improve nutrition outcomes as well as mitigate the risks to population health. The architectural framework developed by this research provides the necessary theoretical basis on which to develop the HAIS.

10.1.2 Quality of the HAIS

In order for the HAIS to be useful in real-life settings the recommended strategies need to be based on high-quality evidence. There is concern that the evidence of the health risks and benefits might not be strong enough to ensure that the resulting HAIS is useful in real-life. This research takes the position that the evidence available right now to populate the HAIS is mixed. The direct risks of urban agriculture to health have been well studied and documented and the evidence in this area is, for the most part, quite strong. It is therefore relatively straightforward to provide risk mitigation strategies for direct health risks. As evidence becomes weaker for indirect health risks, so too does the strength of the recommendations. With regards to the nutritional benefits, the current research does not provide sufficient evidence on the impact pathway between small-scale agriculture interventions and nutrition outcomes. The position taken in this doctoral study is that just because the evidence is not uniformly strong does not mean that development of systems like HAIS should be abandoned. Rather, once such an information system is developed, it should be continuously updated as the evidence improves. Therefore, during the development stage of the HAIS, a mechanism to update the various libraries within the HAIS needs to be included.

In summary, this research posits that there is sufficient evidence for the risks to population health as well as for the strategies that would mitigate these risks. On the other hand, evidence for outcomes along the complex impact pathway between the intervention and nutrition outcomes is still in its infancy. As new evidence becomes available it should be included and rated for strength and reliability in the HAIS. Thus, the HAIS needs to include:

1. a component that updates the evidence-based strategies,
2. a facility for updating the Tools Library with new tools, and
3. a facility for updating the Tools Library with latest evidence or changing the strength of evidence as appropriate.

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These mechanisms should ensure that as the field evolves and matures, so should the evidence stored in different HAIS libraries.

10.1.3 Does the Architectural Framework Capture the Soft Elements of the HIA?

Chapter 3 demonstrated that the HIA is more than just a technical six-step process. Rather this step-by-step process is underpinned by a set of values and related soft elements. These soft elements include multi-stakeholder engagement; the ability to make accommodations for others' intentions, priorities, and needs; making trade-offs between evidence, values and preferences; creatively developing a set of evidence-based strategies aimed at a variety of levels; and utilizing a wide variety assessment methods. The use of SSM to design the architectural framework for the HAIS has enabled the architectural framework to capture the 'soft' elements of the HIA approach. The section below discusses how these soft elements have been captured within the architectural framework.

10.1.3.1 Multi-stakeholder Engagement

The architectural framework for the HAIS encourages program managers to engage stakeholders throughout the process. Early on in the process, program managers will be prompted by the HA Process Executor to identify stakeholders. This will be done by retrieving a Tool from the Tool Library that outlines the minimum requirements for stakeholder engagement along with some specific ways of engaging stakeholders [14, 34]. This Tool will also recommend the inclusion of minority groups to ensure that equity factors are considered [34] when developing the recommendations. Engaging stakeholders earlier on will allow program managers to build relationships and possibly increase subsequent uptake of the recommended strategies. The recommended strategies should be shared with stakeholders. This is particularly important for disadvantaged groups who may not be able to access traditional text-based feedback mechanisms. Therefore, the HAIS needs to include a 'strategy implementation guide' (stored in the Tool Library) along with the recommended strategies.

10.1.3.2 Developing Evidence-based Strategies

The Recommendation Repository is comprised of evidence-based strategies that can be updated as new evidence becomes available. This will allow program managers to access the latest available evidence. This not only increases the effectiveness of the resulting strategies, but may also increase the confidence of decision-makers in the proposed strategies. It is important to

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note that the HAIS can only provide information to inform decisions. There is no guarantee that the recommended strategies will be actualized. A range of strategies will therefore be provided by the Report Generator to allow maximum flexibility on the part of decision-makers who can then decide which mitigation or enhancement strategies to put in place [14]. Because HIAs have been criticized for not always providing transparent reporting of the linkages between the evidence and the recommended strategies [79-81], the HAIS will have a component built-in to the Report Generator that makes this linkage between evidence and recommendations explicit, thus increasing the transparency and confidence in the resulting recommendations.

10.1.3.3 Utilizing a Wide Variety of Methods.

The HAIS includes a wide variety of methods in the Tool Library and in the Data Analytics Module. This variety in methods includes both those that are the 'Gold Standard' and also those that represent minimal resource use. For example, soil quality can be assessed with lab tests that are quite expensive and time-consuming, but it can also be assessed using a historical analysis that analyses the previous uses of the land. This second 'test' is less accurate, but far cheaper and faster to undertake and may be the only feasible option in a low-resource setting.

A wide variety of methods will also be made accessible to program managers because they will be 'packaged' for non-expert users. Program managers can thus utilize methods and analytics that they would otherwise not have access to. For example, the Data Analytics Module may include a regression analysis tool to estimate the relationship among variables. The program manager would not need to know statistical manipulations behind the regression analysis and instead might be asked: "Would you like to assess whether there is a relationship between dietary diversity score and income?" In this way the complicated analytics toolbox can be made accessible to non-expert program managers.

10.1.3.4 Accommodations for Others' Intentions, Priorities and Needs

A decision may positively affect the health of one subgroup, but negatively affect the health of another subgroup. Therefore, careful attention needs to be given to the distribution of the effects of the intervention within the population of interest. The impact of the intervention should be measured not only for the target group, but unintended consequences for the health of other subgroups, particularly marginalized subgroups, should be considered. The HAIS will therefore include sub-group analysis of disadvantaged groups in the Data Analytics Module to

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ensure that equity factors are considered. In addition, going through the step-by-step planning process of the HAIS will help program managers to think though stakeholders' intentions, priorities, and needs as these are invoked by the HA Process Executor.

10.1.3.5 Making Trade-offs Between Evidence, Values and Preferences

The HAIS recognizes that the implementers of the recommended strategies are not merely seeking to maximize outcomes, but rather function within an environment where politics and relationships influence their decisions. Although implementation of evidence-based strategies is ideal, an explicit discussion of the trade-offs needs to be undertaken and evidence needs to be balanced against values and preferences [14] of both the program managers and the stakeholders. Particular attention needs to be paid to disadvantaged groups to ensure that their needs and priorities are also taken in account [34]. The HAIS therefore provide a 'Recommendation Priority Tool' (stored in the Tool Library) that can guide program managers in making trade-offs between the recommended strategies and their own or stakeholders values, priorities, and needs.

This section has outlined some of the ways in which the architectural framework has captured the soft elements of the HIA approach.

In summary, the relevance of the architectural framework was assessed in three ways. First, it was demonstrated that the architectural framework addresses the gaps in knowledge and should theoretically allow program managers to develop their own strategies. Second, it was determined that the HAIS has the potential to address the underlying problem situation. However, since the underlying evidence is not yet adequate, it will need to have a functionality that updates the relevant libraries as the latest evidence becomes available. Third, the architectural framework was assessed to determine whether it adequately considers the soft elements identified in Section 3.2. A review of the architectural framework showed that it does indeed incorporate the soft elements.

10.2 Assessment of Rigour of the Research Process

The research rigour refers to how well the research was conducted. Four criteria for assessing the rigour of research was presented in Section 6.4. These are (1) truth value, (2) applicability, (3) consistency, and (4) neutrality. Each of these will be explored in detail below.

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10.2.1 Truth Value

Truth value refers to the level of confidence that the researcher has in whether the research is an accurate reflection of the situation studied. Under the action-research paradigm, confidence in the accuracy of the research can be increased by using multiple sources of information, which creates a dialectic. This research has used a dialectic in two ways to increase the 'truth value'. Firstly, this research used a number of different expert informants to create a dialectic that increases the accuracy of the information and therefore the confidence in the results. Secondly, confidence in the results was increased by creating a dialectic between the data sources. Expert consultation, document analyses, and a structured analysis of the literature were utilized to determine what activities program managers in low-resource settings should undertake. Taking the multiple perspectives of the experts in addition to other sources of data increases opportunities for dissent and therefore debate and consensus with the goal of convergence on the truth.

10.2.2 Applicability

Applicability refers to the degree to which the findings are generalizable to other contexts and the degree to which the findings are transferable to other contexts. This research does not seek to generalize the architectural framework for the HAIS to other contexts outside of urban agriculture interventions in low-resource settings. It is, however, possible that the method for designing an architectural framework could be transferable to another situation. This research provides a demonstration of how to design an architectural framework that identifies and captures both the technical process as well as the soft elements of the process. The methodology developed in this research could be used to develop similar knowledge representation systems for health assessments in other settings. In order to transfer the methods to another similar situation, the research process needs to be recoverable [44]. Information, data, and process information has therefore been included in the appendices so that future researchers can judge whether the methods are transferable to their situation. In summary, although the resulting architectural framework is not generalizable to other settings, the methods used to develop this framework are transferable.

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10.2.3 Consistency

Consistency refers to whether a study would reach the same conclusions if it were conducted again. Consistency can be maintained in a study by presenting in advance the research themes to be investigated [44]. Such transparent reasoning and reporting increases likelihood that the research could be repeated with similar results, thus increasing its rigour. This research increases consistency by using several declared-in-advance themes with which to structure the interpretation of the findings. This allows findings to be arrived at openly and not based on hidden hunches and intuition [44].

In Chapter 2 the conceptual model of the impact pathways between agricultural interventions and nutrition outcomes was used to explore the relationship between small-scale agriculture and nutrition. Using the impact pathways model together with the MRC's framework on complex interventions led to the conclusion that the failure of urban agriculture to demonstrate an effect on nutrition was likely not due to the lack of efficacy of the intervention, but rather to the ways in which these interventions are designed and implemented. This led to a search for ways in which to better design urban agriculture interventions.

The knowledge to action model was then used in Chapter 4 to conceptualize the transformation and transfer of the expert knowledge contained in the HIA into a non-expert tool that could be used by program managers to design their own strategies. Chapter 4 also presented the waterfall approach to information system design. Taken together, these two models delimited the scope of this study.

Chapter 5 presented the soft systems theory approach to information system design. This provided a conceptual basis for the research question and subsequent design of the research. In this way the conceptual framework was used to link the research questions to the research design.

SSM was used in all three phases of the research (Chapters 7-9) to interpret the large and varied amounts of data that were utilized. The human activity system models as well as the formal analysis and questioning of these models using SSM resulted in transparency in the reasoning and reporting of the results.

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Through the use of these declared-in-advance frameworks, this research aimed to ensure that the results were arrived at through a logical transparent method that could be repeated with similar results.

10.2.4 Neutrality

Neutrality refers to the degree to which findings are purely a function of the informants and conditions, and not of biases, motivations, or perspectives [73]. Within SSM, the neutrality of the researcher cannot be established as the researcher is an integral part of the study; therefore, neutrality of the data is of utmost important. In order to increase the neutrality of the data, SSM follows a logical, transparent process for defining the requirements of the architectural framework. This process is well documented in the body of this thesis as well as in the appendices. Every effort was made to accurately interpret the data and report the results in an effort to improve the neutrality and rigour of this research.

In summary, this section assessed the quality of the research process using the four criteria outlined in Section 6.5 of the chapter on research design. These criteria maintain that if the results are arrived at through a dialectic, the methodology is appropriate to the question, the research process is transparent and recoverable, and it is based on declared-in-advance themes, then one can be confident in the results.

10.3 Next Steps in the Development Process

As was outlined in Section 4.3, the design of the HAIS framework follows the waterfall approach to information system design, and specifically the first three stages of this approach. These stages rely on original theoretical research to design the architectural framework. This architectural framework forms the theoretical foundation for the development of a future information system. In order to develop this information system, the remaining waterfall stages need to be completed. These stages will be described below as they relate to the development of the HAIS.

10.3.1 Designing the Platform, Coding, and Testing of the HAIS

The next stages require system design coding and testing based on the HAIS architectural framework. This entails the involvement of a software engineer who can translate the

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architectural framework into computer system components, considering the best available technologies and computer platform(s) technical requirements. Once full technical specifications are embedded into the system design, software development and testing may start.

In order to ensure that it is feasible to turn the architectural framework for the HAIS into a fully functioning technology-supported information system, a software engineer, who specializes in application software development, was consulted to determine whether the proposed framework for the HAIS was feasible from a technological standpoint [83]. This verification exercise consisted of walking the engineer through scenarios to demonstrate the functionality of the HAIS. This software engineer concluded that it is feasible to develop the architectural framework for the HAIS into a technology-enabled information system.

10.3.2 Implementation of the HAIS

The final stage in the software development process involves the implementation of the fully functional HAIS into real-life settings. It is useful to return to the KTA model (presented in Section 4.1) to conceptualize the implementation of the HAIS. According to the action cycle of the KTA model, the first step in implementing the HAIS is to adapt it to the context in which it will be utilized. This adaptation to the local context is based on local knowledge of the value, usefulness, and appropriateness of the HAIS to the local setting and circumstances.

The next step is an assessment of the barriers to the uptake of the HAIS. During the course of this research, it was found that program managers likely do not value health as an important component of urban agriculture interventions, nor do they view health assessments as important to conduct in these settings. Therefore, it will be important to address the attitudes of program managers, funders, decision-makers, and others involved in developing the urban agriculture interventions towards health and health assessments approaches prior to implementation of the HAIS. Other barriers to uptake may include lack of resources, such as time and money. It is important to identify the barriers that may impede or limit the uptake of the HAIS so that they can be targeted and diminished by intervention strategies in the next step.

Intervention strategies should be selected and tailored to overcome the barriers identified in the previous step. This could improve the uptake of the HAIS by the identified stakeholders. For example, the barriers of lack of knowledge, skills, and attitudes can be combated with interventions such as interactive educational interventions and outreach visits

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[84]. Once the interventions have been implemented, the next step is monitoring the uptake of the HAIS. Monitoring the use of the HAIS is necessary to determine how and to what extent the interventions put in place have diffused throughout the potential-adopter group. The monitoring strategy should provide feedback on whether the interventions have been sufficient to bring about the desired change or whether more of the same or new interventions may be required. If the adoption of the HAIS is less than expected, it may be useful to reassess whether the lack of uptake is related to stakeholders' lack of interest in change, other barriers beyond their control, or new barriers that may emerge after the initial introduction of the adapted knowledge [43].

The next step is to determine the impact of using the HAIS. This step is important in order to determine whether the use of the HAIS is actually leading to improved outcomes. It is only at this stage that the utility of HAIS can be proved or disproved. Until that point, the assumed utility of the HAIS is based on sound conceptual knowledge, experience, and a solid research base [43].

The last step of the action cycle concerns sustaining the use of the HAIS. While the barriers to the ongoing use of the HAIS may be different from the barriers present when the knowledge product was first introduced, the process for planning and managing the change should be the same: (1) assess barriers to knowledge sustainability, (2) tailor interventions to these barriers, (3) monitor ongoing knowledge use, and (4) evaluate the impact of initial use and sustained use of the knowledge. This sets in motion a feedback loop that cycles through the action phase of the KTA model [43].

10.4 Conclusions

This chapter assessed the relevance of the resulting architectural framework, the rigour of the research process, and contextualized this study within the larger information system development process. The relevance was assessed in terms of the HAIS' ability to address the original gap in knowledge, the expected quality of the resulting information system, and the ability of the HAIS to capture the soft elements. The rigour was assessed using the four criteria outlined in Section 6.4. Finally, this study was placed within the larger information system development context by referring back to the waterfall approach and KTA model presented in Chapter 4.

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11.0 Conclusion

This chapter concludes the research by summarizing the research process, summarizing the findings of this research, outlining the contributions to knowledge, discussing the limitations of this research, and finally presenting avenues for future research.

11.1 Summary of the research

Urban agriculture interventions have not demonstrated the positive impacts on nutrition that were expected. The reasons for this were explored by a preliminary study conducted as part of this research project (Chapter 2). This study found that program managers of urban agriculture interventions do not regularly consider the complex impact pathways between the intervention and health or nutrition outcomes, nor do they regularly consider the potential health risks of urban agriculture interventions. The resulting gap in knowledge, and conversely the research issue addressed by this research, was regarding **how to support** program managers to develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health.

The health impact assessment (HIA) was viewed as one approach that could support program managers in developing such strategies, particularly as it includes not only a technical process, but is also underpinned by a set of values and related soft elements (Chapter 3). These soft elements play a crucial role in assessing the potential impacts within the complex organizational context of urban agriculture interventions. Unfortunately, the HIA approach was not seen as a feasible approach for program managers to utilize in low-resource settings as it is an expensive, expert-driven process requiring access to a variety of expert knowledge and skills. Therefore, this research reasoned that if the HIA process could be captured into a decision support tool for use by non-experts, then program managers could use that tool to design strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health.

A technology-supported information system (the HAIS) was viewed as a means of making this expert knowledge available to non-expert program managers (Chapter 4). The waterfall approach was selected as the most suitable approach to developing the HAIS in this context. The **scope** of this research was limited to the first three steps of the waterfall approach namely the

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initial investigation, requirements definition, and system design. The intended outcome of these three steps was the architectural framework for the HAIS. These three steps comprised of original, inductive research and built the theoretical foundation for the next steps in the development of a future information system (outside the scope of this work). Thus, the **purpose of this research** was to identify and capture the elements of the expert-driven HIA approach and operationalize them as an architectural framework for the HAIS.

In order to capture both the technical process and the soft elements of the process, this research based the methodology on a soft systems theory approach to information system design (Chapter 5). This approach was selected to design the architectural framework of the HAIS as its theoretical foundations were a much better fit with the complex reality of organizational settings than the more traditional hard systems approach. The conceptual framework of the soft systems approach to information system design (Fig. 5.5) was used to define the research questions and design this research study. This conceptual framework was applied within the context of the waterfall approach to determine what activities need to be supported (corresponds to step 1 of waterfall approach: initial investigation), what information is required to support these activities (corresponds to step 2 of waterfall approach: requirements definition), and how to structure that information (corresponds to step 3 of waterfall approach: system design).

Because each phase in this conceptual framework builds on the previous one and culminates in a practical solution that also has a theoretical component, action-research was selected as the guiding paradigm. SSM was selected as the guiding methodology as it provided a conceptual link from the theoretical foundations of soft systems theory to the research methodology. In addition, it provided a well-established inductive research approach that aids in the generation of theory and could be used in complex organizational settings. In this way, the research questions were linked to the research design by an underlying conceptual framework (Chapter 6). The result of answering these three questions was the architectural framework for the HAIS (Chapter 7, 8, 9). The relevance and rigour of this study were assessed to ensure that it was both useful to real-life settings and met high standards of scholarship (Chapter 10).

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11.2 Summary of Findings

The findings of this research can be separated into factual conclusions that resulted from answering the three research questions and also the larger conceptual conclusions.

On a factual level, this study sought to answer the three research questions:

Research question 1: What activities should be supported so that program managers can develop strategies?

Research question 1 was answered in Chapter 7. Using purposeful human activity system models, it was found that the following activities should be supported so that program managers of urban agriculture interventions can develop strategies:

1. HIAs should be valued and seen as important to assess the potential health effects of interventions.
2. Health should be seen as important and integral to an urban agriculture intervention.
3. Program managers should have knowledge and skills to assess health effects prospectively.
4. Health assessment should not be constrained by resources.
5. Program managers should be able to develop strategies.

Research question 2: What information is required to support these activities?

This question was answered in Chapter 8, wherein it was found that the following information would be required to support program managers to develop strategies:

1. Knowledge on the health assessment process.
2. Knowledge of (or access to) the evidence base.
3. Skills in data collection and analysis.
4. Knowledge on how to predict the potential outcomes.
5. Skills in developing mitigation and improvement strategies.

Research question 3: How can this information be structured?

Chapter 9 answered research Question 3. A technology-based information system was deemed the most appropriate, given the large amounts of data that program managers would require. The resulting architectural framework (Fig 9.1) has several components that function

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together to support program managers to develop strategies within a complex organizational context.

On a conceptual level, this research found that if the HAIS was to be successful in supporting program managers to develop strategies, then it would need to take into account both the technical process and also the soft elements of conducting an HIA. These soft elements include multi-stakeholder engagement; the ability to make accommodations for others' intentions, priorities, and needs; making trade-offs between evidence, values and preferences; creatively developing a set of evidence-based strategies aimed at a variety of levels; and utilizing a wide variety of assessment methods. This research used soft systems theory as the theoretical foundation and based the research design on the soft systems approach to information system design framework. SSM was selected to guide the design of the architectural framework for the HAIS. This ensured that both the technical process and soft elements of the process were included in the resulting architectural framework.

11.3 Contribution to Knowledge

As per the action-research paradigm, this research sought to develop a practical solution as well as generate theoretical knowledge. The main contribution that this research makes is a novel architectural framework for the HAIS. This architectural framework represents one possible avenue for fulfilling the gap in knowledge identified in Section 2.3. Specifically, this architectural framework represents the first steps towards developing a tool that could support program managers of urban agriculture interventions in low-resource settings to:

1. Assess the potential health impacts of their proposed intervention, during the design phase of the intervention,
2. Assess a broad range of potential health and nutrition outcomes, based on the social determinants to health,
3. Identify the potential risks to population health,
4. Develop strategies to mitigate those risks,
5. Identify the various impact pathways between the intervention and nutrition (or health) outcomes, and
6. Develop strategies to improve nutrition outcomes, based on the identified impact pathways.

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This research is unique as it represents the first attempt to use SSM to identify and capture the technical and soft elements of the HIA approach into an architectural framework for an information system that, when developed, can be used by program managers to develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health.

A secondary contribution that this research makes is the demonstration of a methodology that can be used to develop health assessment information systems for other similar interventions in complex organizational settings where the benefits of the interventions are not clear and there exist potential health risks [85].

11.4 Limitations

The main limitation faced by this research is the fact that it was not possible to fully develop, implement, and evaluate the HAIS in real-world settings. The implication of this limitation is that it is not possible to determine whether the HAIS actually addresses the underlying problem situation. This can only be demonstrated after the fully-developed HAIS has been implemented into real-life settings and its effectiveness has been rigorously evaluated. At this point, one can only assume, based on rigorous theoretical work, sound conceptual knowledge, experience, and a solid research base, that the fully-developed HAIS will be able to support program managers to develop strategies that strengthen the impact pathways to nutrition and mitigate the risks to population health.

This main limitation arose because the scope of the research was confined to the design of the architectural framework. The reason for this is that the development of a fully functioning information system is a very long and involved process that cannot be achieved within the resource and time constraints inherent in a doctoral research project and it requires input from computer programming specialists. Using the waterfall approach, the scope of the study was limited to the first three steps of information system design namely, the initial investigation, definition of the system requirements, and the system design. These three steps were selected as they consist of original, inductive research and build the theoretical foundation for the next steps in the development of a future information system. The next steps in the development process are relatively straightforward from a theoretical perspective, albeit resource intensive and time-consuming.

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Had time and resources been available, it would have added value to the research process to validate the resulting architectural framework with a larger group of HIA practitioners to ensure that all the relevant elements of the HIA process were captured in the architectural framework for the HAIS. In addition, it would have been useful to validate the architectural framework with a small group of program managers in low-resource settings to ensure that the HAIS is useful to their work. This would have provided some preliminary evidence as to whether the HAIS will be successful in supporting program managers to develop strategies in the future.

11.5 Future research

During the course of this research a number of potential avenues for future research arose. The presentation of these areas for future research concludes this research dissertation.

(1) Future research should validate the completeness of the architectural framework.

Because this study is in the explorative stages and dealt with conceptualizing the architectural framework, it was deemed satisfactory that it included only a small number of HIA experts. However, future research into this area would be useful to ensure that all aspects of the health assessment process are captured in the HAIS. This could be done by validating the HAIS, once it is populated, with health assessment practitioners in the field.

(2) Future research should validate the utility of the HAIS for program managers.

This research did not involve program managers in the design of the architectural framework. The rationale behind this decision came from knowledge transfer specialists who counsel that only those who are in a position to make decisions or affect change should be involved in the process [43]. Program managers were not included as they do not generally have experience conducting health assessments and would not have known what challenges they could hypothetically face because they are not familiar with the approach. It is the HIA practitioners that hold this knowledge. It will be critical to involve the program managers in later stages of the information system development process to test and validate the HAIS in their settings, as per the action cycle. The HAIS will need to be adjusted at that point to consider the needs and preferences of the users.

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(3) Future research should ensure that the HAIS addresses the underlying problem situation.

Deductive research that evaluates whether the HAIS does indeed support program managers of urban agriculture interventions to develop strategies will be needed. One way of doing this may be to include an evaluation component into the HAIS. This component might measure how easy the process was to follow, whether the recommendations were appropriate, whether the recommendations were considered during the design of the intervention, and whether the resulting intervention achieved the intended outcomes. This would assist evaluators of the HAIS in determining whether the HAIS was effective [79-81]. Including this type of evaluation component into the HAIS could be an important component in determining the extent to which the HAIS not only influences the decision-making process, but also the extent to which it ultimately influences population health outcomes.

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Appendix A: Search Strategy for Conceptual Models that Describe the Relationship Between Small-scale Agriculture Interventions and Nutrition Outcomes

Goal: To search the literature for conceptual models that have been used to define the relationship between community-based vegetable gardening interventions and food and nutrition security outcomes.

Description of Literature Review

Standard systematic review methodology following the handbook of the Centre for Reviews and Dissemination[A1] was utilized. The results are reported following the manuscript PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) for reporting of systematic reviews and meta-analyses [A2].

Eligibility Criteria

The following eligibility criteria were applied:

1. ***Type of studies*****:** Any type of discussion article (e.g. peer reviewed studies, conference proceedings, and published reports) that proposed and discussed a conceptual model. Only articles that specifically focused on conceptual models that linked agriculture to nutrition and excluded studies were considered.

2. ***Type of population*****:** Conceptual models had to focus on community-based interventions. The conceptual model had to detail the impact of small-scale agriculture on the grower and/ or on the community they were providing vegetables to, termed the community of interest.

3. ***Type of information:*** Descriptions of the concepts that link small-scale agriculture to nutrition outcomes.

4. ***PICOT:*** *Population (P)***:** Discussion articles that described the relationship between vegetable gardens and food or nutrition security outcomes.

*Intervention (I)***:** Small-scale agricultural interventions

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Control (C): None

Outcome (O): Nutrition outcomes

Time (T): Start of database history - January 2018

5. ***Inclusion criteria*****:** The conceptual model needs to include the concept of urban agriculture or small-scale agriculture (which is an umbrella concept that includes small-scale agriculture in both urban and rural settings). In addition, the model needs to include the concept of either nutrition or food security. The conceptual model should elaborate on the relationship between these two concepts in some way. No publication date or publication status restrictions were imposed.

6. ***Exclusion criteria*****:**

1. Articles that in which only some parts of the introduction or discussion sections addressed this topic.
2. Only English articles were searched.
3. All publications prior to January 2018 (the time of the most recent search) were included.

Information sources and search

The literature search was conducted in three steps:

(1) Searches of the following electronic databases: Embase, Medline, PsycInfo were conducted.

Additionally, because it was expected that some documents on conceptual models may not be published in the public domain and that electronic searches may miss relevant articles because of inconsistent indexing of articles in databases, two manual searches were also performed:

(2) A purposeful web-based search using Google Scholar; and

(3) A scrutiny of reference lists of selected full texts to increase the capture of relevant material [A3].

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Variations of the following search terms were used: Food security or nutrition or malnutrition or hunger; agriculture or gardening or food supply; theoretical model or theoretical framework or conceptual framework.

Management of references

The bibliographic details of all retrieved articles were managed in EndNote. Duplicate records resulting from the database searches were removed.

Study selection

The reviewer [LI] assessed the title and abstract of each identified citation. The decisions of the reviewer (order or reject) was recorded in EndNote in the research notes field. Near-miss studies that did not fulfil all of the predefined criteria were excluded, and their bibliographic details were listed with the specific reason for exclusion.

Data collection process

A data extraction Microsoft® Office Excel spreadsheet was developed. Because the number of included studies was very small, a random pilot test was not feasible. To overcome this limitation and to avoid losing relevant information, the reviewer tested the form, which was refined prior to the final extraction process. The final version of the data extraction form was used by the reviewer to screen the full text of the included studies.

Data extraction

The following information was extracted from each included study: (a) bibliographic details such as author, journal, year of publication, location of authors, impetus for creation of the conceptual model and (b) details about the characteristics of conceptual models and definitions of concepts and domains.

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Summary measures

Each of the conceptual models was qualitatively analysed highlighting the relationship between the models, the research paradigm that was used, and the major innovations of each model.

Summary of studies

A total of 593 references were identified from electronic database searches (515) and through hand-searching other sources (78). (see Fig. A1). After deleting duplicates, 535 references remained. From these, 563 were excluded after screening based on the titles and abstracts. Thus 49 full text articles were assessed for eligibility and 32 were excluded. Of these papers, 20 articles were excluded because they did not focus on linkages between small scale agriculture and food or nutrition security; 7 articles were excluded because they did not represent a new model, I.e. they summarized other models; 3 articles were excluded as they did not fit the pre-defined type of study (2 were pre-conference abstracts and 1 was a technical guidance document); 1 article was excluded as it did not include the concept of small-scale agriculture/ urban agriculture/ or vegetable gardening; and 1 article was excluded as it did not include the concept of food or nutrition security. In total, 17 papers were included in the final review of conceptual models.

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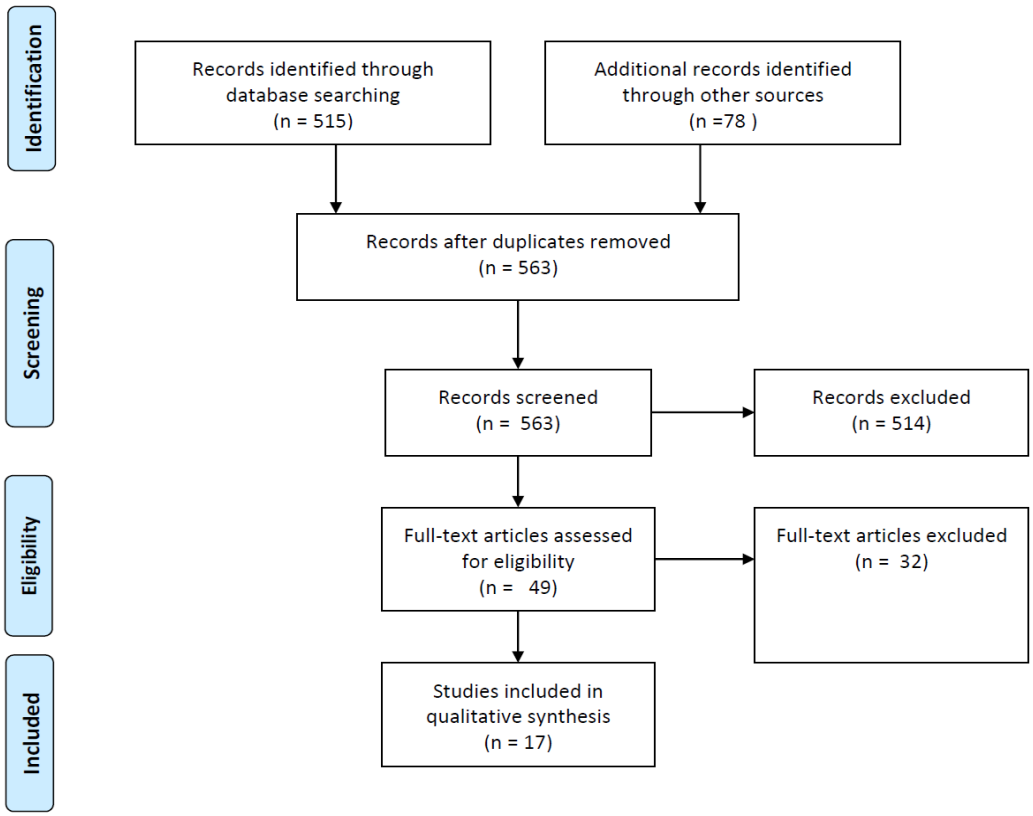

Figure A1: Flow diagram showing the systematic literature search.

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Appendix B: An Analysis of the Complex Causal Chain between Small-scale Agriculture Interventions and Nutrition Outcomes in 21 Evaluation Studies

Introduction

Small-scale agriculture with the intent of improving nutrition is being widely implemented by a number of organizations. This intervention, however, has not demonstrated the expected results, and evidence from a number of literature reviews has demonstrated the limited effect of agricultural interventions on nutrition outcomes [B1-B4]. It is generally believed that the interventions are effective, but that the expected outcomes are not achieved because of the complexity of the intervention pathway. This research seeks to test the following hypothesis: The failure of urban agriculture to demonstrate an effect on nutrition is likely not due to the lack of efficacy of the intervention, but rather to the ways in which these interventions are designed and implemented. In order to test this hypothesis, an analysis of 21 evaluations of small-scale agricultural interventions that aimed to improve nutrition outcomes was conducted.

In addition, a number of potential health risks of small-scale agriculture to population health and nutrition have been identified. It is not clear whether or not organizations take these potential health risks into account before implementing their agricultural intervention. An analysis of 21 studies that implemented small-scale agriculture interventions with the intent of improving nutrition outcomes was conducted to determine: (1) what indicators were generally assessed along the impact pathway from intervention to outcome; and (2) whether or not the potential health risks were assessed. The conceptual model of the chain for agricultural interventions for nutrition outcomes by Hawkes et al. was used to assess indicators along the impact pathway. The health risks were classified according to communicable disease risks, noncommunicable disease risks, risk of injury, and psychosocial health risks.

Methods

Study Selection: This research analysed 21 studies included in a systematic review conducted on the effectiveness of agricultural interventions that aimed to improve the nutritional status of children by Masset et al. [B4]. This systematic review was selected as it included a wide range of agricultural interventions (not only vegetable gardens) and the studies

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included were of a high methodological quality available. It is important to note that although the systematic review included the most methodologically sound studies findable, they concede that the overall quality of these studies is lacking.

Original Systematic Review Details: The original systematic review by Masset et al. searched for both published and unpublished literature in ten databases covering nutrition, agriculture, rural development, and social sciences between 1990 and 2010. Included studies had to assess a small-scale agricultural intervention, be published in English, conducted in a low- or middle-income country as defined by the World Bank, and report on the effect of at least one nutrition outcome indicator. Studies that did not use a control group were excluded. The authors evaluated the internal and external validity of each study. Twenty-three studies were included in their final systematic review. These studies focused on home gardens (16), bio-fortification (2), fisheries (3), dairy development (1), and animal husbandry (1).

Exclusion Criteria: Two studies [B5, B6] were excluded from our analysis as they were reviews or meta-analyses of other studies and did not include a clear impact pathway for each agricultural intervention. Therefore, a total of 21 studies were included in our analysis. Table B1 lists the studies included in our analysis.

Data Extraction: The reported outcome measures of each study were extracted by two independent reviewers [LI, SH]. After extraction, the outcomes were mapped onto a standardized spreadsheet representing the conceptual model for the chain of agricultural interventions for nutrition outcomes. The results were compared between the two reviewers and any disagreements were discussed and resolved by both reviewers. The final outcomes were then compiled into a single map of each intervention pathway for each individual study.

Results

Twenty-one studies on the effects of small-scale agriculture on nutrition outcomes were included in the final analysis. All studies were conducted in low-resource settings with 13 studies conducted in South East Asia (Bangladesh, Cambodia, India, Indonesia, Nepal, and Thailand) and 8 studies conducted in Africa (Kenya, Lesotho, Malawi, Mozambique, South Africa, and Tanzania). The type of organizations implementing the studies included governments, local NGOs, international NGOs, community-based organizations, and university or research institutes.

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Table B1 The 21 studies included in analysis of the complex causal chain between small-scale agriculture interventions and nutrition outcomes.

First Author	Year	Country	Objectives
Aiga [B7]	2009	Malawi	Promotion of small-scale fish farming with intent of improving undernutrition and income.
Attig [B8]	1993	Thailand	To improve knowledge, attitudes and practices (KAP) concerning the consumption of vitamin A-rich foods among preschool children, pregnant women and lactating mothers and to increase vitamin A intake. A systematic social marketing approach with an operational plan containing three overlapping dimensions was applied.
Bushamuka [B9]	2005	Bangladesh	To assess the benefits of homestead gardening. Part of a nutritional surveillance project that encourages poor households to produce vegetables rich in vitamin A all year round.
de Pee [B10]	1998	Indonesia	To assess the vitamin A intake and status of women with a child (<24 months) following a social marketing campaign that aims to increase production and consumption of vitamin A rich foods.
Faber [B11]	2002	South Africa	To determine whether the dietary intake of yellow and dark-green leafy vegetables and the serum retinol concentrations of children improve with a home gardening program.
Greiner [B12]	1995	Bangladesh	To increase the production of foods that are high in carotene or fat and are therefore likely to improve vitamin A status.
Hoorweg [B13]	2000	Kenya	Promotion of intensive dairy farming to improve milk consumption, undernutrition rates, and income.
Jones [B14]	2005	Nepal	To increase vitamin A and iron intakes by promoting kitchen gardens (training, technical assistance, and seed distribution) and nutrition education.

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Kidala [B15]	2000	Tanzania	To evaluate the long-term effects of a horticultural and nutrition education intervention in rural Tanzania.
Laurie [B16]	2008	South Africa	To compare participating and non-participating households in terms of child morbidity, nutritional knowledge, dietary intake and gardening practices 3 years after initiation of the project
Low [B17]	2007	Mozambique	Promotion of orange-fleshed sweet potato by agricultural, nutrition education, and marketing
Makhotla [B18]	2004	Lesotho	To assess the contribution of household gardens to the nutritional status of preschoolers in Lesotho.
Marsh [B19]	1998	Bangladesh	To evaluate a home gardening intervention and nutrition education program for landless or near landless women in Bangladesh.
Murshed-e-Jahan [B20]	2010	Bangladesh	Promotion of aquaculture through training and low-cost technology with the intent of improving income and consumption of fish.
Nielsen [B21]	2003	Bangladesh	Promotion of semi-scavenging poultry production to improve consumption of eggs, chicken and other promoted foods as well as income.
Olney [B22]	2009	Cambodia	To evaluate the impact of a homestead food production program in Cambodia on household production and consumption of micronutrient-rich foods and on maternal and child health and nutrition (intake of micronutrient-rich foods, anthropometry, hemoglobin, and anemia prevalence); and to assess pathways of impact on maternal and child health and nutrition.
Roos [B23]	2003	Bangladesh	Promotion of small-scale fisheries to improve consumption of fish.
Schipani [B24]	2002	Thailand	To assist rural Thai families to increase home food production and security is the implementation of home gardens that produce fish, small animals, and vegetables.

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Shmidt [B25]	1995	South Africa	To evaluate a communal vegetable garden project in a former homeland of South Africa.
Smitasiri [B26]	1999	Thailand	This project was designed as a follow-up of the Social Marketing of Vitamin A–Rich Food (SM/VAF) Project in north-east Thailand.
Vijayaraghavan [B27]	1997	India	To assess the feasibility of home gardening to increase the availability of beta-carotene-rich foods and to assess the impact of the increase in availability on the consumption of these foods by pre-school children and the effects, if any, on the prevalence of vitamin A deficiency.

Data on the intervention pathway was extracted from each individual study and mapped onto the conceptual model. This revealed the intended impact pathway between agriculture and nutrition that each study assessed. This also revealed where each study was lacking along the impact pathway. The results of the mapping process are summarized in Table B2.

Table B2 Data from original studies mapped on the conceptual model by Hawkes et al.

<table>
<tr><td></td><td colspan="3">Policy and governance: 5% of studies</td><td></td></tr>
<tr><td rowspan="3">Climate and environment: 5% of studies</td><td>Agricultural inputs: 33% of studies</td><td>Nutritional status: 66% of studies</td><td>Health status and well-being: 38% of studies</td><td rowspan="3">Political and economic context: 5% of studies</td></tr>
<tr><td>Agricultural practices: 100% of studies</td><td>Food consumption: 90% of studies</td><td>Healthcare: 38% of studies</td></tr>
<tr><td>Food value chain: 5% of studies</td><td>Food environment: 57% of studies</td><td>Economic outcomes: 57% of studies</td></tr>
<tr><td></td><td colspan="3">Culture, Gender, and Equity: 43% of studies</td><td></td></tr>
</table>

Agricultural inputs: refers to technology transfers such as seeds, fertilizers, and irrigation systems. 33% [7/21] of studies reported measuring the agricultural inputs.

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Agricultural practices: includes development of home gardens, crop diversification, year-round production, and demonstration gardens. Not surprisingly, as this was an inclusion criterion for the systematic review, 100% [21/21] of studies reported measuring the agricultural practices of the population.

Food value chain: includes the storage, processing, distribution, and retailing of food. A few studies did report whether the food was consumed by the participants or sold, but only one study measured indicators along the value chain.

Food environment: refers to the availability, affordability, and acceptability of fruit and vegetables from the garden and from other sources. 57% [12/21] of studies reported measuring at least one indicator of the food environment.

Food consumption: the large majority of studies measured food consumption, with 90% [19/21] of studies having reported measuring the food intake of participants (usually measured as dietary recall over the last 24 hours).

Nutritional status: refers to anthropometry measures, such as weight-for-height or weight-for-age, as well as biomarkers taken from blood samples, such as ferritin, haemoglobin, and serum retinol, for micronutrient deficiencies. 66% [14/21] of studies reported measuring nutritional status.

Economic outcomes: refers to both household income and income from selling vegetables. 57% [12/21] of studies reported measuring at least one economic outcome.

Healthcare and nutrition education: includes education sessions for mothers, exclusive breastfeeding of infants under six months, and general health knowledge such as sanitation knowledge. 38% [8/21] of studies reported implementing and measuring healthcare and education interventions.

Health status and well-being: includes the prevalence of night blindness and the presence of fever, diarrhoea, and measles among children. 38% [8/21] of studies reported measuring at least one indicator of health status and well-being.

Overall, no study measured everything on the pathway from agricultural interventions to nutrition. One study [B17], however, did measure everything on the pathway except health status and well-being. The study included a very clear model of change based on three separate

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intervention pathways. By not including the health status and well-being, this study missed the opportunity to identify diseases (e.g. diarrhoea) that may have lowered the impact of the intervention. Only this study measured effects of the climate and environment, the policy and governance structures, and the political and economic context. However, 43% [9/21] studies did measure the effects of the intervention on women as a subgroup of the larger population.

All of the studies measured at least one indicator of the direct pathway from agriculture interventions to nutrition outcomes. These may have included an indicator of the food environment, food consumption, or nutritional status. On the other hand, very few studies measured the indirect pathways to nutrition, through education, economic outcomes, or health status. No study considered the potential health risks of the interventions.

Discussion

This analysis found that assessment of the full intervention pathway, both through direct and indirect channels, is not generally undertaken. Although the full direct pathway between agriculture interventions and nutrition outcomes are seldomly considered, most studies seem to measure at least one indicator along this pathway, most often dietary diversity. On the other hand, it is rare that a study will measure the indirect pathways to nutrition and health through the social determinants of health, even though this pathway may have a greater impact on health and nutrition outcomes.

An interesting, although not unexpected finding, was that studies that clearly laid out an impact pathway, based on a conceptual model of the relationship between agriculture and nutrition or health, measured a wider variety of intermediate outcomes. These studies were able to be responsive and to tweak the intervention between intervention cycles because they had data on how the intervention was working. This provides some support for the importance of understanding the full intervention pathway between the agricultural interventions and nutrition outcomes. Without knowledge of the full intervention pathway, it is very difficult to design, implement, or monitor agricultural interventions as one does not know how or why an intervention is working or not working. Thus, it is important that implementers of small-scale agricultural projects, including urban agriculture, understand the full intervention pathway and measure at least some indicators along this pathway.

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With regards to assessment of the health risks, this analysis found that no original study reported either real or perceived health risks of the agricultural intervention. Given the types of interventions described, including studies on livestock, it is unlikely that there were no health risks of the intervention. More likely, the health risks were not considered and therefore no data was collected on them. It is important to measure these health risks as they may 'cancel out' the health and nutrition benefits of the agricultural intervention. Or they may be causing detrimental effects to population health that are not captured by the instruments used or the population sampled if the health effects are outside the population of study.

A potential limitation of this study is reporting bias. It is possible that negative results were not reported and so the health risks were not reported, even if data was collected on them. In addition, indicators may not have been reported if they showed no change, therefore more indicators on the intervention pathway may have been measured, but not reported and therefore not captured in this analysis.

Conclusion

This research found that outcomes measured along the intervention pathway from small-scale agriculture interventions to health and nutrition outcomes were sparse. This provides support for the hypothesis that the failure of urban agriculture to demonstrate an effect on nutrition is likely not due to the lack of efficacy of the intervention, but rather to the ways in which these interventions are designed and implemented. This research agrees with other studies that have called for more rigorous analysis of the links between urban agriculture and nutrition. As predicted by many academics in this area, very few studies explicitly stated the conceptual model on which they are based, however, when they did, they tended to design more robust and responsive interventions [B17, B28, B29]. In addition, no studies discussed the possible negative impacts of urban agriculture on health and nutrition.

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Appendix C: Search Strategy for Health Impact Assessments of Urban Agriculture Interventions

Search Description: A literature search was conducted to identify health impact assessments (HIAs) that have assessed the health impacts of urban agriculture in low resource settings. This search was expanded to include high resource settings as there were minimal studies conducted in low resource settings (n=3). The selected health impact assessments were reviewed to identify the health benefits and risks reported.

Search date: February 2015

Updated Search date: January 2016

Inclusion Criteria:

Population: Persons undertaking urban agriculture activities

Intervention (instrument): Health Impact Assessment and evaluations of HIAs of urban agriculture

Outcome: Health outcomes

Time frame: All

Publication type: Reports or peer-reviewed publications of HIAs

Language: English

Data management: References were imported into a single Reference Manager database (Zotero) and tagged to indicate the source database. De-duplication was done after all results were imported. MEDLINE records were retained where possible in the case of duplicates.

Results Summary: A total of 30 HIA reports were retrieved (23 after de-duplication). Following full text retrieval and review 11 HIA reports were included in the final literature review. The summary of these results can be found in Table C1.

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Table C1 Summary of results of literature search.

Database	HIAs (# report identified by abstract)
EBSCO	3
AGRICOLA	0
Pub Med Central	0
IDL (IDRC)	3
Hand search of HIA Databases	11
Grey Literature search	13
TOTAL	30
Number after deduplication	23
Number selected after full text retrieval	11

Concepts and Synonyms:

CONCEPT 1: HIA (and HIA evaluations)

Synonyms:

Health Impact Assessment or HIA

Health Equity Impact Assessment or HEIA

Equity-Focused Impact Assessment or EFHIA

Health Impact Assessment eval*

Health Impact Assessment monitoring

Impact of Health Impact Assessment

Assessment of health impact assessment

CONCEPT 2: Food gardens

Synonyms:

Kitchen gardens

Community gardens

Urban agriculture

Garden*

Vegetable growing

Agriculture

Food

Food production

CONCEPT 3: Nutrition

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Synonyms:

Nutrition security

Food security

Malnutrition

Search Strategies:

IDL (IDRC)

1. “Health impact assessment” [72 results, 3 full text retrieved]

Grey Literature Search (Google)

1. “Health impact assessment” and “urban agriculture” (first 7 pages reviewed until saturation was reached)
2. “Health impact assessment” and “urban agriculture” and file type:pdf (saturation after 5 pages)
3. "health impact assessment" and garden policy filetype:pdf (first 5 pages reviewed, no new results)
4. "health impact assessment" and urban food production policy filetype:pdf (first 5 pages reviewed, no new results)

[13 results]

EBSCO (Medline, CAB Abstracts, SocIndex, Academic Search Complete)

1. health impact assessment [subject heading SU] [1416 results]

2. urban agriculture [all text]

3. food [all text]

4. policy [all text]

5. vegetable* [all text]

6. 1 and 2 [2 results; 0 full text retrieval]

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7. 1 and 3 and 4 [35 results; 1 full text retrieval]

8. 1 and 5 [19 results; 2 full text retrievals]

AGRICOLA

1. "Health impact assessment" [14 results; 0 full text retrieved]

PubMed Central

1. "Health impact assessment" [subject heading SU] [27 results; 0 full text retrieved]

Table C2. Manual searching of HIA organizations and databases.

Organization	Website	# HIAs found
3IE	www.3ieimpact.org/	0
Australia HIA Connect (New South Wales University)	http://hiaconnect.edu.au/	0
Centre for Health Equity Training Research and Evaluation (CHETRE)	http://cphce.unsw.edu.au/our-member-centres/centre-health-equity-training-research-and-evaluation	0
Centre for Health Services and Policy Research	www.chspr.ubc.ca/	0
Department of Health (UK) on Health Impact Assessment	https://www.gov.uk/	0
Finland National Institute for Health and Welfare	http://www.thl.fi/fi/web/thlfi-en	0
Habitat Health Impact Consulting	www.habitatcorp.com/	0
Health Impact Project	www.pewtrusts.org/en/projects/health-impact-project	4
HIA Blog	http://healthimpactassessment.blogspot.co.uk/	0
HIA Gateway	www.hiagateway.org.uk/	0
HIA in ASEAN	www.hiainasean.org	0
Human Impact Partners	www.humanimpact.org/	0
IMPACT consortium	https://www.liv.ac.uk/psychology-health-and-society/research/impact/about/	0
Institute of Public Health in Ireland	www.publichealth.ie/	0
International Association for Impact Assessment	www.iaia.org/	0
London Health Commission	www.londonhealthcommission.org.uk/	0

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National Collaborating Centre for Healthy Public Policy	www.ncchpp.ca/	0
National Collaborating Centre for the Determinants of Health	http://www.nccdh.ca/	0
National Collaborating Centre for Tools and Methods	www.nccmt.ca/	0
New Zealand Ministry of Health	http://www.health.govt.nz/our-work/health-impact-assessment/completed-nz-health-impact-assessments	0
Oregon State HIA Database	https://public.health.oregon.gov/HealthyEnvironments/TrackingAssessment/HealthImpactAssessment/Pages/data.aspx	1
San Francisco Planning Department	www.sf-planning.org/	0
Society of Practitioners for Health Impact Assessment	hiasociety.org/	1
The Netherlands Health Impact Assessment Database	http://www.ph.ucla.edu/hs/health-impact/links.htm	0
UCLA Health Impact Assessment Clearinghouse	www.hiaguide.org	5
Wales HIA support Unit	http://www.wales.nhs.uk/sites3/home.cfm?OrgID=522	0
WHO Collection of HIAs	www.who.int/hia/examples/en/	0
World Bank	www.worldbank.org	0
Total		11

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Appendix D: Ethics Approval

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Ethics Letter

15-Jun-2016

Ethics Reference #: S13/07/134
Clinical Trial Reference #:
Title: Using Problem Structuring Methods to Explore the Relationship between Vegetable Garden Intervention Programmes and Food and Nutrition Security Outcomes.

Dear Miss Leanne Idzerda,

The HREC approved protocol amendment #3 dated 14 January 2016.

If you have any queries or need further assistance, please contact the HREC Office 219389657.

Sincerely,

REC Coordinator
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Health Research Ethics Committee 1

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Appendix E: Results of Cultural Analysis

Box 1 Analysis One – Examination of the Intervention

Analysis 1 (based on Checkland 1981, Appendix 2)

1.1 Client: A malnourished community that does not have access to healthy, fresh foods.

1.2 Client Aspirations: To improve their nutritional and health status.

2.1 Problem Solvers: Organizations putting in place urban agriculture activities that intend to improve nutritional status.

2.2 Resources available: Varies, depending on organization but may include expertise in urban agriculture, land, tools, seeds, seedlings, animals, water, infrastructure, micro business support, micro lending, soil.

2.3 Constraints: Financial, tight timelines for results, need to appease funders, need to abide by local laws, adequate water or supplies, lack of knowledge of unintended consequences, lack of knowledge of complex causal pathways between intervention and outcomes.

3.1 Problem owners: Target community, broader community, urban farmers, local government, funders, organization implementing the UA activity

3.2 Implications of problem owner chosen: The intended consequences (nutrition) needs to show improvement or at least a logical argument for improvement in nutrition outcomes otherwise the target community, urban farmers, and funders, may withdraw their support for the project. In addition, if the UA intervention has unintended negative consequences on health, the project could be stopped by the community, urban farmers, local government, and funders. Therefore, it is important to assess the health effects for both the efficacy and survival of the project.

3.3 Reason for regarding the problem as a problem: Urban agriculture has the potential to contribute to improving nutritional outcomes, however, UA has not achieved these aims. In addition, there are a number of potential unintended consequences for the health of the population that have not been addressed.

Urban agriculture projects have many potential health benefits and risks, however they are usually not accounted for at the beginning of the project. The health benefits are therefore not

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capitalized on or monitored correctly and the health risks are not mitigated before they affect population health.

3.4 Value to the problem owners: assessing the health effects is valuable as it would increase the confidence of the target groups, broader community, funders, and government in not only the intervention, but also in the credibility of the implementing organization. This is very valuable to the organization and could result in more projects/ collaborations/ funding and thus more impact.

Box 2 Analysis Two – Examination of the problem as a social system

Analysis 2 (based on Checkland 1981, Appendix 2)

Program manager

***Role*:** To work with urban farmers to develop and implement successful urban agriculture interventions.

Norms: The expected behaviours are that they support the urban farmers; they seek funding and other resources for the projects; they continually try to improve their interventions, possibly through monitoring and evaluation.

Values: They are valued if the program is successful (meets the project objectives – including improved nutrition); if they have good relationships with the urban farmers and community; they use resource in an efficient manner.

Urban farmers

Role: To work with the program to grow vegetables, or other food, either for consumption or for resale.

Norms: The expected behaviours are that they grow food. Consume the foods they grow. Sell a portion of the foods. Assess and mitigate risks to their produce, for example infestations, water shortages, and vandalism/ theft.

Values: They are valued if they grow a large amount of food. They sell the food as part of a successful business. They and their children have better health and nutrition status.

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Target Community

Role: Provide a market for the urban farmers, provide feedback on the intervention process on their perspectives.

Norms: The expected behaviours are that they are happy with the UA intervention in their community and are a willing customer base.

Values: They are valued if they buy food from the urban farmers. They and their children have better health and nutrition status.

Box 3 Analysis Three – Examination of the distribution of power

How is power expressed in this situation?

Disposition of power:

Power may be held by the program managers over the urban farmers who provide resources (such as money, support, training, access to a livelihood, etc).

Power may also be held by the funder of the urban agriculture intervention (usually separate from the implementer of the intervention).

Power may be held by the target community and broader community who could stop the urban agriculture activity if they deemed that it was not appropriate for their community (particularly if the intervention is having clear negative consequences on health).

Power may be held by local governments who could in theory shut a project down if it has health and safety infractions on population health.

How is power protected, preserved, passed on, relinquished? Through what mechanisms?

Process by which power is obtained, exercised, preserved, and passed on:

program managers are bestowed the power as a result of their position and resources in with the implementing organization. They exercise their power through the opening and closing of UA interventions as well as hiring of urban farmers. They preserve their power through control of their resources. Finally, they could pass this power on by helping urban farmers and the target community to become independent of the organization's resources.

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Funders obtain power through their provision of funding for interventions as well as core funds. This power may be exercised through the increase or decrease of funding over time. Power may be preserved through the supply of core funds which keeps the organization alive. Power may be passed or relinquished through the provision of 'no strings attached' funding.

The target community, urban farmers and broader community obtain power from the fact that they are needed for the intervention to exist (and thus for the implementing organization to exist). If they were to pull out, the intervention would cease to exist. Their power is exercised by continual participation in the urban agriculture activity (or lack of opposition to the UA activity). Their power is preserved through maintaining the option to oppose the intervention.

Local governments obtain their power from the people, legislation, and regulations. They can exercise their power through the enforcement of legislation, regulations, and policy. Their power is preserved by the fact that they are elected officials working on behalf of a government. They can however be voted out at elections or ousted at any time.

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Appendix F: Consultative Survey Guide

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM

For a research project that forms part of a PhD study at the Division of Human Nutrition, Faculty of Medicine and Health Sciences, Stellenbosch University, South Africa

TITLE OF THE RESEARCH PROJECT: Development of a health impact assessment cognitive technology framework for urban agriculture projects in low-resource settings.

REFERENCE NUMBER: S13/07/134

PRINCIPAL INVESTIGATOR: Leanne Idzerda

CONTACT NUMBER: Copyright

CONTACT EMAIL: Copyright

CONTACT SKYPE: Copyright

You are being invited to take part in a research project. Please take some time to read the information presented here which will explain the details of this project. Please ask the study staff any questions about any part of this project that you do not fully understand. It is very important that you clearly understand what you are being asked to do. Also, your participation is **entirely voluntary** and you are free to decline to participate at any time. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part now.

This study has been approved by the Health Research Ethics Committee at Stellenbosch University and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

What is this research study about? Health impact assessments (HIA) are commonly used to determine the potential impacts of a project or policy on health outcomes. HIAs are not commonly conducted in low resource settings, despite the significant potential for health risks

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and the lack of demonstration of health benefits of urban agriculture. This research seeks to (i) determine the reasons that HIAs are not commonly conducted in these settings, and (ii) determine what modifications need to be made to the traditional HIA so that they can be conducted in low resource settings.

What will I be asked to do? You will be asked to take part in a participatory exercise. The exercise will solicit your expert opinion on conducting health impact assessments for urban agriculture in low resource settings.

Where will the study be conducted and how long will it take**?** This study will be conducted at a location of your convenience and will last no more than 15 minutes.

What are your responsibilities? You will be asked to answer all the questions based on your own thoughts and opinions.

Are there any risks involved in taking part in this research? Although the questions will focus only on your expert opinion, you may feel uncomfortable answering some of the questions. Please note that your answers will be grouped together and any comments will be made anonymous. You may choose not to answer any questions at any point in time. You may also withdraw from this study at any point in time. Although we have tried to minimize the time it takes to complete the surveys, it may still inconvenience you.

Who will have access to the information that you provide? The information that is collected through the course of this study will remain confidential and protected. All comments will be made anonymous before going back to any group. The results of this research program will be used for my doctoral thesis. The identity of all participants will remain anonymous unless explicit consent is given to utilize your name. In this case, a separate consent form will need to be signed by you. Besides me, the only persons that will have access to your personal information are my two supervisors, Milla McLachlan, a professor at Stellenbosch University, and Wojtek Michalowski, a professor at the University of Ottawa.

Are there any costs involved and will I be paid to take part in this study? There will be no cost to you to participate. You will also not receive any form of payment.

Is there anything else that you should know or do?

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- You can contact Leanne Idzerda at email Copyright or on skype at Copyright if you have any further queries or encounter any problems.
- You may also contact the principal investigator's supervisors, Prof. Milla Mclachlan at Copyright or Prof. Wojtek Michalowski at +1Copyright xCop should you have any queries or complaints.
- You can contact the Health Research Ethics Committee at +27 (0)21-938 9207 if you have any concerns or complaints that have not been adequately addressed by the principle investigator or her supervisors.
- You will receive a copy of this information and consent form for your own records.

This questionnaire should take you no longer than 20 minutes to complete and consists of 13 questions. All the questions in this survey appear on one page.

Declaration by participant

By signing below, I …… agree to take part in a research study entitled "Development of a health impact assessment cognitive technology framework for urban agriculture projects in low-resource settings".

I declare that:

- I have read or had read to me this information and consent form and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressured to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the study doctor or researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) ..... on (*date*) ..... 2015.

Signature of participant

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CONSULTATIVE SURVEY QUESTIONS

1. Do program managers in low-resource settings typically conduct HIAs on their own projects (for example urban agriculture projects)?

a. Yes
b. No
c. Unsure

2. If they seldom or never conduct HIAs on their proposed projects, what might be likely reasons?

3. What challenges do program managers in low-resource settings face when trying to conduct an HIA prior to implementing their project?

4. Are program managers in low-resource settings typically able to access the evidence base themselves (for example studies or data on the health benefits and risks of urban agriculture)?

a. Yes
b. No
c. Unsure

5. If they seldom or never conduct HIAs on their proposed projects, what might be likely reasons?

6. If program managers in low-resource settings are typically not able to access the evidence base themselves, why not?

7. Are program managers in low-resource settings typically able to collect their own primary and secondary data as part of an HIA?

a. Yes
b. No
c. Unsure

8. If program managers in low-resource settings are typically not able to collect their own primary and secondary data as part of an HIA, why not?

9. Do program managers in low-resource settings typically understand the links between their intervention (for example, urban agriculture) and the 'social determinants of health' and health?

a. Yes

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b. No
c. Unsure

10. If program managers do understand the linkages, what information do program managers use to understand these linkages? If program managers do not understand the linkages, why do they not understand these linkages?

11. In your opinion, is it desirable to replace (or augment) the HIA team with a decision support system that could support program managers in identifying the health benefits and risks of their proposed project?

a. Yes
b. No
c. Unsure

12. In your opinion, why is it, or why is it not, desirable to replace (or augment) the HIA team with a decision support system that could support program managers in identifying the health benefits and risks of their proposed project?

13. In your opinion, is it feasible to replace (or augment) the HIA team with a decision support system that could support program managers in identifying the health benefits and risks of their proposed project?

a. Yes
b. No
c. Unsure

14. If you know of any other similar initiatives, could you please indicate as much information as possible below so that I might locate these initiatives.

15. Thank you for your responses to this survey. Your input is greatly appreciated. If you would like to be involved in future input-gathering exercises or would like to be informed of the outcome of this research, please leave your name and contact details below. Please note that we will store your personal details separately from your responses to ensure that your responses remain anonymous.