Sustainable Transformation of Individuals and Families

Design and Implementation of Holistic Personalised Socially Driven Persuasive Systems

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Abstract

Sustainability is a topic that has matured and has evolved from organisational sustainability to societal sustainability and more recently to individual sustainability. As an individual is the core, basic component of society, and plays a critical role in societal transformation, there is growing interest and discussions on individual sustainability and wellbeing. Since the publication of Our Common Future – the report commissioned by the UN General Assembly in tackling environmental and natural resources issues – the concept of 'sustainable development' has taken root in firms and governments, both in optimising their supply chain and in the planning of the sustainability of the society. However, counterintuitively, the fabric of the society – individuals and families – has been neglected in this journey of understanding their roles in sustainability, as well as in the nexus between their decisions and social outcomes. This thesis bridges the gap.

Sustainability is a transformative process of improving the quality of lives by balancing various of our life aspects, such as economic, ecological, and societal dimensions. In this process, information systems often take a critical part as an analytical tool, which provides insightful decision support and recommendations based on collected data and information. In contrast to systems employed by corporates and governments, the development of sustainability systems for individuals and families is still in its infancy. Existing systems mostly are only focusing on one aspect of life and prescribe a single-dimensional solution, without regard to the contextual and circumstantial complexities of life. In this light, this thesis aims to design and implement systems that adopt a holistic approach in understanding users' individualistic needs, and in synthesising their life status and goals.

The vision is to recognise the multifaceted aspirations of the users, and to nudge them toward a lifestyle that is sustainable, practical, and, above all, enjoyable. To realise this vision, the thesis adopts the multimethodological design science approaches (Hevner, March, Park, & Ram, 2004; Nunamaker, Chen, & Purdin, 1991) with the design evaluation methods from Hevner, March, Park, and Ram (2004) to address the challenges.

First, the thesis defines individual and family sustainability and a set of nine principles named SSHARRPPP (Sustainable, Social, Holistic, Adaptive, Real-time, Real-world, Precise, Personalised, Persuasive). Based on these principles, the thesis develops sustainable transformative processes that are applied to key activities and can bring fundamental changes for one's life. From these conceptual and procedural foundations, the thesis designs system architectures and implements four systems as proof of concepts. They are, namely, the SSHARRPPP *Measurement*, *Shopping*, *Modelling*, and *Games*.

SSHARRPPP systems support individual and family sustainability holistically as they work together seamlessly. SSHARRPPP *Measurement* and *Shopping* measure key activities that are performed by individuals and families. Based on the measured data, SSHARRPPP *Modelling* grasps causal effect relationships of one's life dimensions and develops models. Lastly, SSHARRPPP *Games* helps people to stick with sustainable lives by making their journey enjoyable. All systems are designed to educate people to transform their lives. During the research, all of these conceptual, procedural, and system artefacts are validated through publications, presentations and peer-review processes.

This thesis fills the gap in individual and family sustainability by bringing understanding of human nature and systems together. Taken as a whole, it provides holistic understanding on sustainable life transformation and benefits researchers in both information systems and sustainability. The thesis also lays the ground for future work in health and self-management, as it provides system solutions by synthesising core ideas from purposes of life and values, various human processes, and mechanisms to transform our lives. At the practical level, the system architecture and the applications guide the system developers to design and implement systems for the sustainable transformation of individuals and families. Importantly, this thesis benefits individuals and families by making their sustainable life transformations holistic.

Acknowledgements

This adventure could not be completed without:

David, no word can express how grateful I am for your guidance and supports.

Mum and Dad, I am sincerely feeling lucky that I am your daughter.

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Sun Young, Yvonne, Ron and Su Min, thank you for being my best buddies.

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I wish I were your proud mum.

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1.1 Research Background

Sustainability has increasingly captured our attention in recent years. Although different stakeholders developed the concept broadly by incorporating their interests, the generally accepted idea of sustainability encompasses economic development, social equity and environmental protection (Murphy & Drexhage, 2012). To make significant progress on sustainability, the UN World Summit has proposed 17 Sustainable Development Goals (Figure 1) and more than 150 world leaders adopted the 2030 Agenda for Sustainable Development in 2015 at the United Nations Sustainable Development Summit (United Nations Development Programme, 2015).

Figure 1. Sustainable Development Goals (United Nations, 2015a)

The sustainability concept aims to give holistic guiding principles to businesses and organisations who traditionally advocate sustainable development at the global level (Sneddon, Howarth, & Norgaard, 2006). The sustainability concept has diffused downward to capture focus on individual and family's roles in sustainability (Hobson, 2003; Seyfang, 2006). An analysis of the 17 SDGs very clearly shows that SDGs 1-8 and 10 are significantly focussed on individuals and/or families. Making progress on these 9 SDGs will help individuals and families become more sustainable. The other eight SDGs also indirectly contribute to individual and family sustainability and wellbeing. While businesses' and organisations' main foci of sustainability are ecological and environmental responsibilities, individuals' and families' foci of sustainability are more concerned with wellbeing and having a balanced lifestyle. Despite the growing interest in individual and family sustainability, it has not yet been formally identified, defined and developed in the research literature as much as organisational, supply chain, community, and societal sustainability.

Most of us aspire to wellbeing and having a balanced life. Therefore, people are continually improving their living status by pursuing their life goals. It is a transformation process conducted through a series of decisions and actions. People consciously and subconsciously try to make the best decisions based on their situation. This decision-making process is significantly affected by data and information acquired in various aspects of life: health, career, education, family relationship, social status and so on. Human life consists of many life dimensions; this engenders requirements for the holistic presentation of information and insightful recommendations, which shows dynamics and interrelationships among the life dimensions. Unfortunately, studies in these multifaceted activities are rare and under-developed.

Like the individual's decision-making and transformation processes, the family also makes decisions and goes through a transformation process based on life stage of the family. From a family system theory perspective, families make unique decisions through the interaction of family members. At the same time, these decisions also significantly influence each and every family member (Balswick & Balswick, 2007). For example, a family may decide to move to a new house in a rural location as the parent's generation retires. This family decision can, in turn, impact on other family member's health, career and social relationships. Therefore, the family level decision-making is even more complicated, as it involves not only a more intense usage of information but also the interaction of members within a family.

To make an effective decision, we often recruit the help of information systems. Due to their complementary cognitive characteristics, information systems collect, process, and analyse data to contextualise a decision environment for users (Turban & Aronson, 1997). For personal decision-making, personalised preferences and multifaceted data should be collected and analysed (Chung, 2006). With the development of smart technologies and wearable devices, individuals and families have become heavy users of information and communications technology (Baskerville, 2011). Individuals' and families' activities leave traces of data daily, to be collected and analysed by information systems. For example, the movement called "quantified-self" shows a recent trend of using technologies to collect various personal data, such as physical exercises, biometric, sleep patterns and financial data to understand our lifestyle (Lupton, 2012). And "Smart Home" technology helps to collect residents' home data to improve the quality and safety of life (Sapci & Sapci, 2018). With the use of smart homes, the daily activities and behavioural patterns of residents can be monitored easily through sensors embedded within various areas in the home.

Although these systems and technologies are designed for behavioural changes and habit formation of users, most systems fail to motivate or persuade sustained behavioural transformation (Hänsel, Wilde, Haddadi, & Alomainy, 2015). Various motivational features are offered in self-tracking systems and technologies to facilitate the users' action-taking. It is vital to make these systems and technologies efficient as the real values and benefits will come when the user can form intended habits. It is believed that a habit can be created within 21 days. However, Lally, Van Jaarsveld, Potts, and Wardle (2010) find that, on average, it takes up to 66 days to form a habit. The variations across participants range between 18 and 254 days. Likewise, sustainable transformation is a long-term process, with time and willpower needed to make observable changes. As willpower is limited and runs out through the day (McGonigal, 2011), techniques that promote the persistence of individuals become all the more valuable and should be implemented into the systems (Fritz, Huang, Murphy, & Zimmermann, 2014). Some self-tracking systems and technologies use gamification, goal setting and social community features as motivational techniques. However, most of these motivational tools are not personalised to offer a strong motivation (Conroy, Yang, & Maher, 2014; McTigue et al., 2009) nor designed for the sustainable transformation of individuals and families.

Life is a long journey of managing and balancing many life dimensions. Sustainable life transformation may minimise impacts from various life events and enable individuals and families to be well and happy while they are dealing with their many life dimensions and challenges. Therefore, this study is initially driven by two simple questions:

(1) How can we make our lives well, happy, and sustainable?
(2) How can information systems support and transform individuals and families?

Supporting solutions should be developed with a holistic understanding of our lives, which requires sound philosophical backgrounds and theories from relevant disciplines. Therefore, this thesis identifies challenges and issues with the sustainable transformation of individuals and families first through various perspectives in the following section.

1.2 Challenges and Issues

This study aims to provide solutions that help individuals and families to transform their lives sustainably. To design and implement practically useful information systems, this research conducted the initial literature and existing system review. From this review, several key problems and issues became apparent and have thus informed the direction of this research.

1. There is a paucity of research on formalising the concept of individual and family sustainability.
    a. Apart from few notable researchers (Wilber, 1995), insufficient efforts have been spent in understanding the importance of a holistic view of our lives, causal and interdependent relationships among various life dimensions.
    b. Although the sustainability concept guides a holistic view of businesses and organisations' multi-dimensional balance, the concept has not been formally established as holistic guiding principles for individuals and families.

2. There is a lack of research interest in studying multi-life dimensional human activities or lifestyle from the individual and family sustainability point of view.
    a. Causal relationship models of life dimensions are under-developed.
    b. Interdependency among life dimensions is under-studied.
3. Although there are several well-studied and advanced human behaviour theories (Ajzen, 1991; Prochaska, DiClemente, & Norcross, 1992; Triandis, 1977), sustainable life transformation processes of individuals and families are rarely proposed by researchers.
    a. Decision support and recommendation models are under-developed from an individual asnd family sustainability perspective.
    b. There is a lack of research interest in developing sustainable transformation processes that embrace the dynamics and interrelationships of life dimensions and family dynamics.
4. Few systems support the sustainable transformation for individual and family sustainability.
    a. Systems that capture data at the individual level outnumber and dominate those at the family level.
    b. Most systems for individuals measure users' health data only and focus solely on a single life dimension. Few systems measure the multi-dimensional daily data of individuals.
    c. Few systems have models and frameworks that integrate heterogeneous daily data and interpret their relationships in a holistic view for individuals and their families.
    d. While many systems support a single habit formation process, few systems support the transformation process holistically.
    e. Few systems provide personalised decision support and recommendations by integrating online social networks for individual and family sustainability.
5. Many systems fail to motivate/persuade sustained behaviour changes.
    a. Applications and services that offer well-established persuasion techniques for bridging user's intention to behavioural changes are rare (Conroy et al., 2014).

b. While many applications and systems use gamification and online social networks as motivational features, not many of them are designed for the full sustainable transformation.

Overall, the research on designing and implementing holistic personalised socially driven persuasive systems for sustainable transformation of individuals and families is lacking. The biggest challenges are understanding interactions between various life dimensions, such as health, wealth, relationships and careers and family dynamics. All identified research problems are connected to the principal issue of pursuing individual and family sustainability. Once these challenges and issues are understood, the acquired knowledge is applied to develop systems that can provide holistic, personalised, socially driven persuasive information for decision-making and recommendations to users. Therefore, to address these issues and challenges, the research vision, aims, and objectives are outlined in the next following sections.

1.3 Research Vision and Objectives

The vision of this research is:

To provide effective support for sustainable transformation of individuals and families by designing and implementing holistic adaptive real-time precise personalised and socially driven persuasive systems.

To pursue this vision, the essential research objectives are as below.

- Define a *concept* of individual and family sustainability. This will provide a clear conceptual background and scope of the study.
- Shape guiding *principles* for individual and family sustainability. These principles will help people to evaluate sustainable life transformation and guide researchers to conduct the study.
- Explore and identify enabling *activities* and *behaviours* that help individuals and families to transform their lives sustainably. For this, the study aims to find

core human activities and behaviours that involve various life dimensions and can make holistic changes in their lives.

- Define and propose sustainable transformation *processes* of individuals and families.
- Design and develop conceptual artefacts (*models*, *processes*, and *frameworks*) that support the sustainable transformation of individuals and families.
- Explore and identify *technologies* that support individual and family sustainability.
- Design and implement *system* artefacts that support sustainable life transformation of individuals and families.
- *Validate* and *evaluate* the proof of concept systems through observational, analytical, experimental, testing and descriptive methods (Hevner, March, Park, & Ram, 2004).

This research will fulfil the vision and objectives above by adopting the multi-methodological by Nunamaker et al. (1991) due to its holistic nature and range of the outlined research objectives. Also, the research will adopt the design evaluation guide of Hevner et al. (2004) to validate the rigidness and effectiveness of systems.

The multi-methodological approach provides an iterative research process. Therefore, the research will follow iterative and incremental processes. Insightful academic literature and existing system review (i.e. observation) is a starting point to develop understanding of the theoretical background for individual and family sustainability. This observation step will let the research propose various conceptual theories for system design. In the system development stage, various system artefacts for sustainable life transformation of individuals and families will be implemented. Accomplishing these objectives will contribute to the fields of individual and family sustainability and relevant system development by delivering a series of research artefacts. In the following section, the expected research contributions are briefly outlined.

1.4 Research Contributions

Individual and family sustainability is still a topic that has garnered far less attention than other topics such as ecological sustainability, organisation sustainability, and supply chain sustainability. Therefore, guiding principles to achieve individual and family sustainability are still lacking. Hence, the key purpose of this research is to contribute to the field of knowledge by suggesting and outlining sustainable holistic adaptive **principles** that can lead to the transformation of individuals and families. These principles will be supported by the twin **pillars** of the research: (1) "You can't *manage*, what you don't *measure*" (McAfee & Brynjolfsson, 2012, p. 4) and (2) "you can't *transform,* what you don't *model*". These principles and pillars will be realised through four distinct yet interwoven **approaches**, namely (a) measurement (b) shopping (c) modelling and (d) games. These approaches will be used as the core mechanisms for achieving individual and family sustainability. The research will identify, define, design, and implement multiple **artefacts** (concepts, models, processes, frameworks, architectures, and systems) that support the principles, pillars, and approaches. Through these *artefacts*, this research will validate and realise the *approaches* and *pillars*, which in turn would validate and uphold the *principles*, and all of these will hopefully lead to the sustainable transformation of individuals and families.

These research contributions can benefit mainly, but not limited to, three groups of people:

1. Researchers – This research brings benefits to researchers in several disciplines. Primarily, researchers in information systems would have better understanding on conducting individual and family sustainability and designing and implementing systems that support their sustainable transformation. Notably, the research synthesises core concepts and technologies from decision support systems and recommender systems to provide personalised persuasive information and recommendations for the sustainable life transformation of individuals and families. Secondly, researchers in sustainability understand the importance of individual and family sustainability and how it should be approached in order to achieve overall sustainability. Thirdly, digital health

researchers can utilise research outcomes to develop and provide adequate health and self-management solutions based on data and information analysis.

2. Individuals and Families – This research ultimately benefits users of the systems. The study will design and implement system artefacts for the sustainable life transformation of individuals and families. By using the integrated systems, users can observe and analyse their daily activities and form a series of positive habits to reach and maintain a sustainable lifestyle.
3. Developers of systems – Developers who wish to develop holistic adaptive real-time precise personalised and socially driven persuasive systems can anticipate benefits from this research. As the core concept of this research is individual and family sustainability, various life dimensions are considered and reviewed for designing and implementing systems for the sustainable life transformation of individuals and families. Therefore, they can utilise conceptual, procedural, technological and system artefacts developed by this research for their systems.

1.5 Structure of the Thesis

In chapter 2, this thesis reviews relevant literature on concepts, processes, technologies, and systems of individual and family sustainability. This review identifies research requirements, gaps, and opportunities. After reviewing relevant literature and systems for the research topic, the researcher conducts the study progressively, as illustrated in Figure 2.

In chapter 3, research requirements are discussed, and several seminal research methodologies are reviewed to design and propose the multi-methodological research approach to conduct individual and family sustainability research.

From chapter 4 to chapter 9, research outcomes are discussed from conceptual, procedural, technological, and leading gradually to system artefacts. In chapter 4, conceptual responses to individual and family sustainability are discussed. This chapter proposes a definition and philosophical principles for individual and family sustainability and their sustainable life transformation.

Procedural responses are developed and suggested in chapter 5. Firstly, the thesis discusses human processes in terms of how people can transform their lives sustainably. Secondly, the purposes and processes of systems in terms of supporting these human processes will be discussed. After that, the study suggests processes for sustainable transformation.

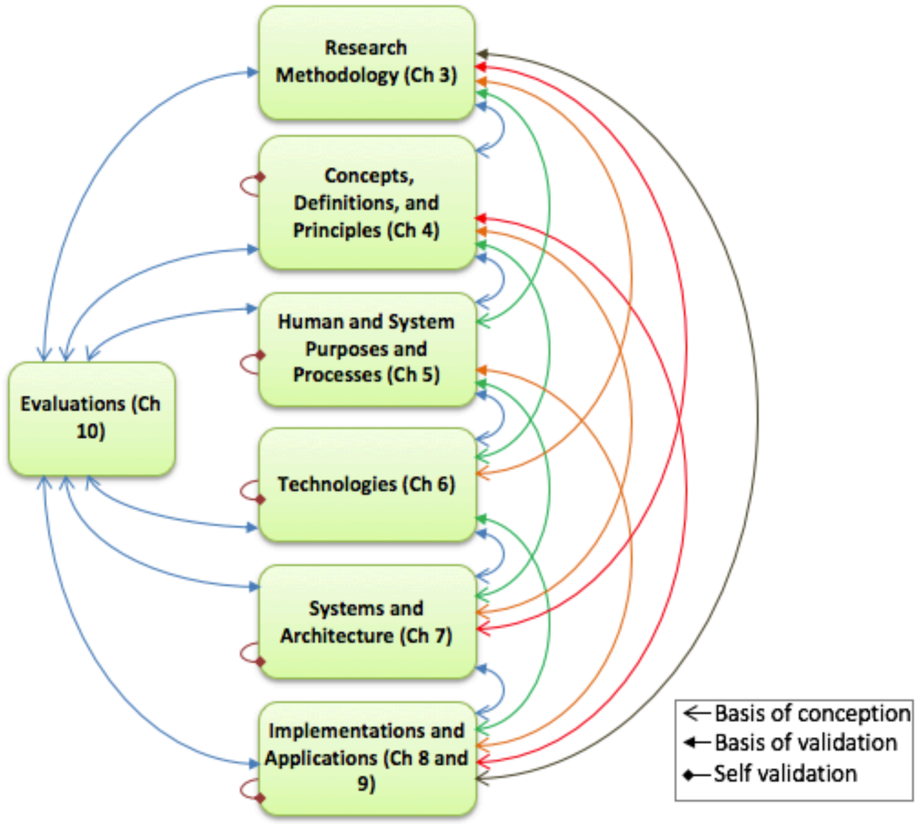


FIGURE 2. CHAPTER STRUCTURE AND THEIR RELATIONSHIPS

In chapter 6, technological responses are discussed. The study initially discusses technologies to support human and system purposes and processes for sustainable transformation. Then it will propose various artefacts, such as system frameworks and architectures, to guide how systems should be integrated and work together to deliver adequate support for the sustainable life transformation.

In chapter 7, the study starts to explain system prototypes that have been developed during the research time as proof of concept. Each system, which has been designed and implemented for individual and family sustainability, is justified and explained through the overarching system framework and interactions. The holistic view of each system architecture is also introduced in this chapter.

In chapter 8, the system features are explained using a case of chronic disease. Mainly, systems use persuasion and affiliation mechanisms to educate and transform people's lives and lifestyles. In chapter 9, the study describes the implementation details of systems that are specifically designed to cater to individuals and families who want sustainable life transformation.

Chapter 10 evaluates research artefacts by adopting Hevner et al.'s (2004) methods. In this chapter, all research outcomes are explained how they are validated in various ways. Finally, chapter 11 concludes the research by summarising research outcomes, contributions, limitations, and future directions.

As Figure 2 illustrates, from chapter 3 to 10 are organically forming relationships as the basis of conception and validation. Therefore, the thesis will explain the structure of chapter using a diagram like Figure 2 from chapter 3.

2 Literature Review

Insightful academic literature and an existing system review are the starting point to develop an understanding of the theoretical background of individual and family sustainability. To contribute to the knowledge of a discipline, a researcher should identify the research problems, issues, and requirements by conducting an initial investigation in the research area. This observation step ensures that the relevant research questions are asked and that the knowledge gained during this process provides various conceptual, procedural, and technological theories as to the basis of the study.

The main aim of this research is to find solutions to individual and family sustainability, especially by designing and implementing systems for their sustainable transformation. In this chapter, the researcher aims to investigate the core background concepts, models, processes, technologies, and systems of individual and family sustainability in cross-disciplinary academic literature and existing systems.

Therefore, this chapter elaborates the following questions:

- What is sustainability, and what are the main agendas in the current/mainstream sustainability discussion?
- What are the facets of sustainability, and what are the individual's and family's roles in making the world sustainable?
- What is individual sustainability and what is family sustainability?
- What are the individual and family processes that are involved sustainable transformation of lives of individuals and ultimately the family as a whole?
- What are the available technologies and systems that can support individual and family sustainability?
- What are the problems, issues, and opportunities in current conceptual, procedural, technological and system approaches to support individual and family sustainability?

To answer these questions, this thesis will:

- Discuss the concepts of sustainability and its facets in 2.1.
- Understand the meaning of sustainability for individual and family. Various life dimensions are identified and discussed in 2.2.
- Review the individual and family processes that are involved in transforming our lives in 2.3. In this section, the research will study several behavioural theories, theories and processes relating to decision-making, learning, and habit formation in terms of individual processes, and family lifecycle and dynamics for family-level processes.
- Review currently available technologies and systems that can help us to measure, model, benchmark, and entertain for education purposes. The thesis reviews technologies and systems that support decision-making and offer recommendations. Also, the thesis will discuss persuasive technologies, mHealth systems, habit formation, and shopping systems that can support changes and transformation of our lives in 2.4.
- Identify research problems, issues, and requirements based on what the research has studied and reviewed so far and find opportunities and solutions for the research in 2.5.

This chapter is organised based on the outline illustrated in Figure 3. In this way, literature review can highlight research gaps to bridge or narrow. Also it will construct an essential foundation for the proposed research artefacts in later chapters.

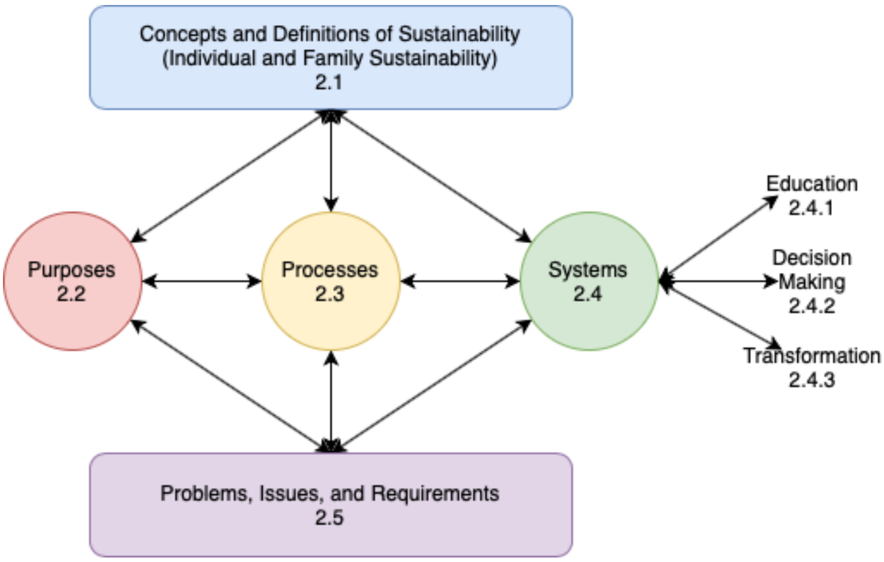


FIGURE 3. LITERATURE REVIEW OUTLINE

2.1 Concepts and Definitions of Sustainability

Sustainability has become a hot topic and there are multiple perspectives to approach this topic. It is because the topic has been approached by many different stakeholders and developed broadly by incorporating interests that each stakeholder is involved in. Therefore, it is important to understand concepts and definitions on sustainability, facets of sustainability, and any studies on individual and family sustainability.

2.1.1 Sustainability

After the Brundtland Commission's brief definition of sustainable development (World Commission on Environment and Development, 1987) was announced, the concept of sustainability became a master topic of environmental academic journals, and its concerns were discussed with the dual emphases of environment and economic development. Marshall and Toffel (2005) noted that there had been over 100 definitions of sustainability in the 1990s. Most of the sustainability concepts were tightly integrated into environmental issues with political, societal and economic activities.

Sustainability concepts are well studied and practically used in the business and management contexts. For example, the Triple Bottom Line (TBL) is one of the well-known accounting frameworks that measure three different dimensions of corporate sustainability: social, environmental, and economic aspects (Slaper & Hall, 2011). Sustainable development, which is often referred to as management discipline, has become a centre of ecological discussions (Elkington, 1994). As businesses and industries used to focus mainly on profit and often ignored ethical and ecological responsibilities in the past, the concept has matured by emphasising ethical and ecological issues. Therefore, during the last three decades, sustainability was mainly discussed and practised at international, national and institutional levels. For example, several corporations have made sustainable performances across many disciplines. Alcoa has achieved safety, diversity and environmental stewardship; GE integrates sustainability into the company's culture, ranging from hiring practices and training to employee wellbeing programmes (Confino, 2014). Notably, once the UN World Summit identified Sustainable Development Goals (SDGs), they have become central missions of many organisations, national institutions, corporate enterprises, and governments (Kates, Parris, & Leiserowitz, 2005a).

Along with environmental and economic sustainability, there is growing interest in and discussion of societal sustainability. In the past, businesses and organisations were considered as the main contributors to sustainability. However, the social side of sustainability also has a significant impact on environmental and economic sustainability. This is because societal sustainability is all about understanding people's needs and the effects of our actions on the broader community, including the economic and environmental side of sustainability. For example, 46% of British consumers state that they consider organisations' social and environmental contributions and responsibilities when they are making purchasing decisions (Nawroth, 2013), and this makes businesses and organisations work on their social and ecological duties for better corporate images.

As such, sustainability can be approached in various perspectives. In what follows, the research will discuss how sustainability can be approached from multiple facets and levels.

2.1.2 Sustainability Facets and Levels

When Starik and Kanashiro (2013) discuss sustainability within a management context, they identified multi-levels in sustainability: individual, organisations and society. Also many academics and stakeholders in sustainability agree that sustainability is a multifaceted concept and practice (Starik, 2004), and its characteristics at these different levels and interactions between multi-levels should be understood. The rationale of considering multi-levels in sustainability is that it can enhance our understanding and decision values of comprehensiveness and integration on sustainability (Suzuki, 1996).

Based on the idea of multi-levels in sustainability from various academics (Benn, Dunphy, & Griffiths, 2014; Starik, Rands, Marcus, & Clark, 2010; Stead & Stead, 1996), sustainability levels are illustrated in Figure 4. Individuals and families are at the heart of sustainability, surrounded by organisational, political-economic, socio-cultural, and ecological levels. The interaction between adjacent levels influences on inputs, processes, outputs, and feedback (Starik, 2004). This means that individual and family sustainability is as important as any higher level's sustainability.

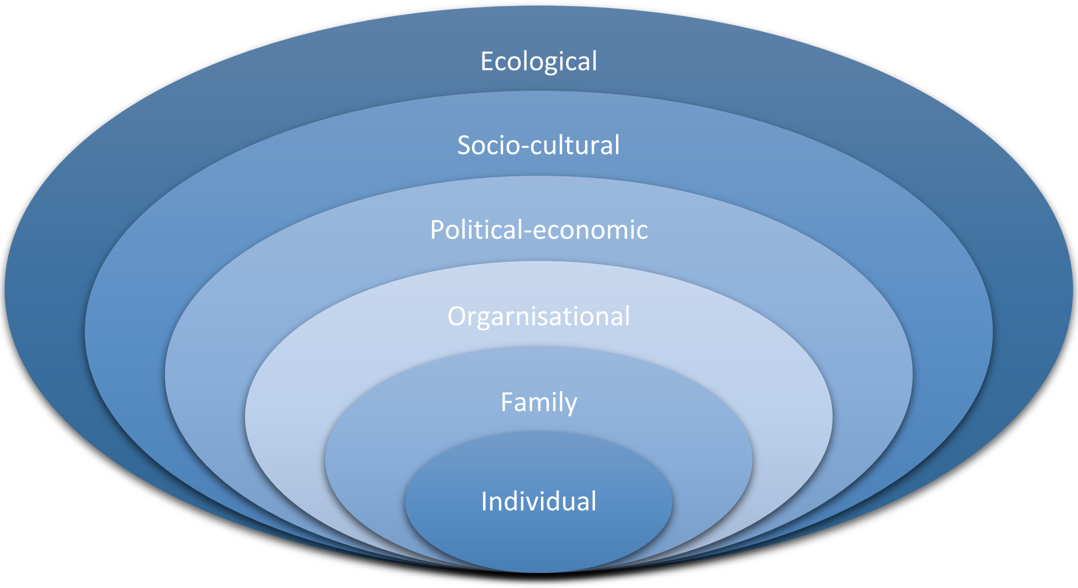


FIGURE 4. SUSTAINABILITY FACETS AND LEVELS, FROM THE AUTHORS' CREATION (CHUNG, PROSKURYAKOV, & SUNDARAM, 2015)

In addition to this, individuals and families are the real decision-makers and the core actors in achieving sustainability. For instance, individuals tend to engage with choices that contribute to the positive changes in every aspect of our lives and society. Through these choices, people find personal satisfaction and feel good about their choices (Venhoeven, Bolderdijk, & Steg, 2013).

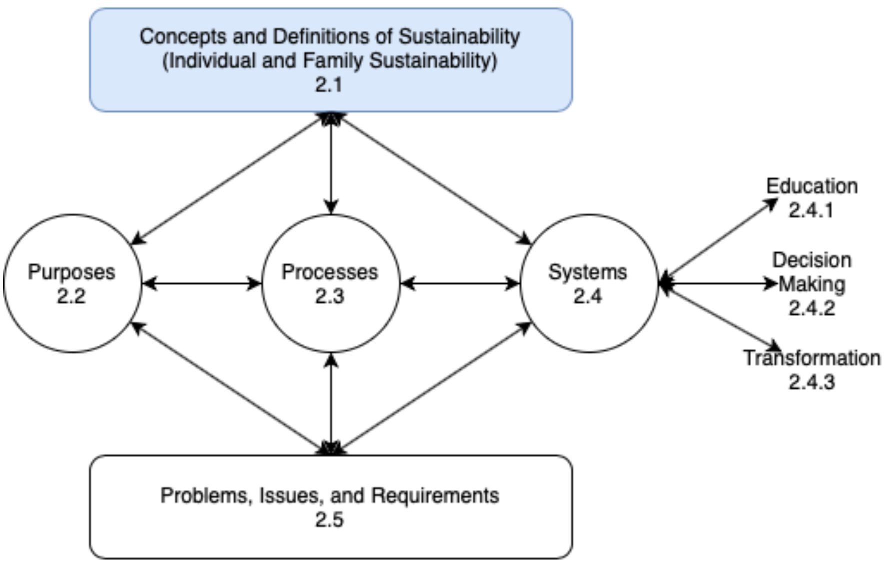
As sustainability is closely related to our quality of life, we are responsible for understanding and improving awareness of sustainability and adopting sustainable attitudes and behaviours in our lives. In this regard, the thesis will look at meaning of individual and family sustainability in the following section.

2.1.3 Individual and Family Sustainability

Pappas & Pappas (2015, p. 12) advise that *"sustainable individuals are characterised by creating harmony, interconnection, and relatively high levels of self-awareness in their values, thoughts, behaviours, and actions, as well as cultivating continued individual growth in their physical (health), emotional, social, philosophical, and intellectual abilities."* In other words, individual and family sustainability enables people to be well and happy while they are pursuing a balanced life in various dimensions. Individuals and families also have started to become aware of their essential roles in sustainability. According to Tapia-Fonllem, Corral-Verdugo, Fraijo-Sing, and Durón-Ramos (2013), individuals are showing sustainable behaviours by taking pro-ecological, frugal, altruistic and equitable actions, and they perceive these actions as being closely related to their wellbeing.

However, the individual and family aspects of sustainability have often been overlooked in mainstream sustainability discussions (Brain, n.d.), despite the fact that the original sustainability has the concept of people's wellbeing at its core (World Commission on Environment and Development, 1987). When the research searched sustainability literature on organisational, political-economic, socio-cultural, and ecological sustainability through Google Scholar, it returned a total of 4,104,000 results compared to a search on individual and family levels, which returned only 2,479 results. Although this was a simple search comparison without an intensive data validation, it showed a clear research gap between macro and micro levels in sustainability.

So far, the thesis has reviewed concepts and definitions on sustainability, facets of sustainability, and any studies on individual and family sustainability.



Now the thesis moves on to the individual and family purposes in life dimensions and values.

2.2 Individual and Family Purposes in Life Dimensions and Values

Having a purpose in life contributes to human development (Benson, 2006) is a crucial element of flourishing of life (Seligman, 2002), and is associated with greater levels of happiness (French & Joseph, 1999) and resiliency (Benard, 1991). In general, people would like to be well physically, financially, emotionally, environmentally and so on. They find a purpose in life while they are playing multiple roles in different life dimensions. For example, a man tries to achieve wellbeing, satisfaction, and happiness in his daily tasks as a husband, father, professional, colleague, friend, and neighbour. Also, finding and sharing the purpose in life within the family is especially important as people experience the most intimate relationship in our families and often this relationship impacts on our wellbeing and happiness significantly.

Life dimensions can be categorised based on the roles that people play in daily life (Hall & Richter, 1988). Among the wide-ranging life dimensions, Rojas (2006) used the factor analysis to identify several main life dimensions which people generally put most weight on. They are health, wealth, job (i.e. career), family, friendship, personal development (i.e. education), community, and environment (Figure 5).

These life dimensions reciprocally influence each other. The boundary between each life dimension is generally interdependent. Therefore, they often establish causal relationships mutually. For instance, it is a fact proved by many clinical experiments from various countries that obesity, which has a significant impact on health, is higher in the lower socioeconomic band (Devol & Bedroussian, 2007; Finkelstein, Fiebelkorn, & Wang, 2003; Nasreddine et al., 2014; Pouliou & Elliott, 2010; Wake, Hardy, Canterford, Sawyer, & Carlin, 2007; Xie et al., 2007). An opposite example also explains the interdependency. Studies show that adopting a healthy diet and lifestyle can increase the daily productivity, while lowering the burden of medical expenditure (Arora, 2001; Finkelstein et al., 2003; Riedel, Lynch, Baase, Hymel, & Peterson, 2001). Therefore, it is important to balance and maintain these life dimensions to pursue a happy life.

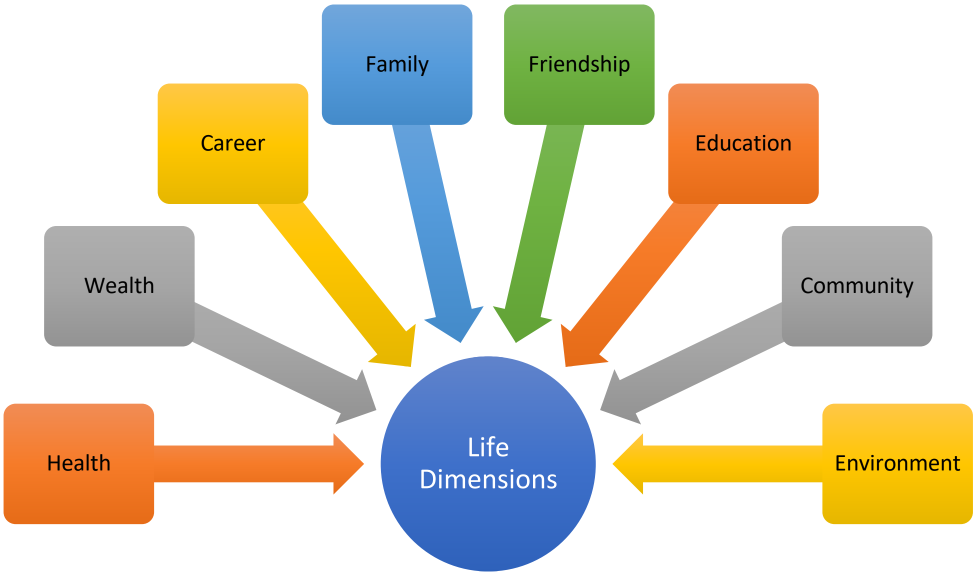


FIGURE 5. VARIOUS LIFE DIMENSIONS, FROM THE AUTHORS' CREATION (CHUNG & SUNDARAM, 2014)

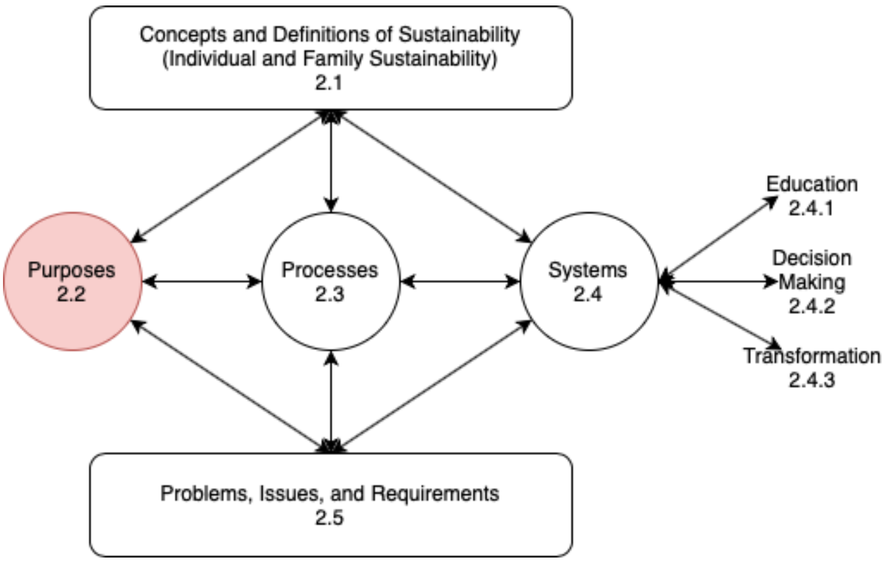
Besides, life values should be considered in terms of pursuing a happy life. Values shape and determine purposes of life, and they are the most fundamental drivers of human activities and behaviour (Locke, 1991). Rokeach (1973, p. 5) defined that value as *"an enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence."* Hence, values are both desired goals and the means to achieve those goals.

Rokeach classified 36 values and categorised them into 18 instrumental and terminal values each. Terminal values are the most desirable states of existence that people work towards to achieve during our lifetime. Instrumental values are the desired and preferred behaviours and attitudes that define our characteristics or personality traits (Figure 6). As illustrated, life values cover a broad spectrum of life, and not all values are treated the same to all individuals and families. Therefore, distinct variances in values can be expected to play an essential role in determining ones' tendency to engage in actions.

Terminal Values	Instrumental Values
A comfortable life (a prosperous life)	Ambitious (hard-working, aspiring)
An exciting life (a stimulating, active life)	Broad-minded (open-minded)
A sense of accomplishment (lasting contribution)	Capable (competent, effective)
A world at peace (free of war and conflict)	Cheerful (lighthearted, joyful)
A world of beauty (beauty of nature and the arts)	Clean (neat, tidy)
Equality (brotherhood, equal opportunity for all)	Courageous (standing up for your beliefs)
Family security (taking care of loved ones)	Forgiving (willing to pardon others)
Freedom (independence, free choice)	Helpful (working for the welfare of others)
Happiness (contentedness)	Honest (sincere, truthful)
Inner harmony (freedom from inner conflict)	Imaginative (daring, creative)
Mature love (sexual and spiritual intimacy)	Independent (self-reliant, self-sufficient)
National security (protection from attack)	Intellectual (intelligent, reflective)
Pleasure (an enjoyable, leisurely life)	Logical (consistent, rational)
Salvation (saved, eternal life)	Loving (affectionate, tender)
Self-respect (self-esteem)	Obedient (dutiful, respectful)
Social recognition (respect, admiration)	Polite (courteous, well-mannered)
True friendship (close companionship)	Responsible (dependable, reliable)
Wisdom (a mature understanding of life)	Self-controlled (restrained, self-disciplined)

FIGURE 6. THE NATURE OF HUMAN VALUES (ROKEACH, 1973)

Understanding life dimensions and their interrelationships help the researcher to see the importance of a holistic approach to individual and family sustainability. Also, studying life values allows the researcher to comprehend core life values that shape and drive purposes of life.



Based on this background knowledge, the thesis moves on to study the individual and family processes.

2.3 Individual and Family Processes

In life, people follow various processes to make decisions, take actions, form habits, and interact with others. Some processes are at the individual level, and some are at the family level. For individual and family sustainability, it is important to study both individual and family level processes, as people try to improve their life status through these processes.

2.3.1 Individual Processes

The question of how people change behaviours or why people resist change have been studied in various contexts. In many ways, disciplines demarcate and define human behaviour and identifies contexts in which scholars are interested. In social science, various theoretical models and frameworks have been proposed to answer how people change their behaviours and what factors influence behavioural changes. Also, many decision-making processes and models have been suggested and developed by academic scholars as most of our actions and behaviours are the results of decision-making.

Understanding influencing factors from behavioural theories and decision-making processes are essential for this study as they help the researcher to identify behaviour change motivation factors that can transform people's lives to become sustainable. Therefore, in the following sections, the thesis will try to understand how people change their behaviours by discussing various seminal theories and models.

2.3.1.1 Behavioural Theories

Theory of Planned Behaviour (TBP) (Ajzen, 1991) is one of the widely cited and applied behavioural theories. Ajzen posits "intention" as the best predictor of behaviour. The influencing factors on "intention" are "attitude", "norm", and "perceived behavioural control", such as self-efficacy and facilitating conditions (Figure 7).

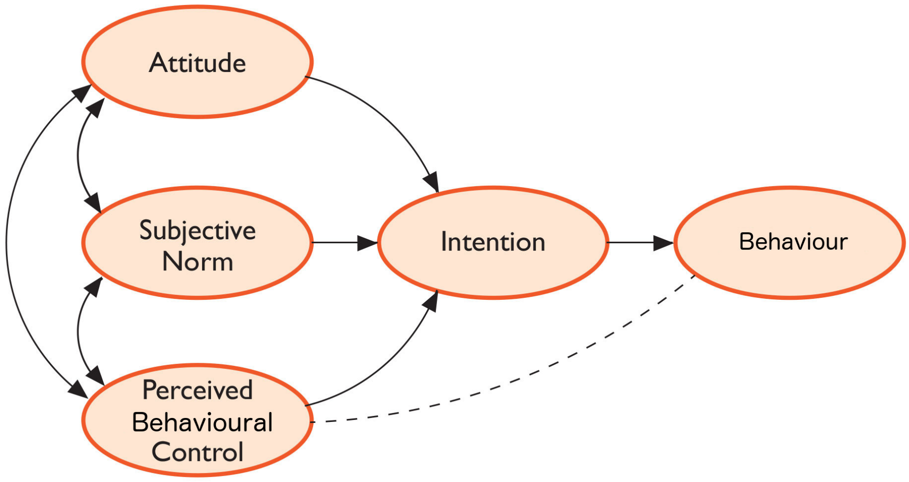


FIGURE 7. THEORY OF PLANNED BEHAVIOUR (TBP) (AJZEN, 1991)

Attitudes are formed through a deliberative calculation (i.e. weigh our beliefs about behaviour with our life values or prior experiences) followed by rational choices (Jackson, 2005). Norms represent perceptions of how people should behave socially and personally. In particular, personal norms are closely related to a sense of moral responsibility that often causes altruistic behaviours (Schwartz, 1977). The perceived behavioural controls are internal and external capabilities required in performing behaviour.

On the other hand, Triandis' (1977) **Theory of Interpersonal Behaviour (TIB)** extensively includes emotions and less deliberative behaviour factors like habits to explain behaviours that bypass intentions (Figure 8). Although emotions describe many human behaviours, most of the models embed emotions in the process of attitudes formation (Bamberg & Schmidt, 2003). However, the TIB includes emotion as the concept of 'affect', which is a direct path to the intention (Triandis, 1977). Another distinct element in the TIB is habit. Habit is an automated behaviour that is formed when repeated behaviours are undertaken at a low level of consciousness (Darnton, 2008). TIB sees habit as one of the primary elements of behaviour. According to Triandis (1977), some behaviours are habitual responses, and those behaviours are natural due to the frequency of particular behaviour performed in the past. Including these two elements in the model explains our multifaceted and complex phenomenon of behaviours by illustrating both cognitive and automated behaviour processes.

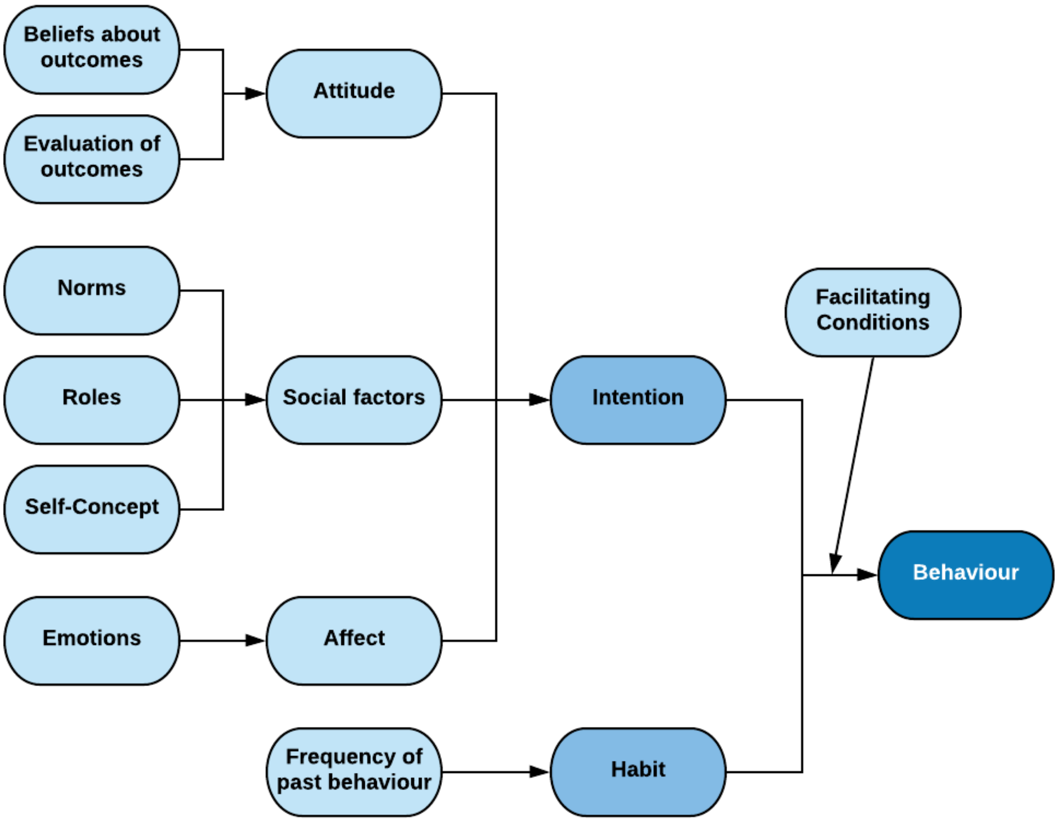


FIGURE 8. THEORY OF INTERPERSONAL BEHAVIOUR (TIB) (TRIANDIS, 1977)

While TBP and TIB try to explain and identify factors that determine human behaviours, some models seek to understand processes of taking actions and changing behaviours. The **Transtheoretical Model (TTM)** (Prochaska et al., 1992) is one of the well-adopted behavioural change process models. TTM consists of three constructs, which are the *stages of change*, the *processes of change*, and the *levels of change* (DiClemente & Prochaska, 1998). Among them, the *stages of changes* is often used as a synecdoche of TTM. Furthermore, many scholars, including authors, use Transtheoretical Model of Change (TMC) to refer the model in their studies (Kidd, Reed, Weaver, Westneat, & Rayens, 2003; Prochaska, 2008). TMC shows how people change through five stages: pre-contemplation, contemplation, preparation, action, and maintenance (Figure 9).

Pre-contemplation is the stage that people do not realise a need for change. In this stage, people are not aware of their problems. People in the contemplation stage are aware of their problems but have not yet made any commitment. Often people in this stage analyse the costs and benefits if they commit effort for changes. Preparation is the stage that people try out things and make small behavioural changes. For example, people may reduce the number of cigarettes they smoke but have not yet made significant actions for change. People in the action stage make serious modification in their behaviours. Once people step into the maintain stage, they do not need to take hard work to change but should reinforce actions for real changes.

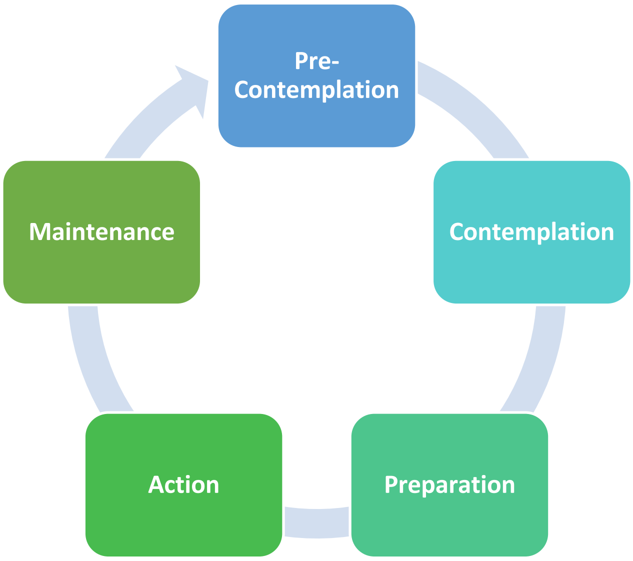


FIGURE 9. STAGES OF CHANGES FROM TRANSTHEORETICAL MODEL, SUMMARISED FROM (PROCHASKA ET AL., 1992)

At the action stage, the intended actions to change their behaviours are repeated; thus, the repeated actions are settled in the maintenance stage. This means that people can form intended habits by repeating and settling their actions during these two stages.

Habits are formed gradually by the individual's behaviours taken during everyday life. Repeating small behaviours and having achievement feelings (i.e. small wins) from doing it engrave the behaviour patterns in the brain (Neal, Wood, & Quinn, 2006). Many studies show that a significant part of our life is filled with various habits. For instance, a study found that 45% of our daily behaviours are habitual actions (Quinn, Pascoe, Wood, & Neal, 2010). Commonly, people have both good habits and bad habits. When life is composed of more good habits than bad habits, life is perceived as healthy and sustainable. Therefore, people keep trying to form good habits or eliminate bad habits to have a better life. In other word, habits only become problematic when they are not aligned with intentions or benefits. Otherwise, habits can be the most effective ways to ensure daily life is healthy, smooth, and continuously sustainable.

According to Duhigg (2012), habit is formed through the iteration of a three-step loop: cue, routine, and reward (Figure 10). Cue is the intrinsic or extrinsic stimuli, which make people crave for rewards. Routine is the habitual activities to achieve rewards. Rewards are the craved results of the loop that people want. Through these repeated three steps, habits are formed and reinforced.

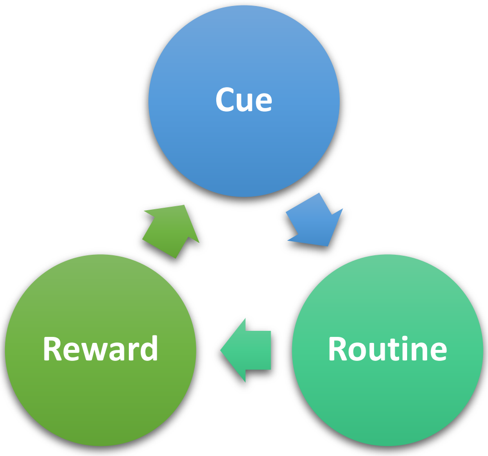


FIGURE 10. HABIT FORMATION PROCESS, ADAPTED FROM (DUHIGG, 2012)

Neurologists have tried to find a relationship between human brain and behaviours. Through various studies, they have reported that habits are automated responses by our brains (Yin & Knowlton, 2006). When a "cue" is presented either intrinsically or extrinsically, the brain reacts to the cue. Once the brain realises the cue, then it starts to crave for the reward. When the habit has not formed yet, the brain keeps people aware of the actions they are carrying out.

However, if this process is repeated, the brain converts these series of actions into the automated process (Figure 11). This is called "chunking" (Graybiel, 1995; Yin & Knowlton, 2006). Therefore, once the brain has noticed the cue, the series of actions are followed automatically. The set of activities will produce a result, and the brain reacts to it and records it as a reward of actions (Howe, Atallah, McCool, Gibson, & Graybiel, 2011). When the brain is chunking the series of actions, the habit is formed, and 95% of habitual actions are carried out through the chunking process (Martin, 2008).

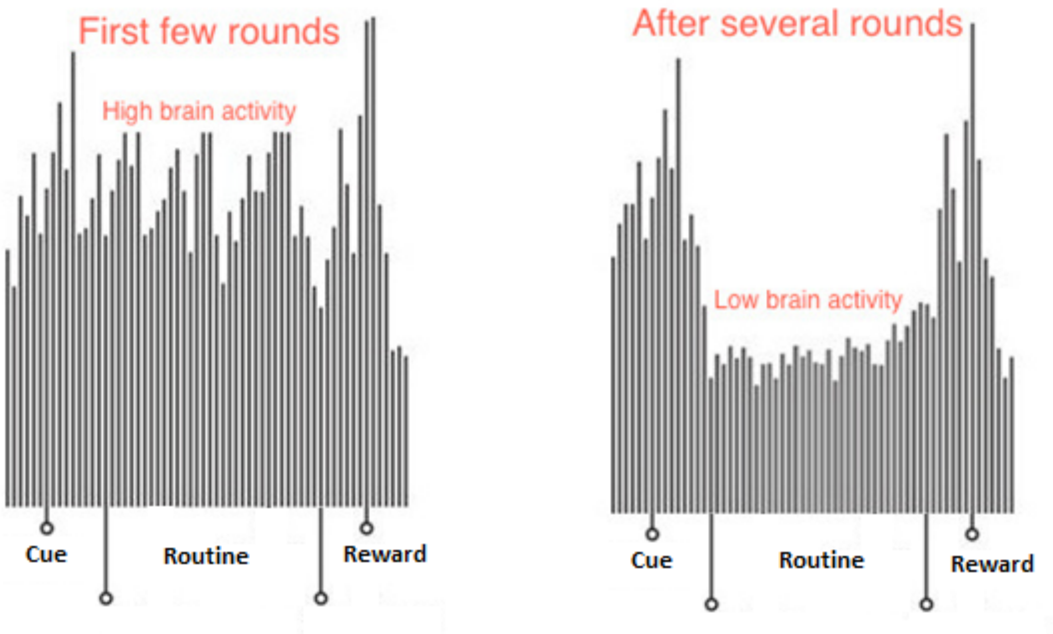


Figure 11. Habit Formation Brain Activities (Duhigg, 2012)

Therefore, to form or eliminate a habit, the behaviours controlled by the automatic process should be intervened by using a reflective mind. For example, once people decide to build or break habits, they should consciously control stimulus in the cue step, perform the chosen alternatives repeatedly in the routine step, and reward making changes in the reward step. Furthermore, people should try to increase the non-problematic options available near us to avoid relapse. Likewise, forming and breaking habits is a constant struggle between a reflective mind and automatic process, and it is not an easy process to go through. Especially when the habit is believed to be tedious, or the formed habit is strong, it is harder to break it as the habit became part of our daily life. For this reason, it is vital to understand how and why people make decisions to form or eliminate these habits. Therefore, the thesis will study decision-making theories and models in the following section.

2.3.1.2 Decision-Making Processes

Many conceptual decision-making models, which focus on an individual, have been proposed in the past. Simon's (1960) decision model is one of the fundamental and widely mentioned theories (Figure 12). His model has been used as a foundation of **rational decision-making** theories. The original model is structures in three steps: intelligence, design, and choice that explains how human beings are sequentially seeking information related to the problem, developing an analysis, and making selection among the suggested alternatives.

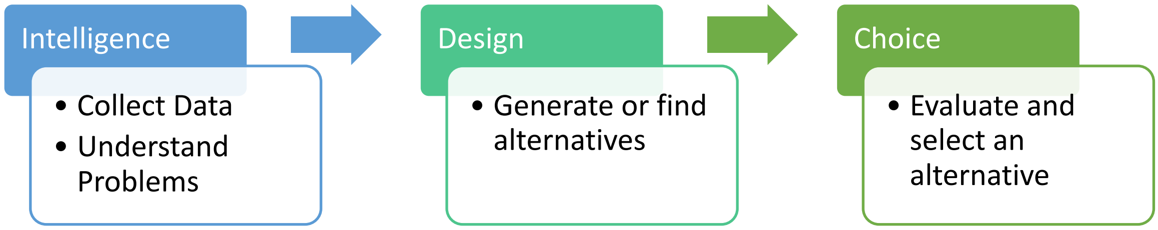


FIGURE 12. DECISION-MAKING PROCESS, ADAPTED FROM (SIMON, 1960)

Many other decision researchers (Mintzberg, Raisinghani, & Theoret, 1976; Rowe & Boulgarides, 1994) extended and enriched their models from Simon's (1960). Mintzberg et al. (1976) have proposed a model that has three stages (identification, development, and selection) with a set of general steps after examining 25 decision-making processes used in many businesses and organisations. Figure 13 illustrates the model that shows decision-making as a process that can be iterative. In the identification stage, a decision-maker can recognise and diagnose problems, then search, or design alternatives in the development stage. In the selection stage, the decision-maker can screen the searched options, and judge/evaluate/bargain choices, then finally authorise choices. At each step, the decision-maker can go back to the previous actions if they are required.

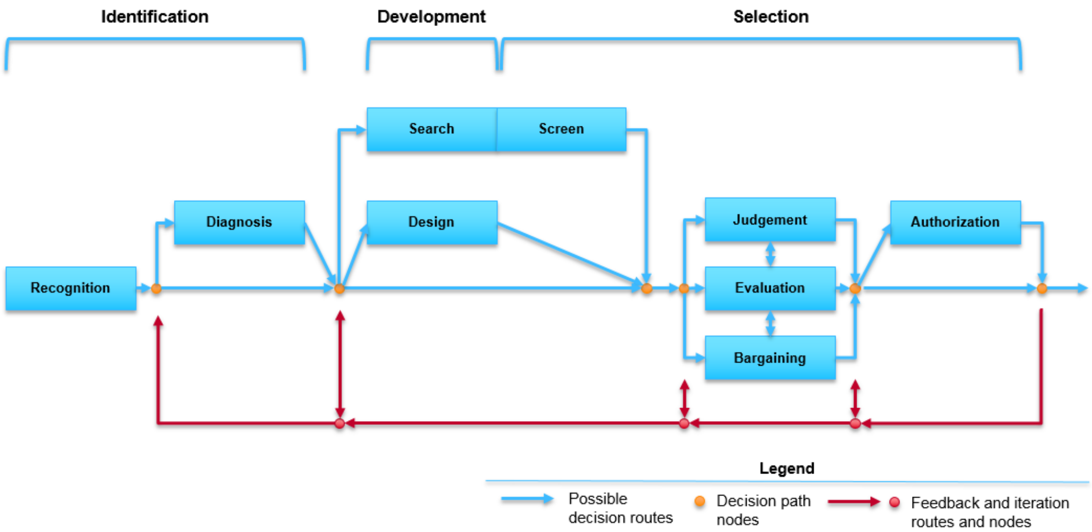


FIGURE 13. MODEL OF DECISION-MAKING PROCESS (MINTZBERG ET AL., 1976)

On the other hand, some decision-making can be unstructured. **Naturalistic decision-making** studies try to understand decision environments where goals and tasks are not clearly defined, and elements involving in decision-making are dynamic and changing over time (Klein & Klinger, 1991).

Langley, Mintzberg, Pitcher, Posada, & Saint-Macary (1995) assert that decision-making can be intuitive. There are chances that a decision-maker can get influenced by irrational factors such as intuition, emotion, memories and imagination. For instance, people choose a movie to watch due to their good memory from similar films or select a dish at the restaurant using their gut feelings. In these cases, decision-makers can obtain instantaneous understanding of a problem situation without following decision-making procedures. Once decision-makers develop strong intuitive and judgemental skills, they can be more action-oriented and alleviate time pressure issues on decision-making.

In addition to the intuitive decision model, Langley et al. (1995) proposed the linkage-driven decision-making model. This model captures the interwoven influences among issue streams, activities related to decision-making and decisions. Three basic types of linkage have been identified and explained in this model (Figure 14). Sequential linkages show the relationship between choices that are at the same issue stream but happened at a different time (e.g. choosing activities sequentially for a trip). Lateral linkages show interrelationships when the unrelated (at the different issue stream) decisions are considered at the same time (e.g. choosing priorities on allocating resources in different areas). Precursive linkages show the relationship when unrelated choices at different times are affecting each other (e.g. learning occurred from the past decision experience helps to choose better option at present).

Like the interwoven decision model, a “good” decision should be made by considering multiple dimensions and suitability for these boundaries and constraints (Langley, Mintzberg, Pitcher, Posada, & Saint-Macary, 1995; Marakas, 2003). Interwoven decision-making model and consideration of multiple dimensions for decision-making are useful concepts in the sustainable transformation because it should help individuals and families to make integrated and balanced lifestyle choices.

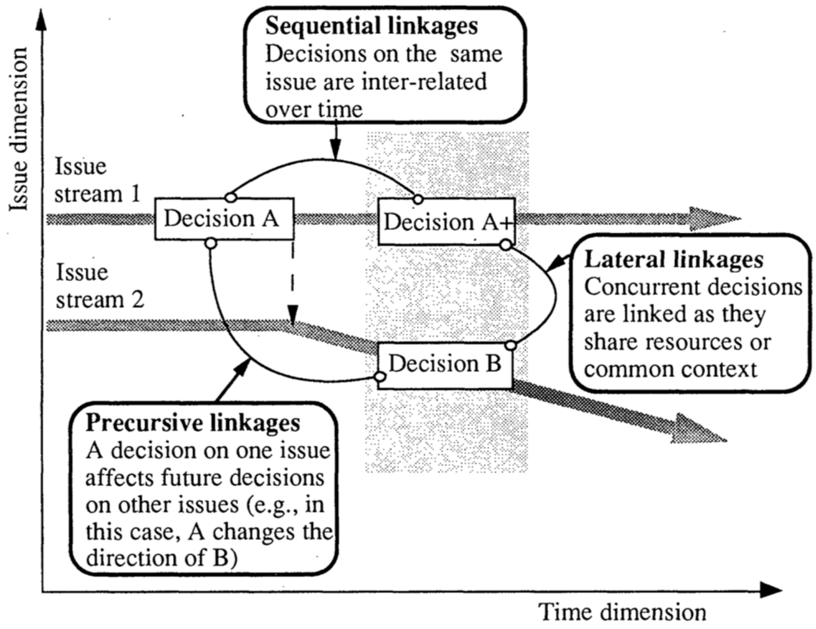


FIGURE 14. LINKAGE-DRIVEN DECISION-MAKING MODEL (LANGLEY ET AL., 1995)

In what follows, the thesis discusses how people learn and what the involving steps in learning are by reviewing several theories and models.

2.3.1.3 Learning Processes

Research in learning has an old history. For example, Plato (428 BC–347 BC) raised a question that sought an answer for how an individual learns when the topic is new to that person (Phillips & Soltis, 2015). Among many different philosophies, theories and approaches to learning, Kolb (1984) proposed a model of experimental learning that identifies four modes in the learning cycle. The learning cycle can be started at any point among these four. However, it often begins by taking a particular action (concrete experimentation) and then observing the outcome of the action in this situation (reflective observation). The next step is to comprehend all effects in the case so that a person can anticipate what will be the outcomes when the same action is taken towards similar circumstances. This is called “abstract conceptualisation” which attempts to understand and grasp the general rules that are valid under certain conditions or circumstances. Then, the general rules through action can be applied to a new circumstance (active experimentation). By doing so, the learner can anticipate the possible outcomes of the action under a different set of conditions (Figure 15).

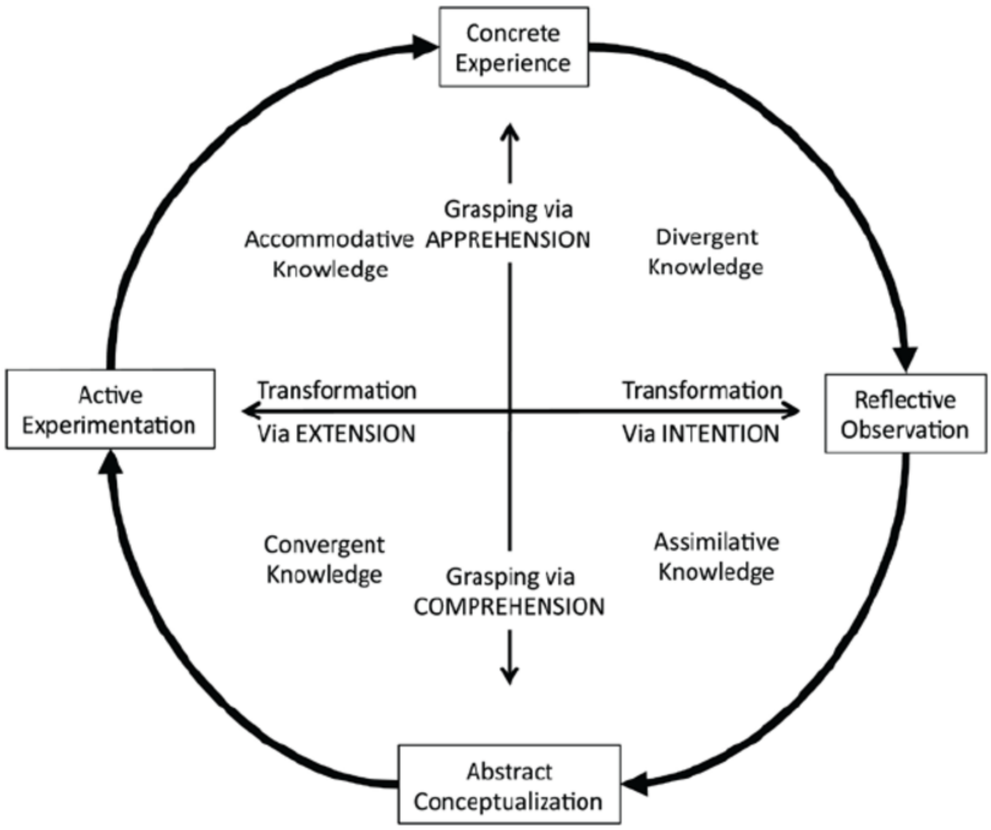


FIGURE 15. MODEL OF EXPERIMENTAL LEARNING (KOLB, 1984)

Kolb's model is often found in discussions of adult education and lifelong learning because it highlights the developing nature of the exercise and an appreciation of Dewey's philosophical pragmatism, Lewin's social psychology, and cognitive development based on the work of Piaget (Kolb, 1984; Kolb, Boyatzis, & Mainemelis, 2014).

Another learning process that the researcher reviews for this study is Argyris and Schön's (1974) loops of learning. Argyris and Schön (1974) argued that people have mental models regarding how to act in situations. The mental model guides the way we plan, apply, and reflect our actions towards the situation exposed to the self. With single-loop learning, people make decisions or follow rules and customs that they have learned. Through this learning, we only change our actions by reflecting the results out of our actions. Besides, the double loop learning entails the change our mental models by taking feedback from the results of the action. As such, this model shifts our understanding on issues and problems from a monolithic perspective to a dynamic and holistic view. Lastly, people can get change behaviours at the maximum level by changing our perceptions on issues. This is where people learn new beliefs that influence their thinking and therefore transform on what we do and how we do it (Figure 16).

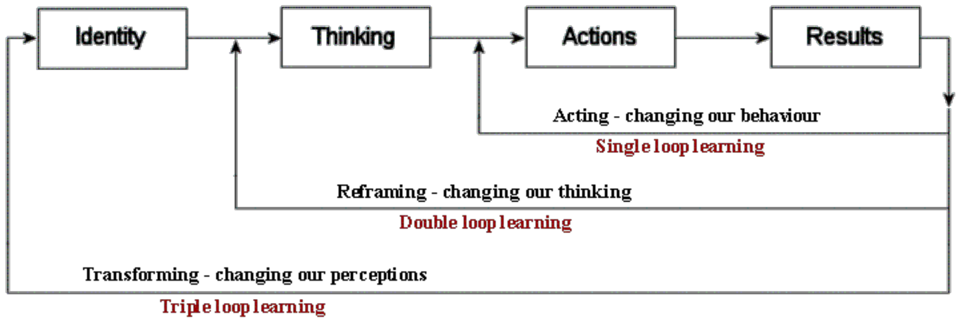


FIGURE 16. THE LOOP OF LEARNING (ARGYRIS & SCHÖN, 1974)

The triple learning loop model shows how learning can make a simple behaviour change to the transformation of an individual. Therefore, if the individual wants to change his/her life, especially a scalable change that impact on his/her family as well, people need to reach the transformation stage (the third loop in the model). In this loop, the individual and his/her family can understand the big picture and have an awareness of subjects to be changed and how they can benefit from the changes and ultimately, transformation.

In general, people follow processes to behave, decide, and learn. Also, there are multiple influencing factors that this study needs to consider for sustainable transformation. Now, the thesis will examine family processes and how these are influencing people's lives to become sustainable.

2.3.2 Family Processes

Families play a critical role in the wellbeing of all family members. Individuals feel a sense of wellbeing when they are connected and have a strong feeling of belonging and inclusion within the family (Zuna, Summers, Turnbull, Hu, & Xu, 2011).

In our society, there are many different types of families. Demo and Acock (1996, p. 457) identified the four most prevalent family structures in the United States: (a) intact first-married family units, (b) divorced, single-parent families, (c) stepfamilies, and (d) continuously single mothers and their children. Our society now has diversified family structures, and each family follows different life stages in terms of its unique circumstances. Although many family studies try to embrace all family structures and family functions by expanding family life stages and events (Rodgers & White, 1993), it is still impossible to capture family lifecycles for every single family.

In what follows, the thesis will review family lifecycles and dynamics based on the intact first-married family unit. This is because this family type is still the most prevalent family structure and most family studies are conducted on them.

2.3.2.1 Family Lifecycles

A process of changes in a family is called the family lifecycle, and the sequence of stages is the most critical moment of family development (Rodgers & White, 1993). Initially, the family lifecycle idea was introduced by Duvall (1985). He explained the family lifecycle with eight stages, which start with a couple married with no children. The couple then has children who will go through pre-school, school, the adolescence period and launching their own lives. In the mid-age, the couple empty their nest (children leaving home) and having their retirement as the last stage of their family.

Carter and McGoldrick (1989) also described and explained the family lifecycle model with six stages. Single young adults leave their home, then the couple gets married, which form a new family system. When children are born, the family accepts the new family members. In children's adolescence stage, the family goes through various emotional conflicts and children are being raised to be independent. Once children become grown-ups, the family start to launch children. In this stage, parents and children are forming adult-to-adult relationships and family is going into the later life stage. Then the family life cycle starts again when young adults begin their own families again (Figure 17).

In each stage of the lifecycle, a family will experience changes, and family members will be exposed to making various decisions. Through these changes and decisions, the family can make a significant impact on the family members' wellbeing. The reviewed models are indeed too classical; therefore, they attract criticisms in recent studies, as they assume that all families have children and go in one direction. However, this traditional concept helped the family study scholars to understand the changing characteristics of families in an analytical point of view (Rodgers & White, 1993).

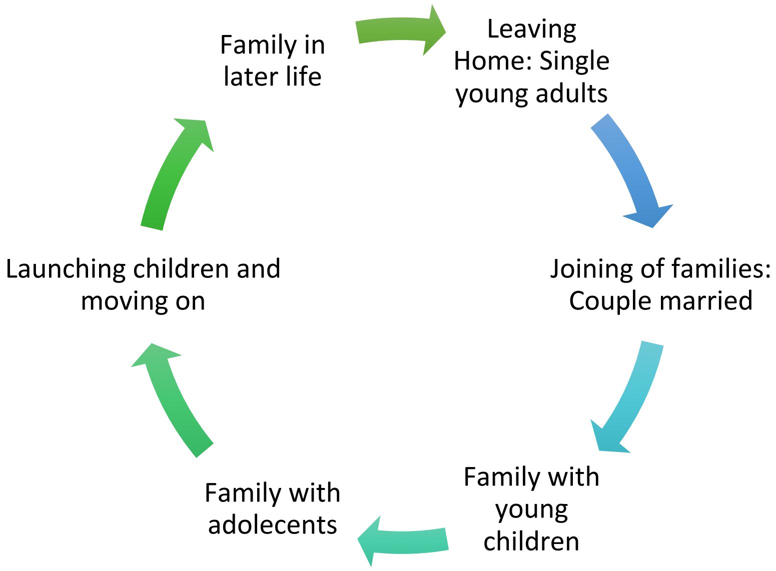


FIGURE 17. FAMILY LIFE CYCLE, SUMMARISED FROM (CARTER & MCGOLDRICK, 1989)

2.3.2.2 *Family Dynamics*

Interaction and interrelationship within a family and between family members are also essential wellbeing factors. Bowen (1966) initially suggested the family system theory. The family system theory sees the family as a functioning system and changes in one family member can lead to compensatory changes in other family members within the system. Figure 18 represents the boundaries of the family system. Family life is a result of the interactions of all family members working as interconnected subsystems and units in a family system (Balswick & Balswick, 2007).

This theory emphasises the individual should be understood as part of their family. Inputs for change can be initiated both internally and externally. Internal demands are biological, psychological and social needs. For example, if one family member becomes alcoholic, then family lifestyle can be changed through the interaction among family members (Bowen, 1974). External demands can be from society. Some of the examples are social expectations and ecological constraints (Rodgers & White, 1993). As such, right developmental/transformation tasks should be addressed at critical family life cycle stages with consideration of each family member's role and interaction for the sustainable family transformation.

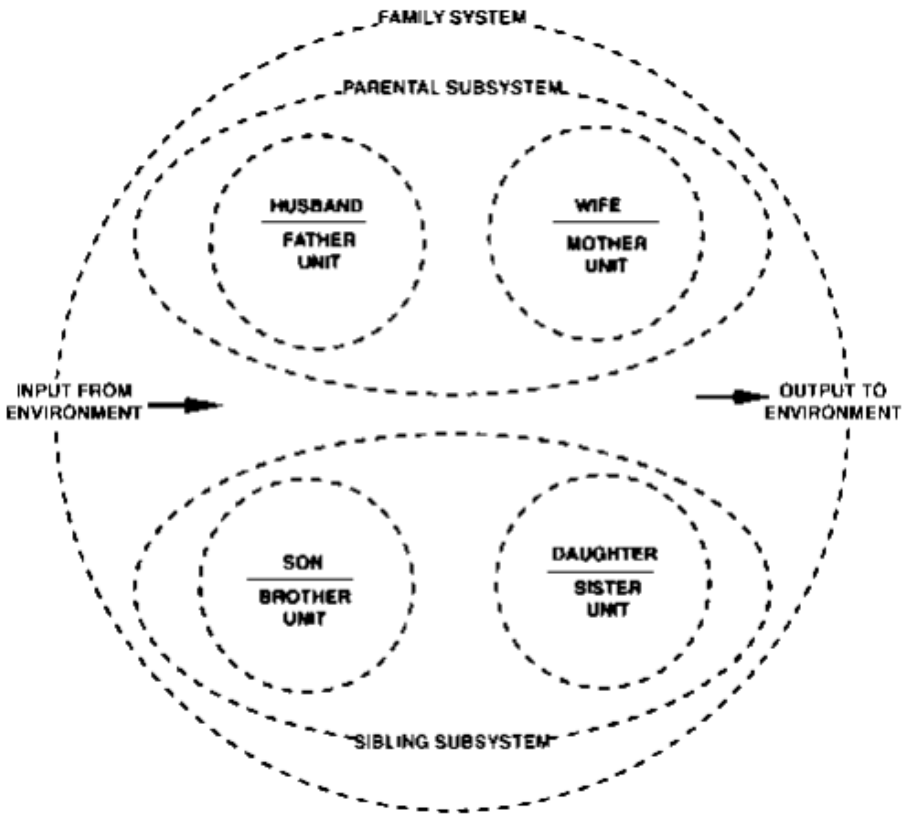
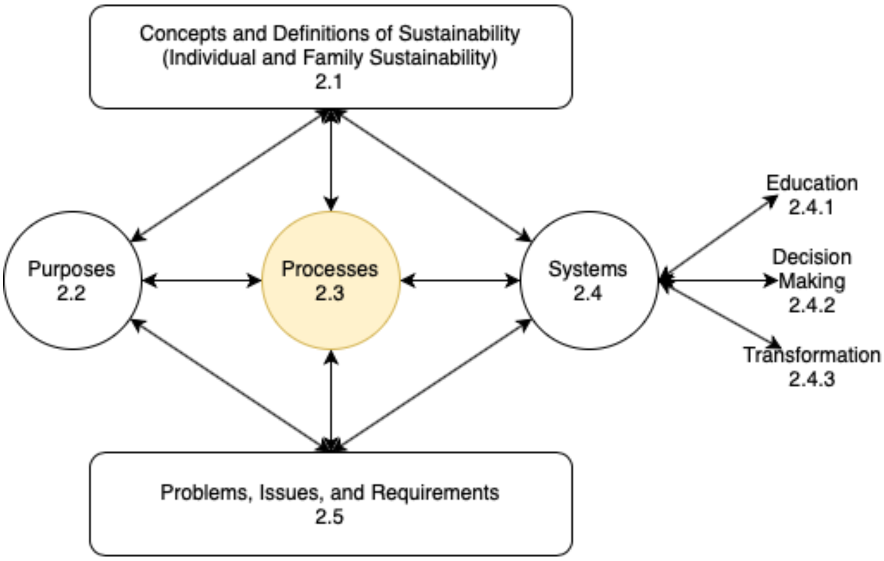


FIGURE 18. FAMILY SYSTEM (BALSWICK & BALSWICK, 2007)

Olson, Waldvogel, and Schlieff (2019) focus on family relationships and their interactions to address family issues and problems. Olson has developed the "Circumplex model of Marital" and family systems for clinical assessment and treatment planning. The model explains that a family relationship can be determined by a degree of cohesion (emotional bonding) and flexibility (change in its leadership, roles, and rules), and communication is a facilitating dimension that can move one relationship to another. A functioning family should have a balanced relationship in terms of cohesion and flexibility. In this model, communication dimension is a critical factor as it is an enabler to make marital and family system functioning at the optimal level.

An individual is part of a family and builds a close interrelated relationship as a family member. A family gives one of the most important physical and emotional foundations for individuals; culture, values and lifestyles are often shared and inherited from parents or other family members. From a societal sustainability perspective, a family is a basic unit of our society that should not be neglected in the sustainability discussion. For this research, studying how individual follow processes to behave, decide, and learn as well as how family works, performs, and interacts can open avenues to find holistic solutions for individual and family sustainability.



Based on the attained knowledge so far, the thesis will review systems that can support education, decision-making, and transformation for individual and family sustainability.

2.4 Technologies and Systems for Individual and Family Sustainability

Individual and family sustainability embraces all activities, behaviours, habits, and values across the broad spectrum of our life dimensions. Therefore, the researcher needs a systematic approach to review the literature on technologies and systems that support individual and family sustainability. After reviewing the interdisciplinary research on concepts, theories, and processes, the researcher is convinced that individual and family sustainability can be achieved by transforming their lives sustainably. To transform their lives to be sustainable, individuals and families can 1) educate themselves, 2) make better decisions, and 3) change behaviours and habits for transformation.

2.4.1 Education

The key to the sustainable transformation of individual and family is balancing the various life dimensions, such as health, wealth, career, family, social relationships, and personal development. It is well understood that these life dimensions are interrelated. Educating individuals and families to examine interrelationships and understand impacts between life dimensions help them to make sustainable decisions and ultimately transform their lives.

Computing technology has proven its effectiveness in teaching and learning environments over past two decades: to increase learner's motivation, to draw higher scores out from students, to lower the educational costs and improve effective on-task time (Amory, 2007; De Freitas & Griffiths, 2007; Kiili, 2005; Quinn, 2005). Due to the increasing demands of the digital age for education, technological devices and resources have become necessities rather than options (Oncu & Cakir, 2011). Educational systems offer the latest technologies for teaching relevant skills that a rapidly and ever-changing society requires (Kelly, McCain, & Jukes, 2009).

In a narrow context, educational systems encompass different ranges from learning software to classroom management software that makes some parts of education more effective and efficient. For example, courseware lets teachers, trainers, and students access educational materials and tutorials easily and quickly through a computer. Many schools are using courseware to support teaching and learning environments.

In a broad context, any system and software can be used for an educational purpose as a fundamental functionality of information systems is providing meaningful information to users. Naturally, users can attain knowledge from it. Especially for sustainability, many systems can describe our current life situations, explain how life dimensions impact each other and predict how our lives can be changed by measuring, modelling, and benchmarking data. People can even learn through entertainment, and many scholars in education have proposed pedagogy with entertainment elements based on the "pedagogy as play" concept (Colby & Colby, 2008; Wood, 2004).

Therefore, the thesis will review systems that can be used to educate people to make sustainable decisions and ultimately transform their lives through measurement, modelling, benchmarking and entertainment in the following sections.

2.4.1.1 Measurement Systems

To improve one's life sustainably, major daily activities should first be recorded for analysis (Neuringer, 1981). Collecting and measuring data is one of the fundamental functionalities of any information system. As this thesis scope is systems and devices for individuals and families, the researcher only looks at systems and technologies, which are developed for collecting and measuring data and information for individuals and families.

Living in the digital era means that we are generating streams of personal data every day. Whether we intend to do it or not, we throw data shadows wherever we go or whatever we do. Since smart and wearable digital technologies have been introduced, self-tracking systems and device developments have mushroomed. The market for smart wearable devices and systems, which make this self-tracking possible, is one of the fast-growing industries in recent days. Self-tracking systems and technologies collect a broad spectrum of personal data. The data range is from users' behavioural data to physiological data. These systems help users to collect their data to gain a better understanding of themselves (Li, Dey, & Forlizzi, 2010). This personal data can help users reflect on their behaviour and habits, and then find better ways to transform them to their desired status. Health data, such as frequency of exercises, sleep patterns, blood pressure and food intake are the most common self-tracking data measured and collected. Wearable devices track personal behavioural information, such as physical activities, calorie intake and sleep patterns (https://www.fitbit.com/). Further health information can be followed using digital health peripherals, like smart scales, blood pressure cuffs or sugar level metres (http://www.vitadock.com/).

Financial institutes record financial data such as income, investments, and expenditure for their customers. Individuals can access and transact these data anywhere and at any time through Internet banking or mobile banking systems available on their smart devices. Furthermore, financial support applications and web services provide information to help individuals and families to make intelligent decisions on their money. For example, these applications and web services provide budgeting, mortgage handling, saving, and retirement planning help (https://www.sorted.org.nz/), and teach individuals and families to manage their current and future financial situations better and wiser. Some services provide personalised financial information by integrating their customers' banking and credit card data (https://www.mint.com/).

Environmental data, such as carbon footprint, waste emissions, and water and energy consumptions, are available to be collected at individual and family levels to a certain extent. Individuals and families can access such data from their water and electricity bills. Many electricity companies provide a mobile app that shows daily, monthly, and yearly usage of electricity. Some companies even offer the national level of carbon emissions and a specific household's impact on it (Figure 19). Also, some mobile applications promote an environment-friendly lifestyle by introducing a point reward system. These applications award badges and points to users when they take environment-friendly actions. For example, bringing a tumbler to a café or a bike to work are all rewardable actions. Furthermore, some of the applications sync up to users' utility bills to show their savings from environmental-friendly activities and lifestyles (http://joulebug.com/; https://howgood.com/; http://www.oceanconservancy.org/do-your-part/rippl.html).

Many studies report that self-tracking systems and devices are useful tools to reflect and change users' behaviours. However, most of the systems are collecting monochromatic life dimension data, rather than a holistic integrated users' lifestyle point of view. Also, many of these applications and devices are still at rudimentary data collecting and reporting system levels, which hinders supporting sustainable individual and family transformation (Swan, 2013). According to Lingg, Leone, Spaulding and B'Far (2014), an integrated wellness application trial was conducted in an organisation for its employees. In this trial, they combine wearable devices with human resource and other enterprise application data. After this trial, they could generate integrated wellness information to their employees. Although the sample size was very small; it showed the application's potential to make positive behavioural changes.

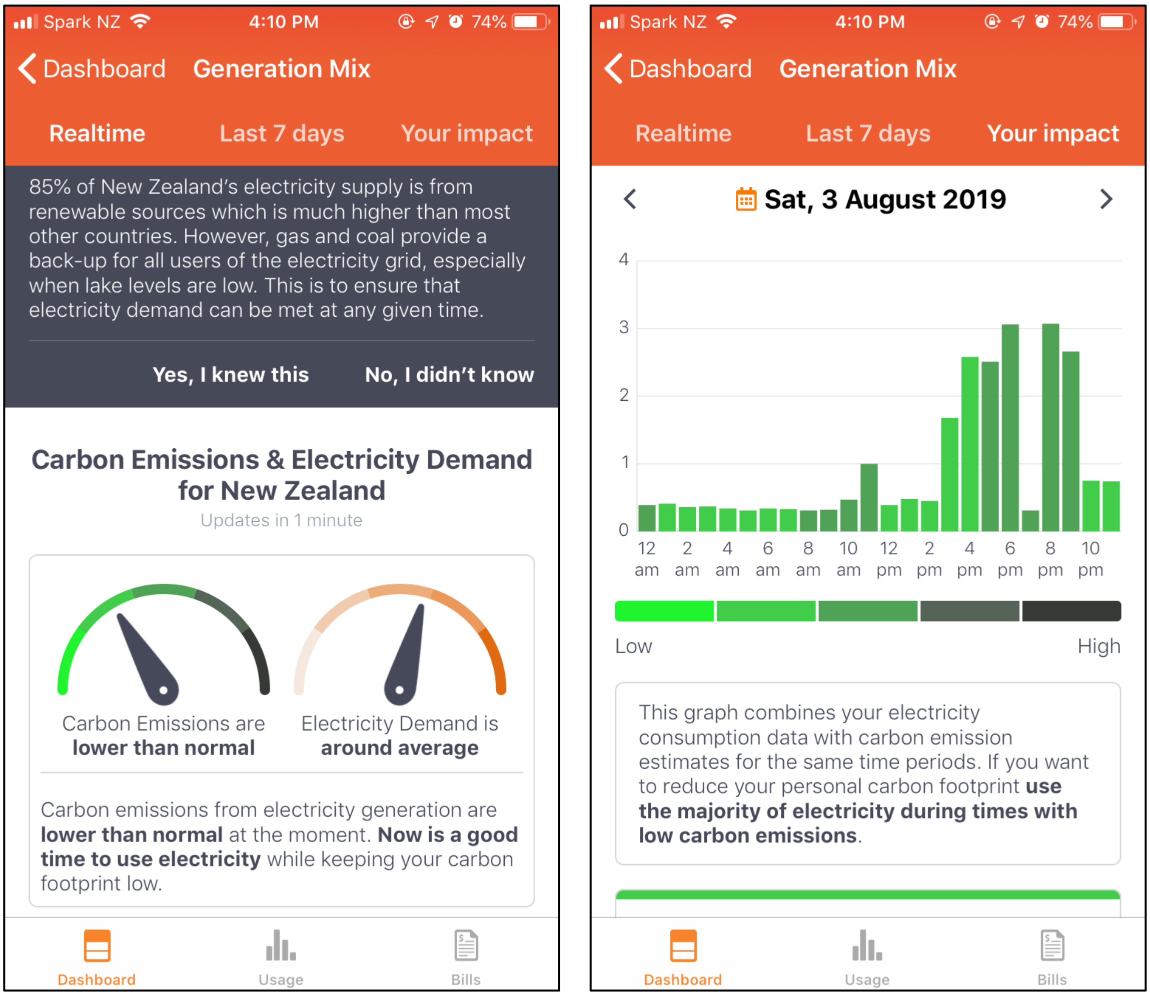


FIGURE 19. EXAMPLES OF ELECTRICITY DATA FROM ENERGY IQ APP FROM (GENESIS ENERGY, 2020)

2.4.1.2 Modelling Systems

Information systems can create values when the interaction and relationship of data are understood. Information or knowledge should be derived from the data analysis to assist users' decision-making. Modelling and simulation systems are broadly used in a variety of industries and disciplines from aerospace to geography studies. In business, these systems are often used to help analyse changes in business process design. They collect multidimensional business data, and the investigated data interactions are presented as relationships in various forms (e.g. numbers, graphs, and graphics). These are frequently used to explain the meaning of data, answer the "what if" questions and forecast the results based on changes of data.

The Architecture of Integrated Information Systems (ARIS) is a popular modelling system which helps businesses to redesign business processes based on a holistic analysis of business processes. Initially, ARIS divides highly complex business processes into individual views; each view is represented clearly without any interruption by the other views (IDS Scheer, 2000). Afterwards, the relationships between the views are incorporated into the model without any redundancies. Hence, it improves business processes and usefulness in Total Quality Management (TQM), Business Process Reengineering (BPR), and Workflow Management (Green & Rosemann, 2000).

For a sustainable business transformation, Ahmed and Sundaram (2012) developed a Sustainability Modelling and Reporting system using real-life business scenarios. This system takes diverse modelling paradigms (economic, social, and environmental) and has various models and simulations (sustainability, balanced scorecard, business process, scenario, domain object, report, data and document modelling). These models and simulations support micro and macro levels of decision-making based on multidimensional business data, and ultimately, they help the transformation of sustainable businesses and organisations.

At the individual and family level of modelling, Stella® can be used. Originally Stella® was used in various business sectors, but certain features can support modelling the individual and family sustainability. Stella® is a system dynamics tool that provides mapping, modelling, and simulations of various scenarios (isee Systems inc, 2019). It supports the conceptual model mappings to mathematical equations and constructing simulation with a graphical interface (Peirce, 1998). Stella® is widely used in analysing non-linear issues and provides understanding grounds for complexity.

As discussed, many modelling systems and techniques are available for businesses and organisations. However, limited modelling features are offered in information systems for individuals and families. Multidimensional data modelling of individual and family life facets is rare. Although wearable devices and applications show progress on individual's health with various graphs, such as weight and BMI changes and sleep patterns, these data representing models hardly provide relationship insights to the users. Some financial systems and applications offer models and simulation features that report the financial information or predictions on future outcomes. However, not many modelling and simulation systems are available for individual and family use.

2.4.1.3 Benchmarking Systems

Benchmarking is a practice, method and technique used in the business context that evaluates a company's performance by comparing it to its historical performance or that of other companies within the industry. The benchmarking processes help companies to 1) reflect their performances, 2) learn best practices from other companies, and 3) target their performance goals strategically (Boxwell, 1994). In this context, any information systems and software that enable effective and efficient work in comparing the company's performance can be identified as benchmarking systems. In the management discipline, these systems are called performance management systems.

Performance management systems collect business-critical data that can link internal and external indicators together to provide business performance information. Performance management systems are used as tools that control operational tasks, plan strategies, provide management reports, and facilitate change management (Sharif, 2002). As such, the goal of performance management systems is to provide visibility and insight into the business's information and data. Therefore, Enterprise Resource Planning (ERP) systems, legacy and database management systems are also taking the role of performance management and benchmarking.

There are several solutions to deploy systems. Firstly, the system can be deployed through internet solutions. These solutions use bespoke database instances as performance management data and bring benefits like personalisation, accessibility and visibility to businesses. An example solution is Microsoft My Insights (https://partner.microsoft.com/en-us/membership/my-insights). Secondly, the portal approach can bring benefits of understanding value drivers and visibility of strategy by using data modelling, extraction, and cleaning. Example solutions are SAP business objects (https://www.sap.com/australia/products/bi-platform.html), CorVu (https://www.rocketsoftware.com/products/rocket-corvu), and SAS (https://www.sas.com/). Thirdly, enterprise packages are available for that can benefit businesses with a single set of tools and a consistent working environment. Oracle PeopleSoft (https://www.oracle.com/applications/PEOPLESOFT/) and SAP (https://www.sap.com/index.html) are typical examples of products that provide insights for businesses.

2.4.1.4 Entertainment Systems

Entertainment systems aim to deliver any form of amusement and support hobbies. Multimedia, simulations, and gaming are the most popular formats of entertainment software, and they also can deliver informative or educational value to the users (Corti, 2006). Multimedia software use interactive contents like audio, video, images, and text to provide entertainment for users. Examples of multimedia platforms are Netflix, Hulu, and YouTube. These multimedia platforms account for a large portion of the Internet traffic today (Deloitte, 2015).

Recently, there is fast-growing attention to simulation software, which is called Virtual Reality (VR). The software involves the interplay of advanced graphics that simulate a user's presence in a virtual environment in real-time. As it could be used for real-world activities, companies like Google, Apple, Microsoft, Amazon, and Samsung have allocated a large number of technology-centred resources to develop VR platforms (Cipresso, Giglioli, Raya, & Riva, 2018; Shilov, 2019).

Computer and video games are one of the most popular entertainment software and are rapidly being developed and popularised, aided by the emergence of virtual worlds, social networking and rich Internet applications. Many researchers and educators in the gaming field have tried to categorise games for many purposes (Alvarez, Djaouti, Ghassempouri, Jessel, & Methel, 2008; Esposito, 2005). According to Alvarez et al.'s classification (2008), games can be categorised into three types: casual games, serious games, and advergames. They have classified games in terms of gameplay, purpose and scope.

Casual games are general games that gamers play purely for entertainment. This game sector is the fastest-growing segment in the gaming industry. Casual games are played through different consoles (e.g. Playstation, Xbox), computers, handheld games (e.g. Nintendo Game Boy, Sony play station portable (PSP)), and mobile devices (Alpert, 2007). Examples of casual online games range from simple card games like Solitaire to social network games like Farmville or Sim city. One of the interesting aspects of casual games is surprising the demographics of gamers. Although casual games are designed to reach the broadest amount of gamers (Dillon, 2005), a study shows that middle-aged women are also major players of casual games (Dobson, 2006).

Another genre of games is advergame. *"Advergames are interactive online games embedded with brand messages"* (An & Stern, 2011, p. 43). Advergames are a more effective advertisement method than other online advertisements like banner ads (Deal, 2005). Examples of advergames are various video games from M&M's (https://www.playstation.com/en-us/games/mms-adventure-ps2/) and "Doritos VR Battle" (Figure 20).

FIGURE 20. DORITOS VR BATTLE - ADVERGAME EXAMPLE FROM (HTTPS://VRMYOFDARKNESS.COM/2017/02/24/DORITOS-VR-BATTLE-REVIEW/)

Serious games are designed with the intention of learning and teaching specific skills (Michael & Chen, 2006). Simulation types of serious games are becoming more popular in the educational sector, as their advanced visualisation and creativity can provoke learners' active involvements in learning (Westera, Nadolski, Hummel, & Wopereis, 2008). The simulation game called Rochester Castle project, which involves 3D online role-play games, showed collaborative and team-building learning occurred amongst students (Lee, Eustace, Fellows, Bytheway, & Irving, 2005). Most students reported that they had developed an awareness of multiple aspects of decision making regarding natural resource selection, team-building skills and electronic communication skills through simulation games (Kirkpatrick, McLaughlin, Maier, & Hirsch, 2002). These simulation games are used in higher education to teach nursing and medical students, pre-service teachers, and business students with specific scenarios (Gregory et al., 2013; Guillén-Nieto & Aleson-Carbonell, 2012; Imison & Hughes, 2008). Han (2011) argued that "Second Life" is also a great virtual place to deliver education to students. As "Second Life" provides a 3D animated virtual world, students can practice and build up specific skills without limitations of resources.

As games mirror images of real life but do not impact on gamers' reality, games are often used to train skills without adverse risk to participants in real-life. Lockheed Martin Corporation provides a simulation-learning platform for various military tasks, including aircraft flying (https://www.lockheedmartin.com/en-us/capabilities/training-logistics-sustainment.html). A commercial training example is McDonald's customer service training (Figure 21) that teaches employees how to deal with customers in various situations (Derryberry, 2007).

As such, educational entertainment systems can serve an educational purpose while they bring entertainment values as well. Also, the systems provide educational contents using video games, audio services, or social media applications to disseminate information to influence people's attitudes and behaviours.

So far, the thesis reviewed the literature on measurement, modelling, benchmarking, and educational entertainment technologies and systems for learning. Education for life transformation involves two requirements. The first requirement is understanding current situations that people are in, and the second is learning how they can transform their lives to be sustainable. For these, people often start with recording and measuring our activities in their daily lives. Then they begin to find out what the causes are and how factors and activities are interrelated together. At this point, people try to understand a relationship using various models and their situations by comparing their conditions with standards, best practices, and so on. Entertainment is one of the well-studied techniques that make education efficient and effective. After learning about their status and ways of transforming, people make decisions. Therefore, this study will examine technologies and systems for supporting decision-making in the subsequent section.

FIGURE 21. MCDONALD'S CUSTOMER SERVICE TRAINING GAMES FROM (HTTPS://WWW.KINEO.COM/CASE-STUDIES/MCDONALDS-TILL-TRAINING-GAME)

2.4.2 Decision Making

Everyday activities and decisions are often repeated over time. Generally speaking, individuals and families are trying to improve their behaviours and daily decisions by making smart decisions (Hammond, Keeney, & Raiffa, 2002). For this reason, a study on decision-making is an ever-popular topic among scholars.

2.4.2.1 Decision Support Systems

In the 1970s, Decision Support Systems (DSS) were developed to assist the handling of complex managerial tasks by providing timely analysed information. Since then, it has gained popularity and different types of DSS have been developed (Marakas, 2003). This popularity brought confusion to define and categorise DSS in IS research. In response to this issue, Power (2001) proposed an expanded DSS framework that helps IS researchers to classify DSS by dominant technology, targeted users, purposes and deployment technology. Classification by dominant technology identifies five types of DSS. *Data*-driven, *Knowledge*-driven and *Document*-driven DSS are focusing on access to and manipulation of the database. Every kind of DSS uses a specialised database component. For example, Data-driven DSS database is a group of structured current and history data. In contrast, Document-driven and Knowledge-driven DSS are designed for dealing with unstructured data to produce data content relationships by finding hidden data patterns. *Model*-driven DSS often use mathematical and analytical models to help decision-makers by providing a prediction of results. *Communication*-driven and Group DSS use communication and decision models to facilitate a solution to the problem by supporting group communication and collaboration. Most of the DSS are developed for businesses and organisations. Also, these days we are often exposed to too much information, which ironically hinders us from making effective decisions.

2.4.2.2 Recommendation Systems

Recommender systems (RS) were invented and developed for suggesting and recommending more relevant items based on an individual's needs (Konstan, 2004). There are various definitions for RS; therefore, it is hard to grasp a comprehensive concept of RS. Recommender systems are evolving and broadening their areas. Despite these difficulties in defining RS, core traits of RS are collaborative filtering, relevant recommendations and being focused on the individual's needs. Initially, RS collects data from the customer, community data, and item data. Then RS combines the data and generates recommendations using recommendation methods: raw-retrieval, statistical summarisation, attribute-based, user-to-user correlation, and item-to-item correlation. These methods are used in actual E-commerce recommender systems, but the combination of these processes and the degree of personalisation and delivery method can increase the quality of recommendations. Then, recommendation outputs are produced. If a customer responds or provides feedback, then RS will use this data for future recommendations (Figure 22) (Schafer, Konstan, & Riedl, 2001; Sinha & Swearingen, 2002).

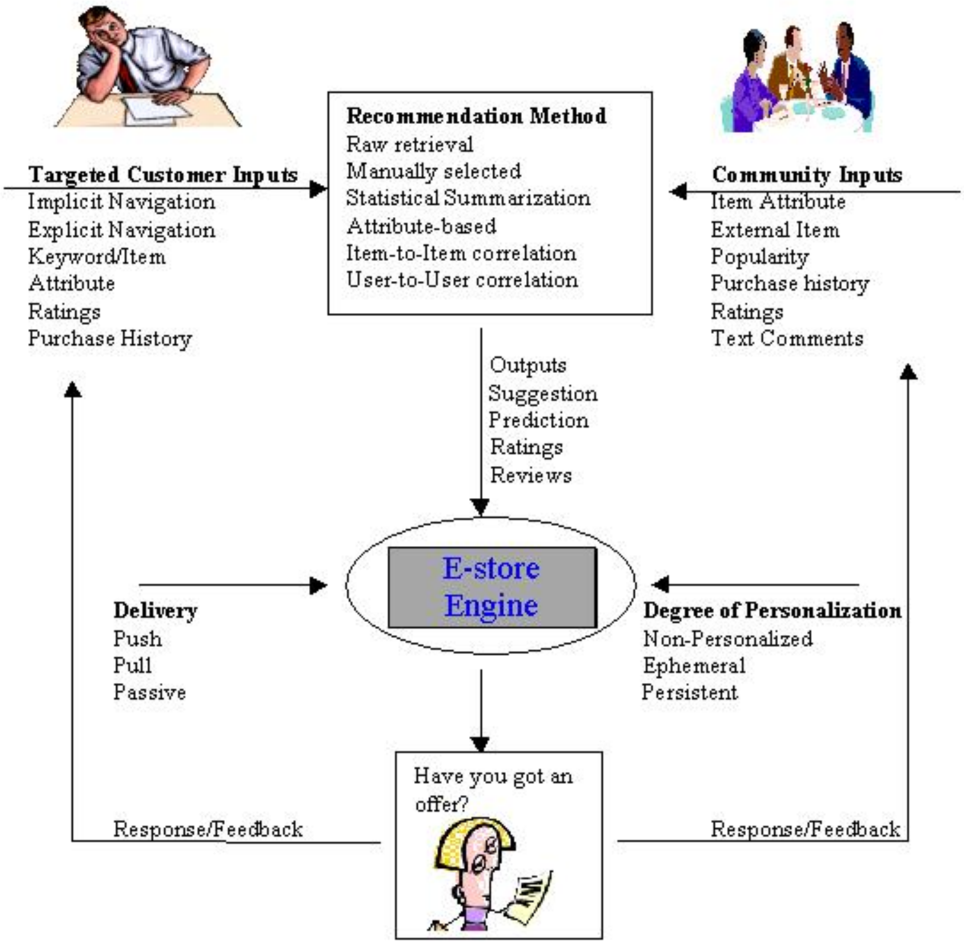


FIGURE 22. COMPONENTS AND ELEMENTS OF RS (SCHAFER, KONSTAN, & RIEDL, 2001)

Although RS are predominantly used for E-commerce, it has great potential to be used for individual and family sustainability systems as it generates recommendations for individuals based on personal and community data.

Sustainable life transformation can be achieved by making better and smart choices for their living. Through education, people can make appropriate decisions by considering their current circumstances and desired outcomes. Recommendations are often provided to support decision-making. In what follows, this research studies various technologies and systems that can support the sustainable transformation of individuals and families.

2.4.3 Transformation

Individuals and families should take actions and change behaviours to transform their lives to be sustainable. For this, the researcher will study technologies and systems that persuade human beings to take actions, help them to form/destroy habits, and support to manage themselves. Also, the thesis reviews shopping systems, because shopping is a daily and family level activity that can make fundamental changes in various life dimensions like health, wealth, and the environment. Through shopping, individuals and families can play an important role in sustainability.

2.4.3.1 Persuasive Technologies

Fogg (2003, p. 1) defined persuasive technology as *"any interactive computing system designed to change people's attitudes or behaviours"* in his book "Persuasive Technology: using computers to change what we think and do". Although information systems were not developed to persuade people, recently they have become persuasive tools in many areas. One of the earliest persuasive systems was developed in the late 1970s, for teaching young adults to enhance their behaviours and address health issues (Bosworth, Gustafson, & Hawkins, 1994). Since the emergence of the Internet, the domains and persuasive applications have diversified from commercial use to personal management and self-improvement. Persuasive systems can be more effective than human beings as they are more persistent, ubiquitous, and can make suggestions after manipulating a massive amount of data (Petty & Cacioppo, 1986). Also, persuasive systems can intervene at the right time and place as networking and mobile technology opened this possibility. However, the researcher recognises the fine line between persuasion and manipulation. It can deliver tailored encouragement or motivation based on users' data. Recent systems that heavily use persuasive technology are Mobile Health Applications (mHealth) which is the focus of the following section.

2.4.3.2 mHealth Systems

According to the World Health Organization (2011), *"Mobile Health (mHealth) is an area of electronic health (eHealth), and it is the provision of health services and information via mobile technologies such as mobile phones and Personal Digital Assistants (PDAs)"*. mHealth is an emerging industry which is viewed as an innovation to transform healthcare systems. Many experimental studies report that mHealth solutions like medication adherence and health care education positively impact on behaviour changes and patients' self-management skills (Boulos, Wheeler, Tavares, & Jones, 2011). A broad literature review was conducted through a web-based and library database search. This review reported that the mobile phone could be used as a competent health care intervention (Kaplan, 2006).

mHealth has the potential to persuade people to change their health behaviour, but many health mobile applications fail to maintain retention rates. Compared to health and fitness mobile apps' growth rate (62% in usage) in 2014, the retention rate (15%) is relatively low (Khalaf, 2014). Notably, health education mobile applications have failed to entice users. For example, research reported that HIV/STD education applications were infrequently downloaded. Only 11 from 69 reviewed applications were downloaded over 1,000 times, and some scored low on customer ratings (Muessig, Pike, Legrand, & Hightow-Weidman, 2013). This is due to the fact current mHealth's supporting features are not customised to each patient but just work as general reminders. Unfortunately, not many mHealth applications employ motivation features based on behavioural models or personal circumstances (Chesanow & Fogg, 2013). Without robust motivation and behavioural models, it is hard to make patients adhere to healthy behaviours (Spil, Kijl, & Romijnders, 2019).

The ultimate reward is indeed living a sustainable life, but behavioural changes take time and consume much effort. To motivate people to stick to their habit formation or sustainable transformation process, persuasive motivation features should be facilitated in the systems. Online social network features are also important. In many motivation studies, interactions and collaboration from family, friends or people who have similar interests can make significant contributions to individuals in achieving their goals. This is because people can share useful information and get the support they are looking for and enjoy interactions with other people who have similar interests (Pfeiffer & Benbasat, 2012). The benefits of gamification feature as motivational tools are also recognised in many areas, such as education and health sectors. Gamification is a new trend in supporting user engagement and enhancing positive patterns. The peer-reviewed empirical studies on gamification found that most studies showed positive effects and benefits of gamification on motivational affordances, psychological and behavioural outcomes (Hamari, Koivisto, & Sarsa, 2014).

2.4.3.3 Habit Formation Systems

A sustainable transformation process is often achieved by sequential behaviours within an individual's social context (Duhigg, 2012). What you eat and what exercise you do often determines your health; how you spend money significantly impacts your financial status; what environmental values you have contributes to environmental issues.

The initial step of forming a habit starts with an understanding of our daily routine. To do this, individuals should log their daily activities. This used to be a manual process (Neuringer, 1981; Swan, 2012) but, with the emergence of smart devices and technologies, it is now easier to capture individuals' daily activity data. Besides, technologies have become more accurate and easier to use. Alongside these devices and technology development, many applications and services have developed to capture and report various life dimensions. For example, individuals can collect their health data (physical exercise, sleep pattern, and biological data), financial data (their spending and savings). Wearable devices can collect health data, and financial data can be obtained by signing up e-receipts services or by using their bank services.

While these devices, services and applications are increasing in popularity, the concerns about the efficacy of these solutions are also growing. This is because most of these solutions are only focused on a single life aspect and provide insufficient means to address the root problem (Patel, Asch, & Volpp, 2015). For example, most smoking cessation mobile apps intervene in users' smoking habits by sending a series of text messages (Abroms, Padmanabhan, Thaweethai, & Phillips, 2011). However, to get rid of the bad habit, the routine should be replaced with a good habit. It is hardly improved by text messages (Duhigg, 2012). Other points are behaviours that are interrelated, and some that are habitual. Interventions should be made on fundamental behaviours or habits. For instance, many studies found that limited income causes an unhealthy diet, which can result in serious health problem to an individual. This vicious circle can continue to worsen the individual's financial situation due to the extra medical costs. Unfortunately, not many current systems have effective models to support understanding of these dynamics among multi-dimensional life aspects. To make these systems become useful for habit formation, the services or systems should be able to offer insightful and holistic information to users. By incorporating information from multiple life dimensions, we can have a better picture and understanding of one's status or performances. However, this kind of holistic approach is not present in current habit formation systems. A classic example of a habit that is not well supported by positive persuasive systems is shopping. This thesis will explore shopping systems their strengths and weaknesses in the following section.

2.4.3.4 Shopping Systems

Shopping is an activity that affects people's lives from financial and health considerations to philosophical values (Seyfang, 2005) and influences businesses' profits, and the global environment. As shopping is habitual and often reflects life values (Young, Quist, & Green, 2000), it can bring fundamental changes in our life.

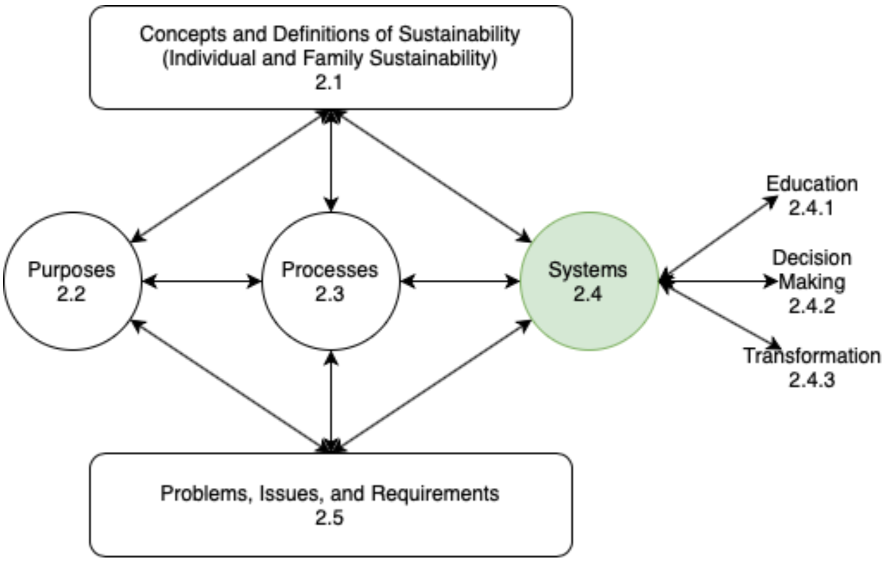
In recent years, the online shopping industry has mushroomed from supplementing offline shopping to a mainstream powerhouse (Kim, Suh, & Lee, 2013). It has expanded rapidly based on its unique characteristics which can provide richness of information and highly personalized interactions (Häubl & Trifts, 1999). Many researchers are attempting to develop practical shopping tools while businesses are spending enormous effort in improving their online services in order to increase their sales.

Most of the effort from academia and industry has focused on online shopping aid tools that incorporate a recommendation agent (RA) and a comparison matrix (CM). RAs are utilized to help consumers in screening for potential products they could purchase based on their profile. CMs are algorithms that help consumers to compare multiple products' attributes for taking effective decisions. It has been proven that these two tools do significantly impact on consumers decision-making process (Häubl & Trifts, 1999) and have become standard features in most online shopping sites.

As the online shopping trend is growing, grocery shopping retailers also provide online shopping sites to expand their customers. Most grocery shopping sites provide beneficial financial information, such as the amount that the customer has saved during the shopping session. For example, mySupermarket.co.uk, an online shopping and price comparison website, helps customers to save money. The website shows different prices from different grocery shopping sites with insightful information like recent price trends. However, it does not provide health information or environmental information (mySupermarket Limited, 2014). Often health and ecological information are offered from independent non-commercial apps and websites. Packaged food nutrition information app “FoodSwitch” shows calories, salt, sugar and saturated fat information in easy traffic light form. By suggesting better nutritional products within a similar product range, this app helps individuals and households to make better food choices (Hunt, 2013). However, the problem is all these services and information are offered separately in silos in monolithic systems. Integrated and balanced information that interweaves economic, environmental and health dimensions together is virtually non-existent. Due to this information asymmetry, individuals and households are often powerless to transform themselves to be sustainable (Newton & Meyer, 2013).

Another recent online shopping trend is social shopping. Social shopping connects shops and consumers to discover, share, recommend and purchase products. This means customers can interact with their family and friends during the entire shopping procedures (Olbrich & Holsing, 2011). Sommer et al. (1992) found that families and friends’ roles are tremendously important in shopping. Shoppers tended to spend more time and money when they could share opinions and get supports from families or friends. Social shopping spans a wide range of definitions, including group shopping, shopping communities, and recommendation engines (Yin, 2010). Group shopping sites encourages customers to purchase together to drop the same prices and shopping communities bring like-minded people together to discuss, share, and shop. Recommendation engines promote sales by suggesting products that have been purchased by similar customer profile. All of them use technology to provide the social interactions found in brick and mortar stores. Also, with the rise of social media, retailers utilise actual social media to generate a new revenue stream (Harris & Dennis, 2011). These retailers are implementing applications, such as Facebook Connect, Twitter API and Instagram API, that allows customers to have shopping experiences with their social media friends.

Based on the review of concepts and definitions of sustainability, life purposes in life dimensions and values, individual and family processes, and technologies and systems visualization for individual and family sustainability, the researcher summarises the research problems, issues and requirements pertaining to these perspectives in the subsequent section.



2.5 Problems, Issues and Requirements

This literature and system review allowed us to identify problems, issues, and requirements for the individual and family sustainability research. This process helps the researcher to find research gaps in the existing literature, but also provides foundational concepts, processes, technologies, and systems. Following the literature and system review, the identified problems, issues, and requirements were categorised into four groups: conceptual, procedural, technological, and systems. The subsequent sections summarise and analyse what has been studied in the preceding sections.

2.5.1 Conceptual Perspective

Identifying conceptual problems, issues, and requirements for designing and implementing systems for individual and family sustainability is vital as they will provide a philosophical background for the research and guide the researcher to contribute to related disciplines and ultimately society.

1. **Concepts and definitions of individual and family sustainability** – Sustainability is not a new concept; it has been discussed for a while in various

disciplines. However, the Sustainable Development Goals have not yet been sufficiently practised or achieved in any single area. As it is discussed previously, overall sustainability should be achieved by balancing all three aspects of sustainability: social, environmental, and economic dimensions (Elkington, 2004). Although the topic has been conceptualised and defined by various stakeholders (Marshall & Toffel, 2005), the social angle of sustainability often has been neglected in the mainstream discussion of it. As a result, there is a research gap in the conceptual backgrounds of the social side of sustainability, compared to economic or environmental aspects of sustainability, especially when it comes to individual and family levels. Therefore, it is important to build the concepts and definitions of individual and family sustainability, which can guide researchers to set the study scope.

2. **Links between life values of individuals and families and sustainability** – Most people agree that sustainability is a crucial social agenda and show their support by doing various sustainable activities, such as purchasing products and services from organisations who are seem as exemplars of CSR (Corporate Social Responsibility) and actively engaging in waste reclamation. However, it is common to see an inconsistency between what people believe and how people behave; a sustainable choice often becomes the second-best interest, when a choice involves substantial economic benefits or convenience. This is because people normally cannot gain immediate benefits from sustainable actions. This discrepancy makes sustainability hard to achieve. As many studies point out, the benefits of sustainability are not instant and direct but holistic and indirect. Therefore, corporate sustainability studies emphasise that corporate sustainability should be approached from a holistic viewpoint and for the next generation. Likewise, individual and family sustainability should be approached holistically. In addition to this, studies for individual and family sustainability need to connect a link between life values of individuals and families and sustainability. By doing so, people can have a better understanding and feel empowered to achieve sustainability within their lives and lifestyles. Therefore, this research suggests discussing sustainability levels and life dimensions from the holistic approach of individual and family sustainability.

Also, the study tries to link life values and sustainability to explain why sustainability should be exercised as a lifestyle and how it contributes to our society ultimately.

3. **Strategic and philosophical guidance for Individual and Family Sustainability** – In 2015, United Nations (2015) announced 17 Sustainable Development Goals (SDGs) and subsequent 169 targets as the 2030 agenda for sustainable development (United Nations, 2015b). Once SDGs have been provided as strategical guidance to the national, regional, and global level of authorities, discussions on sustainability have become more active and popular in public these days. As such, individual and family sustainability also needs strategic and philosophical guidance. For individual and family levels, most approaches focus on sustainable activities that provide the detailed guidelines of what should and should not be done (Office of the Minister for the Environment, 2007). Although the detailed instructions make people follow sustainable activities and practices, they cannot make individuals and families autonomous in sustainability, as strategic and philosophical guidance can. Also, the strategic and philosophical guidance can provide appropriate research scope and approaches to individual and family sustainability.

2.5.2 Procedural Perspective

Sustainable transformation of individuals and families involves various processes such as behaviour and lifestyle changes, decision making, and learning. Therefore, studying relevant processes, then utilising them for solutions to sustainable transformation are essential steps for this research.

1. **Processes suggested for sustainable transformation of individuals and families** – Our life is composed of many life dimensions that influence a greatly in making decisions and changing behaviours. There are many well-studied theories on how people make decisions or change their behaviours in the existing literature. These background understanding can provide clear guidelines to researchers. Furthermore, having a process of sustainable trans-

formation helps researchers to find various solutions for sustainable transformation of individuals and families. However, not many studies suggest or propose sustainable transformation processes. Therefore, it is required to have a sustainable transformation process which embraces core concepts and steps from behaviour changes, prompt decision making, and learning (education) processes.

2. **Effective key habits that help individuals and families to make their lives sustainable** – Many people find that transforming their life can be an overwhelming task as it is hard to identify an effective way to achieve sustainable transformation. To help people to be sustainable, several activities have been suggested by various studies. However, most of the suggested activities are at the individual level, not at the family level. As many individuals learn and have lifestyles from their families, the family level and collective behaviour changes make a significant impact on individual and family sustainability (Mahajan & Graves, 2018). Furthermore, an effective way of transforming lives to be sustainable is providing a sustainable environment seamlessly into people's lives, so they can practice a sustainable lifestyle without hassle (BBC World Series, 2019; Buettner, 2008). For this, the researcher needs to identify key activities both at individual and family levels that can create a sustainable environment and utilise those activities to provide solutions.

3. **Holistic system processes that support the sustainable transformation of individuals and families** – Individual and family sustainability embraces many life dimensions, such as health, wealth, social relationships and careers. People feel happy when there is no major breakdown in any of these life dimensions. Also, over time, people would like to see continuous improvement in these life dimensions. Therefore, the systems should be able to support sustainable transformation processes holistically, so individuals and families can balance life dimensions while they are gradually making progress on each aspect. Although many studies suggest that sustainability and its solutions should be sought with holistic approaches, most technological solutions are designed and implemented to treat one dimension in a single dimensional manner. To overcome the limitations, the researcher should develop the holistic

multi-dimensional system processes that support the sustainable transformation of individuals and families and utilise the processes to design and implement effective solutions to achieve sustainability.

2.5.3 Technological Perspective

Technologies can take a critical part in supporting sustainable transformation. For example, smart and wearable technologies have made various stakeholders interested in developing self-tracking systems that help users to change their behaviours on specific activities (Swan, 2012). As such, identifying the right technologies for appropriate purposes is vital to find technological solutions for individual and family sustainability.

1. **Guidance on choosing technologies for system purposes and processes** – Numerous technologies are ready to be used for various purposes these days. Also, these technologies are being developed rapidly to meet the different user needs and sustainable process requirements. Unfortunately, there are not many criteria and guidance on selecting technologies to provide solutions for developing systems for individual and family sustainability. Therefore, the researcher needs to conceptualise and propose system purposes and processes that can be used as the criteria for choosing suitable technologies for developing individual and family sustainability systems. The ideal technologies should be able to serve system features and functionalities.

2. **Guidance on integrating technologies and systems** – Individual and family sustainability involves a wide range of concepts, processes, and technologies. Therefore, it is necessary to integrate various technologies and systems to support the sustainable transformation of individuals and families. However, the integration of heterogeneous systems and data is one of the significant challenges in developing a holistic system. For example, the emergence and sudden popularity of smart and wearable technologies made each developer and service provider develop their ways to collect data and structure applications. Hasselbring (2000) explained that there are three major issues when system integration is required: autonomy, heterogeneity, and distribution. When there

is no all-encompassing system, the distributions of individual systems are greater. Autonomy happened when developers chose different components in their systems such as programming models and naming concepts. The autonomy of the component system can be minimised or reduced by limited technical methods. Among these three integration issues, the most difficult tasks of system integration come from the heterogeneity of technologies and system models. For technologies and system integration, some common models, processes, frameworks, and architectures need to be suggested. Especially, designing and defining a general system framework and architecture to integrate can help the researcher to mitigate heterogeneity problem in system integration for individual and family sustainability systems.

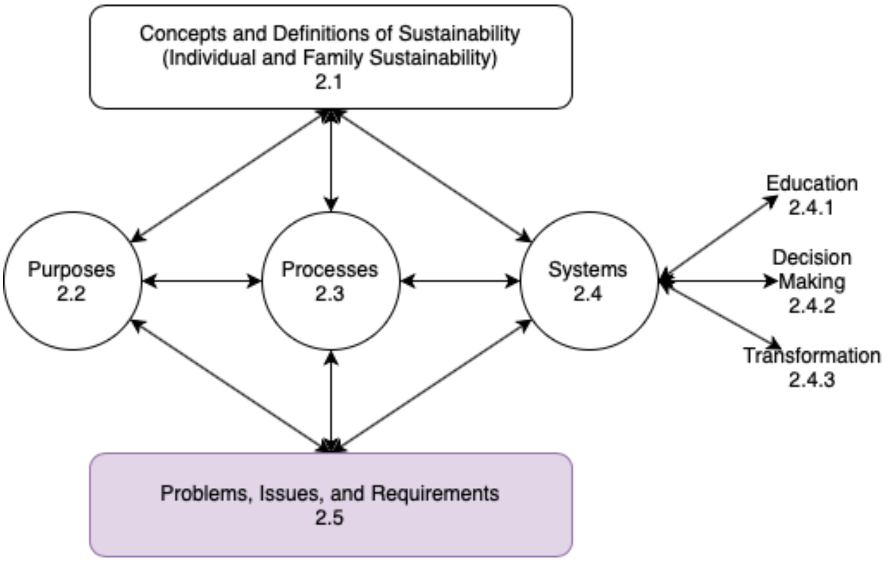
2.5.4 System Perspective

After reviewing the literature, technologies, and systems key requirements were identified. Software, systems, and technologies to support the sustainable transformation of individuals and families should be able to 1) collect various individuals and families data and *integrate* them easily, 2) analyse and understand dynamics and relationship between these data through various *system dynamic* and *workflow* models, 3) provide *personalised* information for habit formation and sustainable transformation, and 4) provide *persuasive* decision support/recommendations by utilising online social media.

1. **Integrated system framework, interactions, and workflows** – To help individuals and families have a sustainable life, systems need to provide a variety of features and functionalities that will allow users to form a series of positive habits. Therefore, various systems can be used in combination. For example, a system collects data from the user's activities, another system may analyse the data through modelling, especially to find patterns or routines, and another system persuades users to form good habits gradually. For this, the researcher needs to 1) understand all-round human nature in terms of purposes, processes, and behaviour change mechanisms, 2) identify related technologies and systems based on system purpose, processes, mechanisms, and 3) design and implement effective system interactions and workflows.

2. **Holistic Personalised Socially driven Persuasive Systems for Individual and Family Sustainability** – Anke and Sundaram (2006) explained three degrees of personalisation in their paper: non-personalisation, transient personalisation, and persistent personalisation. For sustainable individual and family transformation, systems should be designed and implemented at the level of persistent personalisation. Persistent personalisation systems are preserving each user's settings and preferences to provide highly accurate personalised services by use of user-to-user and user-to-social network correlation models and algorithms (Etaati & Sundaram, 2014). Another issue with the current systems is that these systems provide very simplistic motivational features (e.g. goal setting or feedback) that rely mostly on users' willpower. Applications and services that offer well-established persuasion techniques for bridging user's intention to behavioural changes are rare (Conroy et al., 2014). Despite the popularity of self-tracking systems and technologies, many users do not continue to use the behavioural change applications because they provide information and feedback merely based on users' data inputs. Hence, systems must have well-established techniques for providing continuous persuasion and motivation. "Gamification", which is a recent trend in persuasive technology and behavioural studies (Groh, 2012), can be used to provide continuous persuasions and motivations to users. According to a literature review by Hamari et al. (2014), most studies show positive effects and benefits of gamification on behavioural outcomes. Therefore, systems should be designed and implemented to have various features that support the sustainable transformation of individuals and families.

All identified research problems, issues and challenges are connected to the principal issue of pursuing individual and family sustainability. To meet the research requirements and provide solutions, this research is interested in synthesising sustainability concepts, persuasive technologies, personalised information systems, habit formation/transformation models, and online social networks to develop concepts, models, processes, frameworks, architectures, and systems for supporting individual and family sustainability.



Keeping these problems, issues and requirements in mind, the researcher proceeds to discuss the strategy adopted for guiding and evaluatisng the research in chapter 3.

3 Research Methodology

Academic research is defined as an original study leading to the production of new knowledge in a particular discipline (Myers, 2009). Academic researchers follow a process involving understanding the research domains, asking valid intellectual questions either of a theoretical or practical nature and applying appropriate methodologies to address these questions (Nunamaker et al., 1991). Researchers should understand research domains thoroughly to formulate meaningful research questions and apply appropriate methodologies to produce a valid study.

This research tries to find answers for the research questions and objectives explained in the previous chapters by proposing, designing, and implementing conceptual, procedural, technological, and system artefacts which support decisions, actions, and behaviour changes for the sustainable life transformation and individuals and families.

Therefore, the thesis will ask the following questions in this chapter:

- What are the methodological requirements for answering the research questions and objectives addressed in the previous chapters?
- What are the methodological approaches suitable for this research?
- Which methodology is most appropriate to achieve the research objectives?
- How this research should be conducted using the selected research methodology?

To answer these questions, this chapter will discuss topics below. The relationships between sections are illustrated in Figure 23:

- Discuss methodological requirements that motivate the development of a new research path for this research in 3.1.
- Review seminal design science research methodologies to develop the research methodology for this study in 3.2.
- Based on 3.1 and 3.2, the thesis will propose the multi-methodological research approach for studying individual and family sustainability by synthesizing elements from the various research methodologies in 3.3.

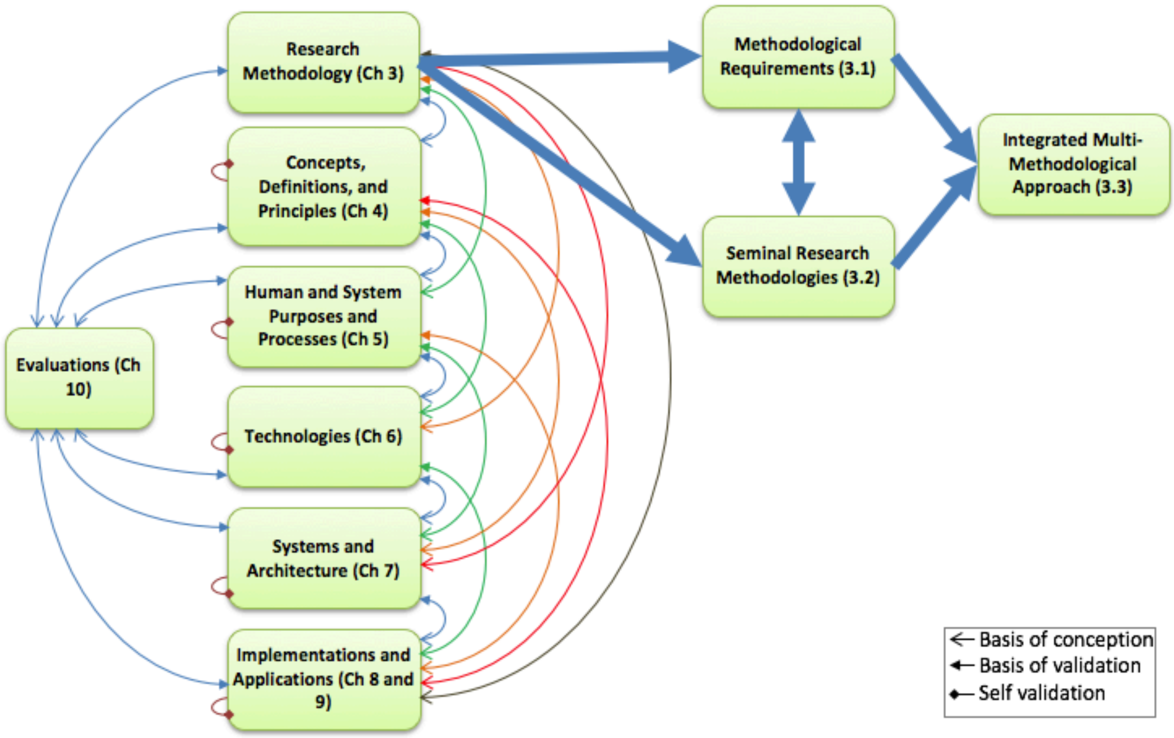


FIGURE 23. CHAPTER 3 STRUCTURE AND RELATIONSHIPS

3.1 Methodological Requirement

Traditionally, Information Systems (IS) research has mainly targeted economic value to create a competitive advantage for businesses and organisations. Most of IS research has been focused on the organisational uses of information systems and treated IS as a property of organisations (Crowston, Fitzgerald, Gloor, Schultze, & Yoo, 2010). However, recent IS research has diversified to develop values along with other dimensions: political, social, cognitive, affective, physical, and psychological values (Briggs & Nunamaker, 2013). Also, research on personal usage of ICT and developments of systems for individuals and families have made rapid growth. Baskerville (2011) elaborated the use of information systems theory as a platform for designing individual information systems and examined its potentials in the arena of design theorising.

IS research often stimulates critical thinking by integrating existing research from different disciplines (Benbasat & Zmud, 1999). Therefore, adopting a combination of different methodologies may result in better and more fine-tuned research outcomes (Mingers, 2001). Hevner and Chatterjee (2010) opine that IS research to date has produced knowledge by two complementary but distinct paradigms, behavioural sciences and design sciences. Behavioural science seeks to develop and verify theories that explain or predict human or organisational behaviour and design science seeks to extend the boundaries of human and organisational capabilities by creating new and innovative artefacts (Hevner et al., 2004). Therefore, when IS research has characteristics of behavioural science and design science research paradigms, a single research methodology should not be viewed as the pre-eminent research paradigm (Cao et al., 2006).

As it is discussed in 2.5, this individual and family sustainability research: 1) focuses both on human behaviours and information systems' capabilities to support them, 2) falls into the study that involves multiple academic disciplines, and 3) has a goal to provide rigorous research outcomes by designing and implementing conceptual, procedural, technological, and system artefacts. Therefore, the identified methodological requirements of this study are as below.

- IS research methodology
- Be able to embrace multiple academic disciplines
- Be able to guide the research to produce various conceptual, procedural, technological and system artefacts
- Be able to evaluate various research artefacts meticulously

In this regard, this study considers adopting the Design Science Research (DSR) as its base methodology to develop a multi-methodological approach. DSR *"invents a new purposeful artefact to address a generalised type of problem and evaluates its utility for solving problems of that type"* (Venable & Baskerville, 2012, p. 142). In other words, the purpose of DSR is to change and improve the world where people live in by building original artefacts, such as concepts, processes, models, frameworks, architectures, and systems (Myers & Venable, 2014). Also, Nunamaker et al. (1991) posit that systems must be developed to test and measure the underlying concepts; 'proof of concept by design, implementation and evaluation' is a valid design science research methodology.

In the following section, the thesis reviews seminal design science research methodologies to develop an integrated multi-methodological approach that helps the researcher to achieve the research vision and objectives, which were discussed in 1.3.

3.2 Review of Research Methodologies

IS research is dynamic and complex as it deals with multiple domains in general. From the theory building to system development, it produces a variety of research artefacts (Burstein & Gregor, 1999). In particular, this research involves multiple real-world dimensions, for example, health, financial and environmental facets of our lifestyle (Mingers, 2001) as it aims to understand the individual, and family's sustainable life and design systems for their sustainable transformation. Therefore, this research adopts multi-methodological frameworks under the design science paradigm for implementing information systems for individuals and families. To attain guidance for the research, the researcher reviews key design science research methodologies to shed light on developing the integrated multi-methodological approach.

3.2.1 Nunamaker, Chen, & Purdin (1991)

Nunamaker, Chen, and Purdin (1991) suggested a multi-methodological approach, as no single methodology is enough to guide the IS research activity. The multi-methodological research framework is composed of four critical research components: observation, theory building, system development, and experimentation (Figure 24).

- **Observation:** IS research starts with a good understanding of practical and research areas and problems. There are various research techniques, such as case study, survey and field observation can be used to identify practical and research problems.
- **Theory Building**: New concepts, models, processes and frameworks that guide IS research are developed through in this research component.
- **System Development**: In the design science, this is one of the core research components, which involve in conceptual and physical artefacts development.

- **Experimentation**: System simulation, field or lab experiments are conducted under these research components. The results of experimentation will be the base of refining the developed systems and theories.

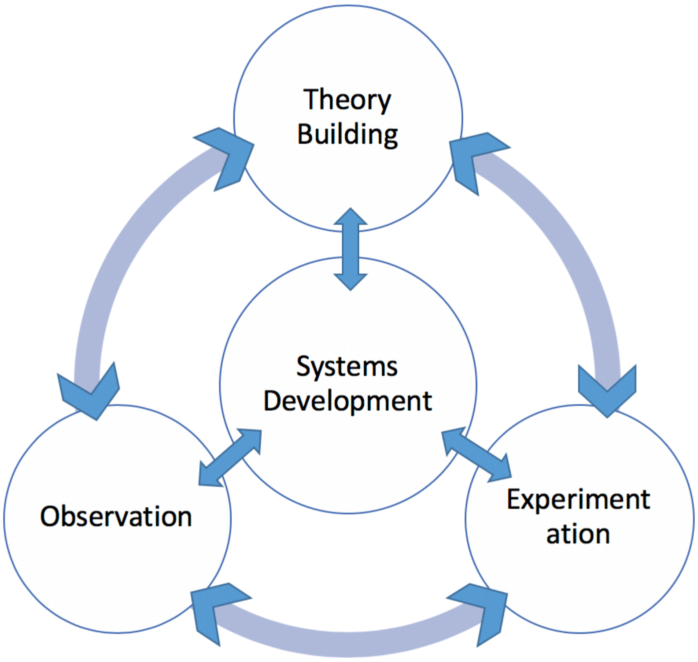


FIGURE 24. THE MULTI-METHODOLOGICAL APPROACH TO IS RESEARCH (NUNAMAKER, CHEN, & PURDIN, 1991)

The multi-methodological approach is widely adopted by most of the design science researchers as it embraces a broad range of research methodologies from problem identification to solution provision. Also, Nunamaker et al. (1991) assert that system development is a central research strategy that can make the research more complete and dynamic. However, their framework has several shortcomings. Firstly, it does not consider the research environment like people, organisations, and technologies which can make a significant impact on the study. Secondly, there is no clear indication of the initiation point of the research procedure. Thirdly, this framework does not propose systemic ways of evaluating research outcomes. These shortcomings can be complemented by Hevner et al.'s (2004) research guidelines and framework.

3.2.2 March & Smith (1995)

March and Smith (1995) posit that IT research should deal with the design issues raised by practitioners. The real-world problems should be conceptually articulated and represented to construct proper technologies for suggested solutions. Also, solutions should be implemented and evaluated using valid assessment methods. To guide design science researchers, Mark and Smith proposed the two-dimensional IT research framework that has consisted of four design science activities and four research outcomes. The design science research activities build, evaluate, theorise, and justify. The general design science research outcomes are representational, constructs, models, methods, and instantiations (Figure 25).

		RESEARCH ACTIVITIES			
		Build	**Evaluate**	**Theorise**	**Justify**
RESEARCH OUTPUTS	**Constructs**				
	Model				
	Method				
	Instantiation				

FIGURE 25. DESIGN SCIENCE METHODOLOGY (MARCH & SMITH, 1995)

This two-dimensional IT research framework is a high-level generalised approach. Therefore, it may need additional support from the theories from natural phenomena to provide a deeper understanding of the research. However, the nature of explaining and evaluating research artefacts, which this framework has, ensures that no research efforts will be wasted even in the rapid IT development environment.

3.2.3 Hevner, March, Park, & Ram (2004)

Historically the role of design research has been confused in the IS field. However, Hevner, March, Park and Ram (2004) contribute to clarifying its role by expanding the IS environment with people, structures, technologies and systems, then proposing an IS research framework which integrates two basic IS research paradigms: behavioural science and for design research.

The framework assists researchers to conduct a relevant and rigorous IS research by providing three essential research building blocks: Research Environment, IS Research and Knowledge Base. It suggests understanding research environment to identify a business's needs, which lead the application of research in the appropriate environment. The knowledge base will provide applicable knowledge for a rigorous IS research and IS research will contribute to the knowledge base. IS researchers develop/justify theories and build/evaluate artefacts to fulfil business needs (Figure 26).

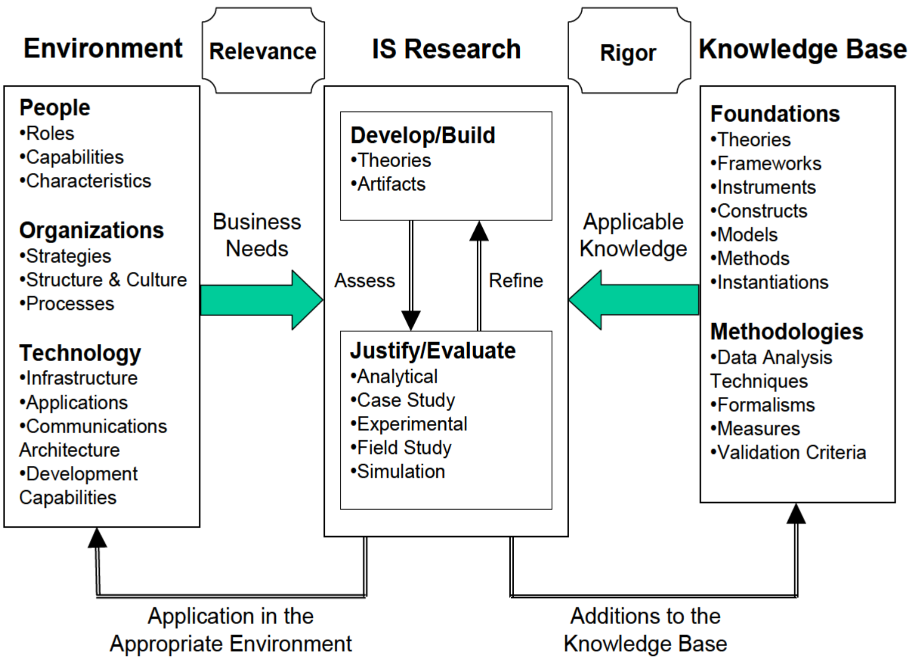


FIGURE 26. IS RESEARCH FRAMEWORK FOR DESIGN SCIENCE (HEVNER, MARCH, PARK & RAM, 2004)

Hevner et al. (2004) also suggest a set of design science research guidelines by considering the design as 1) an artefact, 2) a process, and 3) a practical problem. When the design means an artefact, the research must produce a feasible artefact. When it indicates a process, the study should be the process of building and evaluating artefacts. When it is a wicked problem, the research deals with unstable requirements and constraints and interacts among complex components of issues. Table 1 summarises the research activities of design science within the IS discipline for conducting and evaluating proper design science research.

Guideline	Description
Guideline 1: Design as an Artefact	Design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies.
Guideline 5: Research Rigour	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact.
Guideline 6: Design as a Search Process	The search for an effective artefact requires utilising available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

TABLE 1. THE RESEARCH ACTIVITIES OF DESIGN SCIENCE WITHIN THE IS DISCIPLINE (HEVNER ET AL., 2004)

Later, Hevner (2007) suggests the three cycles of design science research: relevance cycle, design cycle, and rigour cycle (Figure 27). The relevance cycle is in between the application domain and design science. In this cycle, the researcher needs to find research problems, opportunities, and potentialities. Sometimes field testing of research results is required.

The rigour cycle is happening between design science and the knowledge base. The researcher applies the design theories, engineering methods, existing artefacts and processes in the knowledge base to extend the theories and methods, create new experiences and expertise, and develop new artefacts and design processes. The researcher's skilled selection and application of appropriate theories and methods are important in this research cycle.

The design cycle is happening within design science area. The researcher often takes a rapid iteration of build and evaluate activities to make artefacts ready for testing in an application environment and to contribute new knowledge for an incursion in the knowledge base.

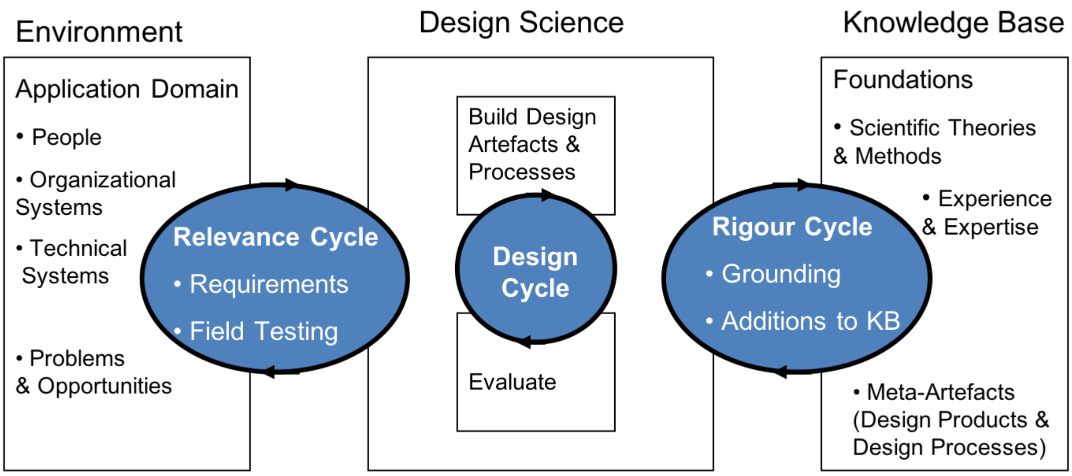


FIGURE 27. THE THREE CYCLES OF DESIGN SCIENCE RESEARCH (HEVNER, 2007)

Lastly, Hevner et al. (2004) propose a set of design evaluation methods to validate functionalities, completeness, consistency, accuracy, and performance of the research artefacts and outcomes. Table 2 summarises validation methods, and this thesis will adopt these methods to evaluate our research artefacts and outcomes, which will be discussed in chapter 10.

Understanding and reviewing several seminal design science research methodologies help the researcher to lay a sound foundation for developing an approach for this study. By taking all core methodologies into the considerations, this research proposes the integrated multi-methodological approach that is primarily supported by Nunamaker et al.'s (1991) and Hevner et al.'s (2004) research approaches.

3.3 Integrated Multi-Methodological Approach

Researchers should prepare guidelines and procedures before they conduct their research. Although most research is iterative, and researchers should always be flexible to change their approaches as they progress their research. Therefore, well-designed research approaches are vital to convincing the readers that the research is significant, relevant, and feasible to be conducted (Myers, 2009). For this, the research proposes its methodological approach by integrating multiple methodologies reviewed in the previous section. In the following section, the research aim and expected artefacts are discussed first. Based on this discussion, the thesis explains the proposed integrated multi-methodological approach, followed by its application.

1. Observational	Case Study: Study artifact in depth in business environment
	Field Study: Monitor use of artifact in multiple projects
2. Analytical	Static Analysis: Examine structure of artifact for static qualities (e.g., complexity)
	Architecture Analysis: Study fit of artifact into technical IS architecture
	Optimization: Demonstrate inherent optimal properties of artifact or provide optimality bounds on artifact behavior
	Dynamic Analysis: Study artifact in use for dynamic qualities (e.g., performance)
3. Experimental	Controlled Experiment: Study artifact in controlled environment for qualities (e.g., usability)
	Simulation – Execute artifact with artificial data
4. Testing	Functional (Black Box) Testing: Execute artifact interfaces to discover failures and identify defects
	Structural (White Box) Testing: Perform coverage testing of some metric (e.g., execution paths) in the artifact implementation
5. Descriptive	Informed Argument: Use information from the knowledge base (e.g., relevant research) to build a convincing argument for the artifact's utility
	Scenarios: Construct detailed scenarios around the artifact to demonstrate its utility

TABLE 2. DESIGN EVALUATION METHODS (HEVNER ET AL., 2004)

3.3.1 Research Aim and Expected Artefacts

This study aims *"To provide effective support for sustainable transformation of individuals and families by designing and implementing holistic adaptive real-time precise personalised and socially driven persuasive systems."*

To fulfil the vision, this research will propose, design, develop and implement research artefacts as follows:

- Conceptual artefacts: Concepts and definitions of individual and family sustainability should be identified and outlined. The research vision should be discussed, as well. The thesis tries to answer them by discussing interrelationship between life dimensions and values that people pursue. Based on these, the thesis proposes principles that will provide a philosophical and theoretical background for the individual and family sustainability research.
- Procedural artefacts: Sustainable life transformation involves decision-making and action-taking. For this, people need to learn their current situation, then need to know the best ways to transform their lives. Therefore, this thesis proposes a framework of sustainable transformation of individuals and families.

Also, the researcher will study activities, behaviours, and habits from the procedural viewpoint to understand relationships linked among them. This knowledge, why people behave, how they change their behaviours, how habits are formed, and so on, will help the researcher to determine purposes and processes that systems should have to offer features and services for individual and family sustainability. Lastly, the thesis will suggest sustainable transformation processes support individuals and families and system functionalities.

- Technological artefacts: Technologies that can support functionalities required for the sustainable life transformation should be identified and proposed for system design and development. The researcher plans to identify key technologies in terms of purposes and processes that individual and family systems pursue. Also, based on the proposed sustainable transformation processes as a procedural artefact, vital technologies will be discussed and identified. Taking all these purposes, processes, and technologies into account, the researcher will produce system architectures and framework.
- System artefacts: Systems that support the individual and family sustainability should be designed, developed, and implemented. This thesis will focus on designing and implementing systems for measurement, model, shopping, and games. The rationale for these developments is straight forward. People need to measure their activities and behaviours to learn and manage their current situations. The measured activities and behaviours can be modelled holistically to understand better their relationships. This will help people to transform their lives to be sustainable. Through shopping, multiple life aspects (e.g. health, wealth, and life values) can be measured holistically. Also, shopping can be a lens to view and measure family level activity. Lastly, as sustainable transformation is a long journey, strong motivations and persuasive avenues should be considered to make this journey probable. Games are rapidly popularised software that encourages education efficient and effective. After designing and implementing the prototypical system artefacts, the researcher will validate them using seminal evaluation methods.

So far, the thesis has discussed seminal design science research approaches, the proposed research aims and expected artefacts. The researcher decided to adopt and synthesise useful components from the two seminal design science research approaches (Hevner et al., 2004; Nunamaker et al., 1991) and develop an integrated multi-methodological approach for this research.

3.3.2 Integrated Multi-Methodological Approach

By synthesizing seminal approaches, the researcher proposes the integrated multi-methodological approach. The adapted Nunamaker et al.'s multimethodological approach is positioned on top of the Hevner's (2007) Design Science Research Cycles (Figure 28). It means that this research initially follows the three-cycle research approach and at each cycle, the researcher will conduct research by following the Nunamaker et al.'s (1991) multimethodological approach. For example, the researcher starts the research by observing, learning and understanding people, organisations, and technical systems in the application domains then apply valid and relevant knowledge to define concepts, develop artefacts, and experiment those artefacts in the proper contexts for evaluations. Also, systems will be designed, developed, and implemented as proof of concept.

3.3.3 Application of the Proposed Multimethodological Research Framework

Considering methodological and research requirements that have been discussed in earlier sections in this chapter, the researcher instantiates the proposed integrated multi-methodological approach for individual and family sustainability research. All cycles are iterative as Figure 28 illustrates.

- **Relevance Cycle**: From the proposed research approach, the researcher finds answers for vision, individual purposes, processes, mechanisms, and systems from individual and family activity perspective within this research cycle. Therefore, the researcher will ask many "what" and "why" questions. For example, the thesis tries to understand questions like what individual and family sustainability is, why sustainability is important, what factors influence people to behave, why people want to change their lives, and what technologies and systems support sustainable life transformation of individuals and families.

While the research understands the relevant people, organisation, technologies and systems within the application domain, the problems, issues, requirements, and opportunities are identified. Expected outcomes are a definition of individual and family sustainability, individual purposes in life dimensions and values, the relationship between health and sustainability, the understanding of chain reactions for sustainable transformation, keystone habits, shopping and habit processes, and so on.

- **Rigour Cycle**: From the proposed integrated multi-methodological approach, the researcher finds answers and solutions for research principles, individual processes and mechanisms, transformational system purposes, processes, mechanisms, and systems for the individual and family sustainability. Therefore, many "how" questions that seeks conceptual, procedural, technological and system responses are asked for the study. For example, questions like how the research should be guided philosophically; how we form a process for the sustainable transformation; how people can change their behaviour and lives; how system should be designed to support the sustainable life transformation of individuals and families; how system should be organised and working together to deliver functionalities are asked and answered. The research uses existing knowledge, theories, design artefacts and processes to extend to theories and methods, add new experiences and expertise, and create new design artefacts and processes to the design research knowledge base. Expected research artefacts within this cycle are the sustainability principles, sustainable transformation processes, system purposes and processes, system framework and architecture, proof of concept systems, and so forth.
- **Design Cycle**: In this research cycle, conceptual, procedural, technological and system artefacts are iteratively being built and evaluated until it fulfils requirements and refined. All artefacts produced within this cycle should be rigorous to be included in design research knowledge base and tested and used in the application environment.

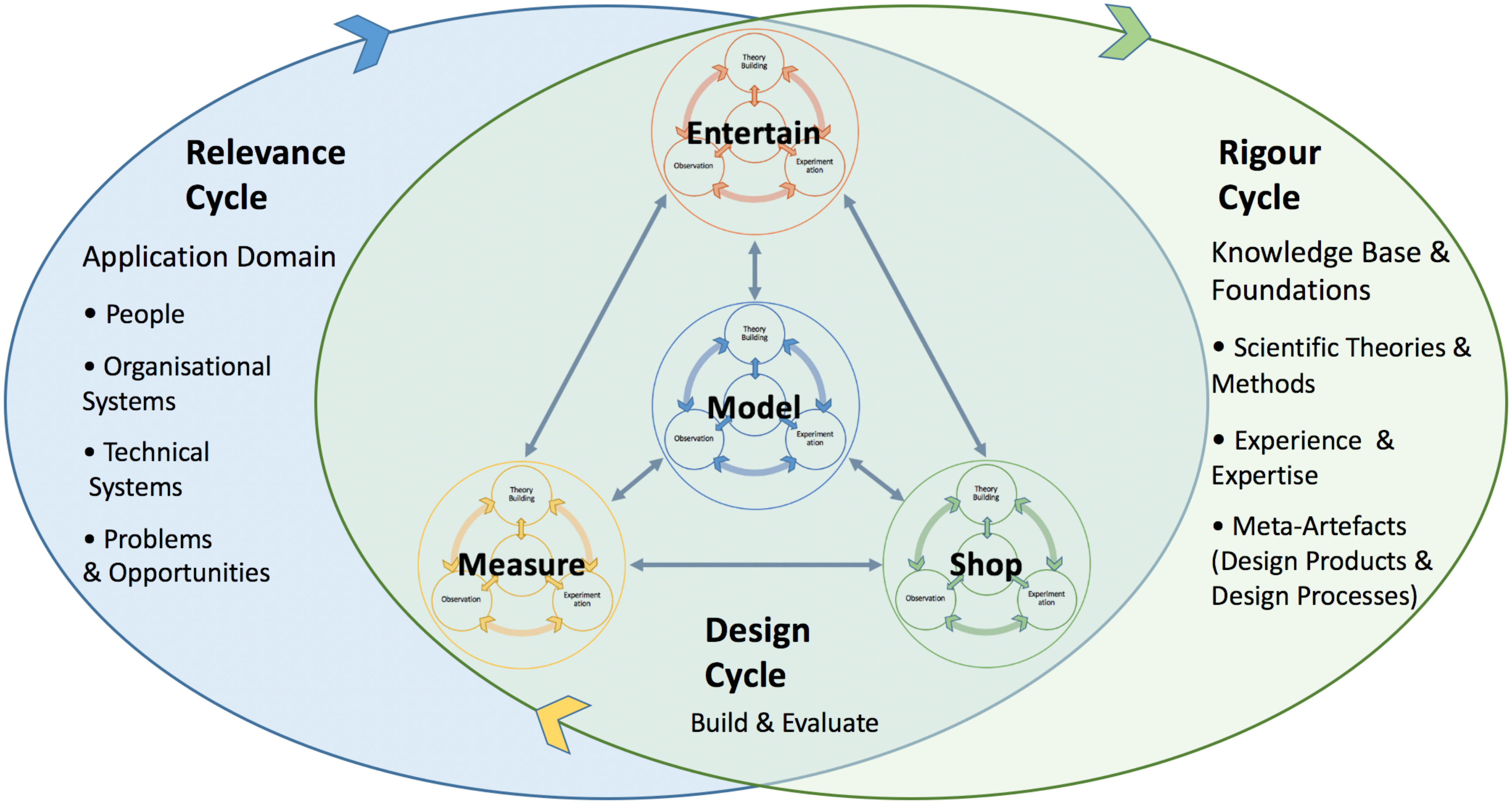


FIGURE 28. INTEGRATED MULTI-METHODOLOGICAL APPROACH, SYNTHESISED FROM (HEVNER ET AL., 2004; HEVNER, 2007; NUNAMAKER, CHEN, & PURDIN, 1990)

Then, four research strategies: observe, theory building, system development, and experiment (evaluation) are conducted within each cycle.

- **Observation**: Cross-disciplinary literature and existing system reviews will be conducted as an observation procedure for this research. In this procedure, the study aims to understand and evaluate 1) individuals and families' behaviours and development processes, 2) existing applications, systems, models, frameworks and architectures, before building a conceptual level of theories. Through the observation procedure, research problems, issues and requirements for sustainable transformation of individuals and families are identified and analysed. This research will conduct the literature review across multiple disciplines, a wide range of technology and system reviews.
- **Theory Building**: Based on the research problems, issues and requirements identified and analysed in the observation procedure, focused literature and existing system reviews will be conducted to develop theories. After further reviews, concepts for the sustainable transformation of individuals and families need to be defined. These concepts then provide a philosophical background for building models, processes and frameworks for the individual and family sustainability and their sustainable transformation.
- **System Development**: Based on the theories built in the theory-building procedure, the research develops Measurement, Shopping, Modelling, and Games as the proof of concepts. These four systems will have a complementary relationship. All systems are mutually feeding data and forming interdependency relationship models with each other. Measurement will feed individual's activity data; Shopping will feed family's multi-dimensional shopping data to all systems. Based on these data, Modelling models relevant factors and simulates them with different scenarios and these models can be used to create Games to teach individuals and families to be more sustainable.
- **Experiment (Evaluation)**: With the background knowledge of Design Evaluation Methods (Table 2) which was suggested by Hevner et al. (2004), evaluations of all artefacts will be carried out. The evaluation will take place iteratively while research progresses and use various methods to guarantee the quality of research outcomes.

Furthermore, this thesis follows the V-model (Sheffield, 2005) to validate during its journey. As the V-model adopts the general concept of 'top-down' design and 'bottom-up' implementation, it can be applied to validate this thesis by testing the strength of linkage between chapters and artefacts (Figure 29).

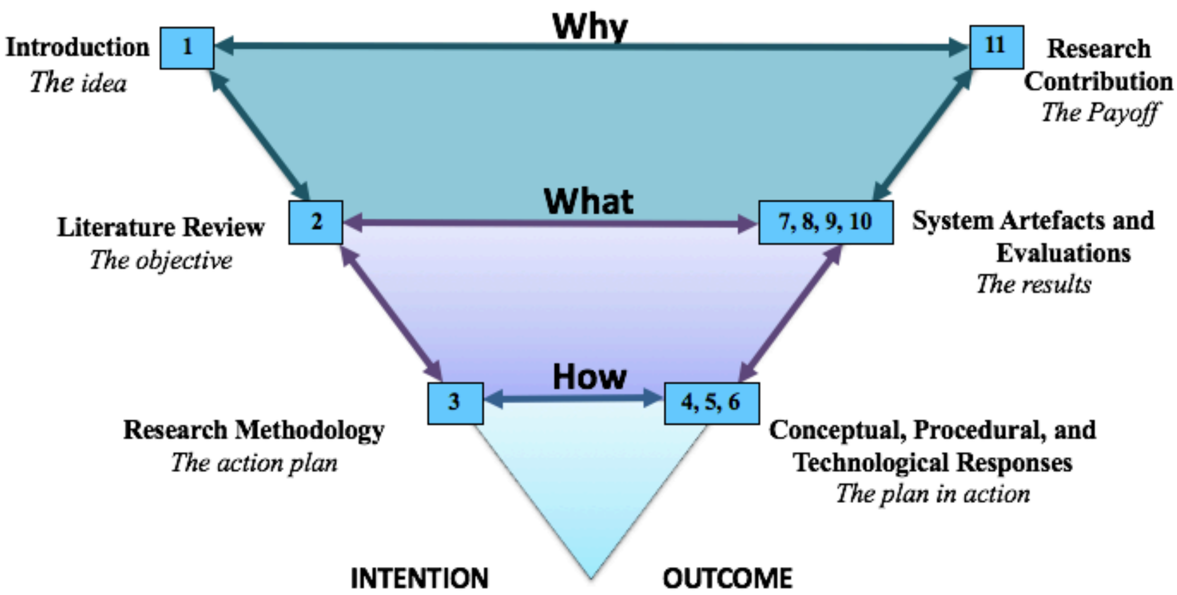


FIGURE 29. THESIS STRUCTURE WITH V-MODEL, SYNTHESISED FROM (SHEFFIELD, 2005)

The introduction chapter explains why pursuing this research topic adds values to the knowledge base (*the idea*). Literature Review helps us to identify the problems, issues, and requirements which in turn motivates our research objectives (*the objective*). Research methodology lets us plan how the research should be conducted (*the action plan*). Then the understanding of conceptual, procedural, and technological responses provides a constructive foundation for implementing system artefacts explained in 3.3.1 (*the plan in action*). Implemented system artefacts and evaluation are the results of this thesis and provide evidence that the researcher has fulfilled the research objectives (*the results*). The conclusion will explain what the payoff from this thesis is (*the payoff*).

As such, this thesis has examined the *intention* of the research topic so far. Now the thesis will conduct the individual and family sustainability study (*outcome*) based on the proposed integrated multi-methodological approach (Sheffield, 2005, p. 96, Figure 6). The following chapters will introduce the outcomes of the thesis.

4 Conceptual Responses for Sustainable Transformation of Individuals and Families

When people hear the term sustainability, it conjures up images like climate change, environmental issues, and conservation. However, the sustainability concept is broader than environmental concerns: it includes social and economic aspects as well (Elkington, 2004). Unfortunately, the societal angle is still new in mainstream sustainability. Most endeavours for achieving sustainability are being tried at mostly the government, organisation, and supply chain levels.

The core of social sustainability is all about people. Individuals and families are the foundation of our society. They are the main decision-makers and actors for overall sustainability. As discussed in section 1.3, this research aims to provide solutions for the sustainable transformation of individuals and families. Thus, its focus is on the social aspects of sustainability, especially at the individual and family levels. Obviously all the environmental and economic dimensions of sustainability also apply to individuals and families.

In this chapter, this research will ask key questions stated below to set the scope, define key concepts, and introduce our philosophical research approach to individual and family sustainability.

- What is individual and family sustainability?
- Why does sustainability matter to individuals, families, and society?
- What principles can guide people to achieve individual and family sustainability?

To answer these questions, this chapter will discuss topics below. The relationships between sections are illustrated in Figure 30.

- Discuss concepts and definitions individuals, families, and sustainability in 4.1.
    - Define individual and family sustainability and sustainable lifestyles and discuss why individuals and families should be studied together in 4.1.1.
    - Discuss the life purposes that individuals and families pursue within life dimensions and values that shape human life in 4.1.2.

- Based on these conversations, the thesis proposes definitions of individual and family sustainability in 4.1.3. Also, this research will explain why sustainability is important to people by linking it with health in 4.1.4.

- Introduce the SSHARRPPP approach with the overarching research vision in 4.2 and following subsections.

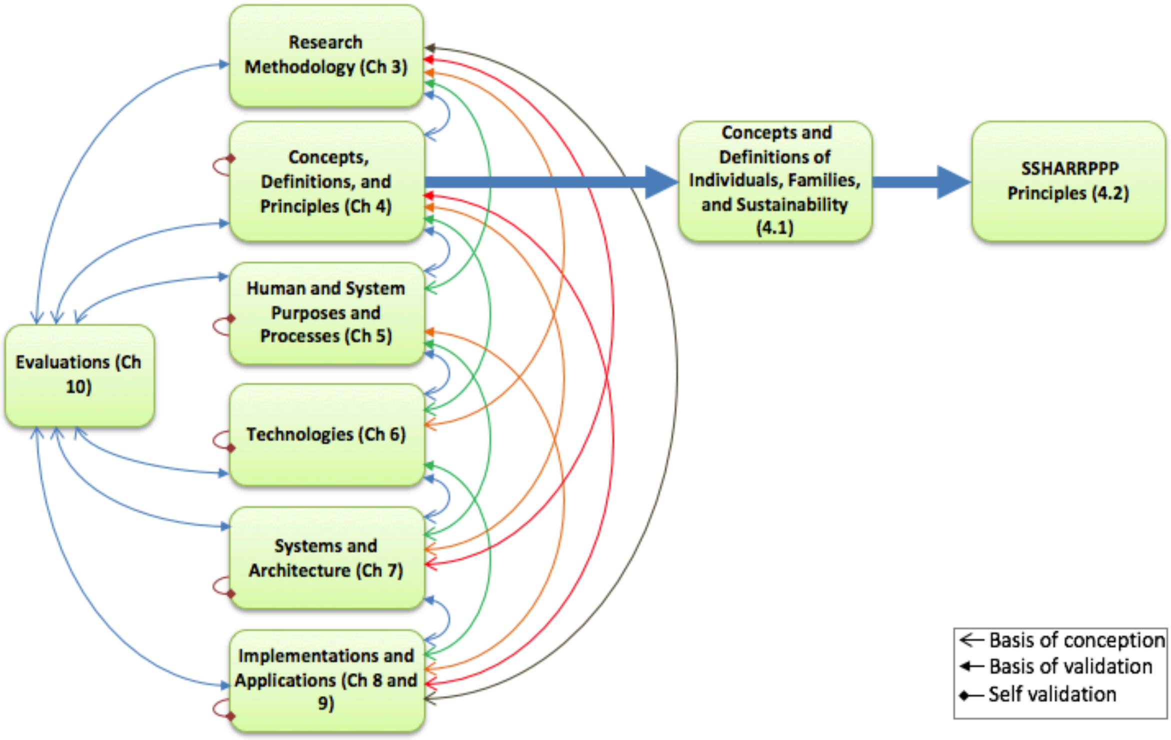


FIGURE 30. CHAPTER 4 STRUCTURE AND RELATIONSHIPS

4.1 Concepts and Definitions

To find ways of making individuals and families sustainable, it is necessary to understand what are meant by individual and family sustainability and sustainable lifestyles. However, there is no conventional definition of individual and family sustainability, which can be adopted as the study foundation. Therefore, the thesis needs to define these concepts based on a broad range of literature and domains of disciplines.

In what follows, this research will propose definitions of individual and family sustainability and sustainable lifestyle by discussing relating concepts and justifications.

4.1.1 Individuals, Families, and Sustainability

Individuals and families are the primary players who make fundamental changes to the society. An individual is a family member and families influence an individual's decision making and actions by providing and sharing material substances, mutual cares and emotional and cultural ties (Schneider, 1984). Also, individuals within a family form the tightest intimate relationship and often share similar worldviews.

Even in single-person households we can observe similar intimate virtual relationships through online social network interactions. Such interactions are generally with like-minded people and each influences others through social media communications (Cha, 2014). This concept is supported by the Māori family concept of Whanau (Māori Dictionary, 2019). Whanau is "*an extended family, family group, a familiar term of address to a number of people – the primary economic unit of traditional Māori society. In the modern context, the term is sometimes used to include friends who may not have any kinship ties to other members.*"

As such, individuals and families are the basic units of society, and their sustainability is equally important as the organisation, national institution, corporate enterprise, and government level sustainability. In this sense, there is a growing interest in individual and family sustainability and their significant roles in achieving overall sustainability have been acknowledged (Kates et al., 2005a).

Achieving sustainable life does not only make individuals and families well and happy, but also makes the entire society sustainable and healthy. This is because people try to achieve their life purposes and wellbeing by devoting themselves in various life dimensions. In the following section, the thesis discusses life dimensions and values and why people need to balance and harmonise the life dimensions for achieving sustainability.

4.1.2 Life dimensions, Values, and Sustainability

Habermas's (1984) posited that the world we exist in is multidimensional. Initially, he defined the world into three sub-worlds: (1) the material world, (2) the personal world, and (3) the social world. The material world is the world of physical facts and measurable elements. The personal world is an internal part of each individual. For example, individual thoughts, emotions, preferences, values, and beliefs are in this world. The social world is where people interact with each other. In this world, internal thoughts and values from the personal world can be expressed.

The subjective wellbeing (SWB) researchers also look at our world multidimensional but identify it in more detail. Commonly identified dimensions for human wellbeing are health, finance, social and family relationships, self-worth, work and career, leisure-time, education, community environment, and safety (Loewe, Bagherzadeh, Araya-Castillo, Thieme, & Batista-Foguet, 2014). These life dimensions can be grouped into three pillars of sustainability (environmental, economic, and societal) and matched with the 17 sustainable development goals. In other words, the life dimensions are areas that people can achieve both personal wellbeing and the goals of sustainability.

To show linkages between life dimensions and economic, social, and ecological aspects of sustainability with the 17 SDGs, the research has adopted Rockström and Sukhdev (2016)'s wedding cake shape framework. Individuals and families are predominantly impacted by the social aspects of sustainability (SDGs 1, 2, 3, 4, 5, 7, 11, 16). They are also impacted by the economic aspects of sustainability (SDGs 8, 10, 12). Individuals and families can impact the biosphere significantly through their actions or lack of action (SDGs 6, 13, 14, 15). And reciprocally their actions or lack of action in these SDGs (6, 13, 14, 15) can significantly impact their quality of life. As such, individuals' and families' actions make significant impact on all three dimensions of sustainability. Therefore, individual and family sustainability is core to all aspects of sustainability (Figure 31).

The needs of individual and family sustainability can be understood by considering human values. As it is discussed in chapter 2.2, personal values cover a broad spectrum of life. To understand, what values drive certain actions for which sustainability area, life values can be discussed under the tripartite dimensions of sustainability.

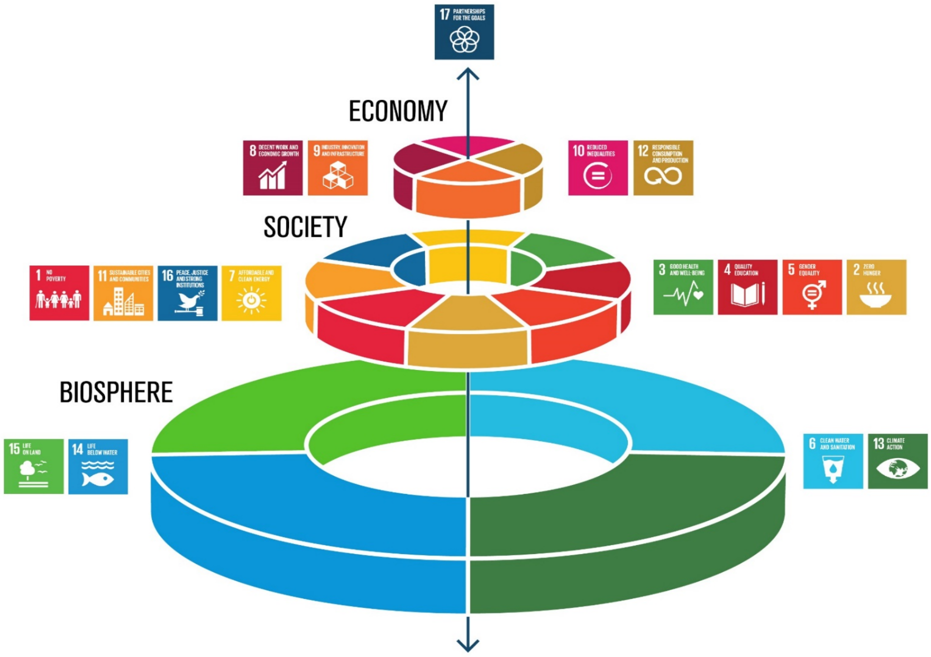


FIGURE 31. SUSTAINABILITY FRAMEWORK (ROCKSTRÖM & SUKHDEV, 2016)

Economic values are primarily maximising and attaining financial ends. Decisions and actions are fully guided by rational self-interest (Marcus, MacDonald, & Sulsky, 2015). They are related to financial objectives and self-oriented motivations. These drive people to be in a position of less inequality and decent employment to make economic growth. Social values often have altruistic characteristics and are related to achieving, maintaining, and improving individual and collective human wellbeing. Therefore, people try to make an inclusive and sustainable society by providing better health, wealth, education and communities. Environmental values are related to achieving environmental integrity, such as reducing wastes, minimising environmental impacts, and maintaining biophysical systems (Gibson, 2001). These values make people protecting the ecological environment for sustainable development.

So far, the thesis examined multiple concepts related to define individual and family sustainability. In the following section, the thesis proposes a definition of individual and family sustainability.

4.1.3 Definition of Individual and Family Sustainability

To propose a definition, this research has examined definitions and concepts of sustainability from various organisations and researchers like the Brundtland Commission (World Commission on Environment and Development, 1987), the National Research Council (1999), Hancock (1993) as well as the educational orientation taken by Pappas et al. (2013), and PRME (2018).

The Brundtland Commission defined sustainable development as "*Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*."(World Commission on Environment and Development, 1987). This definition emphasises that human activities should be harmonised with the ecological circumstances to generate a new era of economic growth. This growth can be created through technological innovation and social organisations by considering both our future as well as present needs

After, the National Research Council brought a detailed focus on meaning of sustainable development. In their report, *Our Common Journey: A transition toward sustainability* (1999), what is to be sustained, what is to be developed, the types of links that should hold between the entities to be sustained and the entities to be developed, and the extent of the future envisioned were analysed and discussed. The National Research Council's focus was straightforward. Sustainable Development only could be achieved by a form of collective actions that derive from the aggregated behaviours and actions of organisations, national institutions, corporate enterprises, and governments. And these actions should be carried out by individuals and families.

Hancock (1993) tried to convert the sustainable development focus from mere economic development to the relationship between health, social, environmental and economic wellbeing. He developed a health model at the community level to advocate his view. Further, Kickbusch (2010) argues that the three dimensions of sustainable development can be achieve together by keeping healthy and sustainable communities at the core (Figure 32).

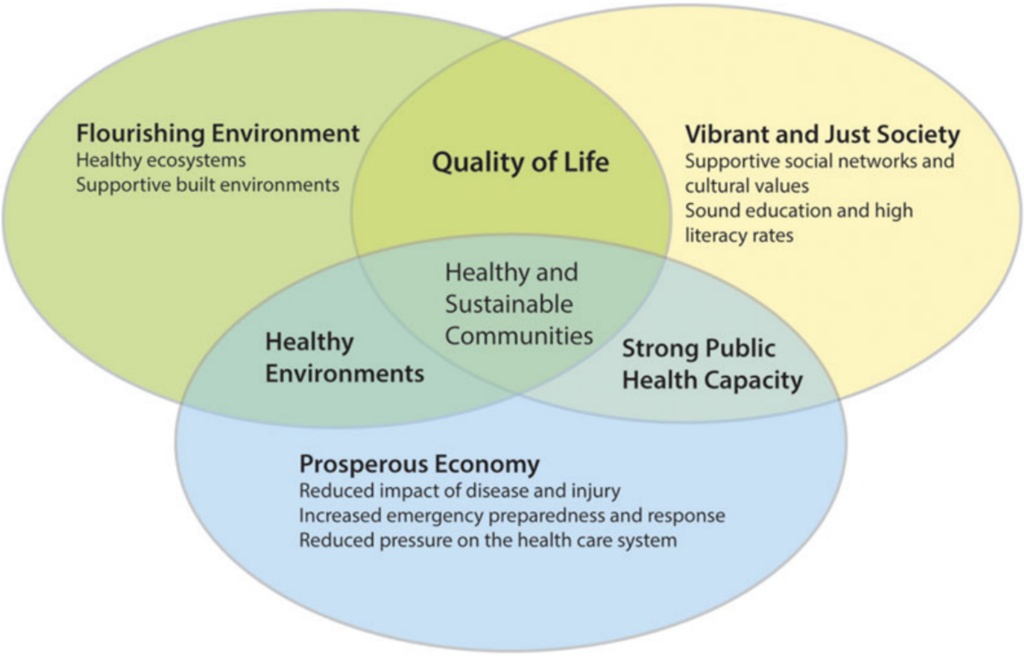


FIGURE 32. THE MODEL OF THE 'RELATIONSHIP – PUBLIC HEALTH AND SUSTAINABLE DEVELOPMENT' (KICKBUSCH, 2010)

This harmonised viewpoint was also taken in the educational orientation of sustainability. Pappas et al. (2013) argued that a sustainable society could grow with respect to the quality of life as well as keeping environmental resources and economic development. Therefore, they hold an opinion that the individual level of sustainability should be taught to the young generation. In teaching sustainability at the tertiary level, the Principles for Responsible Management Education (PRME) is a good example. PRME is a responsible management education platform which follows a recommendation by academic stakeholders of the UN Global Compact (PRME, 2018).

After reviewing a broad range of literature regarding relevant disciplines like sustainable development, subjective wellbeing, human development, and behavioural science, this research proposes a concept of individual and family sustainability. That is:

*"**Individual and family sustainability** is a status and an ability that enable us to sustain and balance various dimensions in life, including ecological, social, cultural, economic and health aspects, while we are taking actions for developing internal and external growth in various life dimensions, such as physical, emotional, social, philosophical, and intellectual abilities."*

This definition is not only for the pursuit of individual and family wellbeing but also co-prosperity of all levels in our society and planet. Transforming people's lifestyle involves life dimensions. Therefore, it will eventually contribute to the ultimate sustainability for economy, society, environment, and beyond. People can reach individual and family sustainability through pursuing a sustainable lifestyle. For the concept of a sustainable lifestyle, this research has employed a definition from the European social platform SPREAD.

*"**Sustainable lifestyles** are patterns of action and consumption, used by people to affiliate and differentiate themselves from others, which: meet basic needs, provide a better quality of life, minimise the use of natural resources and emissions of waste and pollutants over the lifecycle, and do not jeopardise the needs of future generations. Sustainable lifestyles reflect specific cultural, natural, economic and social heritage of each society"* (Backhaus, Breukers, Paukovic, Mourik, & Mont, 2011, p.9).

So far, the thesis has proposed the definition of individual and family sustainability and discussed what are involving values and dimensions to understand why it matters to people. In the next section, the thesis will explain the suggested research principles for conceptualising, designing, and implementing concepts, models, processes, frameworks, and systems to answer how individual and family sustainability can be achieved.

4.2 SSHARRPPP Principles

This research has developed a sustainability approach; so-called "SSHARRPPP". SSHARRPPP stands for "Sustainable Transformation" through "Social", "Holistic", "Adaptive", "Real & Virtual worlds", "Real-time", "Persuasive", "Personalised", and "Precise" principles, processes, technologies, and systems (Figure 33).

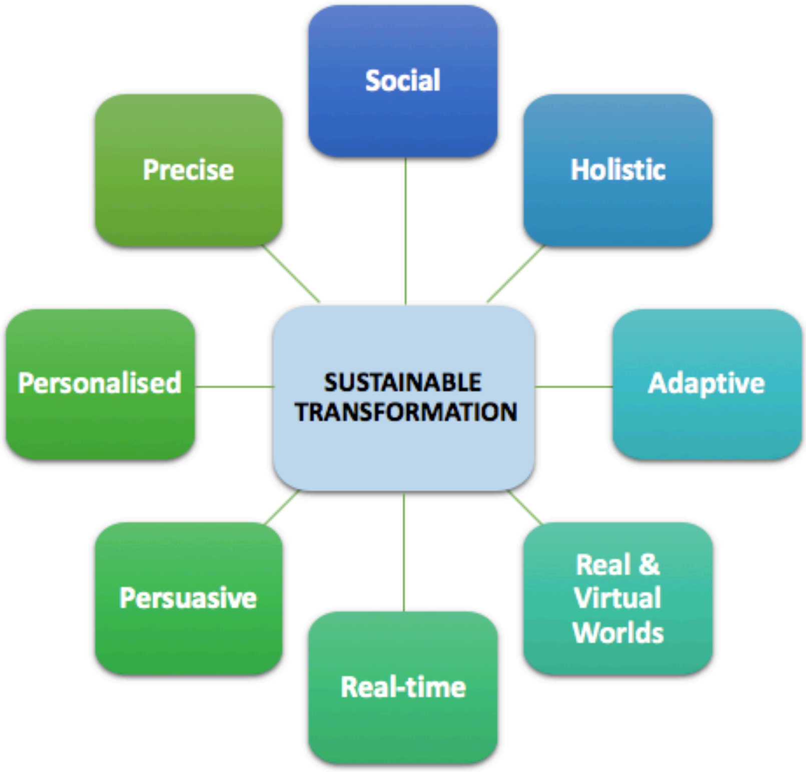


FIGURE 33. SSHARRPPP PRINCIPLES, EXTENDED FROM THE AUTHORS' CREATION (CHUNG & SUNDARAM, 2018)

The reason to choose nine principles for this study is as follows. **Sustainable** transformation can only occur when people approach individual and family sustainability from a **holistic** perspective on all life dimensions. To make sustainable transformation happens, people need to measure various facets of life to manage their actions and behaviours. These actions need to be measured in **real-time** as well as **precise**. Also, these measurements, in turn, instantiate the models that help people to **adapt** and ultimately transform. While models can produce information for changing and transforming, individual and family sustainability can be enhanced and accelerated through **personalisation, social mechanisms**, and **persuasion** both in the **real and virtual realms**.

Individuals and families need to transform their "as-is" to "to-be" life under the vision of sustainable transformation. Each concept from SSHARRPPP provides mechanisms and practices to achieve this vision, so people can transform their current lives to be in the ideal situations (e.g. unhealthy lifestyles to healthy and sustainable lifestyles).

Also, one of the key objectives of this research is to answer how systems should be designed and implemented to support individual and family sustainability. Since the task involves multi-disciplines such as information systems/information technology, computer science, psychology, behavioural science, and health science, the SSHARRPPP principles can guide us to organise a various forms of knowledge (Crosby, Salazar, & DiClemente, 2013) to design, implement and evaluate individual and family sustainability systems.

4.2.1 Sustainable Transformation

The vision is to transform individuals and families' lives sustainably. Individuals and families are at the heart of our society and key people to make real changes for the sustainable community, organisations and society. As it is discussed earlier, sustainability can be achieved through having a sustainable lifestyle. Lifestyles indicate social positions and show true-life values to others, such as financial ability, education, and attitudes. How people think, act, and live form the fundamental shape of society. It means that most of lifestyle-driven behaviours and attitudes are making an impact on various life dimensions, which are closely linked to broader categories of sustainability.

4.2.2 Holistic

To carry out the research vision, a holistic perspective that spans multiple life dimensions is required. However, a lack of holistic approach is one of the core issues that hinders achieving sustainable development. A systemic literature review found that sustainability policies often failed because interrelated structural causes are often approached in silo fashion (Howes et al., 2017). For example, a disconnection between economic markets and environmental sustainability resulted in market failure (Dutta, Lawson, & Marcinko, 2013) and poor economic performance limits the human and material resources available to deal with waste disposal, water supply, and pollution problems in developing countries (Boadi, Kuitunen, Raheem, & Hanninen, 2005).

This issue applies to individual and family sustainability too. The boundary between each life dimension is generally interdependent (Hall & Richter, 1988), and each life dimension influences each other. Hence, they often establish causal relationships. For instance, adopting healthy lifestyles, such as commuting to work by cycling, or eating fresh local food can lower medical expenditure, increase daily productivity, promote ecological production, and eventually contribute to people's environmental wellbeing (Arora, 2001; Finkelstein et al., 2003; Riedel et al., 2001). However, people often focus on one life dimension and neglect to see the overall benefits of the holistic approach. For instance, the economic value is overly emphasised when it comes to purchasing something. Fast food is a clear example. In the short term, fast food can help saving money and time. However, this low-quality food consumption can cause many health issues. In the long run, fast food can increase medical costs and hurt performance and productivity at work. Thus, the holistic approach is essential for transforming life sustainably and systems for individual and family sustainability should be designed and implemented to understand holistic interrelationships of life dimensions.

4.2.3 Real-time

Sustainable transformation does not take place in a vacuum. From the latency perspective, real-time data collection and processing provide a foundation for the sustainable life transformation of individuals and families. Firstly, it reduces the data latency by helping people to understand the current situation with little or no latency (Bentley & Tollmar, 2013). For example, a continuous glucose monitor helps diabetic patients know their current health condition based on scientific data, rather than gut feeling. Secondly, it reduces analysis latency (Alfian et al., 2018). Real-time data is captured via various devices and sensors. These devices and sensors collect different dimensional data. Combining various dimensional data in real-time delivers much meaningful information to users. Continuing with the previous example, combining glucose level data and exercise data explains whether exercise works on glucose level or not. Then thirdly, real-time data helps people making effective decisions and ratify the current situation by suggesting recommendations at the right time. If the glucose level is too high, diabetics can make quick decisions to lower their glucose level. Furthermore, if trending historical data shows a pattern of lowering glucose level after exercise, then a real-time recommendation can reduce the decision latency by suggesting exercise when the glucose level is high. As such, real-time data and information that is available at the right time and right place, support users to make quick and effective decisions.

4.2.4 Precise

The precision angle is a well-established concept in the digital health industry. There is a variation of terminology between precision medicine and precision health: precision medicine focuses on clinical contributions, whereas the notion of precision health is broader and focuses on individual wellbeing (Mirza, Mirza, Chung, & Sundaram, 2016). In the simplest explanation, the precision concept represents the meaning of delivering tailored feedback (or interventions) to the right person at the right time. Due to the uniqueness of lifestyle each person has, precise data, information, feedback, and interventions are important to transform life.

4.2.5 Adaptive

According to the Oxford Dictionaries (2018), adaptability means “the quality of being able to adjust to new conditions.” This definition implies that adapting is finding ways to do things in response to the changing circumstances in all areas of our lives.

During the lifetime, people are constantly experiencing multiple life events (Holmes & Rahe, 1967), and people often face to change the way they live accordingly. Having said that, making growth in life and finding a lifestyle that works for people are endless iterative processes. Therefore, the research should adopt the adaptability concept in individual and family sustainability to develop dynamic capabilities that can respond quickly to new challenges, situations and opportunities to achieve sustainability in an increasingly turbulent world (Reeves, Haanaes, Love, & Levin, 2012). For the sustainable transformation of individual and family, the adaptability concept can be discussed in two perspectives: individual and family perspective and system perspective.

Individuals and families should be adaptive to new lifestyles. Lifestyles that fit their circumstances can be found by repeating trial and error processes and forming new habits. Adaptive individuals and families are both stable and dynamic at the same time (Pappas et al., 2013). With a clear sustainability vision, they are not only sustaining their fundamental life values and health but also being agile to learn skills and knowledge to thrive in various life dimensions. Ironically, individuals and families can have unique opportunities to improve their lives when they are facing the most influential and important life-changing events. For example, many people realise how health is invaluable when they are experiencing illnesses, or why a saving plan is a sensible and important life strategy when they are experiencing financial difficulties. Adaptive individuals and families embrace these challenges as a new development agenda and recognise them as drivers of sustainable life.

From a system perspective, systems should be able to learn and adapt to a user's unique situations and preferences to suggest better life decisions. For example, shopping systems for individual and family sustainability should not recommend highly refined carbohydrate foods to diabetics, even if the economic concern is one of their shopping preferences. Also, systems should be able to support the user's journey of lifestyle adaptation and flexible enough to take most of the user's needs and requirements into recommendation and decision support considerations. To this end, models, processes, and frameworks of the systems need be designed and proposed based on how people behave, make decisions, and change. In this way, systems for individual and family sustainability can lower a barrier of users' resistance to adapting themselves into new lifestyles and deliver the most effective services to the users.

4.2.6 Personalised

Oxford Dictionaries (2019) defines personalisation as *"an action of designing and producing something to meet someone's individual requirements."* However, the notion of personalisation can be explored beyond it in supporting a sustainable life transformation. Personalisation is making or changing products and services to meet personal preferences. Therefore, it helps individuals and families to consume the product or service comfortably. For example, if an individual need to consume certain nutrients, personalisation recommends foods that individuals prefer, rather than randomly selected food. As such, personalisation contributes to people adopting healthy lifestyles in easier and pleasant ways. Therefore, understanding a user's preferences and being able to provide personalised services are essential system features to support sustainable transformation.

4.2.7 Social

The reason of focusing on the social angle in the individual and family sustainability is because humans are social beings and hold social values (Fiske, 2014). Humans share emotions unconsciously and engage together better when they are in a similar situation. Although individuals have unique personalities, people are easily influenced by social situations. Life is affected by social ties and many studies report relationship between social ties and our lives. For example, Lett et al. (2007) found that there was a positive link between high social supports and increasing life expectancy. Kiecolt-Glaser, McGuire, Robles, and Glaser (2002) reported that negative emotions derived from social isolation damaged our immune system.

Also, social psychology advocates that social situations can encourage people to change behaviours. Fiske (2014) argues that people can use peer pressure to make others act in specific ways. To prove this, she experiments in every semester asking her class to fold a paper based on her instruction. Every time, students comply without asking reasons why. She argues that students follow the request not only because they are asked to do so, but also everyone else does. Also, she makes a point that hardly an individual would comply it if all other students refuse to do so. This suggests that people can use peer pressure in a positive way to change individuals and families' lifestyles to be healthy.

As various psychological and medical studies imply, our characteristics as social beings can be used effectively to motivate behavioural changes. Therefore, this research takes a social angle as principles to find effective ways to help individuals and families achieve sustainability, and ultimately contribute our society being sustainable.

4.2.8 Persuasive

Sustainable life transformation is the most important challenge in individual and family sustainability; thus, how to persuade people to make real behaviour changes and draw actions from them should be addressed in this research. Since persuasive technology immersed in our everyday life, people's attitudes and behaviours can be altered by system interventions. In e-commerce, companies use the recommendation systems to promote customer purchase, and in healthcare preventive systems are used to treat patients with an empathic approach or to correct their health-related behaviours (Fogg, 2003).

When it comes to persuasion, information systems can play a significant role as a persuader. Firstly, information systems are persistent and consistent. They persistently remind users to take a decision or action with consistent information. This persistency distinctively increases the chances of changing behaviours. Secondly, users can remain anonymous when their behaviour changes should be made in sensitive areas, such as sexual behaviour, physical and mental health issues, or substance abuse. People can honestly disclose their problems and take it as the first step to solve those issues when there is no human judgement involved. Thirdly, measured and collected data can provide insights into unknown behaviours, issues, or activities. Many information systems use data analytics to understand the in-depth meaning of behaviours and activities. Fourthly, information systems can use many modalities, such as audio, video, graphics, games, and augmentation and virtual reality. In addition, technology can make synergistic effects by integrating various modalities to increase the effective persuasive impact. For instance, Alcohol 101 Plus™ provides interactive games and a virtual bar which highlight realistic drinking issues and challenges to educate college students about responsible alcohol consumption (Foundation for Advancing Alcohol Responsibility, n.d.). Lastly, persuasive systems are ubiquitous. The embedded interactive sensors allow systems to intervene at the right time and place. This ubiquity gives greater persuasive power. A simple example is the walk reminder from health monitoring devices like Fitbit (Prasad, Sorber, Stablein, Anthony, & Kotz, 2012).

One of the best ways to persuade individuals and families to change behaviours without using coercion or deception is by providing personalised recommendations based on precise information. In this research, the persuasive angle is sought in both procedural and technological approaches when systems are implemented.

4.2.9 Real and Virtual Worlds

The real and virtual worlds view is one of the fundamental concepts of this research. This research tries to pipe the real-world into the virtual world, because the virtual world can affect real-world behaviour. Therefore, an intertwined environment is required to be implemented for individuals and families to transform their lives.

Individual and family sustainability is involved in various interaction mechanisms and different modalities – from pure virtual, to the completely real, and a plethora of combinations in between the two. The systems collect real-world behaviour and activity data and then use the various mechanism such as benchmarks and gamification to change users' behaviours and attitudes. In the virtual world, systems can educate people about the need to have sustainable life and how by providing relevant scenarios and simulations based on the real-world data. The two worlds should co-exist together and provide interventions to transform the lifestyles of individuals and families.

The interactions between two worlds help people to transform lives better. Individuals and families can adapt their real-world lifestyle by trying out things learned in the virtual world. While people are adapting themselves to be sustainable, educational interventions can be given as well. An effective mechanism is provided when the two worlds are connected seamlessly and ultimately support the sustainable transformation of individual and family in the real world.

4.3 Summary

Individual and family sustainability is not only status but also an ability to sustain and balance their lives. How people live and what they decide can have fundamental impacts on society. Therefore, individuals and families should not be neglected in the sustainability discussion. Their roles and their contributions make vital changes for societal sustainability as they are equally important as businesses, organisations, and countries. Having said that, transforming individuals and families' lives to be sustainable is an important task for overall sustainability. The 17 SDGs are closely linked with life dimensions and people try to achieve physical, emotional, financial, and environmental wellbeing within these dimensions.

Although, the scopes of life dimensions can be extremely broad as each individual and family can weigh life dimensions differently due to their unique circumstances

(Hofstede, Hofstede, & Minkov, 2010; Kim & Hakhoe, 1994), life values guide the ways to attain overall wellbeing. Health is the most important life dimension and value that can hold different needs and requirements together and make sustainable life transformation possible.

For the systemic progression on individual and family sustainability, this research has proposed SSHARRPPP principles to guide the conceptual, procedural, technological, and system development. Each angle in the SSHARRPPP principles will set the borderlines for this research and provide its unique viewpoint to understand relevant theories, develop processes and models, propose appropriate technologies, and implement systems for individual and family sustainability. In the following chapters, SSHARRPPP principles will be used as a backbone of the research that holds all concepts, processes, technologies, and systems coherently.

5 Procedural Responses for Sustainable Transformation of Individuals and Families

Human behaviours are often tied to one another. When people make a change to one behaviour, it causes a shift in related behaviours. Therefore, changing key behaviours has the potential to significantly transform someone's life. To support a sustainable life transformation for this research, it is imperative to understand human behaviours and habits from a procedural perspective.

Therefore, this research will ask the following questions in this chapter:

- What are the effective ways to transform people's lives and what are the main mechanisms that make transformation happened?
- What are the system purposes and processes that can support sustainable transformation of individuals and families?
- What processes need to be used to achieve sustainable life transformation of individual and family?

To answer these questions, this chapter will discuss human and systems purposes and processes and how together they inform sustainable transformation processes (Figure 34):

- In 5.1, individual and family purposes and processes are discussed in detail to:
  - Propose the sustainable transformation framework – education, prevention, and reversion.
  - Understand chain reactions which make sustainable transformation possible.
  - Identify key activities that create chain reactions. Physiological activities and shopping process are chosen and used in this study.
- In 5.2, purposes and processes that systems need to support for sustainable transformation are discussed. In this section, the thesis will propose and explain system purposes and processes at a higher level.
- In 5.3, the thesis will propose sustainable transformation processes based on the discussions in 5.1 and 5.2.

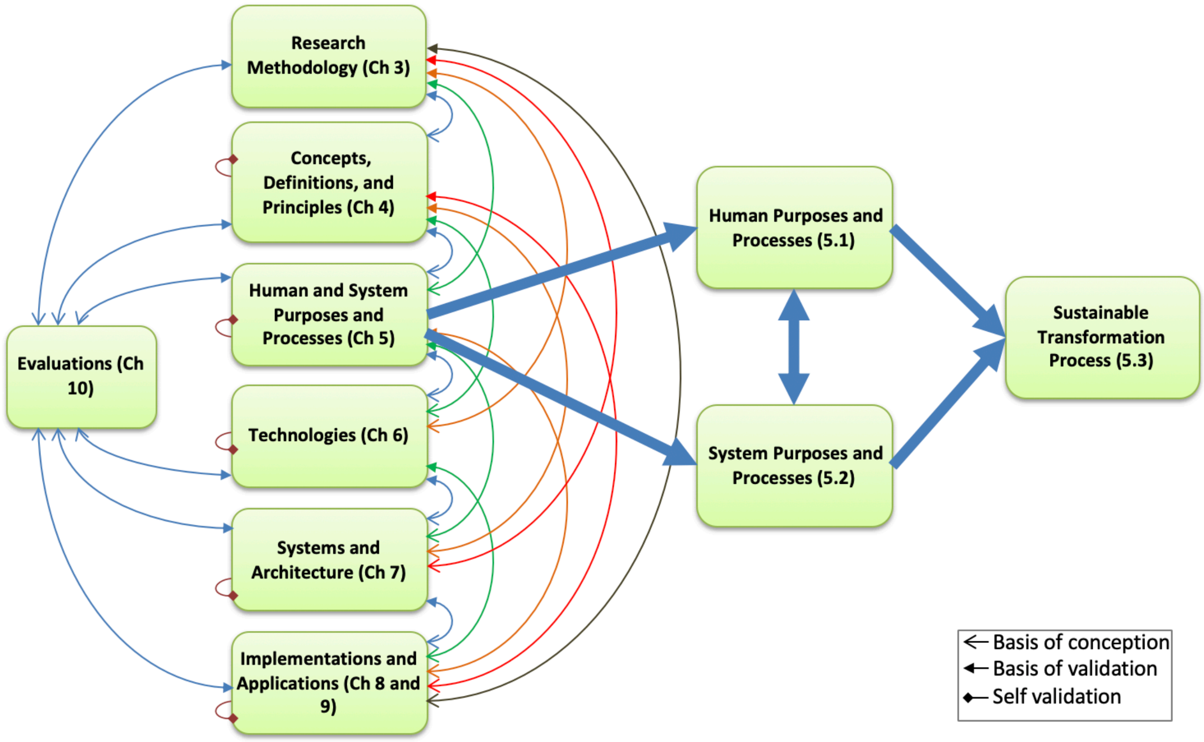


FIGURE 34. CHAPTER 5 STRUCTURE AND RELATIONSHIPS

5.1 Individual and Family Processes

People participate in various processes in their lives. Some are routinely performed daily activities, and some are occasional ones. Through these processes, people form their unique lifestyles (Gaudet, 2014). Also, some activities are beneficial, and some are undesirable based on life goals and purposes that people pursue. Hence, people try to transform their lives favourably and sustainably by keeping beneficial activities and changing undesirable ones. In this way, people can achieve their life goals and purposes. Therefore, identifying appropriate activities that help to achieve sustainable transformation is essentially required for this research.

In the following section, the thesis will discuss vital activities for achieving sustainable transformation by proposing a sustainable transformation framework.

5.1.1 Sustainable Transformation Framework

Sustainable transformation can happen when people improve their lives by performing appropriate activities, changing undesirable behaviours, and forming positive habits. In section 2.3.1.3, the thesis studied learning processes in order to understand how people change their behaviours and which processes help people to be a better decision-maker. Through learning, people can acquire information, knowledge, and wisdom to change activities, behaviours, attitudes, and habits (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010). For example, people can adjust or change their attitudes and behaviours with applicable information and knowledge if they learn about their current situations and the best practices to get their desired results. In this regard, education is an initial and collective approach to achieving sustainable transformation.

Education also can result in prevention or reversion of undesirable conditions. In an example from diabetes, a *prevention level* of education can increase the effectiveness of behaviour changes to pre-diabetics (Concert, Burke, Eusebio, Slavin, & Shortridge-Baggett, 2012; Youngs, Gillibrand, & Phillips, 2016). Likewise, a *reversion level* of education can benefit a diabetic patient's health outcomes. Studies found that educational and behavioural interventions in patient's diet have resulted in modest improvements in glycaemic control; some patients' glucose level has changed back to normal (Gary, Genkinger, Guallar, Peyrot, & Brancati, 2003; Gibbs, 2019).

Prevention and reversion also can lead to education. When people try to prevent or reverse undesirable situations, people can learn more and better about themselves as they get to know what works for them and what does not. This mutual interaction between education, prevention, and reversion makes people achieve sustainable transformation eventually. Figure 35 is the sustainable transformation framework to illustrate how education, prevention, and reversions are interrelated and mutually supporting sustainable transformation.

In the following section, the thesis will discuss sustainable transformation within the context of human activities and how the interrelationship of these activities can make sustainable transformation possible.

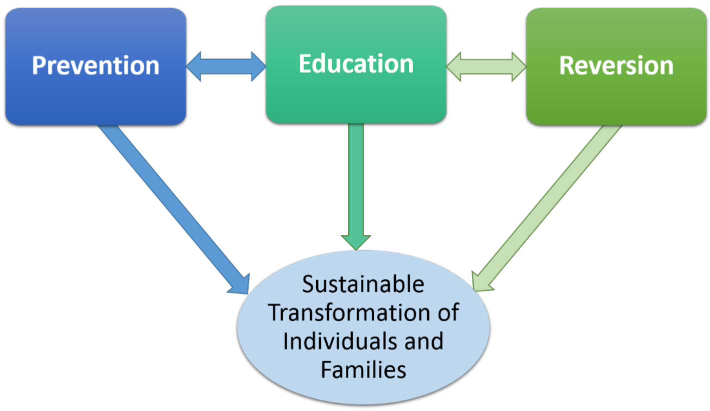


FIGURE 35. SUSTAINABLE TRANSFORMATION FRAMEWORK, ADAPTED FROM THE AUTHORS' CREATION (CHUNG & SUNDARAM, 2018)

5.1.2 Chain Reactions for Sustainable Transformation

Sustainable transformation of life can be an overwhelming task. However, many scholars of behavioural science and practitioners suggest that making a small behaviour change can help make it happen (Clear, 2018; Duhigg, 2012; Fogg, 2019). This is because our behaviours are mutually interrelated, which in turn cause chain reactions (also known as "small wins") (Weick, 1984). A chain reaction means that one behaviour can activate changes in other subsequent behaviours. For example, a study found that decreasing sedentary leisure time each day resulted in improving the participants' diet habits. It is because a less sedentary lifestyle naturally reduced mindless eating as a side effect (Spring et al., 2012). Similar patterns are observed in many other cases. Multiple studies report that physical exercise can result in better focus at work and sound sleep at night even though participants never explicitly planned to improve either behaviour (Fox, 1999; Pretty, Peacock, Sellens, & Griffin, 2005). Opposite chain reactions can happen too. A habit of frequent phone checking might lead to sleep disruption (Christensen et al., 2016).

Many habits and daily activities in life are related to one another. This interconnectedness is a core reason why changing one activity in one life dimension can lead to unplanned changes in many other life dimensions. When the desired chain reaction happens, people try to commit more and be continue with their positive habits and behaviours. This is because human beings honour their commitment and see consistent behaviours and habits as self-image (Cialdini, 2009). As such, the chain reaction is not only a passive phenomenon but also an active action in building good habits that lead to related positive behaviours. Furthermore, active and consistent actions can reinforce and build confidence in their ability to transform their own life. The more positive chain reactions that are created, the more people become confident of achieving a sustainable life.

The interrelationship between human activities create the chain reaction, and the consistent commitments reinforce the desired life transformation. Now, the thesis will identify and discuss key human activities that create chain reactions in the following section.

5.1.3 Keystone Habits for Sustainable Transformation

Duhigg (2012) posits that certain habits can form chain reactions. He calls them as *keystone habits*. For example, a habitual family mealtime brings significant benefits not only to family relationships but also to other areas like health, academic performance, productivity, and emotional control (Evans & Rodger, 2008; Hamilton & Hamilton Wilson, 2009). It is evident that the habitual family mealtime does not directly cause better academic performance or productivity. However, it initiates a chain reaction to achieve better academic performance or productivity, and it offers a steady feeling of accomplishment that motivates people to reach more significant achievement ultimately (Weick, 1984).

However, finding the right keystone habits for everyone can be a tricky task because people perform hundreds of activities each day and each individual and family is in a unique situation. Therefore, specific characteristics of keystone habits need to be understood to find an appropriate one. Firstly, keystone habits and behaviours are interrelated with multiple life dimensions, so that they can create a structural atmosphere wherein other habits flourish. Secondly, they are activities that generate chain reactions (small wins) consecutively. Therefore, it is better to find activities which are performed frequently and regularly in daily life.

To find out what activities can generally establish a contagious behaviour-change culture, this thesis studied human activities based on Maslow's (1943) hierarchy of human needs. The reason for using his model is that his classification is insightful and well generalised as the satisfaction of the proposed needs correlates with happiness in cultures all over the world (Tay & Diener, 2011).

Maslow continued to refine his theory over the decade by critiquing his own model (Maslow, 1943, 1954). Therefore, his model had extended to eight needs from the original five needs model. The model has biological and physiological, safety, love and belonging, esteem, cognitive, aesthetic, self-actualisation needs, and transcendence. Activities that belong to physiological needs are the main physical requirements for human survival, such as diet and sleep. Activities related to the needs for safety are such as abiding laws and conducting economic activities so that people feel safe as their lives are controllable and predictable. Love and belonging needs are related to the activities to generate emotional inclusion, such as healthy family ties, friendships, and romantic attachments. To achieve esteem needs, people act for keeping their dignity and perform a mastery to gain reputations. Seeking knowledge, meaning, and self-awareness are activities belong to cognitive needs. Then people would like to make things balanced and appreciate beauty in their lives. People are seeking constant personal growth to fulfil self-actualisation needs. Lastly, people help others and go beyond the self-actualisation (Figure 36).

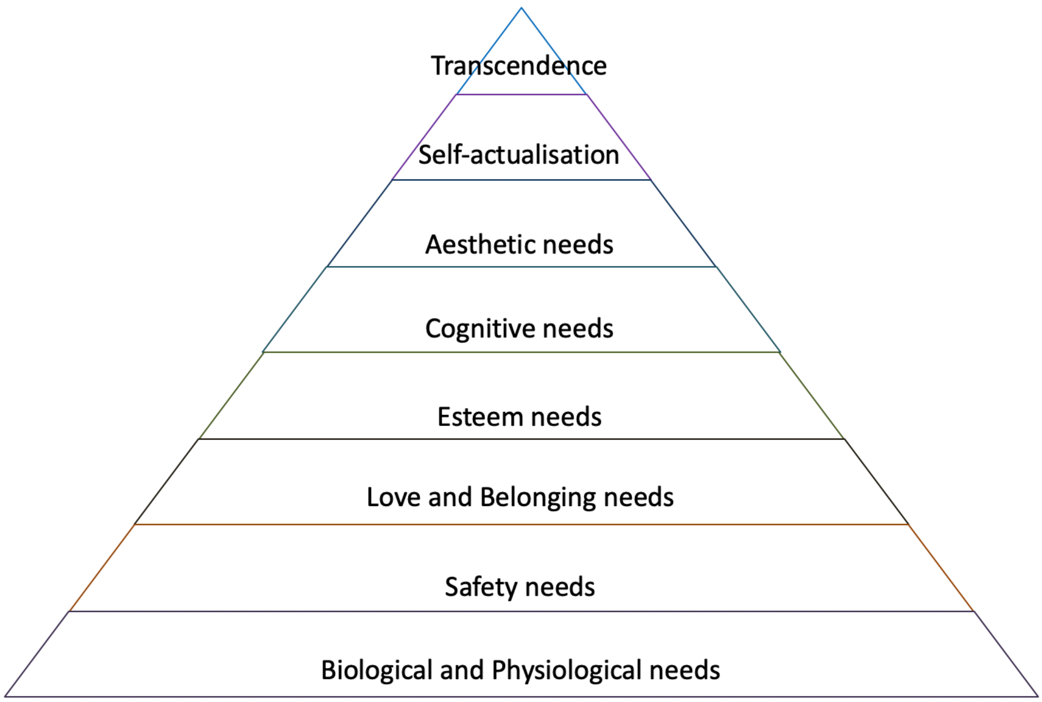


FIGURE 36. MASLOW'S HIERARCHY OF NEEDS (MASLOW, 1943, 1954)

Among these activities, any activities can be chosen as a keystone habit based on individual differences or people's external circumstance, if those activities can be formed as habits. Habits shape human's lifestyle and having a healthy lifestyle is the foundation of sustainable transformation. In other words, to provide the most effective support for sustainable life transformation, it is vital to tackle these key activities and needs as implementing appropriate interventions into these activities and habits can bring positive changes in many life dimensions.

To provide various prototypical proof of concept implementations, the research chose two fundamental human activities: 1) physiological activities like diet, exercise, sleep, and stress-avoidance, and 2) shopping. Physiological activities are chosen as they are closely related to our physical and mental health. One of the key aspects of individual and family sustainability that has a tremendous impact on almost all sustainability dimensions is health. Health and sustainability are mutually playing valuable roles for each other. Health is a gluing agent that ensures issues of human wellbeing, social equity, environmental integrity, and economic developments are balanced and incorporated in the discussion of sustainability. Shopping is chosen as it is often performed at the family level and can show holistic relationships between multiple life dimensions (health, wealth, values, and so on). For this purpose, these two activities are discussed in detail in the following section.

5.1.3.1 Physiological Activities

Diet, exercise, and sleep are the most basic physiological activities that people perform daily, and these activities are directly related to physical and mental health. And health is one of the most important values and life dimensions that provides opportunities, capabilities, and is a contributing factor to our wellbeing. Although stress is not an activity, it has been added to the research consideration as it influences human health significantly. As Figure 37 shows, all daily physiological activities (diet, exercise, sleep, and stress) form mutual interrelationships and are linked to physical and mental health.

This interrelationship becomes more apparent in the case of a diabetic patient. Although the patient ingests carbohydrate food, his/her body cannot use it efficiently as an energy source, causing a low energy level in his/her body. Then the patient becomes incapable of doing any exercise. Also, a diabetic patient cannot have a quality sleep as unused glucose causes frequent urination or hunger during his/her sleep. All these facts increase the cortisol levels and result in higher stress (Musselman et al., 2006; Reeves & Rafferty, 2005; Talbot & Nouwen, 2000).

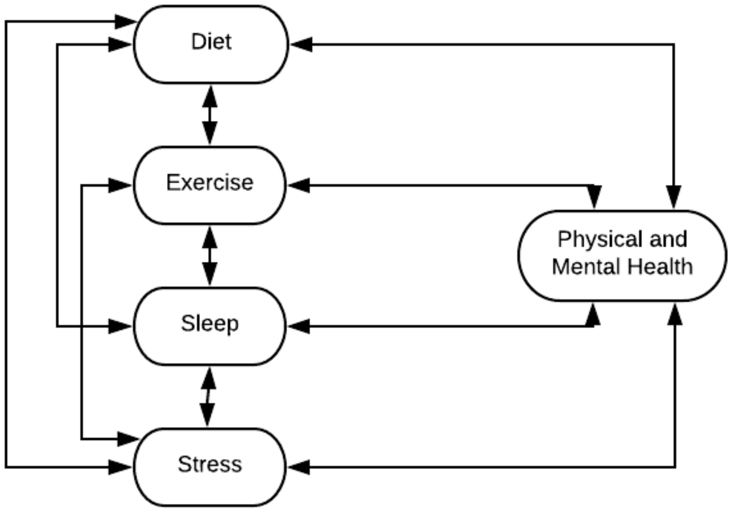


FIGURE 37. MUTUAL INTERRELATIONSHIP OF PHYSIOLOGICAL ACTIVITIES, FROM THE AUTHORS' CREATION (CHUNG & SUNDARAM, 2018A)

Also, it should be acknowledged how one physiological activity can influence many other life dimensions. For example, if a person continues with a low-quality diet, this creates a high chance of developing health problems. If he/she has a health issue, this causes low work productivity as well as increasing medical treatments. As the person cannot work as much as previous and need to spend more time and money on medical treatments, it will put the person in a weaker financial position. This again restricts the person to a lower-quality diet. A poor financial status also can put negative pressure on work performance and health consecutively, creating a vicious cycle in a person's life (Figure 38) (Slater & Carlton, 1985).

On the other hand, there are many other cases where one's physiological activity makes a positive feedback cycle and transforms life sustainably. For example, physical activities such as sport can create close friendships, build confidence and self-esteem, and impact on children's lives positively (Street, James, & Cutt, 2007). Thus, physiological activities can be life change keystone habits as they are (1) performed habitually, and (2) can cause chain reactions as they are interrelated. Therefore, tackling one physiological activity and understanding its interrelationship to others can be a crucial step in promoting individual and family sustainability.

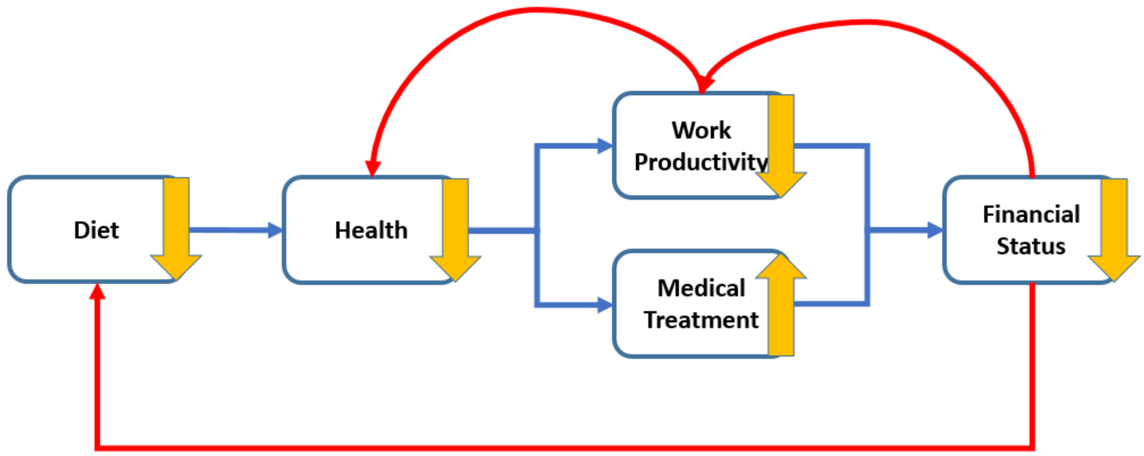


FIGURE 38. PHYSIOLOGICAL ACTIVITIES AND LIFE DIMENSIONS, SUMMARISED FROM (SLATER & CARLTON, 1985)

5.1.3.2 Shopping

Shopping is a critical activity that all humans undertake and can be formed as a habit. It has a significant influence on multiple life dimensions, such as financial, health, emotional, philosophical, and environmental values (Gilg, Barr, & Ford, 2005). For example, frugal, altruistic, and pro-ecological lifestyles can be promoted through shopping (Jones, Hillier, & Comfort, 2011; Seyfang, 2005), and health is tightly linked to grocery shopping. A study found a strong correlation between an impulsive buying habit and eating disturbance propensity (Verplanken, Herabadi, Perry, & Silvera, 2005). So, by modifying shopping, fundamental changes can be brought to one's life.

Shopping is normally considered a combination of cognitive decision-making and automated habitual response processes (Sprotles & Kendall, 1986). This consideration leads this research to combine the conventional consumer buying process (Kotler & Keller, 2011) and the three-step habit loop formation model, proposed by Duhigg (2012) to understand how shopping can become a habitual activity. As Figure 39 illustrates, needs recognition is a cue for shopping, and consumers then perform shopping as a routine. In this step, information searching, evaluation of products, and purchasing decisions are involved. After shopping, consumers experience postpurchase behaviour like the satisfaction of the product as a reward. Combining two processes into one model gives us insightful ideas to design and implement interventions for shopping behaviour changes.

When a shopping routine is carried out frequently and repeatedly, people are making a purchase decision without taking information search and evaluation steps. This is called "chunking", as was explained in section 2.3.1.1. Likewise, often people stick to buying one product without considering alternatives or purchasing a product without checking nutrition and ingredient labels. This habitual shopping can be harmful to certain people like a chronic patient's family. For example, diabetic patients are better to avoid consuming low-quality carbohydrate food as it can result in a glucose spike in their bloodstream. However, habitual shopping behaviour of not checking food nutrition can put patients at harm. Therefore, appropriate interventions are required to shift this habitual shopping activity to a cognitive decision-making process. It is also essential to understand shopping as a keystone habit, as a small change can bring fundamental changes in someone's life.

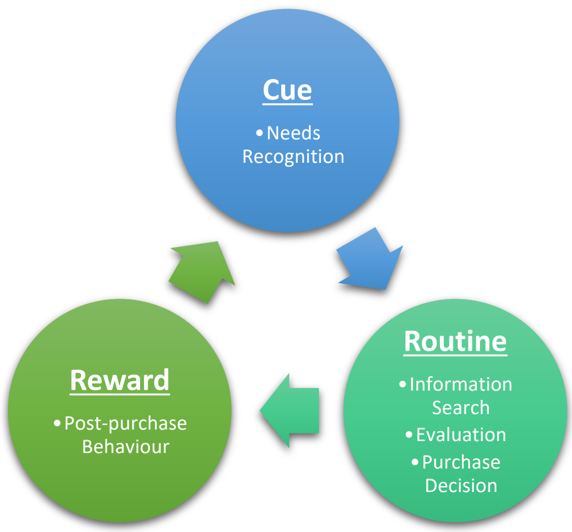


FIGURE 39. SHOPPING HABIT FORMATION PROCESS, FROM THE AUTHORS' CREATION (CHUNG, PROSKURYAKOV & SUNDARAM, 2014)

In this section, the thesis has discussed how sustainable transformation could be achieved in terms of human purposes and processes. Individuals and families can achieve sustainable transformation through education, prevention, and reversion as they are interrelated. This interrelationship among human processes can create chain reactions. Therefore, a change in one life dimension can bring multiple changes in other life dimensions. Keystone habits can form chain reactions and establish a contagious behaviour-change culture. For design and developing proof of concept implementation, physiological activities and shopping are chosen as keystone habits for this research. With assistance from information systems, sustainable transformation can be achieved efficiently and effectively. In the following section, the thesis will discuss and explain what system purposes and processes need to be considered to support individuals and families to achieve sustainable transformation.

5.2 System Purposes and Processes

The goal of this research is to help and persuade individuals and families to take actions so that they can make sustainable life transformations. In the previous section, this research has discussed how individuals and families can achieve sustainable transformation through education, prevention, and reversion. Hence individual and family sustainability systems need to be designed to deliver education, prevention, and reversion to users. As was discussed in 3.3.1, this research will implement four prototypical system artefacts that support individual and family sustainability. Each system will have its own name, but this research names four systems together as SSHARRPPP systems. It is because all prototypical systems will be designed and implemented utilising SSHARRPPP principles, purposes, and processes. Figure 40 shows how SSHARRPPP systems support sustainable transformation framework; education, prevention, and reversion. This figure is related to Figure 35 which was explained in section 5.1.1.

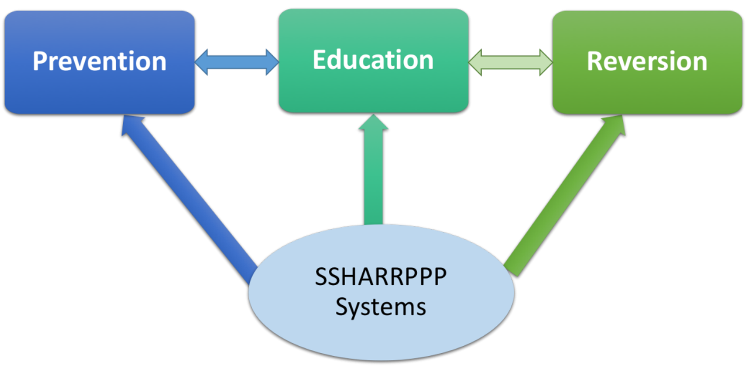


FIGURE 40. SSHARRPPP SYSTEMS – SUSTAINABLE TRANSFORMATION FRAMEWORK, ADAPTED FROM THE AUTHORS' CREATION (CHUNG & SUNDARAM, 2018B)

SSHARRPPP systems (Measurement, Shopping, Modelling, and Games) can persuade individuals and families to take actions. Also, by providing appropriate interventions with information and knowledge to meet people's needs, the systems support their transformation processes effectively and manage their conditions at the optimal level. Therefore, this research suggests six system purposes and associated processes to assist individuals' and families' education, prevention, and reversion that can be delivered by SSHARRPPP systems (Measurement, Shopping, Modelling, and Games). These are: measure, model, benchmark, educate, entertain, and transform. Also, providing services and functionalities that deliver education, prevention and reversion lead sustainable transformation ultimately (Figure 41).

To understand users' current situations and find out appropriate approaches to address issues, the users' conditions, behaviours, and activities should be measured first. For example, to decide whether exercise can lower the glucose level in the bloodstream, the user should measure: 1) before and after exercise glucose levels; and 2) exercise details such as type, intensity, and time. In simple cases, this can provide enough help to transform, because measuring the users' conditions, behaviours, and activities provides feedback to adapt behaviours and actions to correct or improve the situation. However, it is often more efficient to identify relevant factors and model their relationships. The further insights gained by modelling and the benchmarked data and information, with appropriate standards, can help users to reflect whether they are taking the right actions for improving their lifestyles. Users observe their actions and learn by asking how their actions are done and what needs to be changed to transform their lifestyles. Once users learn more about themselves on the broader context and environment, they understand deeper values, paradigms, and visions to adapt their thinking and behaviours in a dynamic environment (Brouwer, Woodhill, Henmmati, Verhoolsel, & van Vugt, 2016). This research believes this can be done through education and entertainment. Furthermore, entertainment can make the education effective (Amory, 2007; De Freitas & Griffiths, 2007; Kiili, 2005; Quinn, 2005), thus making the sustainable transformation easier.

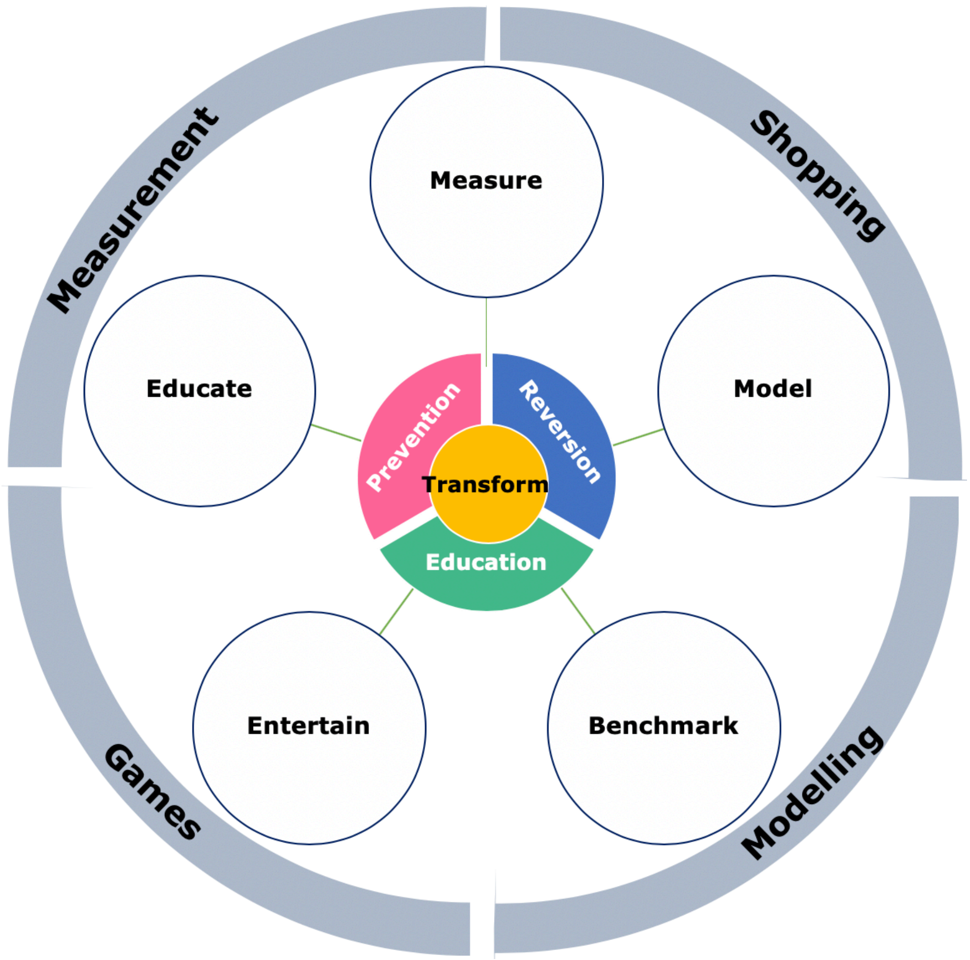


FIGURE 41. SSHARRPPP SYSTEM PURPOSES AND PROCESSES FOR SUSTAINABLE TRANSFORMATION, EXTENDED FROM THE AUTHORS' CREATION (CHUNG ET AL., 2015)

As such, information systems can play critical roles when their purposes and processes are well defined and designed to make the sustainable transformation happen. Hence human and system interaction is vital. In what follows, the thesis proposes the sustainable transformation processes that can be carried out by both humans and information systems (SSHARRPPP systems) and explains how these processes are interacting together to make individuals and families' lives sustainable.

5.3 Sustainable Transformation Processes

To support the individual and family transformation, information systems need to provide relevant information, which can act as a key influencing factor to change individuals' and families' behaviours. For example, information systems can provide total distance comparison information to runners in a similar group, and this information can encourage runners to improve their performance (Spendolini, 1992).

Information systems can generate this type of information easily by conducting measuring, modelling, and benchmarking processes, then educating people with the resulting insights. Such education can be delivered more effectively through entertainment like games and gamifications. Furthermore, all these purposes and associated processes contribute to the sustainable transformation of individuals and families.

Although system purposes and associated processes (measure, model, benchmark, educate, entertain, and transform) provide rich guidance on how information systems need to support individual and family sustainability, interactive processes between human and information systems are required to be designed. In this regard, the researcher proposed sustainable transformation processes (Figure 42). The sustainable transformation processes consist of four major sub processes, sense, interpret, respond, and transform. In the **sense** process, systems collect and measure individual's and family's lifestyle data. The data can be entered directly or sensed (collected) through various devices with sensors. For instance, a running distance can be **sensed** via wearable devices like Fitbit and dietary information can be supplied to systems through direct data input. In the **interpret** process, the collected heterogeneous data is processed, modelled, and analysed to meaningful information, then systems take the **respond** process to individuals and families by presenting data and information or making recommendations.

From the human perspective, people **sense** and **interpret** the data, information, and recommendations presented by information systems, then they **respond** to those data, information, and recommendations by making decisions and taking actions to satisfy their goals. When these interacting processes are repeated, desired habits formed and eventually, people can **transform** their lives to be sustainable unless they **exit** the processes due to a relapse.

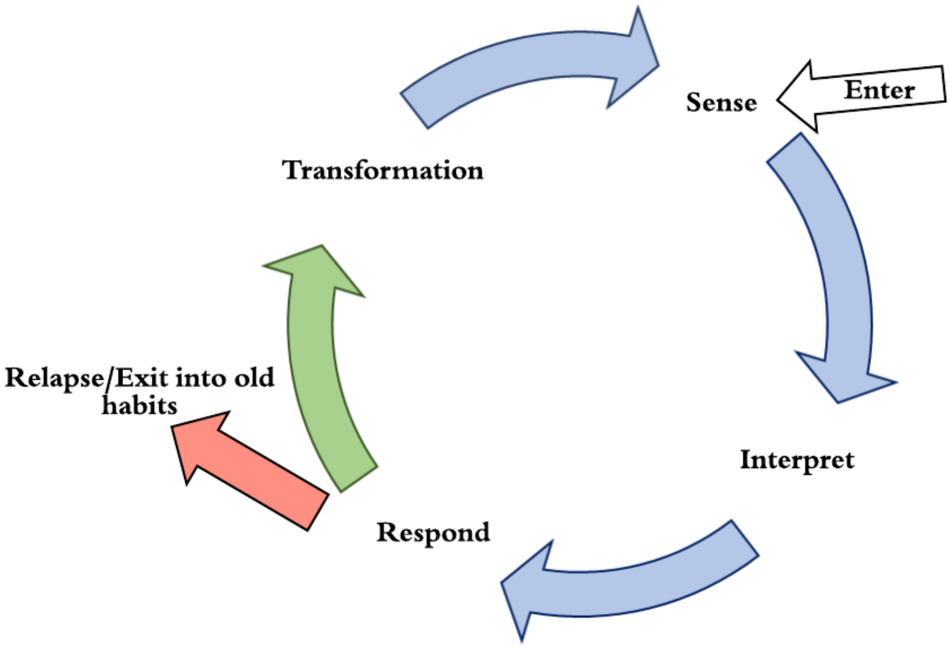


FIGURE 42. SUSTAINABLE TRANSFORMATION PROCESSES (SIRT), FROM THE AUTHORS' CREATION (CHUNG & SUNDARAM, 2018B)

The sustainable transformation processes are designed and proposed based on multiple seminal behavioural theories and intervention models as evidence suggests that interventions based on behavioural theories have greater effectiveness than interventions without a theoretical grounding (Craig et al., 2008). Among many compelling behaviour change theories and intervention models, this research adopts core ideas from the Transtheoretical Model of Changes (TMC) (DiClemente & Prochaska, 1998; Prochaska et al., 1992; Prochaska, 2008). Other behavioural theories are also studied to identify key behavioural change constructs and principles as they were discussed in 2.3.1.1.

There are two reasons that the TMC process is chosen for this research. Firstly, it is a useful model to develop and implement apposite persuasive motivations. The TMC clearly distinguishes five stages of change: pre-contemplation, contemplation, preparation, action, and maintenance (Prochaska et al., 1992), where particular psychotherapy interventions can be applied. Therefore, practitioners often utilise this model for constructing interventions (Morris, Marzano, Dandy, & O'Brien, 2012). Secondly, the TMC model was initially developed and used for addictive behaviour corrections. Addictive behaviours and habits share many similarities. For example, they are both autonomous responses and involve low complexities in decision-making (Fraser, Mooreb, & Keane, 2014). Studies found that our brain circuitry underlying addiction and habitual actions show significantly similar images (Tomasi & Volkow, 2013). Since human lives are a collection of daily habits, sustainable life can be developed through the formation of healthy habits and the dissolution of unhealthy ones. Also, adopting core concepts from the TMC is particularly practical for the sustainable life transformation, as it embraces relapses and exits. Multiple relapses and exits to old habits are painful and discourage people from changing their lifestyle, but they are naturally part of behaviour/habit change (life transformation) processes.

Likewise, the sustainable transformation processes have been designed to correct behaviours for those who are already aware of their behavioural issues by following sense, interpret, respond, and transform (SIRT) processes. Also, the processes can be used to discover behavioural issues for who are not aware of them. Thus, the SSHARRPPP systems will use the sustainable transformation (SIRT) processes to support people who are at any stage of behavioural change and provide appropriate persuasive interventions at the right time to change behaviours.

5.4 Summary

The core players of individual and family sustainability are people – individuals and families. And the role of systems is to support the players to achieve sustainable transformation easily, effectively, and efficiently. In this chapter, this research has discussed the procedural perspectives of individual and family sustainability. As human activities are interrelated, people can transform the multi-dimensional lifestyles by changing several keystone habits and behaviours. To achieve their desired wellbeing (human purposes), individuals and families need to educate, prevent, and reverse their behaviours and attitudes. Therefore, the SSHARRPPP systems are to support education, prevention, and reversion with system purposes and processes (measure, model, benchmark, educate, entertain, and transform), which can be achieved by following the proposed sustainable transformation (SIRT) processes.

6 Technological Responses for Sustainable Transformation of Individuals and Families

There are various available technologies that can be employed in the SSHARRPPP systems and this chapter will identify relevant technologies to bring specific functionalities to individuals and families who desire to change their behaviour and habits for better life.

Therefore, this chapter elaborates on the technological system features, frameworks, and architectures of SSHARRPPP systems, and contributes to addressing the following questions:

- What are the main technologies to support SSHARRPPP principles, human and system purposes and processes for sustainable life transformation?
- How should these technologies be organised to deliver system goals and objectives?
- How should the SSHARRPPP systems be structured and what is an efficient way to provide a system development environment?

To answer these questions, this chapter will discuss technologies to support purposes and processes and sustainable transformation processes. Based on these discussions, overall SSHARRPPP architecture is proposed (Figure 43):

- Discuss the key technologies for human and system purposes and processes: measure, model, benchmark, entertain, educate, and transform in 6.1. In this section, the research will explain technologies under each purpose and how systems should be implemented to build a strong relationship among purposes and processes.
- Discuss the key technologies for Sense – Interpret – Respond – Transform processes in 6.2. In this section, the research will use a diabetes example to explain key technologies that are important and relevant to achieve SSHARRPPP.
- Propose the overall architecture that provides the conceptual, procedural and technological organisation of SSHARRPPP systems in 6.3. In this section, the

research explains system functionalities and supporting components from principles, purposes, and processes perspectives.

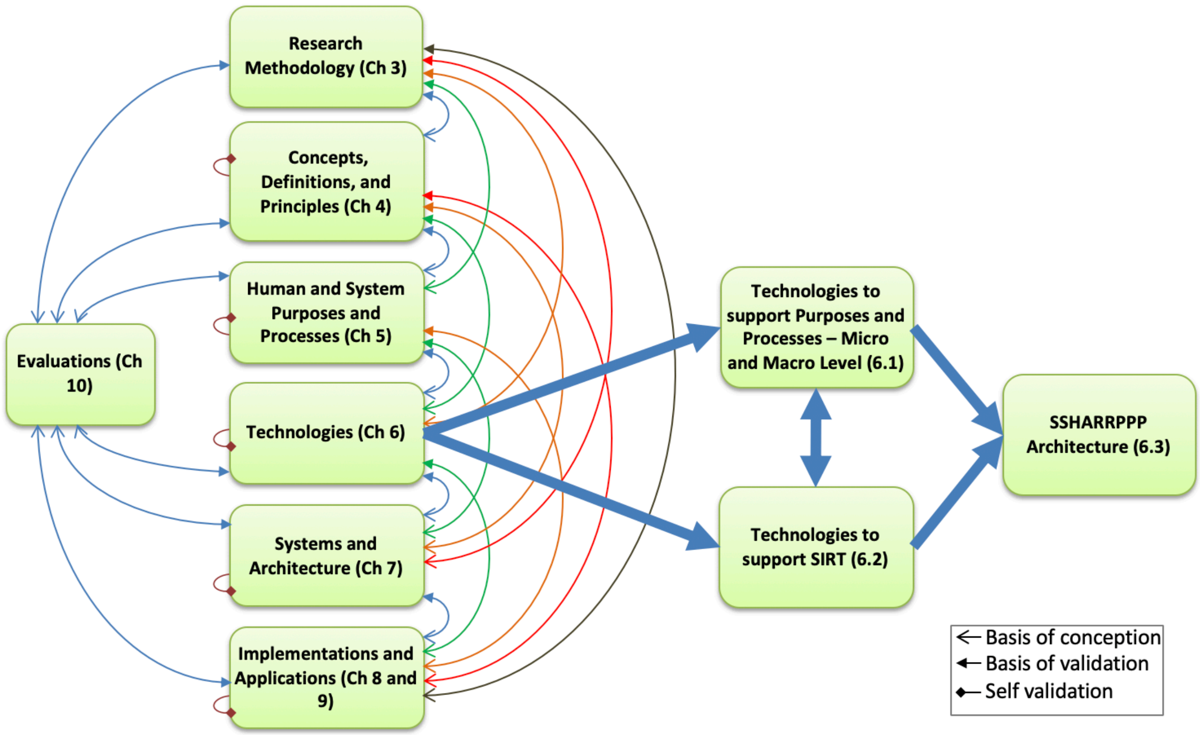


FIGURE 43. CHAPTER 6 STRUCTURE AND RELATIONSHIPS

6.1 Key Technologies to Support Human and System Purposes and Processes

The human and system purposes and processes can be broadly divided into two levels; the macro and micro levels. Figure 44 helps to understand how purposes and processes are interrelated and support the sustainable transformation of individuals and families. The macro-level purposes and processes – "transform", "educate", and "entertain" – are goals and mechanisms that the systems try to achieve; whereas the micro-level of system purposes and processes, "measure", "model", and "benchmark" are practical and foundational system activities to deliver transformational system features.

Among the macro-level purposes and processes, mutual supporting connections exist: "educate to transform", "entertain to transform", "transform to educate", "entertain to educate", "transform to entertain", and "educate to entertain". For example, not only the goal "transformation" can be achieved through education, but also education can happen by experiencing what causes people to be transformed.

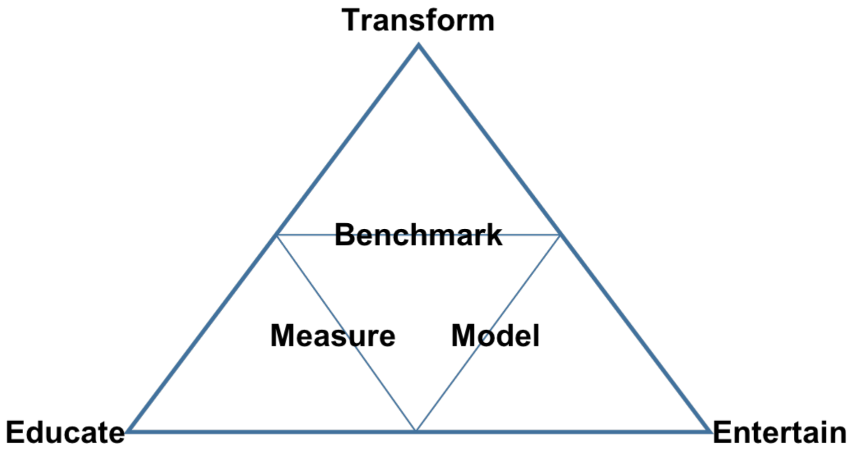


FIGURE 44. INTERRELATIONS OF MACRO AND MICRO LEVELS OF PURPOSES AND PROCESSES

To support these macro-level purposes and processes, systems should be able to measure, model, and benchmark. The micro-level purposes and processes are also interrelated. People cannot manage if they don't measure, people cannot understand if they don't model, and people cannot assure their progress if they don't benchmark. Hence, measuring individuals and families on various life dimensions, modelling their interactions, and benchmarking goals/targets are at the heart of the system purposes and processes.

6.1.1 Measure

Measuring and quantifying the current status, activities and behaviours are the first steps in behaviour changes. Previously, measuring personal data without technology was a time-consuming and tedious task. Collecting the data in reasonable frequency to see and understanding the patterns were even harder task. Therefore, quick and unobtrusive measuring technologies for transformation are essential.

Weiser (2002) suggested that ubiquitous technologies should be immersed in everyday life. In his article "The Computer for the 21st Century", he introduced the devices in tabs, pads, and boards, and their integration through wireless and wired networks. Poslad (2009) extends the idea from Weiser. He added smart devices, environment, and interaction using the metaphor of dust, skins, and clay to explain their rich and flexible connectivity. The measuring technologies should be as seamless as possible, so people even do not notice that they are being measured. For example, the system should be able to tell the users whether they had a good sleep or not by measuring REM, number of wake ups, and sleep duration. Measuring sugar level in bloodstream used to be a chore; but now a Nano-sized implanted sensor can collect data automatically at various intervals (Kirkwood, 2018; NZMS, 2019).

The current technological developments, such as the Internet of Things (IoT), can make this measurement easy and smooth. The IoT is the extended internet connectivity, which has developed with a convergence of wireless sensors, networks, real-time analytics, and automatic systems (Rosencrance, Shea, & Wigmore, 2014). As the IoT connects various physical devices and daily objects through the internet, this technology can capture and monitor the users' daily activities from multiple aspects. A smart home is one of the typical examples that utilise the IoT technology. The smart home is capturing and monitoring various data from the user's home devices and appliances and makes remote control possible (Kang, Moon, & Park, 2017; Meola, 2016).

The potential of the IoT is also well acknowledged by the medical and health industry. Smart Healthcare uses a wide range of IoT devices with sensors that collect, process, transfer, and analyse valuable information in different environments for research and healthcare services (Elhayatmy, Dey, & Ashour, 2018). Moreover, the use of mobile smart devices in healthcare allows patients to play core roles in their healthcare.

This research suggests adopting technologies that do not disrupt the users' lives and allow them to do things freely while their various life dimensions are measured into the SSHARRPPP systems. Measuring real-time and real-world behaviour and status data through sensors permits users to receive precise information about themselves. Also, it persuades them to learn how they can improve their situations by changing and adapting different behaviours, then ultimately transforming their lives.

6.1.2 Model

Models describe purposes and formations, explain functions and current states, and predict future states of factors and their relationships (Rouse & Morris, 1986). Hence, modelling holistic interrelationships among life factors can educate people about which life factors and behaviours are important for adapting sustainable and healthy lifestyles. The education through modelling can be personalised if the users use their situations and data and by observing potential outcomes based on different scenarios. This can strongly persuade individuals and families to change their behaviours and habits.

This research has chosen system dynamics and simulations for modelling techniques that represent the holistic interrelationships among factors. The system dynamics modelling aims to understand nonlinear problems and issues that are characterised by interdependence, mutual interaction, information feedback, and causality (Richardson, 2013). The simulation represents behaviour, functions, and an abstract of the modelled factors. Therefore, system dynamics and simulations are appropriate technologies to understand how factors are interrelated to form life.

System dynamics and solutions applications like Stella® have multiple layers and they serves different features. Once a user defines and identifies constituents that are related to topics (issues to understand), the application represents them as models using diagrams and equations, such as causal loop diagrams and stock and flow models. The related constituents' behaviours and interrelationships are determined in the causal loop diagram to show the structure and the stock and flow model can be constructed for simulations using equations (Maani & Cavana, 2007). As such, the system dynamics and simulations should be able to handle the modelling and equations swiftly. The implementation of using these techniques will be further explained in chapter 7, 8 and 9.

6.1.3 Benchmark

Originally benchmarking techniques are managerial methods to analyse various performances in companies and organisations. However, benchmarking techniques are now used in any area that needs performance assessment and they are useful even at the individual and family level.

Broadly speaking, benchmarking techniques can be used to assess internal or external performances depending on targets to compare. The internal benchmarking compares results with historical records, goals, or theoretical standards. For example, body weight can be compared with historic weight trend, or personal target weight, or BMI. From this practice, individuals can improve and meet their goals. The term benchmarking is most commonly associated with comparing your results to external entities. For external benchmarking at the individual and family level, publicly available data from some organisations like Statistics New Zealand, Mayo Clinic and Harvard Medical School can be used. However, the external benchmarking can be a challenging task for individual and family due to the data availability issue, unlike companies. To address this issue, this research suggests utilising social media and data analytics. Social media is beginning to penetrate more and more into people's daily life. In this sense, we can use valuable data and information shared in the social media for benchmarking. Also, benchmarking through social media can bring unique benefits at the individual and family level. For example, social interactions through social media can provide strong emotional support to achieve the goals and sustainable life transformation.

6.1.4 Entertain

Education has always shown great interest in using entertainment in a learning and teaching environment (Němec & Trna, 2007). It is because entertainment in education attracts learner in a joyful manner, and the stimulating environment ensures maximum output with accelerated learning speed.

Among many entertainment approaches, the game is a well-studied educational tool. In the last 20 years, researchers have proven that digital games can be educational (Van Eck, 2006). It is good at engaging audiences using graphics and multimedia (De Freitas & Griffiths, 2007). Game-based learning is more effective and motivates students better than traditional learning (Brox, Fernandez-Luque, & Tøllefsen, 2011; Dondlinger, 2007). Also, games can be an active learning tool regardless of player's age. The average age of gamers is 35 years old (Ijsselsteijn, Nap, de Kort, & Poels, 2007), and 26% of gamers are 50 years and older in United States (Statista, 2017).

Most adults are playing games by choice. It means that gameplay activity is not only for leisure, but it also can be driven by the desire to learn a skill and socially connect with other people. Games teach people interactive goals, rules, and problem-solving skills (Reeves & Wittenburg, 2015). Often they teach holistic approaches to problem-solving skills using levels (Moursund, 2016). Also, the different levels in games can provide persuasive educational information based on each player's profile and preferences (Chow, Susilo, Phillips, Baek, & Vlahu-Gjorgievska, 2017). This engaging characteristic of games makes people adapt consciously and unconsciously the learned skills or knowledge in their lives.

For these reasons, the research suggests using games and gamifications as a mechanism to achieve individual and family sustainability. Especially, games are a well-used educational tool in healthcare, especially for chronic disease care (Chow et al., 2017). Using real-time data processing can support healthcare professional to monitor patients proactively. Incorporating virtual world settings into the real-world can also put patients at the active player in their healthcare. For example, "Sea Hero Quest" is developed to improve dementia patients' navigation skills. Researchers collect the player's game data, and it is used to early diagnose dementia (Coutrot et al., 2019).

6.1.5 Educate

Education is the most effective approach for the sustainable transformation of individuals and families. Argyris and Schön's (1978) works on the dynamics of learning: single-loop, double-loop, and triple-loop learnings help this research to analyse and increase our capability in sustainable transformation, as was discussed in Chapter 2.

A single-loop learning can happen in "measure to transform" as measuring can provide feedback to the users reflecting their certain activities to detect and correct deviations from the models and rules. A double-loop learning can occur when the users reflect on the models and rules that they initially follow. By modelling life factors holistically and prioritising them, the users can understand why particular solutions work better than others. Triple learning is learning about how to learn. Therefore, this is not only considering changing models and rules, but also changing perceptions on models and rules. As the technologies which do benchmarking can provide insights for constructing a vision and strategies, individuals and families can transform by changing themselves. Furthermore, technologies for entertainment keeps the models relevant, alive and helpful by persuading us to go through the whole transformation journey in a playful way. Finally, when a proper level of education is delivered to the right audiences, transformation through prevention and reversion of the current situation can happen to individuals and families.

6.1.6 Transform

Transformation is a goal of this research. Therefore, all technological approaches and functionalities that this research has discussed so far should be used in SSHARRPPP systems to transform people's lives. Figure 45 shows their relationships and interactions to deliver goals for education and transformation. The delivery mechanism of these goals is entertainment. The foundational activities are supported by technologies that help users to "measure", "benchmark", and "model". These technologies would provide fundamental data and information from our daily activities and behaviours to make "educate" and "transform" happen. "Entertain" is working as mechanisms the transformation journey easy and effectively. The pathways and interactions are illustrated through arrows among system purposes and processes. This framework will be used again to explain how SSHARRPPP systems are designed and implemented to work together to help individuals and families to transform their lives.

Key technologies for measure, model, benchmark, entertain, educate, and transform have been identified and discussed in this section. This thesis will take the understanding of these purposes and associated processes into consideration, then design and implement SSHARRPPP systems as proof of concept artefacts. In the following section, the thesis continues to identify and discuss key technologies that can support sustainable transformation (sense – interpret – respond – transform) processes.

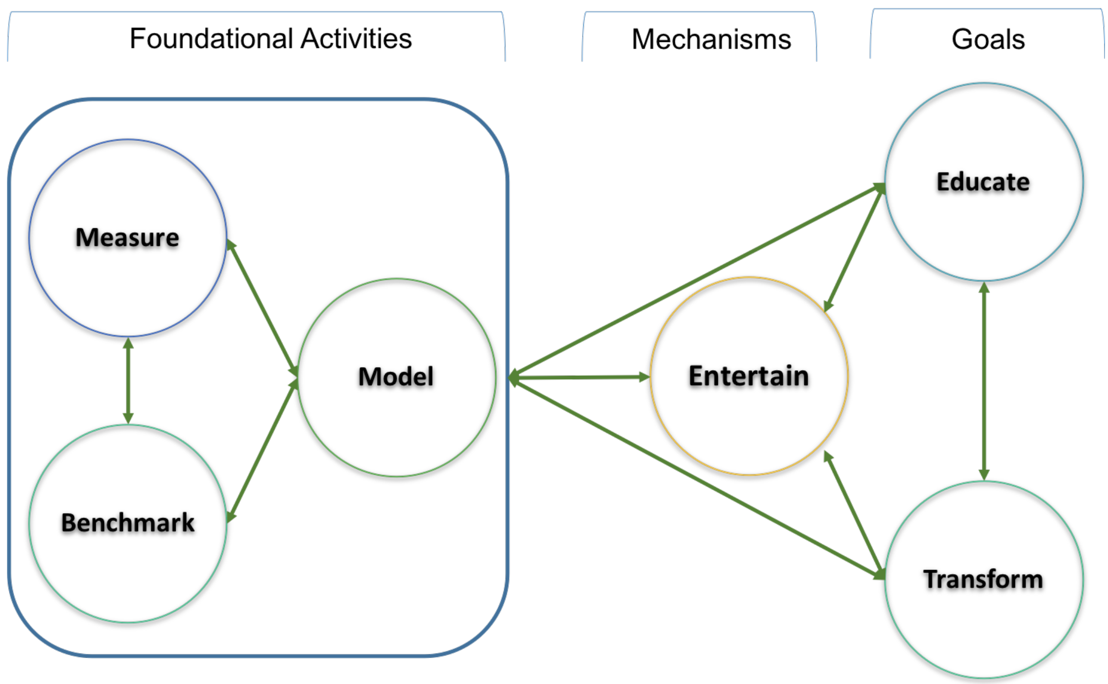


FIGURE 45. TECHNOLOGICAL CONNECTIONS OF PURPOSES AND PROCESSES, FROM THE AUTHORS' CREATION (CHUNG & SUNDARAM, 2019)

6.2 Key Technologies to Support Sustainable Transformation Processes

In chapter 5, this research has discussed individual and family processes and sustainable transformation processes to support the sustainable transformation of individuals and families. To provide meaningful support in life transformation, it is better and efficient that systems deliver services to users at each of **Sense** – **Interpret** – **Respond** – **Transform** (SIRT) processes using appropriate technologies. Therefore, explaining technical requirements in each process step and how they support individuals and families to change their lives are important precedent tasks for designing and implementing SSHARRPPP systems.

Figure 46 shows examples of technological requirements based on the proposed system purposes and processes that can be brought through sustainable transformation processes. At each step of SIRT, systems also deliver services and facilities related to measure, model, benchmark, entertain, educate, and transform. Each process is iterated until individuals and families have sustainable lives. Thus, SSHARRPPP systems provide functionalities and services using technologies iteratively. The technological requirements of each process will be detailed in the following section.

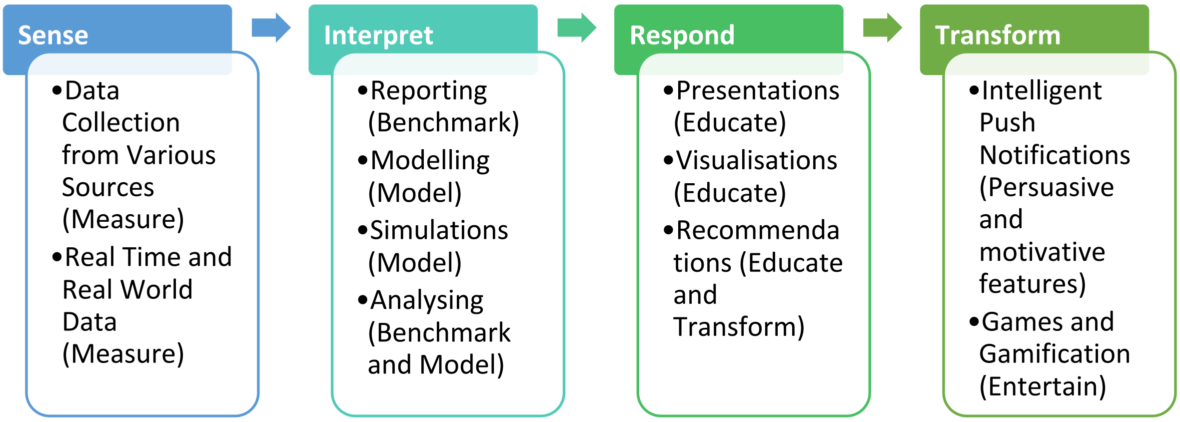


FIGURE 46. EXAMPLES OF TECHNICAL REQUIREMENTS

In what follows, the thesis explains and identifies key technologies that can support sustainable transformation processes.

6.2.1 Sense

In the **sense** process, systems are collecting various daily data that relate to our behaviours, activities, or bodily functions. As it is discussed in 6.1.1, individuals and families *measure* multiple aspects of lives to understand their daily activities and even finding out hidden habits to transform their lives. Although collecting data about oneself and reflecting on the data has a long history, the current popularity was contributed by recent technological developments like self-tracking technologies and IoT systems. For example, Fitbit uses eight sensors to capture physical activities and health-related data, such as step counting, location tracking, and heart rate monitoring (Blaauw et al., 2016).

This process is essential to supply data for the next process, **interpret**. Therefore, it is better to *measure* real-time and real-world data. Collecting real-world and real-time data benefits the individual and family sustainability significantly. First, it reduces recall bias (Sedgwick, 2012) and data related issues (Beckjord & Shiffman, 2014). Also, it permits more sensitive assessments and enables wide-ranging comprehensive data collection as real-time data is automatically collected through sensors and systems. From the intervention point of view, real-time data collection is important, particularly in correcting habits or addictions. In high-risk situation, real-time data collection and intervention make users shy away from temptation as it can help and inform them at the optimal timing (Beckjord & Shiffman, 2014).

6.2.2 Interpret

The data become valuable when insightful information is yield to assist users' decision-making process (McAfee & Brynjolfsson, 2012). To draw insightful information from the collected data, systems should be able to *model* the data for interpretation using models, methods, solvers, and algorithms. The data analysis can be produced using three main data analytics: descriptive, predictive, and prescriptive analytics (Delen, 2015).

Descriptive analytics is used to understand the collected data purely. Descriptive analytics is used for data revealing that is focusing on a current situation or status. For example, what is the average glucose level for three months, what is the highest or lowest glucose level, and so on. Predictive and prescriptive analytics are advanced analytics that can be used to provide sophisticated information to support decision making. Prescriptive analytics are used estimates the future values of factors. Prescriptive analytics offers answers for "What should I do" type of questions (Delen, 2015).

Type of Analytics	Techniques	Interpreted Information	Question Examples
Prescriptive Analytics	• Optimisation • Simulation • Recommendation	• Holistic factor relationships • Personalised Recommendation • Insights for preference and profile	• What are the related life factors and how are they related? • What is a good approach to change behaviours?
Predictive Analytics	• Statistical Analysis • Forecasting	• Expected outcomes	• What is an expected outcomes when behaviours change
Descriptive Analytics	• Dashboards • Reporting	• Precise current situation/status	• What is the current situation?

TABLE 3. DATA ANALYTICS FOR DECISION SUPPORT, SUMMARISED FROM (DELEN, 2015)

For supporting individual and family sustainability, systems can use reporting and dashboard techniques to explain the collected data (descriptive analytics); statistical analysis to predict future events (predictive analytics); simulations to provide prescriptive analytic information (Olson & Delen, 2008). Descriptive analytics can be used as simple reporting without serious modelling involvement. However, predictive or prescriptive analytics require modelling. Table 3 shows each data analytic that can be used to support decision-making. And different *benchmarking* techniques are used in these analytics for a sustainable life transformation of individuals and families.

6.2.3 Respond

Once the data is interpreted using analytics, the insights should be responded to the users for their decision-making or action supports. The interpreted data is ideally presented persuasively. Therefore, SSHARRPPP systems should be able to apply appropriate technologies to produce interpreted insights and respond it to the users. For this, visualisation and recommendation techniques and relevant technologies can be used in SSHARRPPP systems for presenting the interpreted information. Visualisation can show predictive and prescriptive analytics effectively. The recommendation provides prescriptive information to people based on descriptive analytics.

Information visualisation is an essential technological response that transforms information into mental images (Spence, 2014) and is often used to assist decision support intuitively by *educating* decision-maker. For example, various diagrams and charts are used to compare numerical values or show the relationship among variables. The holistic relationship can be presented better in a visual format rather than in written paragraphs. As such, using an appropriate and effective visualisation in the **respond** process to present the interpreted information can strengthen human perception and gain wider insights (*educate*) into the data (Adnan, Noor, & Aripin, 2003). The system need to implement features that support easy data pattern and trend detections, and significant awareness enhancement of situations (Bai, 2015).

Recommendation is another technological response that SSHARRPPP systems can use in the **respond** process. One way of getting an efficient recommendation is reducing the information overload by applying collaborative filtering, content-based filtering or hybrid filtering (Jalali, Mustapha, Sulaiman, & Mamat, 2010; Merve Acilar & Arslan, 2009) and it would provide suggestions with a degree of personalisation (Schafer et al., 2001). Also, users can get a recommendation through social media networks. Especially when there is not enough personal knowledge or experience of the alternatives, social media can help users to attain insightful opinions by finding people who have experienced each option (*educate*). This research will use these technological responses as the key response techniques in implementing SSHARRPPP systems.

6.2.4 Transform

After **respond** process, people can make decisions and take actions. Therefore, in this step, technological methods that help people to stick to the desired actions or behaviours are required to achieve sustainable transformation. For example, an internet-based push notification can be used to reach users anytime and anywhere (*persuasive and motivating features*). Especially, intelligent push notification technology delivers several benefits by engaging the users. The personalised push message, which is sent to the user at the right time, can increase the chances them to take actions. Also, it can suggest the following actions to take by tracking a user's behaviour regularly. For example, after heavy exercise, the push notification can be sent to a diabetic patient to check his/her glucose level (Choi, Huh, & Weon, 2018). To do this, the push notification need to be use used as real-time communication. In the healthcare industry, health professionals can monitor patients and send a real-time message when it is appropriate (Abdullah, Ismael, Rashid, Abou-Elnour, & Tarique, 2015).

Games and gamification are also effective technological methods that encourage positive behaviour changes through *entertainment*. For instance, exergames are in strong trend. These games motivate people to exert to achieve goals by playing active video games, such as Nintendo Wii Fit (King, Greaves, Exeter, & Darzi, 2013). Various promising signs show that people can change their behaviour changes through games and gamification. Especially, health behaviour change interventions often borrow gamification principles like meaningful rewards or offering achievable goals to make digital health interventions fun and engaging (Cugelman, 2013). As such, these methods are required to be implemented in systems to persuade users towards sustainable life transformation.

All these technologies to support individuals and families to educate themselves, to make better decisions, to transform lives sustainably. Based on the knowledge gained in this section, the thesis will propose an overall SSHARRPPP System architecture that can be applied to each system implemented for this study.

6.3 Overall SSHARRPPP Architecture

A system architecture is a blueprint for implementing systems. Therefore, it needs to show various hardware and software components that serve all functionalities and connections that fit together (Schach, 2011). An illustrative demonstration explains what the layers of user interface, application subsystems, and resources are and how communication can happen between layers, and so forth. Some system architectures also include actual programs and available technical services that support the overall system functionality.

The core goal of SSHARRPPP System is to support individuals and families to transform their lives sustainably. To support that, systems will help people to learn (educate) their current status as well as the ideal ways to change behaviours and lifestyles. For this, the system will measure, model, and benchmark to produce meaningful information to support their decision-making. And the system will follow sustainable transformation processes to deliver these functionalities and services. Therefore, SSHARRPPP systems will have components and layers to help individuals' and families' decision makings as well as sustainable transformation.

Overall SSHARRPPP architecture has four layers, namely: component, solution, application, and interface. Also, SSHARRPPP systems can link to social media and real-time and real-world ubiquitous systems. Each layer can interact with adjacent layers and all components can interact with each other within the layer (Figure 47).

In the component layer, there are storage for traditional decision support components, namely, data, models, solvers, knowledge, and visualisations. Data is collected from internal and external systems and devices which were discussed in section 6.1.1 and 6.2.1. SSHARRPPP systems are collecting and sharing data through data storage in the component layer. For example, shopping data is collected from SSHARRPPP

Shopping and it can be shared with other SSHARRPPP systems. As it is discussed in 6.1.2 and 6.2.2, showing the holistic interrelationships among factors can help people to discover root problems of their lifestyle and find solutions. Therefore, systems are required to utilise various models like precision, recommendation, sustainable transformation, and decision-making models. Also, as this thesis using shopping and habit formation as mechanisms, shopping and habit formation models are required to utilise. The system should use appropriate solvers to model the various factors and produce meaningful insights to users. Therefore, mathematical equations, data mining, recommendation, and system dynamics algorithms will be stored as components of the solver. Knowledge has multiple parts that can be used as a source of recommendations. Therefore, research findings, heuristics, rules, and collective social knowledge can be elements of knowledge. Lastly, sustainable dimensions, holistic trends, comparative analysis, causal effect diagrams, graphics, graphs, and animations are stored and used to enhance users understanding in visualisation.

The solution layer provides communication and cooperation between the application layer and component layer. It extracts relevant data and elements from component layer and prepares them to be handled by the manager in the application layer. The initiated tasks from the managers are measure, model, benchmark, educate, and entertain. For example, the modelling manager can initiate a relationship between the glucose level and exercise, then the solution layer pulls out the data (glucose level, exercise duration, and intensity), models, equations, and visualisations from the component layer and prepares them to be used for a certain task.

The application layer has data/profile, modelling, recommendation, benchmark/knowledge, lifestyle, entertainment, and app managers. Data/profile manager deals with data input from various systems and devices. Internally, it handles direct user input data like user profile and preferences. Modelling manager models relative data and components together and produces insightful information through descriptive, predict, and prescript modelling. Recommendation manager provides personalised recommendations utilising the user's profile data. Also, recommendation manager suggests different degree of recommendations based on the user's preference. Benchmark/knowledge manager provides insights of data and information using various analytics. Lifestyle manager deals with the user's personal lifestyle situation and goals. Entertainment manager importantly works for providing persuasive educational contents in playful forms. App manager deals with certain functionalities that each SSHARRPPP system offers. For example, the app manager for the SSHARRPPP Shopping takes care of functionalities related to the online shopping systems. All layers and components in the proposed architecture work together to deliver functionalities that fulfil the principles, purposes, and processes.

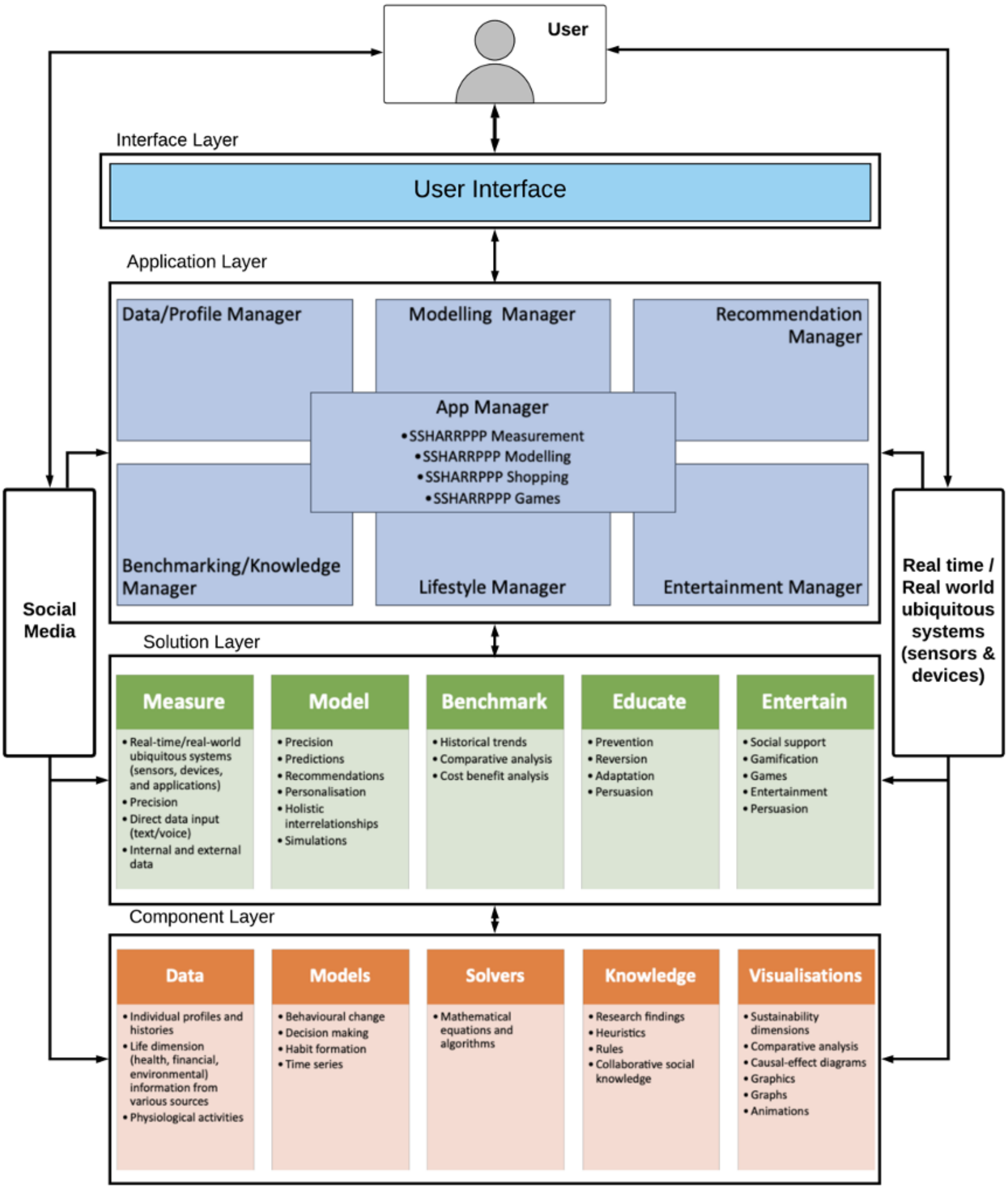


FIGURE 47. OVERALL SSHARRPPP ARCHITECTURE, FROM THE AUTHOR'S CREATION (CHUNG, 2019)

Up to now, each element and layer of SSHARRPPP architecture are discussed. In the following section, the thesis will discuss the overall SSHARRPPP architecture from three different perspectives: system purpose and process perspective, sustainable transformation perspective, and SSHARRPPP principles perspective.

6.3.1 System Purpose and Process Perspective

The high-level functionalities that SSHARRPPP systems serve to support sustainable transformation are the human and system purposes and processes: measure, model, benchmark, entertain, educate, and transform. The system functionalities should be designed to serve in a way of educating people to transform their lives.

System Purposes	Functionalities	Technologies	Components
Measure	Collecting and measuring data	Sensor-based technologies (e.g. IoT)	Real-time and -world ubiquitous systems
			Data/Profile Manager
		Object-oriented Database	Measure
			Data
Model	Modelling factors	System Dynamics	Modelling Manager
	Visually presenting relationships	Modelling techniques	Model
		Simulations	Model, Data, Solver, Visualisation
Benchmark	Analysing internal and external data	Data analytics	Social Media
		Social media	Benchmark/Knowledge Manager, Recommendation Manager
			Benchmark, Educate
			Data, Solver, Knowledge
Entertain	Creating educational games	Games	Entertainment Manager, Lifestyle Manager
		Gamifications	Entertain, Model, Educate
			Knowledge, Visualisation, Solver
Educate	Educating to prevent and reverse the situation through SLL, DLL, and TLL	Profile Analysis	Data/Profile Manager, Recommendation Manager, Benchmark/Knowledge Manager
		Recommendations	
		Personalisations	
Transform	Tracking whether user is following the suggestions or not and provides persuasive notifications	Intelligent push notifications	Data/Profile Manager, Recommendation Manager, Lifestyle Manager
		Recommendations	
		Personalisations	

TABLE 4. EXAMPLES OF SYSTEM FUNCTIONALITIES AND TECHNOLOGIES TO SUPPORT HUMAN AND SYSTEM PURPOSES AND PROCESSES

Table 4 shows examples of system functionalities for the purposes and which technologies are supporting the functionalities and what system components from the architecture are related in each case. For example, in order to measure our activities and behaviours, the key functionality is collecting the data. The system collects the user's data through the connected real-time and -world ubiquitous systems using sensor-based data collection technologies. The collected data can be handled by data/profile manager in the application layer which uses the measurement methods in the solution layer. The collected data is stored in data storage for future analysis in the component layer. As the SSHARRPPP systems consists of multiple systems and apps, the functionalities related to each system is handled through the app manager in the application layer.

6.3.2 Sustainable Transformation Processes Perspective

In section 6.2, technologies related to the proposed sustainable transformation (SIRT) processes are discussed. The sustainable transformation (SIRT) processes can be applied to any of SSHARRPPP systems. For example, SSHARRPPP Shopping (one of the implemented systems) **senses** a user's shopping transactions via shopping app manager. SSHARRPPP Shopping analyses a chosen product detail with the user's preference data to find out whether the product is a suitable one for the user (**interpret**). The interpretation of data is handled by several managers in the application layer. They are data/profile manager, benchmark/knowledge manager, and recommendation manager. Then the system presents the outcome of analysis data. If there is a better product than the user's choice, then the system recommends alternatives (**respond**). When the information or recommendation is presented, the user can make a better decision based on the given information. Also, the shopping system allows the user to share his/her shopping to get feedback from the peers who are in similar situations. This functionality supports users to form or destroy shopping habits, as they can acquire better knowledge on their shopping behaviour (**transform**).

6.3.3 SSHARRPPP Principles Perspective

This research posits that SSHARRPPP principles are the philosophical guidance to achieve individual and family sustainability in the earlier chapters. Therefore, SSHARRPPP systems should allow individuals and families to make decisions about their lives 1) under the vision of sustainable transformation, 2) utilise social support,

3) with holistic information and knowledge, 4) help to be adaptive, 5) at real time, 6) in real world, 7) based on the precise information and 8) personalised recommendations generated for 9) persuading people to change their habits and behaviours.

All components in the component and solution layers provide materials and methods that managers in the application layer can perform tasks and support SSHARRPPP principles. Certain functionalities of SSHARRPPP systems are handled by each app manager with aids from data/profile, modelling, recommendation, benchmarking/knowledge, lifestyle, and entertainment managers. Each system utilises these applications through app manager and delivers services that fulfil SSHARRPPP principles. Figure 48 summaries supporting principles of each manager in the application layer of the SSHARRPPP system architecture.

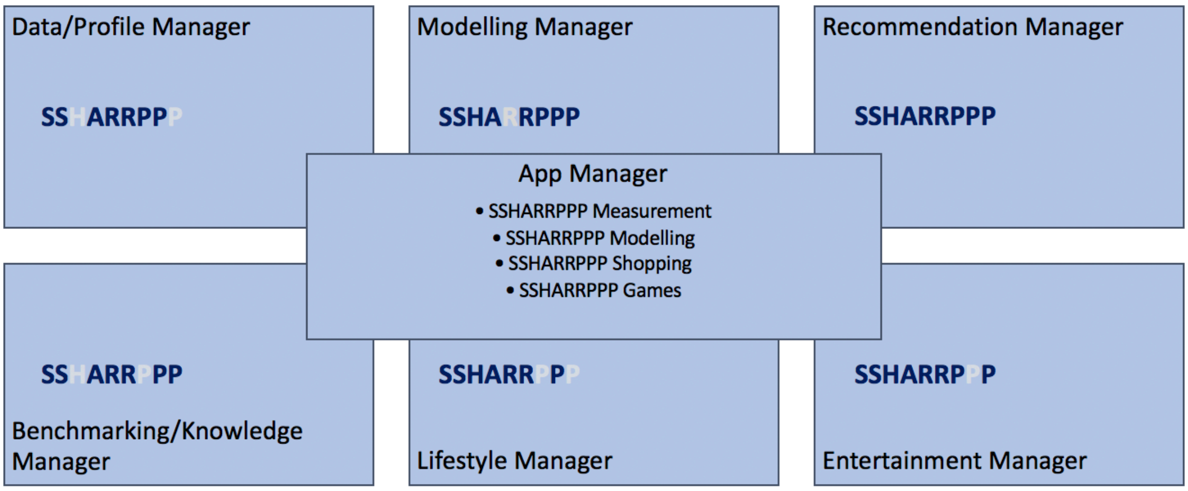


FIGURE 48. SSHARRPPP PRINCIPLES AT EACH APPLICATION MANAGER, FROM THE AUTHOR'S CREATION (CHUNG, 2019)

All systems and managers in the application layer are designed and implemented to support sustainable transformation of user's life. The Data/Profile manager supports social angle as it collects data from social media which can be real-time and real-world data. The collected data should be precise to support personalised angle, and the profile data should be adaptive while a user changes his/her life status or goals. The Modelling manager helps us to see the holistic relationships of life factors. The related data should be precise from real-world and again, data can be collected from social media. If the modelling manager deals with our own life factors, then the outcome is personalised and persuasive to transform our lives.

The Recommendation manager supports all angles to provide the best recommendations to users. To do that, it considers holistic factors, such as internal, external, and user preference data to provide socially adaptable and precisely personalised alternatives. The most persuasive recommendation can be given at the time of users taking actions (real-time and real-world). The Benchmarking/knowledge manager uses scientifically proven knowledge and social supports to provide persuasive goals and feedback on user's actions. The user can adopt new habits and behaviours which meets a personalised lifestyle. The feedback or knowledge from social media supports real-time and real-world aspects of supports for sustainable life transformation.

The Lifestyle manager deals with life factors holistically. For example, it considers a desired habit to form with the user's schedule first then produces a personalised solution to the user, so making an adaptation easy. The aids can be provided in real-time for changing real-world behaviours. Data can be collected from social media and behavioural changes can be supported via social supports. The Entertainment manager provides holistically designed educational contents in joyful ways. The games or gamified outcomes can be shared through social media to get support from community members. Combining the real and virtual worlds together, the entertainment manager can provide a persuasive mechanism to change user's habits and behaviours.

6.4 Summary

In this chapter, various technological responses based on SSHARRPPP principles, human and system purposes and processes, and sustainable transformation (SIRT) processes have been discussed, organised and proposed. Each technological response has been studied to deliver specific goals and objectives for the sustainable life transformation support.

There are many technologies available in the world and each technological development can create its own value. However, organising and building relationships among these technologies based on conceptual and procedural understanding can open new perspectives on system development and bring a vital change to human development. Figure 49 shows our research approach to implement SSHARRPPP systems that integrate functionalities ground from SSHARRPPP principles, human and system purposes and processes, and sustainable transformation (SIRT) processes.

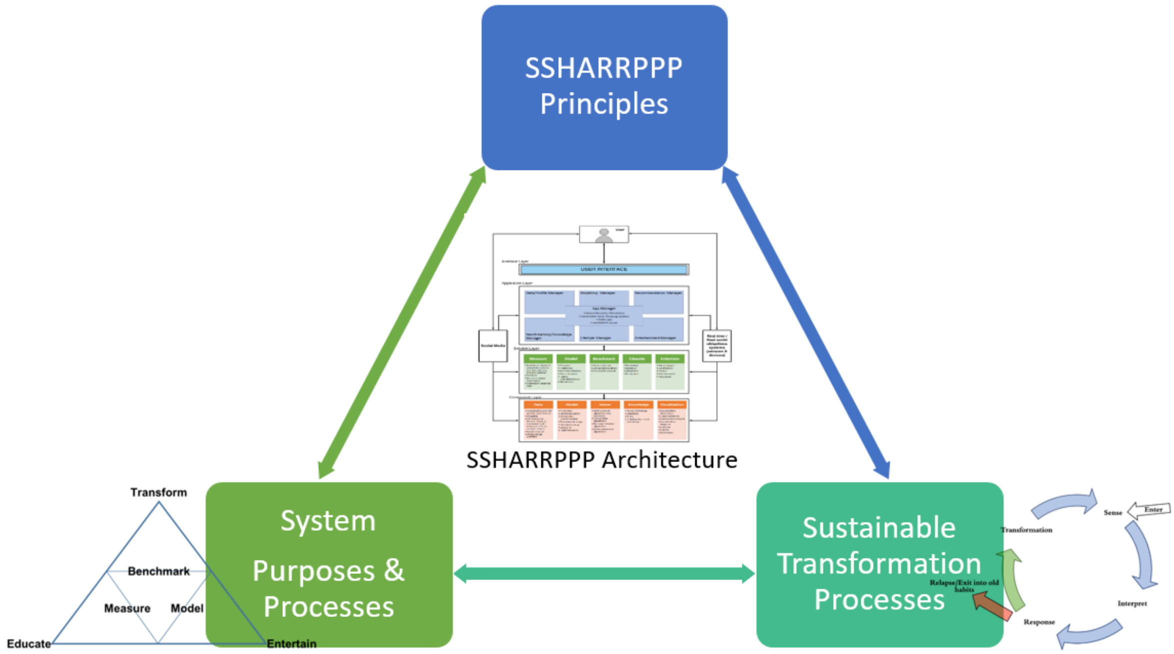


FIGURE 49. SSHARRPPP SYSTEM FRAMEWORK

This illustration is a conceptual structure, which overviews high-level philosophical, theoretical, and procedural components of SSHARRPPP systems. All systems should be designed and implemented under this environment to deliver functionalities to users and support their sustainable life transformations.

7 SSHARRPPP Systems for Sustainable Transformation of Individuals and Families

The proposed SSHARRPPP systems are a set of systems which support the sustainable life transformation of individuals and families. They are proposed to provide specific functionalities and purposes by holistically working together. Therefore, this chapter elaborates on the following questions:

- What systems should be designed and implemented to support the sustainable life transformation of individuals and families?
- How do SSHARRPPP systems interact together to provide holistic, personalised, socially driven, and persuasive features and functionalities?
- How should each SSHARRPPP system be designed and developed to deliver appropriate system purposes and processes to educate and transform individuals and families?

To answer these questions, this chapter will discuss the overarching framework to explain background of prototypical system implementations and specific architectures for each system (Figure 50):

- In 7.1, four SSHARRPPP systems and background of designing these systems are discussed and interactions between these systems are explained.
- In 7.2, the technical requirements for each SSHARRPPP system are stated and system architectures for SSHARRPPP Measurement, Shopping, Modelling, and Games are proposed.

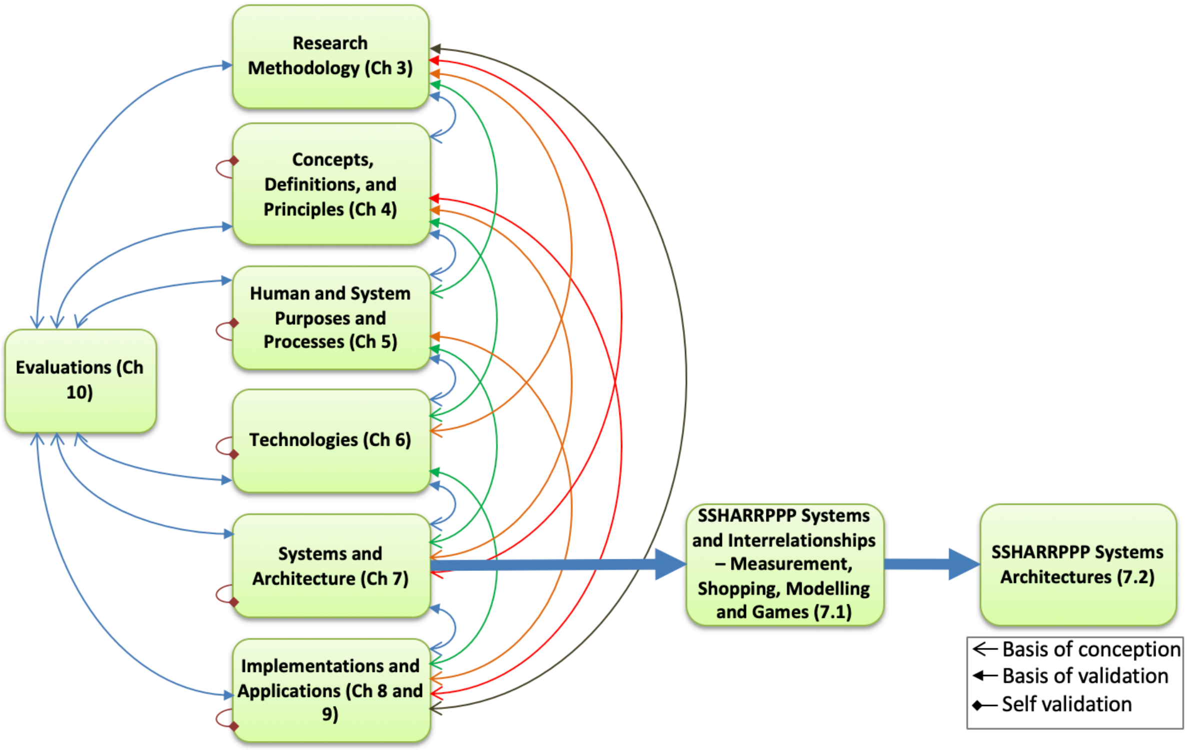


FIGURE 50. CHAPTER 7 STRUCTURE AND RELATIONSHIPS

7.1 SSHARRPPP Systems

SSHARRPPP systems are holistic, personalised, socially driven, persuasive systems that help individuals and families to sustainably transform their lives through habit formation/destruction and behaviour changes. SSHARRPPP systems are comprised of four systems/apps; they are SSHARRPPP Measurement, Shopping, Modelling, and Games. Hence, the research designed and implemented prototypical systems/apps follow the processes of sense, interpret, respond, and transform to provide functionalities that deliver system purposes and processes: measuring, modelling, benchmarking, entertaining, educating, and transforming.

SSHARRPPP Measurement is a customisable activity logging app. It allows users to log various status, activities, and behaviours through multiple logging features like flexible manual logging or automatic logging using sensors. For example, the users can record physical conditions like vital signs and glucose level in the bloodstream using integrated devices and sensors; emotional statuses like stress level and feelings through user's direct input; physical activities like running distances and dieting records using both methods. The app is ultimately helping people to transform their life by changing behaviours and habits.

SSHARRPPP Shopping supports sustainable transformation of individuals and families through their shopping process. Unlike the usual online shopping systems, SSHARRPPP Shopping provides various features including social aspects and mechanisms to form healthy shopping habits and to help users make better purchasing decisions based on their unique situations. Shopping is generally done for family; therefore, the system collects family level data as well as individual's data.

SSHARRPPP Modelling educates interrelationships of various life factors and life dimensions from a holistic viewpoint. The system allows the user to witness actions and their results through simulation. Therefore, the user can test many different situations without performing the actions. SSHARRPPP Modelling is a very useful system to teach sustainable life transformation, as some consequences of improper actions can be costly. For example, to see the consequences of taking too much sugary food can cause a disastrous health outcome for diabetic patients.

SSHARRPPP Games are designed to help people to form or change habits while they are playing games. The uniqueness of the games is that they have various modalities and interaction mechanisms of teaching and helping people to adopt healthy habits and lifestyles. SSHARRPPP Games not only provide pure games but also take the player's real-world data into game playing.

These four systems are designed to interact and work together to deliver the main SSHARRPPP system purposes and processes. To explain this, the thesis discusses the overarching system framework and system interactions in the following sections.

7.1.1 Overarching System Framework

The research focuses on supporting the sustainable, holistic transformation of individuals and families by designing and implementing innovative personalised systems. Figure 51 illustrates how these four systems have been designed and implemented based on two standpoints: (1) individual and family activity perspectives and (2) transformational system perspective. They are positioned on the left- and right-hand side respectively under the vision of sustainable transformation of individuals and families. The SSHARRPPP principles support both perspectives as a foundation.

From the individual and family activity perspective, the purposes of the vision are to have a happy life supported by sustainable physical, financial, emotional, and environmental well-being. These purposes are achieved through various processes of individual and family behaviours and activities, such as decision-making, habit formation, behaviour changes, and transformation. To follow these processes and achieve the purposes to reach the vision, education, prevention, and reversion of their behaviours and activities are the important mechanisms. SSHARRPPP Measurement and SSHARRPPP Shopping are systems that focus on the individual and family activity perspective. These systems use various mechanisms to collect daily behaviours and activities for sustainable transformation.

From the transformational system perspective, the purposes are measuring, modelling, benchmarking, entertaining, and educating people to transform their lives. Therefore, they can prevent or cure undesirable life statuses, such as having a chronic illness. The systems provide information to educate, persuade, and support sustainable transformation by following sustainable transformation processes: sense – interpret – respond – transform. The systems are designed and implemented to understand individual and family processes that are discussed in chapter 2. SSHARRPPP Modelling uses modelling and simulations and SSHARRPPP Games uses games and gamifications as the main mechanisms to aid a sustainable lifestyle transformation.

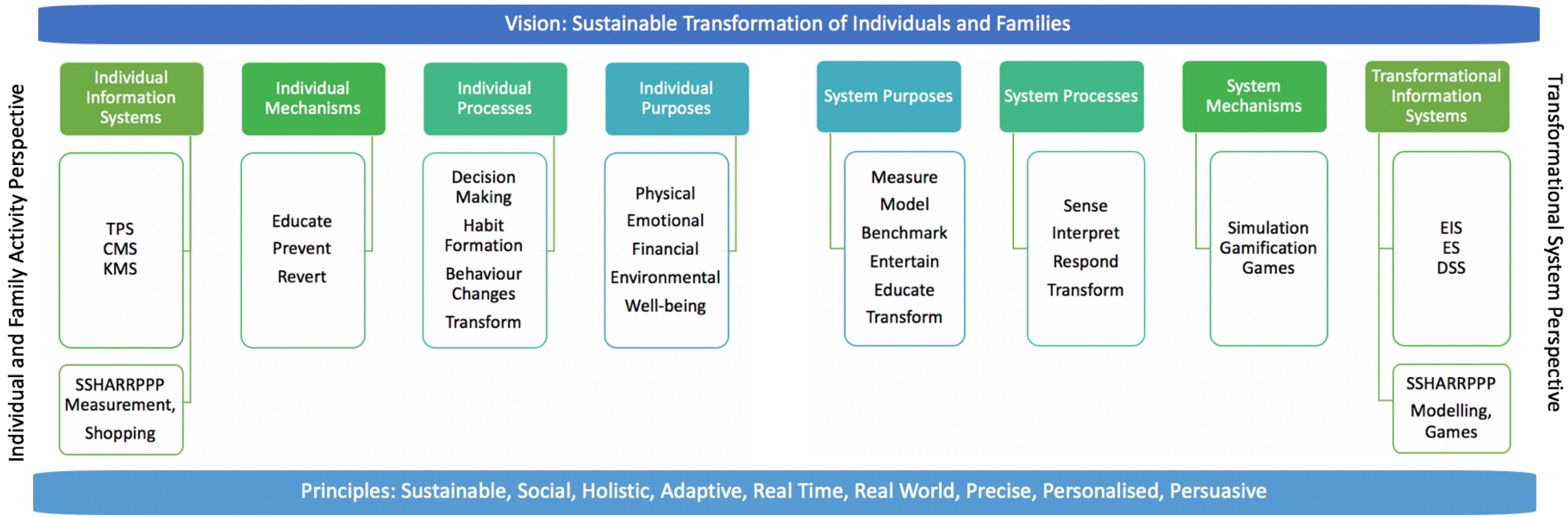


FIGURE 51. OVERARCHING SYSTEM FRAMEWORK, FROM THE AUTHOR'S CREATION (CHUNG, 2019)

The framework can be presented in vertical ways to explain its relationship and interactions between each element. Based on nine *SSHARRPPP principles*, SSHARRPP systems from both perspectives (*individual information systems and transformational information systems*) are working together to educate, prevent, and revert individuals and families' situation via simulation, games, and gamification mechanisms, which are provided by systems (*individual and system mechanisms*). These mechanisms are delivered while systems are following sense-interpret-respond-transform processes. Data, information, and insights gained through these processes help individuals and families to make better decisions to change their behaviours and support them to form desired habits for transformation (*individual and system processes*). The systems provide functionalities and services of measure, model, benchmark, entertain, educate, and transform (*system purposes*), so individuals and families can achieve their purposes of lives that are physical, emotional, financial, and environmental wellbeing (*individual purposes*) that ultimately lead to the sustainable transformation of individuals and families (*vision*) (Figure 52).

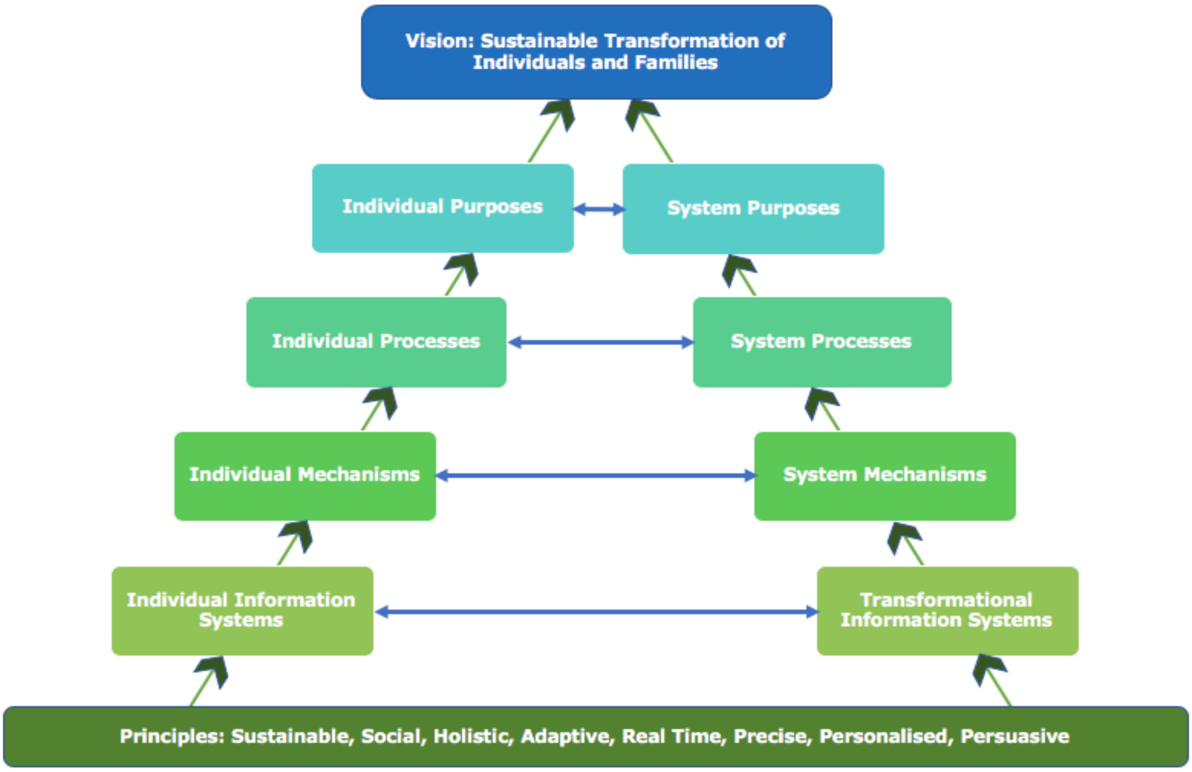


FIGURE 52. OVERARCHING SYSTEM FRAMEWORK PRESENTED VERTICALLY

7.1.2 SSHARRPPP Systems Interactions

In chapter 6.1.6, six system purposes and processes had been presented in Figure 45 based on foundational activities, mechanism, and goals. SSHARRPPP systems need to be designed and implemented to support these technological approaches and functionalities. In consequence, it also guides how the researcher to organise four SSHARRPPP system prototypes and Figure 53 shows how these systems are connected and worked together to educate and transform individuals and families. To bring the meaningful values to individuals and families, SSHARRPPP systems should perform tasks at each SIRT processes in an integrated and collaborative manner.

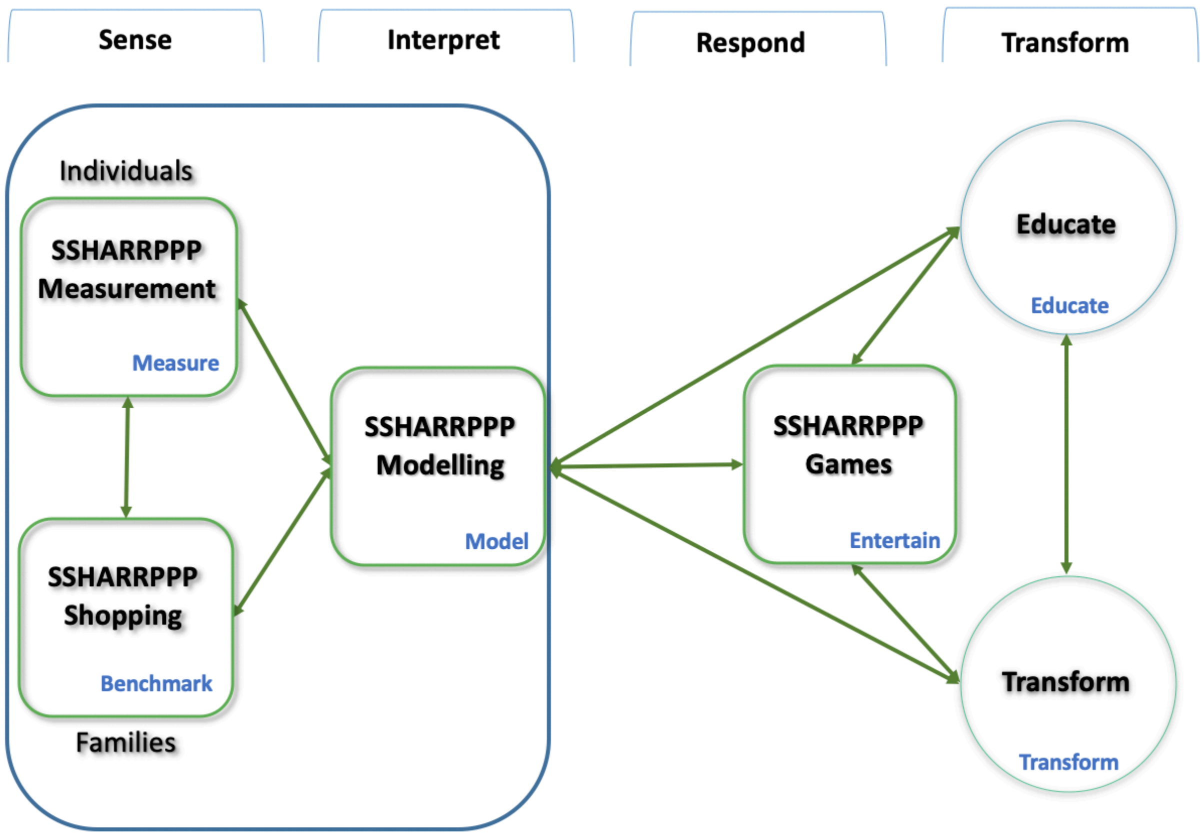


FIGURE 53. SSHARRPPP SYSTEMS INTERACTIONS AND WORKFLOWS, ADAPTED FROM THE AUTHORS' CREATION (CHUNG & SUNDARAM, 2019)

SSHARRPPP systems are working together to achieve the goals – educating people and ultimately transforming them. The systems can be deployed based on SIRT processes. SSHARRPPP Measurement is collecting individual activity and behaviour data while SSHARRPPP Shopping measures family level data. SSHARRPPP Shopping is also important in holistically measuring data from various life aspects. For example, one shopping transaction can provide financial, health and environmental data. The data collected from both systems can be input for the SSHARRPPP Modelling. Then SSHARRPPP Modelling can provide the interpreted information that can describe our current life situations, explain how life dimensions impact each other, and predict how our lives can be changed (Rouse & Morris, 1986). SSHARRPPP Games can utilise models that represent the realities to persuade people to respond toward achieving the goals. The impacts between systems are mutual and interactions happen as various workflows within SSHARRPPP systems.

As discussed here, all functionalities that support interactions between SSHARRPPP systems for the sustainable transformation should be implemented. Therefore, architectures for each of the SSHARRPPP systems are proposed in the following sections.

7.2 Specific SSHARRPPP Systems Architectures

In this section, the research proposes architectures that need be used for implementing each of the SSHARRPPP systems: Measurement, Shopping, Modelling, and Games. Key elements and layers are employed from the overall SSHARRPPP architecture, discussed in section 6.2. Therefore, all architectures suggested here are also believed to deliver functionalities that support SSHARRPPP principles, system purposes and processes, and sustainable transformation (SIRT) processes.

7.2.1 SSHARRPPP Measurement Architecture

SSHARRPPP Measurement employs essential components to serve its key functionalities, such as component and solution layers. These layers have been discussed in 6.3. Therefore, this section explains the proposed SSHARRPPP Measurement architecture focusing on application layer (Figure 54).

The main system purpose and processes of SSHARRPPP Measurement is supporting individual transformation through measurement. When various life data is captured, there is a high chance to understand the causal effect relationships among life factors. For example, a diabetic patient's glucose level might go up after a stressful event or the level might go down after certain exercises. As our life factors can be presented differently, making a measurement of any life factor easy becomes a key idea of SSHARRPPP Measurement.

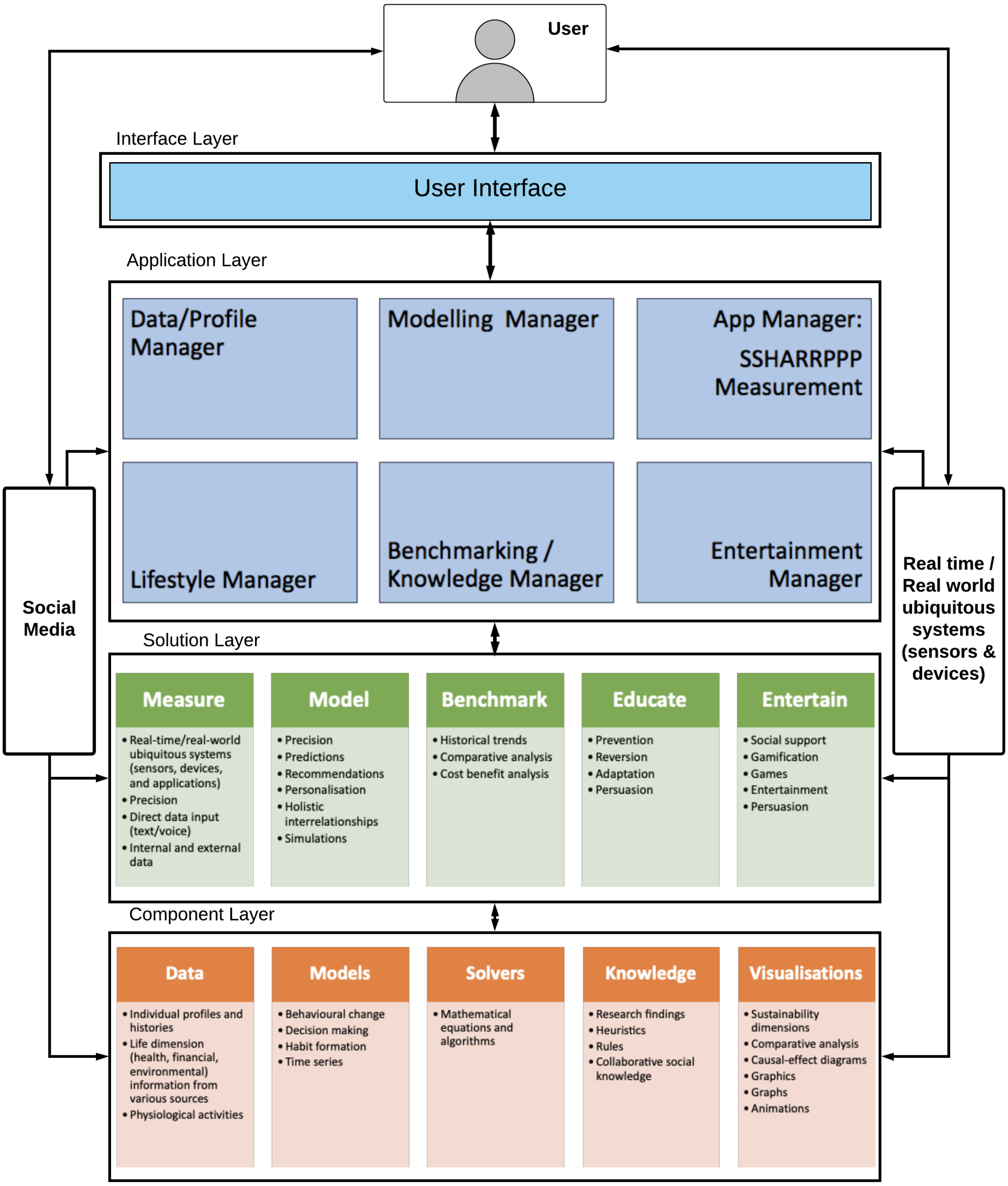


FIGURE 54. SSHARRPPP MEASUREMENT ARCHITECTURE

For this, the app can allow three different data entry methods: 1) manual entry, 2) import data from external systems and devices, and 3) sensor-based automatic data entry. The data collection is handled by data/profile manager and real-time/real-world ubiquitous systems. The collected data is stored in the component layer. The various data logs can be presented in timeline to show the before and after relationships among life factors and events, after treating data through the modelling manager.

The app allows the user to set up goals and the desired habits to form. The goal and habit settings are handled by the lifestyle manager. Benchmarking/knowledge manager and lifestyle manager can work together to encourage a goal achievement. For example, the remaining distance to the goal can be shown to the user during his/her running. Once the user reaches the goal, the entertainment manager can provide badges to reward the user's achievement.

The results can be presented in various formats for the user's reflection on his/her performance. To present the results, all managers in the application layer work together. For example, the data/profile manager extracts related data for each performance, and the benchmarking/knowledge manager analyses the data based on what the user tries to learn (e.g. best performance). Then the results can be presented after applying an appropriate format like visualisation to the user.

This proposed architecture will be a blueprint to implement SSHARRPPP Measurement. This system is measuring the individual level of activities. In the following section, the thesis will discuss SSHARRPPP Shopping, which will provide family level activity measurements and benchmarking services through social shopping.

7.2.2 SSHARRPPP Shopping Architecture

The basic functionality of SSHARRPPP Shopping is purchasing (selling) products. Therefore, the system has common components that can be found in general shopping systems. What makes SSHARRPPP Shopping distinguishable from other shopping systems is that the system supports customer's purchasing decisions and help them to form good shopping habits based on SSHARRPPP principles, especially with social and personalised angles. Due to its business nature, SSHARRPPP Shopping is broadly divided into two sides: the customer side and the business side. There are four layers at each side: component, solution, application, and interface layers. Users on each side (customers and system administrators) interact with their own interface and application layers while component and solution layers are shared and interact with application layers at both sides (Figure 55).

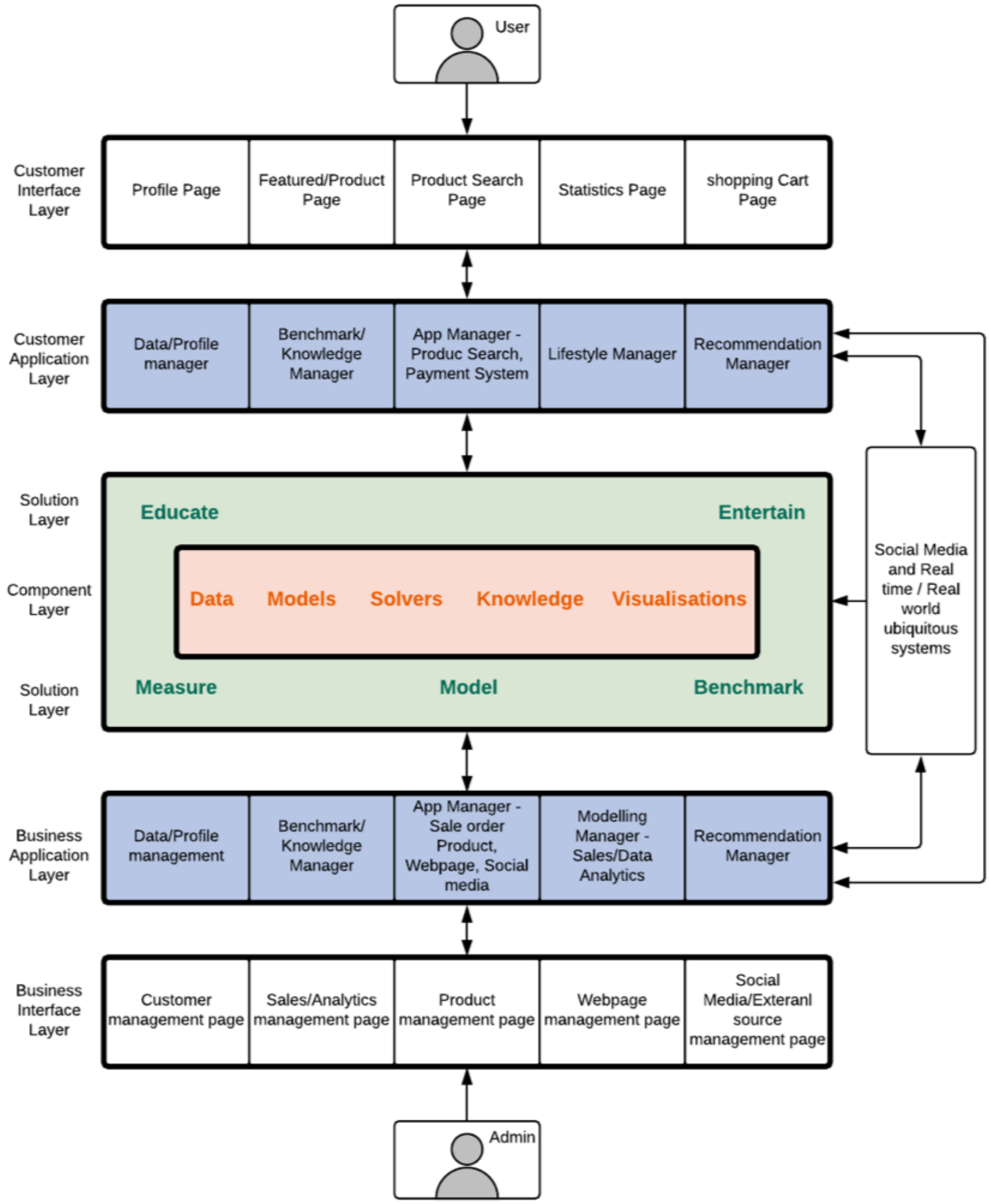


FIGURE 55. SSHARRPPP SHOPPING ARCHITECTURE

One of the unique functionalities that SSHARRPPP Shopping provides to customers is the personalised recommendation. As SSHARRPPP Shopping adopts concepts and idea of recommendations from e-Commerce recommendation applications, which was suggested by Schafer, Konstan, and Riedl (2001), the system combines customer, shopping transactions, and product data from the data in the component layer and data from social media to generate recommendations. SSHARRPPP Shopping uses a degree of personalisation and delivers the personalised recommendations to the customer.

In the component layer, SSHARRPPP Shopping has storages for data, models, solvers, knowledge, and visualisations. Particularly, the system stores various data for shopping system functionalities. Individual/household profiles and histories, shopping transactions, life dimension (health, financial, environmental) information from various sources, and product information will be used to support personalised recommendations and benchmarking. Figure 56 is showing the component layer of SSHARRPPP Shopping that is briefly illustrated in Figure 55.

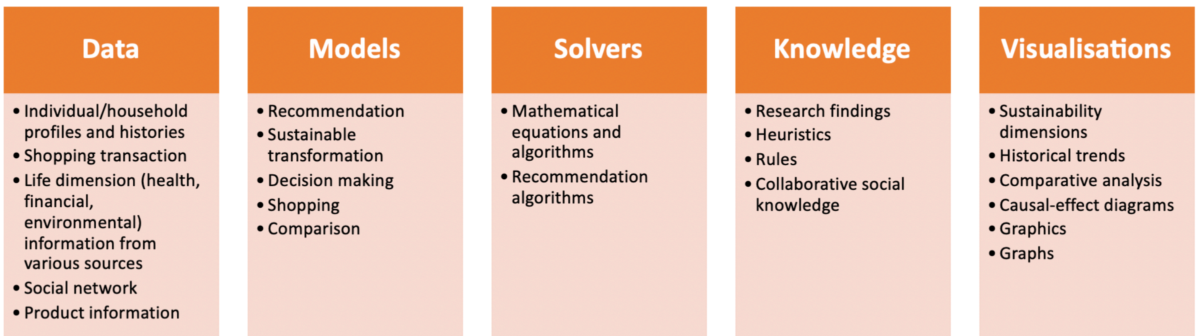


FIGURE 56. COMPONENT LAYER OF SSHARRPPP SHOPPING ARCHITECTURE

The solution layer works as a bridge between the component layer and the application layer at each end. This layer extracts relevant elements from the component layer and prepares them for managers in the application layer. For example, the recommendation manager asks for information for product recommendation, the solution layer will use customer and family profile, product data, shopping transactions and knowledge to recommend products based on user's preferences (Schafer et al., 2001). Figure 57 illustrates the solution layer in detail that is shown in Figure 55.

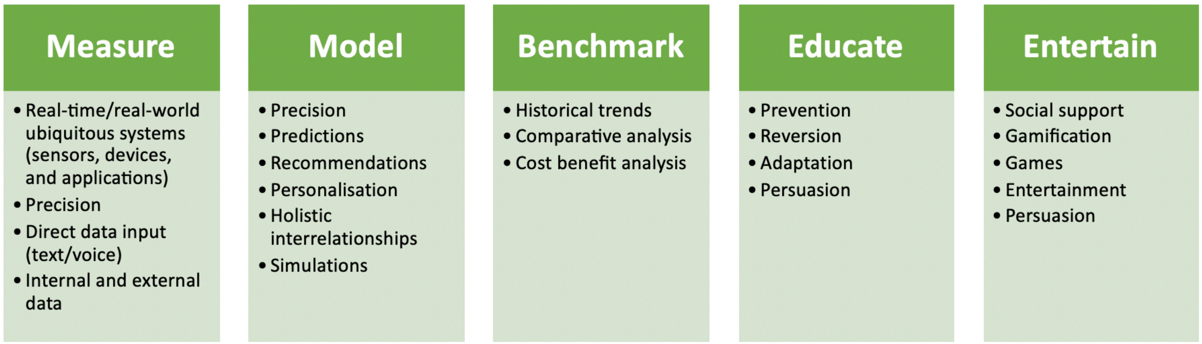


FIGURE 57. SOLUTION LAYER OF SSHARRPPP SHOPPING ARCHITECTURE

Each manager in the application layer performs all functionalities regarding the online shopping cart systems as well as the recommender systems. For example, the benchmark/knowledge manager collaborates with other managers in the application layer; the benchmark/knowledge manager will use various benchmarking approaches, such as internal, external, competitive, and generic (theoretical) approaches (Blakeman, 2002), to provide insightful shopping information.

The top layers in the architecture consist of the customer and business sides of the interface layer. They work closely with the application layer at each side. Both application layers handle interactions between people (customers and administrators) and the system and data layers. For example, when customers manage their profile information through the profile page (interface layer), the data/profile manager handles the input data and stores it in the customer's data. In a similar way, when the recommendation manager provides suggested products for the customer, it works together with the app manager (featured/product management) to show the results on the featured/product page. Customer side functionalities in each page will be explained in SSHARRPPP Shopping implementation section. On the business side, the SSHARRPPP Shopping provides business functionalities, such as sales/analytics, product, and web page management. Administrators can manage these via interface pages. For customer management, customers and system administrators manage information through the same management application, but the system administrator can access more features than customers.

The system architectures for SSHARRPPP Measurement and Shopping are proposed to offer functionalities that measure individuals' and families' activities and behaviours. The measured data from these two systems can be used to gain insights into causal effect relationships among life factors in SSHARRPPP Modelling. In this regard, the thesis will discuss the proposed system architecture for SSHARRPPP Modelling in the following section.

7.2.3 SSHARRPPP Modelling Architecture

The ideas and designs of SSHARRPPP Modelling is inspired by the classical designs of simulation software (Costanza & Ruth, 1998). The architecture of SSHARRPPP Modelling has four layers, which contain progressively detailed information on the structure and functioning of the system (Figure 58).

As it is mentioned previously, SSHARRPPP Modelling will take all data measured and collected from SSHARRPPP Measurement and Shopping to understand the relationships among them. Therefore, it will store data from both systems in the components layer. For example, for data, both individual and family profiles and histories are stored as well as relating data to life dimensions, shopping, social network, and physical activities. More comprehensive models are included as well. To provide insightful information, SSHARRPPP Modelling will utilise prediction, recommendation, sustainable transformation, and shopping models. These data and models are analysed using various solvers and knowledge. For solvers, SSHARRPPP Modelling has data mining, recommendation, system dynamics, and mathematical algorithms and equations. And research findings, heuristics, rules, and collective social knowledge are stored in knowledge. Then the system will employ various visualisation techniques like sustainability dimensions, historical trends, comparative analysis, causal effect diagrams, graphs, graphics, and animations to enhance users understanding. Solution layer is adopting core elements from the overall SSHARRPPP architecture and adding additional elements as described in Figure 58.

The main purposes of SSHARRPPP Modelling are educating interrelationships of various life factors and outcomes to users. These features will be delivered through application layer. In the application layer, the system should be able to support problem structuring, modelling, and simulations. In the problem structuring phase, relevant life factors on phenomena should be identified. For example, diet, exercise, sleep and stress are relevant factors that result in glucose levels. Once factors are identified, the model should be constructed to form relationships among the factors. A causal loop diagram can be constructed to understand the influencing effect between each factor. Based on this conceptual causal loop diagram, stock and flow models can be built for simulation. After the models are constructed with equations and algorithms, the simulations can be carried out at interface layer.

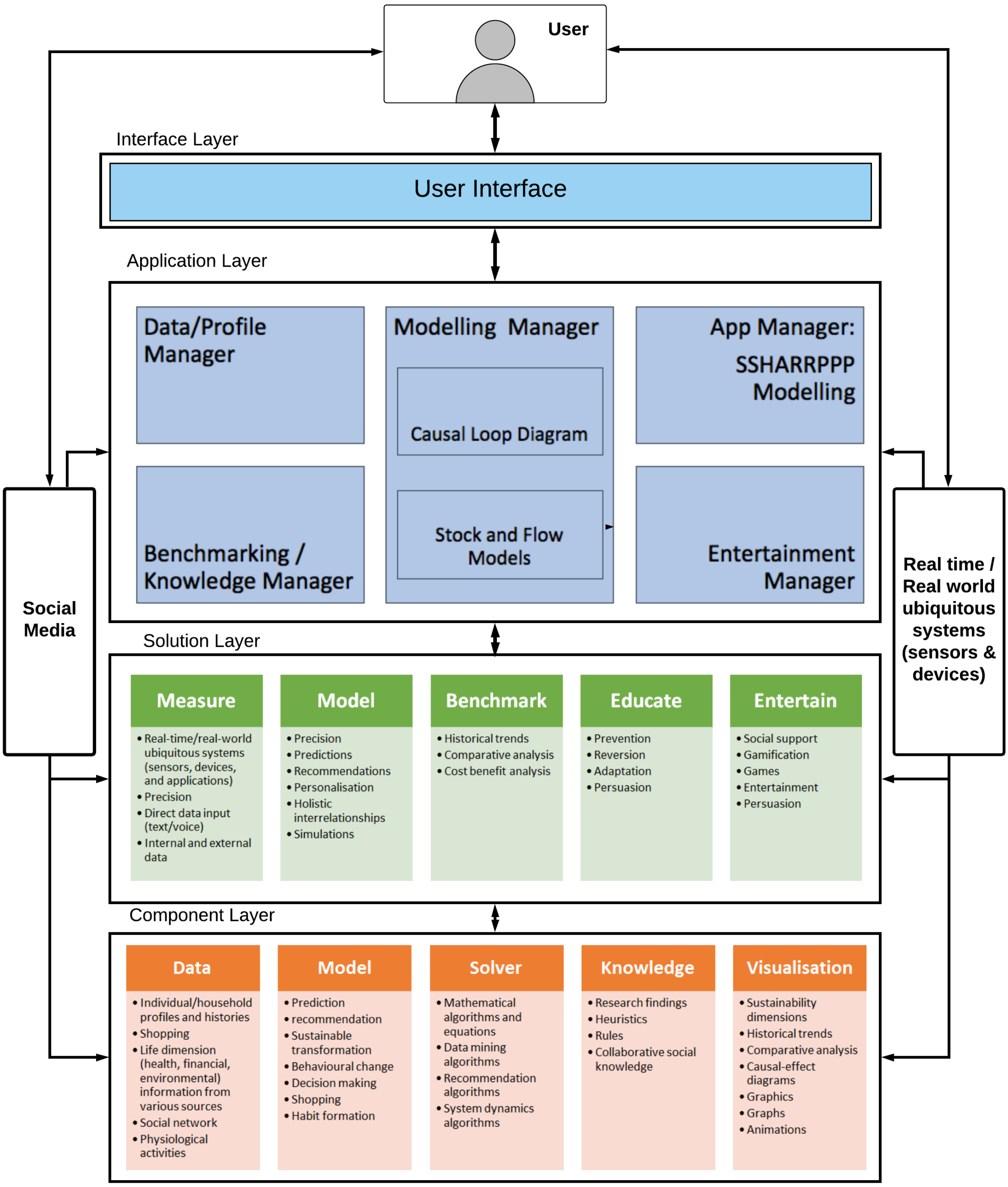


FIGURE 58. SSHARRPPP MODELLING ARCHITECTURE

For simulations, values for variables can be entered by users through variable fields provided in the user interface or the actual data is extracted from the data storage in the component layer. The values for variables are then calculated based on equations that are formed with models through the modelling manager and the results are delivered to users in the best format to present the outcome. The user can change values to test 'what if' scenarios and to find the best option. The benchmarking/knowledge manager handles this functionality with the modelling manager.

Once Modelling helps users to understand their life factors and their relationship better, the modelled interrelationships can be used to implement games. Games can educate users efficiently how people can change their lives and motivate them to pursue sustainable transformation while they are entertained. Therefore, the system architecture for SSHARRPPP Games is discussed in the following section.

7.2.4 SSHARRPPP Games Architecture

SSHARRPPP games have a component layer, a solution layer, an application layer, and an interface layer. Externally, the games are designed to link social media and real-time & real-world ubiquitous systems and devices (Figure 59).

Through the interface layer, players can (a) configure a vision, goals, profile, health, habit, schedule, and games; (b) manage health, habit, and schedule transactions and (c) play games. SSHARRPPP Games have direct connections with wearable devices and social media which update various data into the component layer. The game and user interaction data are automatically updated via real-time & real-world ubiquitous systems and devices, social media and game plays as much as possible.

SSHARRPPP Games are sharing same component and solution layers with SSHARRPPP Modelling as discussed in 7.2.3. In addition to that, data (clinical data, personal data, and environment & social data and their relating models, algorithms, methods, solvers, visualization, scenarios, rules, heuristics and knowledge are in the component layer of the architecture to support the sustainable lifestyle transformation.

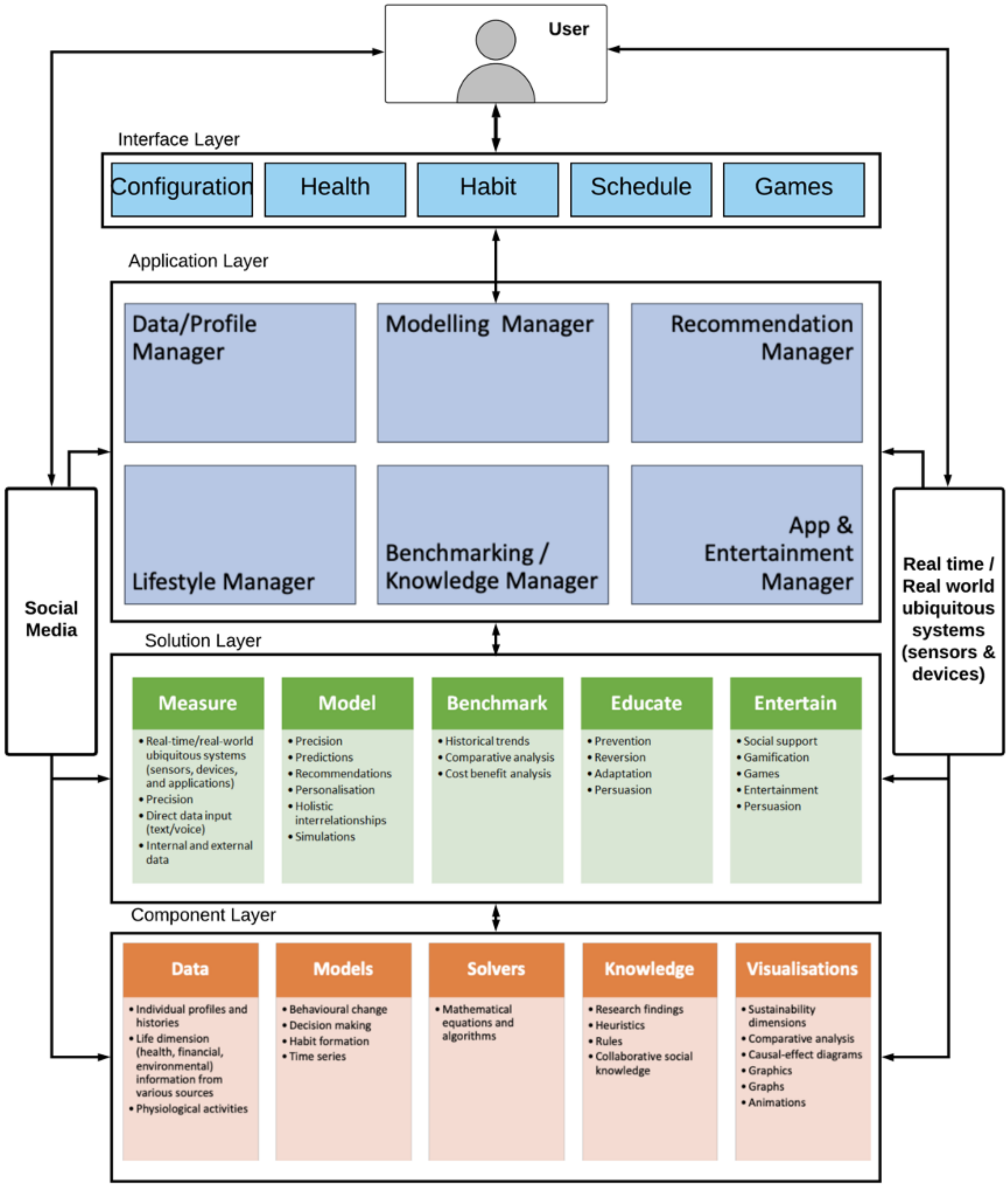


Figure 59. SSHARRPPP Games Architecture, adapted from the authors' creation (Chung & Sundaram, 2018b)

The application layer offers data/profile, modelling, benchmarking/knowledge, lifestyle, recommendation, and app & entertainment managers. The solution layer communicates between elements in the component layer and managers in the application layer. For example, the entertainment manager can use the player's real-world activity data into the game. For this, the solution layer measures the player's activities and provide the data for game use. Then the entertainment manager can incorporate the data into games, so the player can experience real and virtual games. The real-time & real-world ubiquitous systems and devices and social media also contribute to collecting data and information as they are connected to SSHARRPPP games. Especially, the direct connection/integration of social media to users provides social and peer support which can be the most effective persuasive technique (Dadgar & Joshi, 2015) in the SSHARRPPP Games.

7.3 Summary

In this chapter, SSHARRPPP systems have been proposed to elucidate what functionalities each system offers and how they work together to achieve the vision of sustainable life transformation. Each system type has been considered based on SIRT processes. SSHARRPPP Measurement and Shopping have been proposed to **sense** individual and family activities, respectively. Modelling is **interpreting** real life factors and their values for providing better understanding to us. SSHARRPPP Games are **responses** of interpreted models and help individuals and families to **respond** towards to sustainable life **transformation**.

To provide a system development background, this research has explained how originally SSHARRPPP systems have been projected through the overarching system framework. Furthermore, the framework summarises our rigorous research approaches that scrutinise conceptual, procedural, and technological responses in depth to build each SSHARRPPP system. Also, the research has introduced key functionalities that each SSHARRPPP system can offer and the relevant components through the proposed system architectures and their analysis.

SSHARRPPP systems are designed to deliver specific purposes and can support the individual and family sustainability standalone, but, when they are working together, they can provide better supports systemically and holistically under SIRT processes. Now, the thesis will look at how these systems can be used by demonstrating certain features using a case study.

8 Application and Demonstration of SSHARRPPP Systems

SSHARRPPP Measurement, Shopping, Modelling, and Games have been designed and implemented under the vision of sustainable life transformation. This chapter focuses on demonstrating the application of prototypes that measure, model, benchmark, entertain, educate, and transform daily activities and behaviours to form healthy habits and build a sustainable life. For better discussion, type 2 diabetes is used as a case background.

This chapter elaborates on the following questions:

- Why was type 2 diabetes chosen for the application of the SSHARRPPP System prototypical artefacts?
- How do SSHARRPPP systems handle data collections to measure and capture the daily activities and behaviours?
- How do SSHARRPPP systems support the sustainable life transformation of individuals and families in terms of decision-making?
- How do SSHARRPPP systems provide effective learning and educational environment to individuals and families?
- How do SSHARRPPP systems provide persuasive and encouraging behaviour changes?

To answer these questions, the thesis will demonstrate SSHARRPPP systems using an application case (Figure 60):

- Introduce an application case and common lifestyle recommendations for chronic illness patients in 8.1.
- Describe data collection features in SSHARRPPP Management in 8.2. In this section, the thesis explains the manual data logging feature that ensures the flexibility in data entry and an automatic sensing feature that ensures easy data collection.

- Explain how SSHARRPPP Shopping provides recommendations and rich information on health, wealth, and an environment for supporting the customer's decision-making in 8.3.
- Show simulations on glucose inflow through food intake and outflow and their lifestyle effects in 8.4. In this section, the thesis will explain how SSHARRPPP Modelling can provide impactful moments of learning and educational outcomes of our lifestyle and behaviour changes without bearing actual consequences.
- Demonstrate how SSHARRPPP Games uses persuasive features to educate the users with healthy lifestyle habits in 8.5. In this section, we show games that handle each lifestyle and one in an integrated version.

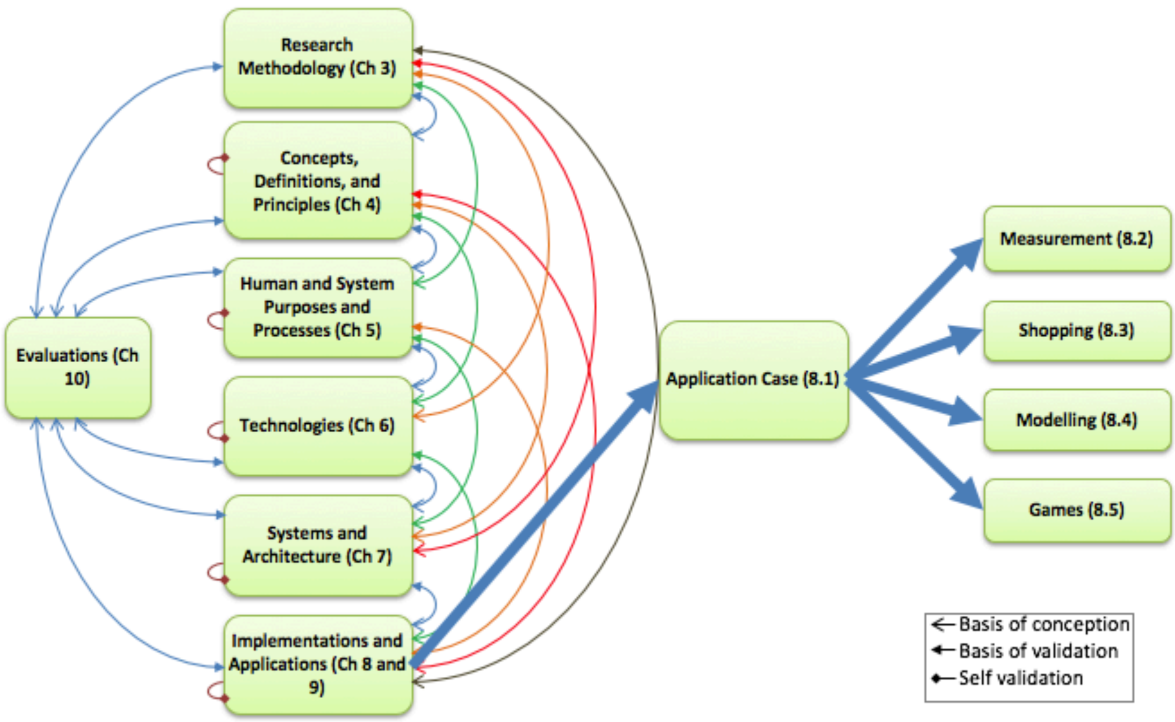


FIGURE 60. CHAPTER 8 STRUCTURE AND RELATIONSHIPS

8.1 Application Case

The research decided to select a group who critically require a sustainable life transformation due to the broad research scope. Chronic diseases are long-term, recurring health conditions that many of the world's population experience in their lives. Chronic diseases have become a more serious problem as the diagnosed age is getting younger and causes 40% of premature deaths under the age of 70. The World Health Organization (Wing & Yang, 2014) estimates that chronic illnesses can cause 52 million deaths by 2030. The increase of chronic patient population also means a significant economic burden and loss to both individuals and society.

Many studies regularly report that unhealthy diet, physical inactivity or tobacco consumption are modifiable, and a healthy lifestyle can effectively prevent critical health conditions (Centers for Disease Control and Prevention, 2011; Johnston, Liddy, Ives, & Soto, 2008). Especially, recent medical experiments and studies report that the reversal of type 2 diabetes was examined after the appropriate medical interventions with healthy lifestyle adoption (Dunaief, Fuhrman, Dunaief, & Ying, 2012; Lim et al., 2011). Dietary and lifestyle risk factors are developed gradually based on the individual's daily behaviours and decisions. Therefore, many health organisations like American Diabetes Association (ADA) (2018) annually provide a better lifestyle guidance to patients for improving their health conditions. Common managements are weight, diet, physical activity, sleep, stress, alcohol, smoking, and medicine management. Also, measuring daily activities including glucose level (sugar level in blood stream) regularly.

For demonstrations of SSHARRPPP systems, this research selects scenarios that diabetic patients should follow for managing their diseases based on the guidelines from health organisations like ADA. Type 2 diabetes became the motivating case for our research because many studies have proven that type 2 diabetes is closely linked with our unhealthy lifestyles. Therefore, the sustainable life transformation is the most crucial requirement for diabetic patients and their families. For the most part, SSHARRPPP systems focus on changing basic daily activities and habits, such as diet, exercise, sleep, stress management, and shopping. The following sections will explain how SSHARRPPP systems support diabetic patients and their families.

8.2 Measurement – Individual Activities

To measure various activities, users can use SSHARRPPP Measurement. This prototypical measurement app has been implemented two ways to collect users' daily data from three different data entry methods explained in 7.2.1. They are manual data entry and automatic sensing.

In the following sections, the thesis will show how data can be entered manually and how data can be collected automatically using a built-in sensor. Also, how their progress that measured by the built-in sensor is presented to the users.

8.2.1 Flexible Activity Logging (Manual)

Personal values cover a broad spectrum of life, and not all values have the same weight to all individuals and families as it is discussed in chapter 2.2. Therefore, distinct variances in values can be expected to play an essential role in determining one's tendency to engage in actions (Breckler, 1984). Therefore, individuals have unique circumstances or intentions when it comes to changing behaviours. Also, to achieve sustainable life transformation, it is crucial to measure various activities and behaviours for gaining a holistic perspective. However, current measurement systems are often specialised one life dimension and offer little flexible activity logging.

Unlike currently available measurement systems, SSHARRPPP Measurement provides flexible activity logging features to accommodate the user's unique circumstances and flexible activity logging needs. Figure 61 is a flexible activity logging category page that users meet first when they instantiate SSHARRPPP Measurement. When users want to log any activity that they would like to measure, users can choose a category of activities in SSHARRPPP Measurement. If there is no appropriate category to choose from, then the user can create a new activity category simply by clicking "Add More" button.

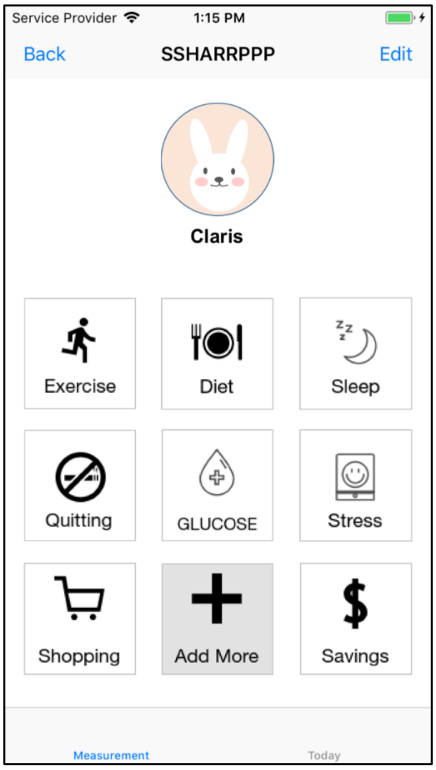


FIGURE 61. SSHARRPPP MEASUREMENT CATEGORY PAGE

Once the user clicks the appropriate category, the system will show an interface for the manual data entry. In this interface, the user can write an activity that need to be measured in the "Habit Name" field. If the activity is important then switch on the "Important?" button. Once the save button is hit, the log shows on the "Daily Logs" table view. As it has been marked as important, an exclamation mark appears in front of the log. The item is stored in the database (Figure 62).

There is possibility that the user makes a mistake while they are logging the activity. In this case, first the user needs to click an activity item to delete in the "Daily Logs" list (the left image in Figure 62).

SSHARRPPP Measurement change its interface, which is like the one for logging, but has "Delete" button at the bottom. If the user still wishes to delete the activity item, the user can click "Delete" button. Once the user clicks the delete button, the activity item also gets deleted from the database (Figure 63). The manual data entry feature is important as it ensures the maximum flexibility of collecting data. This way, the app can cater the user's unique idiosyncratic needs and circumstances.

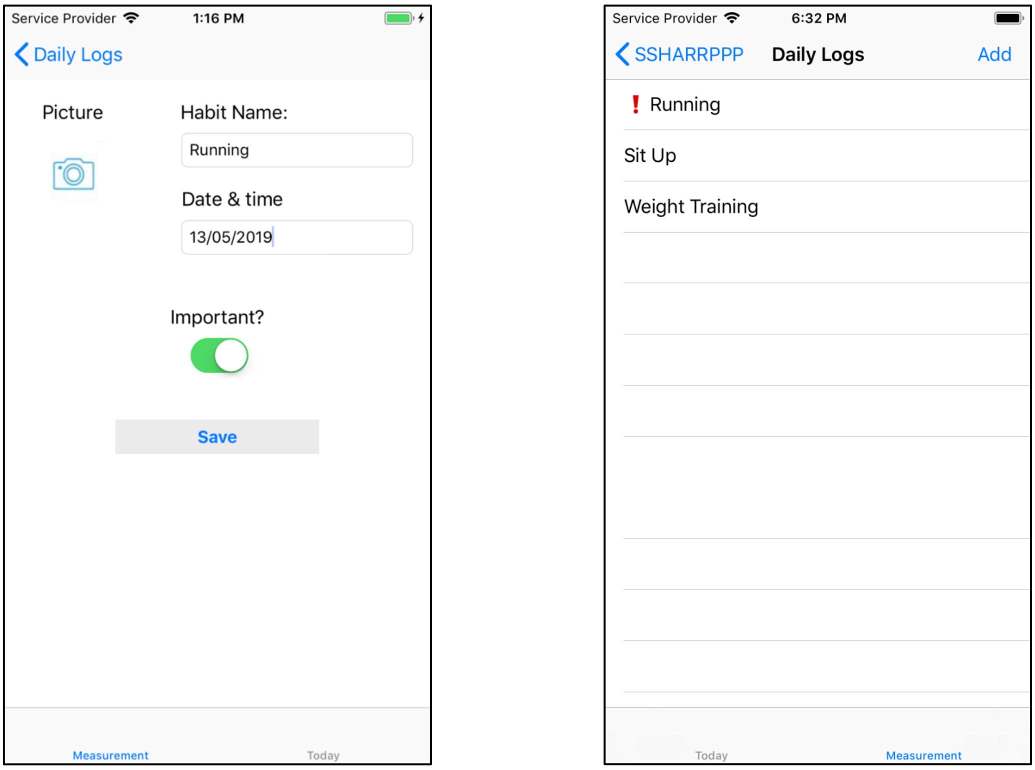


FIGURE 62. SSHARRPPP MEASUREMENT MANUAL ENTRY

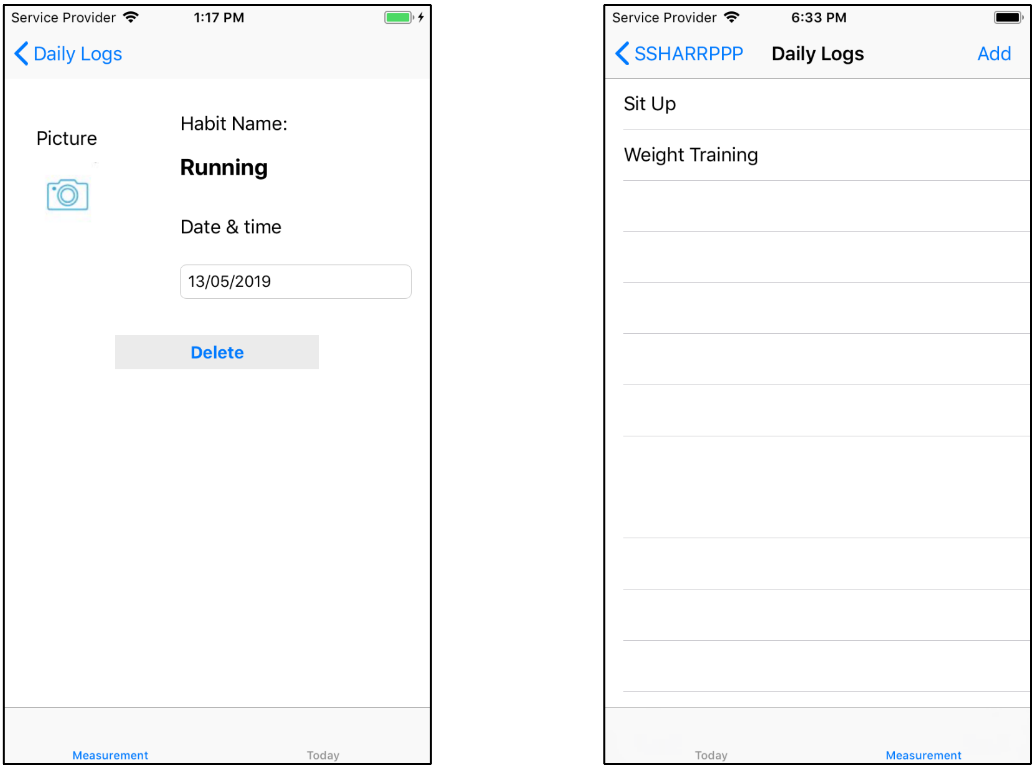


FIGURE 63. DELETE SSHARRPPP MEASUREMENT LOG

8.2.2 Real-time Activity Sensing (Automatic)

Like many other current measurement systems, real-time activity sensing is a vital feature to offer for measuring many activities. As it is automatically measured and sensed, the data measured via this feature can be more accurate than manual logging, as it requires minimum user input. Although it is a common feature that many current measurement systems offer, many existing systems only focus on a single life dimension. Furthermore, they often provide single service, such as measurement only features to users and do not allow users to experience integrated system features. As explained in 6.3, SSHARRPPPP systems provide system architecture that embraces multiple systems. SSHARRPPP Measurement is one of the main systems that collect precise data to provide integrated services to users. Therefore, it is implemented to capture real-time activities by utilising in-built sensors in smart devices. The researcher chose a scenario of building a running habit to explain how SSHARRPPP Measurement collects the real-time running data. Also, it is because being physically active is helpful to regulate glucose for diabetic patients as well as running is the most popular physical activities in New Zealand (Sport New Zealand, 2015).

As illustrated in Figure 64, once the user clicks the “New Run” button, the app initiates a GPS sensor and shows where the user is on the map. By clicking “Start” button, the app starts to track the user’s movement.

The map is zoomed in to show the user’s movement in detail. Time and distance are collected. Then the pace is calculated to show the instant performance to the user. Underneath of the map, a cookie badge encourages the user to run further. The next achievable badge is ‘macaroon’ in this example shown in Figure 65. This cookie badge is based on the reverse psychology that tells how far the user should run to be able to eat the cookies. Once the user hit the “Stop the Run” button, the user can choose whether the run is to be saved or not.

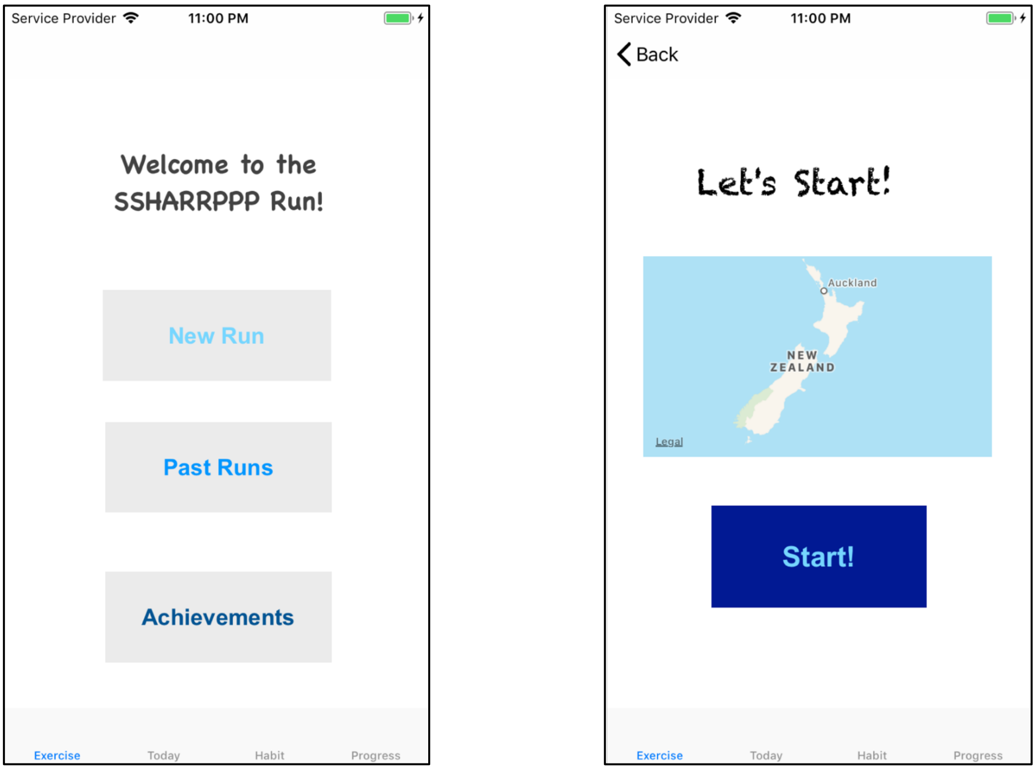


FIGURE 64. EXAMPLE OF SSHARRPPP MEASUREMENT REAL-TIME ACTIVITY SENSING

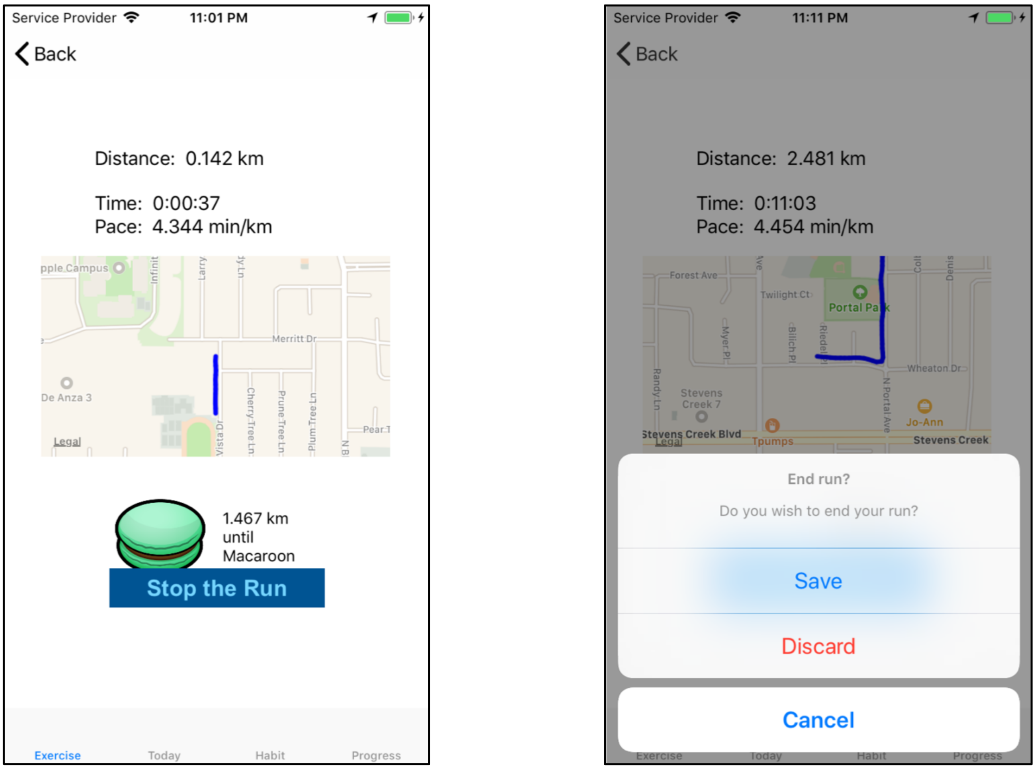


FIGURE 65. MOTIVATIONAL FEATURE IN SSHARRPPP MEASUREMENT

Once the user stops running, the app shows the track that the user has run. The track is colour coded to show the user's performance. A green colour represents that the user's running pace is fast enough; yellow and amber represents normal speed; red means that the user's pace is slow. The blue dots are where the user has earned the cookie badges. The example shows a chocolate cookie earned by the user running at 2.414km (Figure 66).

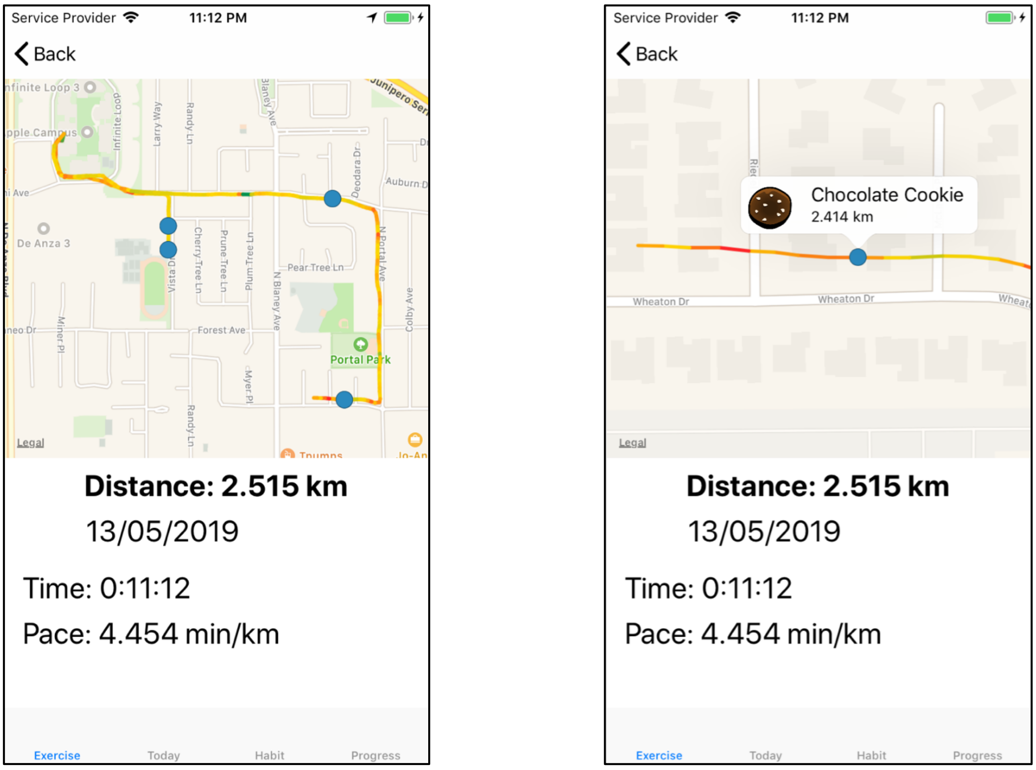


FIGURE 66. PERFORMANCE REPORT

Historical performances also can be checked in the progress page. The earned badges are shown in the table view. This view helps the user to track their performance in the past. Badges which have not been attained remain a secret. This also encourages the user to take further and continuous action. The information related to the run and the earned badge can be checked by clicking them. The example shows the information related to the last earned badge (Figure 67).

So far, the thesis demonstrated the implemented features in the prototypical implementation of SSHARRPPP Measurement. The system mainly focuses on flexible measuring multiple activities based on users' needs. The real-time activity sensing is implemented with an assumption that being physically active is helpful to regulate glucose for diabetic patients. Insightful but straightforward performance information is offered so that users can achieve sustainable transformation through measurements. As demonstrated, SSHARRPPP Measurement is mainly measuring activities that are carried out by individuals. Therefore, in what follows, the thesis will explain how family-level activity, shopping can be measured and promote sustainable transformation to users and their families.

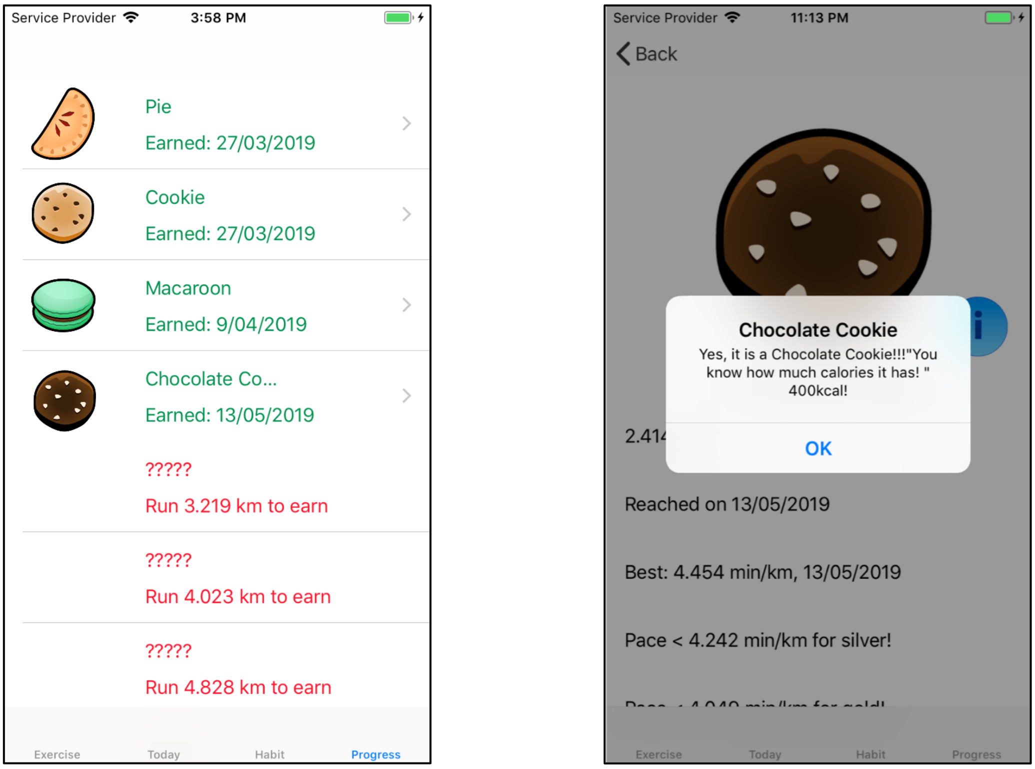


FIGURE 67. HISTORICAL PERFORMANCES

8.3 Shopping – Family Activities

Shopping is a simple daily activity, but it affects many of our life dimensions and values. Shopping is also a family level activity, which affects a whole family. Shopping is a fundamental way of acquiring resources for our living. It is often an inherited habit from parents to their children. For example, many of us habitually buy items without any thought because those are what our family have always used and consumed in the past (Goodwin, 2018). As such, shopping can make significant impacts on decision making and having a healthy shopping habit help us to transform our lifestyles to be sustainable. The prototypical SSHARRPPP Shopping is designed and implemented to support better shopping decisions.

Many current shopping systems often provide single dimensional information (mostly economic values) and the degree of personalisation is relatively low. For example, the recommendations are made based on the users' previous shopping histories. As mentioned earlier, this type of recommendation may become harmful if their current shopping habit is required to change for their wellbeing. The prototypical SSHARRPPP Shopping implemented to offer a different shopping experiences to users. For example, the prototype suggests providing enriched information from multiple life perspectives, different levels of personalised product recommendations, and social shopping features through social media.

In the following sections, the thesis will explain the implemented pages in SSHARRPPP Shopping and demonstrate its features based on the diabetic patient's case (application case).

8.3.1 Featured Page

When customers visit SSHARRPPP Shopping, the first page they will see is the Featured page. A product or a package appearing in the featured page (Figure 68) is a result of a process run by a recommendation engine.

Featured page infrastructure is flexible, which means sections (like Top-Charts, Social Choice, etc.) are easily altered and updated. For new customers, initially the generic products will show on this page, but after customers input their profile information, suggested products will be shown on this page.

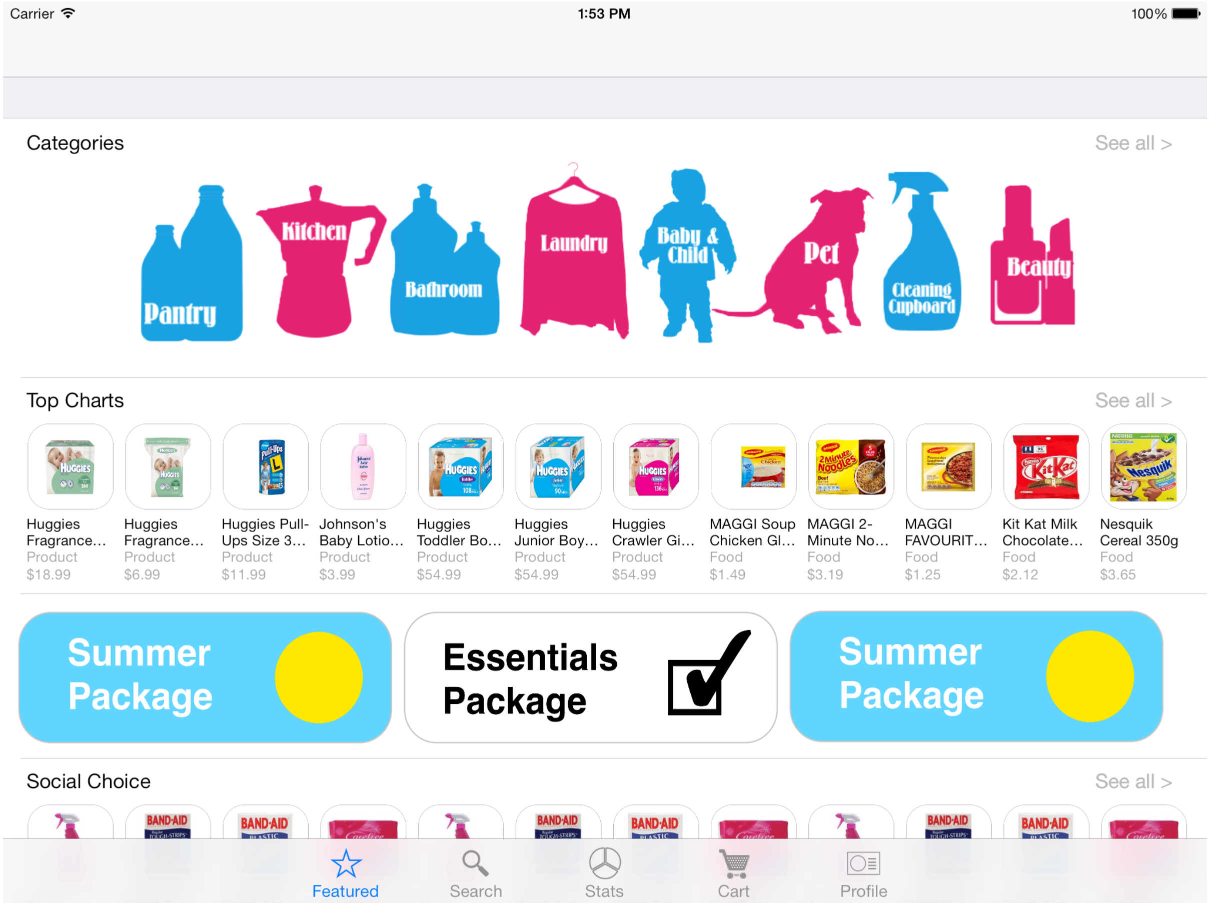


FIGURE 68. FEATURED PAGE, FROM THE AUTHORS' CREATION (CHUNG ET AL., 2015)

The suggestions will be refined and personalised as customers make more purchases and interact with their social groups to get feedback on their shopping. The customers can indicate the desired degree of personalisation in the profile page, then SSHARRPPP Shopping will provide the right degree of personalised recommendations in the Featured page. In this page, customers easily access the Product detail page.

8.3.2 Product Search

The Search page provides search functionality through which customers can find products, categories of products or suggested shopping packages (Figure 69).

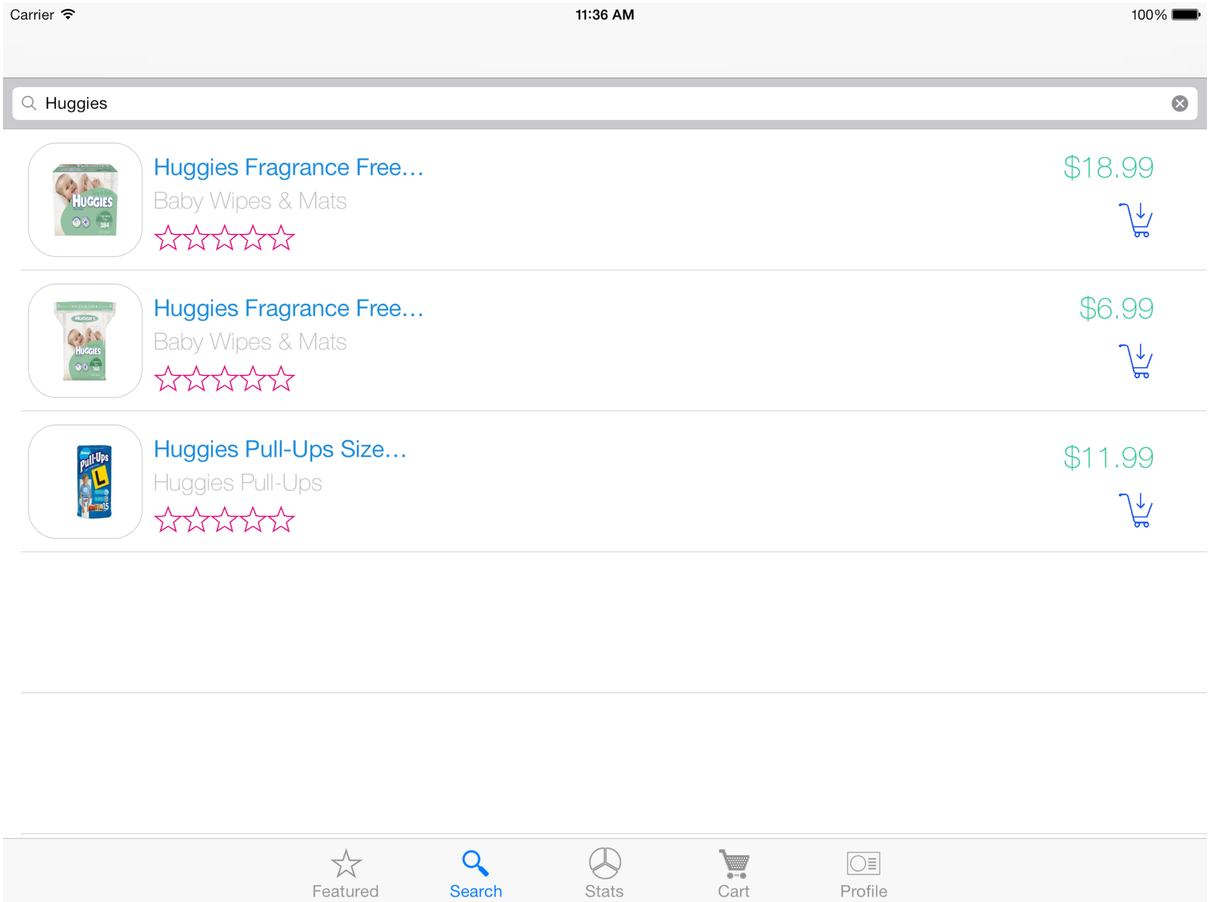


FIGURE 69. PRODUCT SEARCH PAGE, FROM THE AUTHORS' CREATION (CHUNG ET AL., 2015)

Through this page, customer can see the brief description and ratings of each product. Customers can simply choose products into their shopping cart or click a specific product to check its details.

8.3.3 Product Detail Page

The Product detail page is accessed from the Featured page or search page. In this page, customers can check a detailed product information and multi-dimensional sustainability information (Figure 70).

FIGURE 70. PRODUCT DETAIL PAGE, FROM THE AUTHORS' CREATION (CHUNG ET AL., 2015)

SSHARRPPP Shopping will provide practical information like health, environment and financial information such as food prices, carbon footprint and nutrition labels, as they are critical shopping information for their care. Based on the practical shopping information, shoppers can purchase better products for their health and financial circumstances.

For diabetic patients, the systems will show financial information of the potential health benefits by choosing healthy food options. The multi-dimensional product information can be shared to the customer's social media by clicking social media buttons provided in this page. Through this feature, customers can experience social interaction and get support for making purchase decisions.

8.3.4 Shopping Cart Page

All chosen products will be shown in the Shopping cart page. In the Shopping cart page, the health meter will show the number of healthy and unhealthy products that the consumer has purchased in the current shopping, and overall shopping (Figure 71).

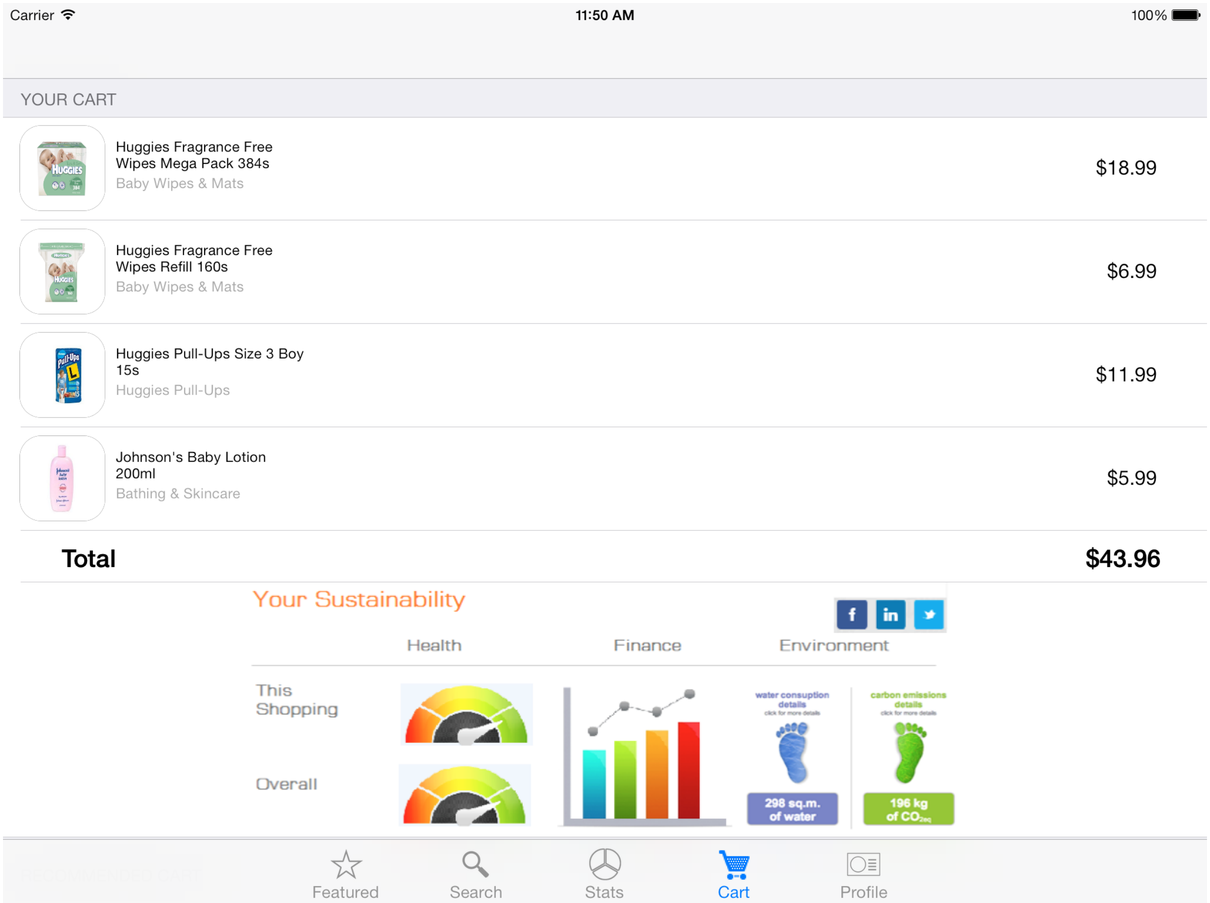


FIGURE 71. CART PAGE, FROM THE AUTHORS' CREATION (CHUNG ET AL., 2015)

8.3.5 Stats Page

The Stats page is responsible for aggregating transactional data, produced by the customer, and presenting useful information acquired from this data to the user in three dimensions (Health, Finance, and Environment). This page is designed to let the user understand his/her online shopping behaviour as well as the level of personal sustainability (Figure 72).

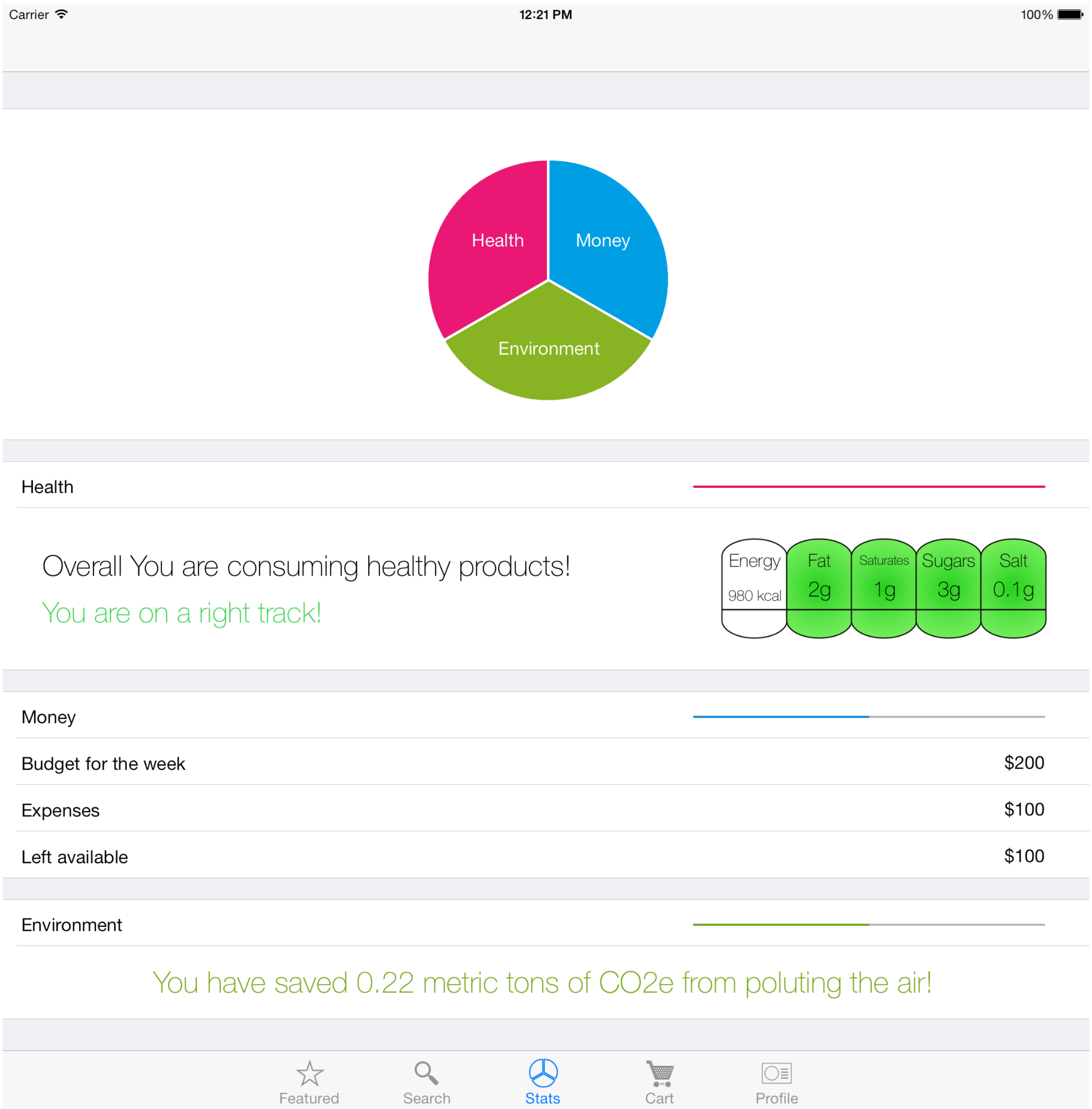


FIGURE 72. STATS PAGE, FROM THE AUTHORS' CREATION (CHUNG ET AL., 2015)

8.3.6 Profile Page

The Profile page includes user's basic personal information. The customers can log in using their social media or fitness device credentials. In doing so, customers can minimise their efforts to input profile information. The social media credential helps not only customers to have social shopping experiences, but also SSHARRPPP Shopping to provide appropriate personalised recommendations. Especially, fitness device credentials help while SSHARRPPP Shopping provides useful information for customer's health (Figure 73).

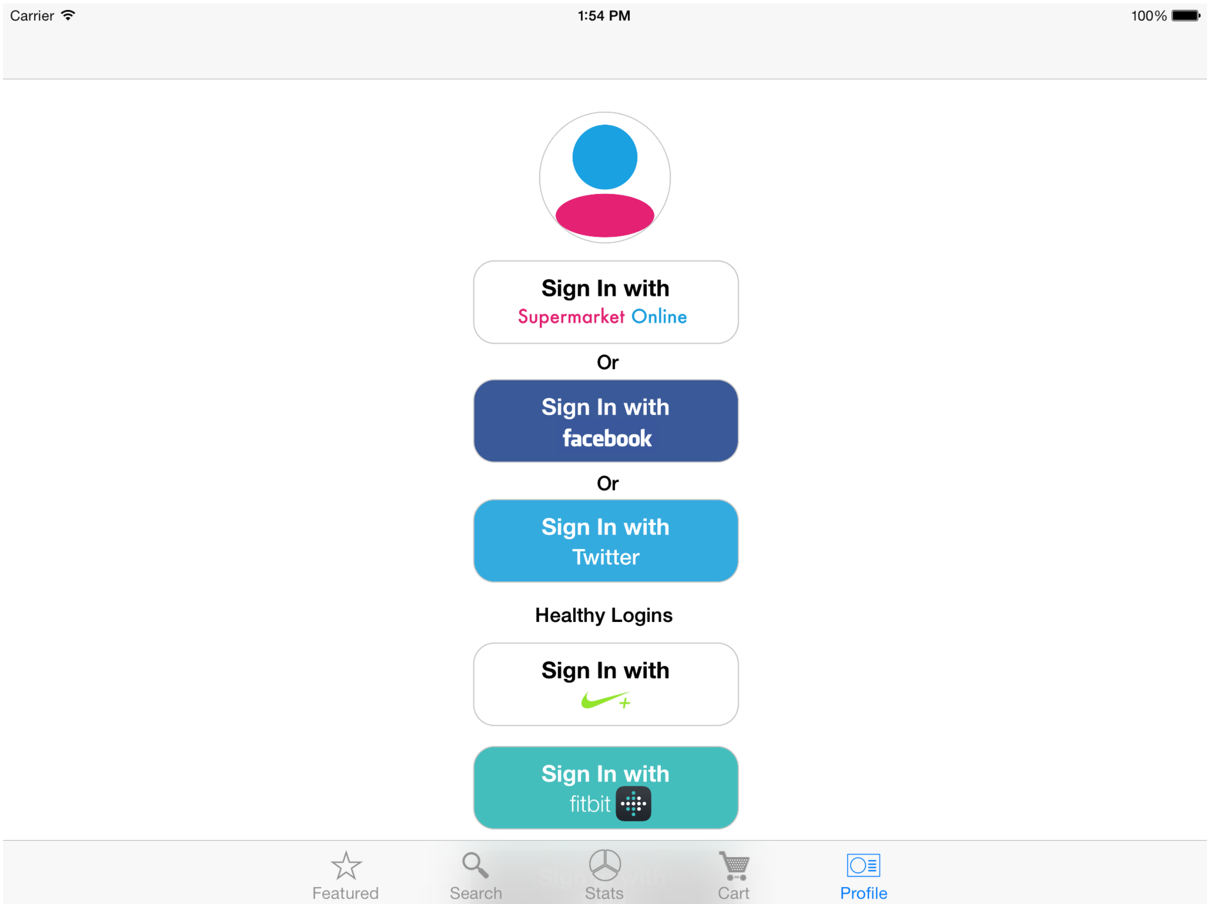


FIGURE 73. PROFILE PAGE, FROM THE AUTHORS' CREATION (CHUNG ET AL., 2015)

The prototypical SSHARRPPP Shopping is designed to collect family-level data and help the family to make better decisions by providing rich information about shopping. Also, users can make better shopping decisions through personalised recommendations and social media that can be offered in SSHARRPPP Shopping.

The data and information collected by SSHARRPPP Measurement and Shopping can be used in SSHARRPPP Modelling to understanding life factor interrelationships. In the following section, the thesis explains SSHARRPPP Modelling, which has been designed and implemented under the application case.

8.4 Modelling – Life Factor Interrelationships

Modelling holistic interrelationships among life factors can educate which life factors or behaviours cause what effect in our lives. However, many current information systems provide limited life factor models and their relationships at the individual level. Furthermore, rare systems provide simulations.

SSHARRPPP Modelling is designed and implemented to provide a deeper understanding of life factor relationship using system dynamics. As modelling and simulation need a scenario, the thesis used the application case (diabetic patient's case), to developing the prototypical implementation. SSHARRPPP Modelling consist of two phases of simulation. The first phase simulates diet effects and the second phase understands sleep, stress, and exercise effects on insulin sensitivity for type 2 diabetes (Figure 74).

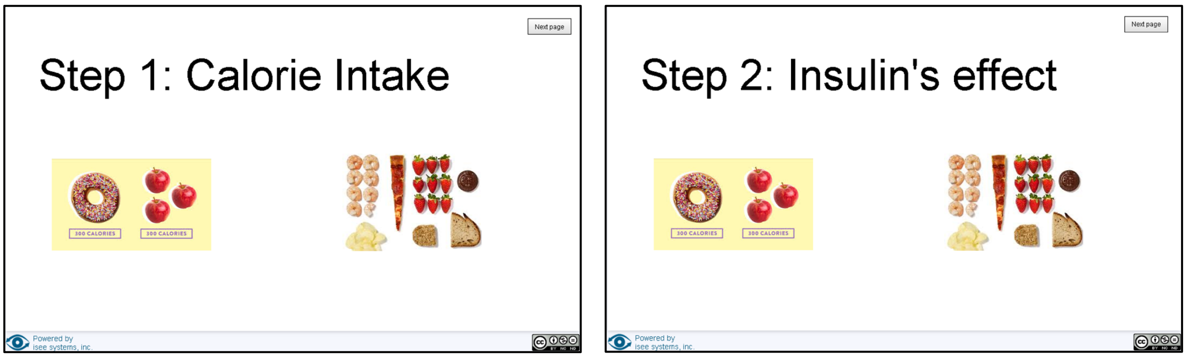


FIGURE 74. FRONT PAGES OF SSHARRPPP MODELLING

There is no single cause of type 2 diabetes, but a range of contributing elements, including genetic and lifestyle risk factors (Farmer, Pearson, & Strong, 2004). As the focus of the Modelling is to understand holistic relationships between the disease and daily lifestyles, genetic factors have been excluded from this simulation. Type 2 diabetes is a complicated chronic disease where glucose regulation is not functioning properly due to the inadequate secretion of insulin and/or a reduction in insulin sensitivity.

8.4.1 Diet Effects – Inflow of Glucose

SSHARRPPP Modelling stores relevant data and knowledge that are collected and shared from other SSHARRPPP systems. In this implementation, the data and knowledge are input into the system for simulations.

The data fields in the highlighted area in Figure 75 shows portion or calories of nutrients, which can make one meal. The portion of nutrients follows the diabetes plate method that helps diabetic patients to control portion sizes of carbohydrate-containing foods that have the most impact on blood glucose levels.

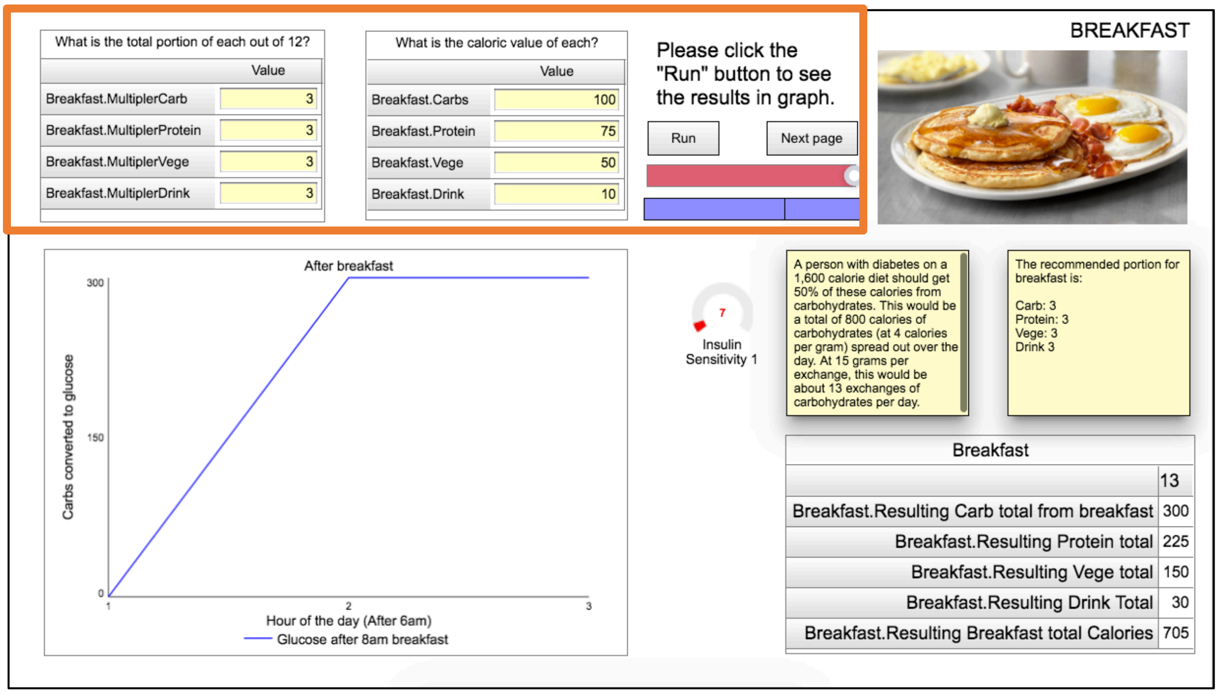


FIGURE 75. DIET DATA INPUT, FROM THE AUTHOR'S CREATION (CHUNG, 2019)

The recommended formula is half of non-starchy vegetables, quarter of protein, and a quarter of starchy vegetables or carbohydrate-containing food per plate at each meal (American Diabetes Association, 2018). SSHARRPPP Modelling has used 12 dividing portions for a plate for easier calculation. For example, the ideal formula can be presented 6 dividing portions of non-starchy vegetables, 3 dividing portions of protein, and 3 dividing portions of starchy vegetables or carbohydrate-containing food for this simulation. Then the user can input calories for each nutrient. These values can be extracted from the data stored in the component layer or easily edited by the simulation user.

Another variable that the users can change for simulations is “Insulin Sensitivity.” From 10 to 100, this variable determines how much glucose is used by body cells naturally. As has been explained, the higher sensitivity means the higher usage of glucose by body cells, therefore healthier people have the higher insulin sensitivity (Kahn, Hull, & Utzschneider, 2006).

Once all values and variable are entered, the user clicks the “Run” button to see the amount of glucose in the bloodstream. The simulation result is shown in both graph and table format (Figure 75). The aims in this simulation are understanding: 1) how to get a lower glucose inflow into the bloodstream by changing values of consumption of carbohydrate, protein, fat, and drink and 2) what is the insulin sensitivity effect to reduce the blood glucose level.

When the user clicks the “Next Page” button then same simulations can be repeated for lunch, dinner, and late-night snack (Figure 76). Late-night snack is added as often diabetics have a bad diet habit to eat late at night.

Once the user clicks “Run” button, SSHARRPPP Modelling uses input data and calculates a result based on the models and equations built in the system. SSHARRPPP Modelling has various models, algorithms, and equations to process the input data. For this prototype, several stock and flow models have been developed based on conceptual causal loop models. These models will be explained in the following implementation chapter.

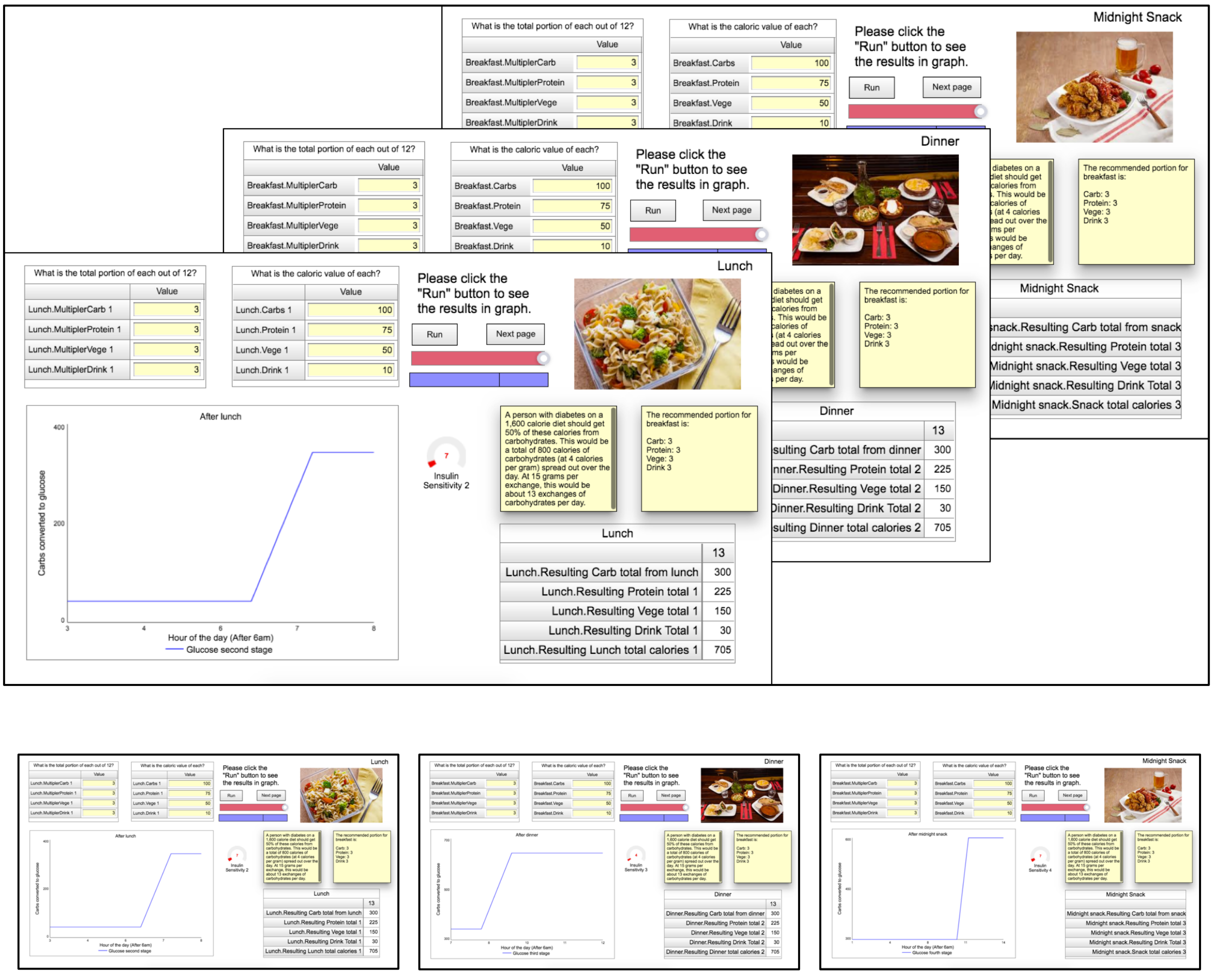


FIGURE 76. DAILY DIET INPUTS, FROM THE AUTHOR'S CREATION (CHUNG, 2019)

8.4.2 Exercise, Sleep, and Stress Level Effects – Changing Insulin Sensitivity

SSHARRPPP Modelling tries to visualise how daily activities make different health outcomes in terms of glucose level. The chosen activities are exercise, sleep, and stress level. SSHARRPPP Modelling educates the holistic interrelationships and causal relationships among various activities and factors in people's lifestyles.

This simulation is for educating individuals and families, especially diabetic patients, and helping them to find out what is the optimal level of sleep and exercise as well as managing stress. Therefore, based on the user's input of sleep, exercise, and stress level, the simulation shows how the glucose level changes. For example, if the user's inputs of sleep quality and duration are within the suggested optimal range, the glucose level gets lower and the graph shows its effect to the user (Figure 77).

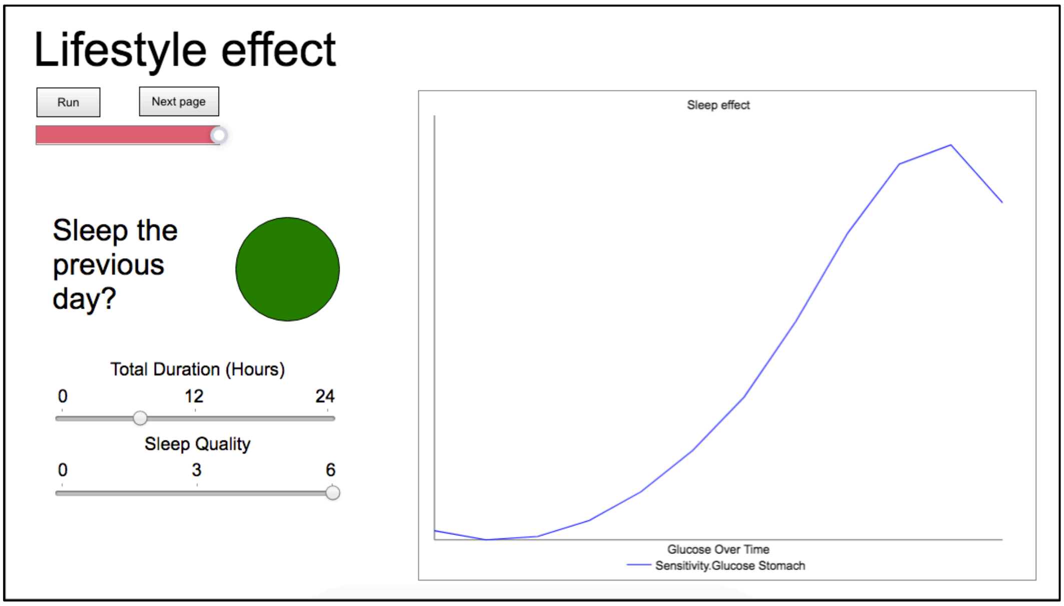


FIGURE 77. LIFESTYLE INPUTS IN SSHARRPPP MODELLING

The user can simulate the effect of exercise and stress levels in a similar way. These simulations have been built based on a conceptual model (causal loop diagram) and mathematical model (stock and flow), which will be explained in chapter 9.

So far, the thesis demonstrated how modelling and simulation could be presented to enhance users' understanding of the life factor interrelationships effectively. These modelled interrelationships and causal effect relationships can be used to implement games and help users to transform their lives easier and enjoyable. In this regard, the following section will demonstrate how SSHARRPPP Games can educate healthy lifestyles to users through entertainment.

8.5 Games – Learning Healthy Lifestyles

SSHARRPPP Games aims to educate healthy lifestyle to users in persuasive and joyful ways. Diet, exercise, sleep, and stress management are the most important activities to regulate the glucose level (American Diabetes Association, 2018). As such, SSHARRPPP Games have different worlds to present each dimension, and each world has different levels. SSHARRPPP Games are implemented to respond to a player's choice seamlessly and can be designed to recommend proper games for players based on their measured data, profile information, and preferences.

In the following sections, the thesis will demonstrate how SSHARRPPP Games are designed to teach healthy lifestyle enjoyable step by step.

8.5.1 Choosing SSHARRPPP Games

Once the player initiates the games, the game shows icons which represent categories of games. Based on what icon is chosen by the player, the games execute a game accordingly. For example, if the player chooses the "Diet" icon, then a diet game is executed (Figure 78).

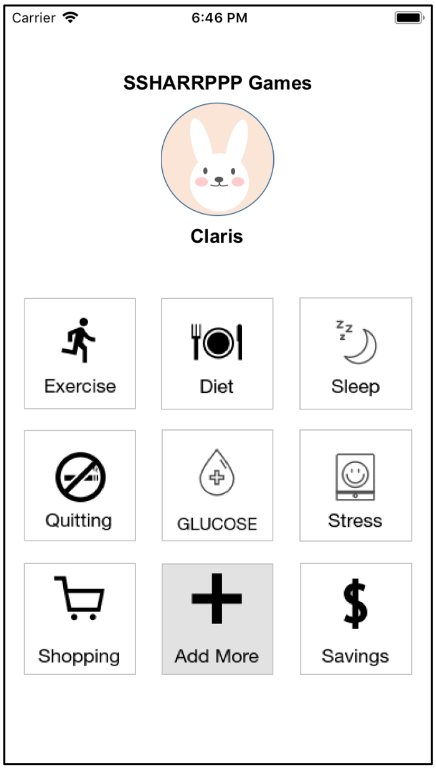


FIGURE 78. SSHARRPPP GAMES MENU PAGE

8.5.2 Diet Game

In the diet game, the player should find and match more than three icons for each healthy food in the objective section. According to self-management programs provided by diabetic health carers, it is advisable to eat food in different colours daily to form a healthy diet. This is because each colour in food represents particular nutrients (American Diabetes Association, 2019). In our case, they are avocado, broccoli, tomato, and milk. They are well-known healthy foods.

The glucose window indicates an estimated glucose level. When the player matches healthy food icons, it shows green. Also, the avatar ("cat face" in Figure 79) smiles while the player keeps matching healthy food. If the player matches a required healthy food, the objectives will be changed to "thumbs up" accordingly. If all requirements are met, the player can play the next level of the diet game (Figure 79).

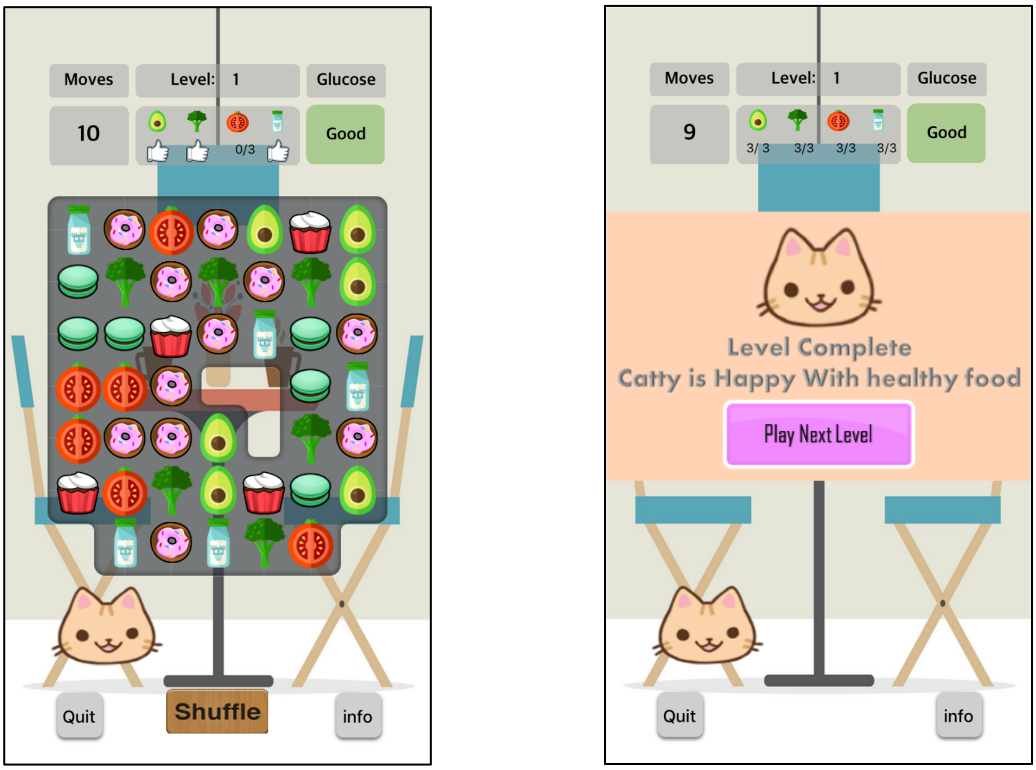


FIGURE 79. DIET GAME (WINNING THE LEVEL), FROM THE AUTHOR'S CREATION (CHUNG, 2019)

When there are series of unhealthy food matchings, the glucose window changes to yellow warning the player. If the player keeps matching unhealthy foods, then the glucose window changes to red, and regardless of remaining moves, the game is finished as failed.

If there are no possible matches, the player can click the "Shuffle" button to reshuffle the food. "Quit" button is provided in case the player wants to stop playing the game while he/she is in game. "Info" button provides general information about the game (Figure 80).

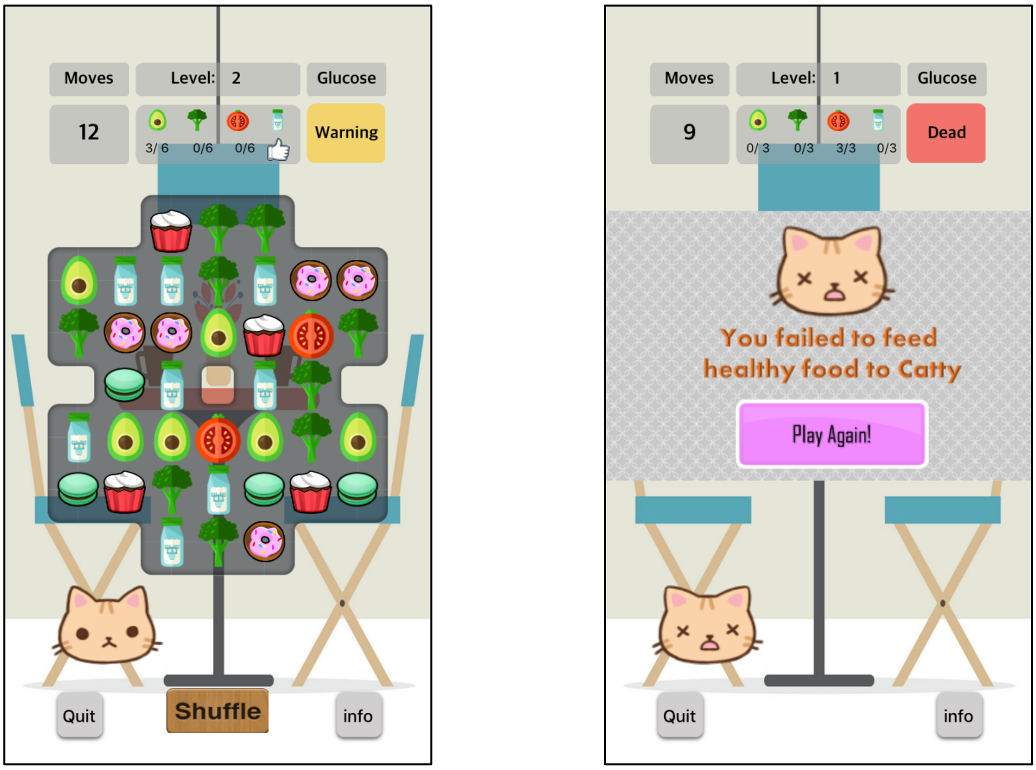
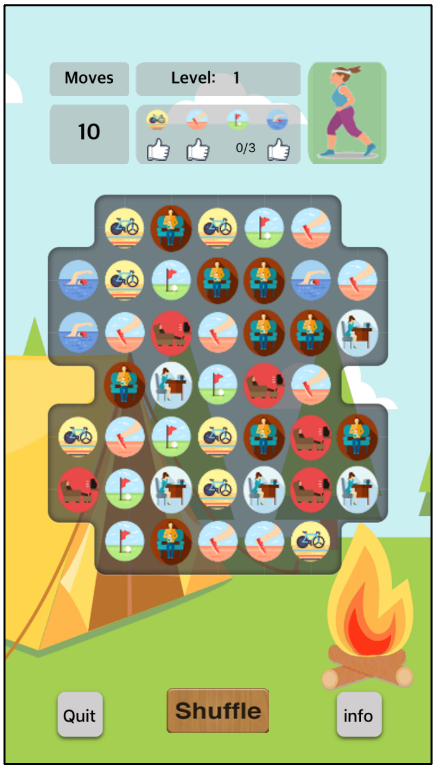


FIGURE 80. DIET GAME (LOSING THE LEVEL), FROM THE AUTHOR'S CREATION (CHUNG, 2019)

8.5.3 Exercise and Sleep Games

Players can learn what good exercises are and sleep habits through SSHARRPPP Games (Figure 81). Exercise game use a similar logic to the diet game that we have explained just before, except the glucose level window is absent. The exercise game shows a fit person image if the player matches good exercises listed in the objective window.

The sleep game has a slightly different goal compared to diet and exercise games. For the sleep game, the player should find out good sleep habits. If the play matches good habits, then the score goes up; if the payer matches bad habits then the score goes down.



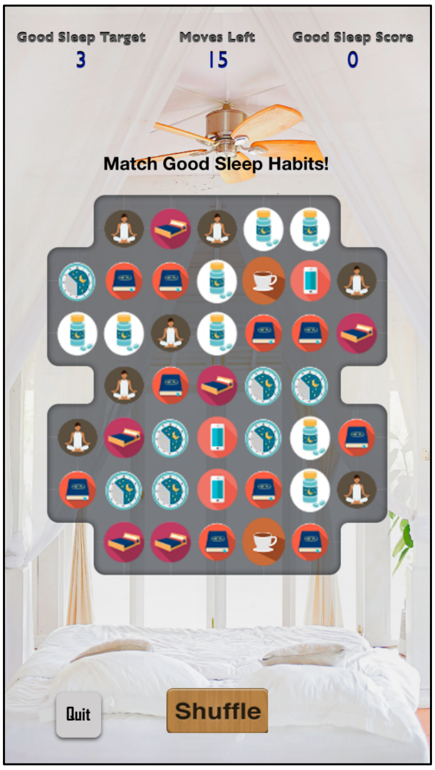


FIGURE 81. EXERCISE AND SLEEP GAMES, FROM THE AUTHOR'S CREATION (CHUNG, 2019)

8.5.4 Integrated Lifestyle Games

SSHARRPPP Games provide integrated lifestyle games to teach what good habits can be combined for sustainable life transformation. The integrated game can be played after learning all games related to the healthy lifestyles. The game logic is the same as the diet game. The player should match all required good habits shown in the objective window.

In this integrated game, the avocado icon represents a good diet habit, the running icon represents a good exercise habit, the meditation icon represents managing stress, and the day/night icon represents a good sleep habit. Figure 82 shows different levels of the integrated game. The first figure shows that the player is matching good habits well, therefore the glucose level is good, and the cat avatar shows smiley face. The second figure shows the warning sign and the cat is not happy, informing that the player is not doing well.

FIGURE 82. INTEGRATED LIFESTYLE GAME, FROM THE AUTHOR'S CREATION (CHUNG, 2019)

8.6 Summary

Scenarios are used in designing computer systems for a number of reasons. Carroll (2000) argued that scenario-based design is useful as it 1) evokes reflection in design, 2) fixes an interpretation of design situation or offers a solution, but revises and elaborates situation or solution easily, 3) helps to see design at different levels from many perspectives and for many purposes, 4) helps design knowledge accumulate across problem instances, and 5) anchors design discussion in a practical environment where stakeholders' participations are involved. Indeed, this research has used scenarios to reflect whether SSHARRPPP systems design is serving appropriate functionalities and purposes for the proposed scenarios.

Diabetes was chosen as the background case to motivate the scenarios used in this research since it is a long-term chronic disease that requires lifestyle changes. Therefore, diet, physical activity, sleep and stress management have been chosen for the scenarios. Those were chosen deliberately for generalisation of SSHARRPPP systems, because every single person (regardless of type 2 diabetes) needs to handle these four activities daily.

SSHARRPPP Measurement will help patients to measure their ordinary life activities to understand the current lifestyle situation at an individual level. The measurement system also measures the changed behaviours to see whether these behaviours are making impacts on their health. Collecting family level data is also important as family support is vital to managing type 2 diabetes. For this, SSHARRPPP Shopping is used to support healthy shopping decisions through recommendations and social media. SSHARRPPP Modelling helps us to understand the dynamics and interrelationships between all life factors. By simulating values in the system, the users can experience health outcomes indirectly. Lastly, SSHARRPPP Games show one example of teaching healthy lifestyles to the users and encourage them to adopt these lifestyles.

9 Implementation of SSHARRPPP Systems

The objective of design-science research is to develop technology-based solutions to important and relevant problems (Hevner et al., 2004, p. 83). And these technology-based solutions can be generalised and become guidance for implementing similar systems. As such, the implementation of SSHARRPPP systems can be used as a template for future research. Also, the implementation of SSHARRPPP systems will provide fundamental architecture, analysis and design patterns to people who want to implement systems that support individual and family sustainability.

SSHARRPPP systems aim to facilitate an environment where individuals and families can achieve a sustainable life transformation easily and holistically. They do so by providing system purposes and processes: “measure”, “model”, “benchmark”, “entertain”, “educate”, and “transform” through “sense – interpret – respond – transformation” processes. SSHARRPPP Principles provide the philosophical and conceptual background for functionalities and services that SSHARRPPP systems offer to the users.

This chapter details the following questions:

- What is the prototype implementation approach that can validate conceptual, procedural, and technological responses sought in our research?
- How have SSHARRPPP systems been implemented to provide key functionalities for supporting the sustainable life transformation?

To answer these questions, the thesis will explain implementation of each SSHARRPPP system (Figure 83):

- Explain the adopted vertical prototypes for our implementations in 9.1.
- Explicate the implementation details of each SSHARRPPP System in 9.2, 9.3, 9.4, and 9.5. In these sections, SSHARRPPP systems are explained based on each system’s key functionalities. Technical background is also explained for each system implementation and brief history of system development.

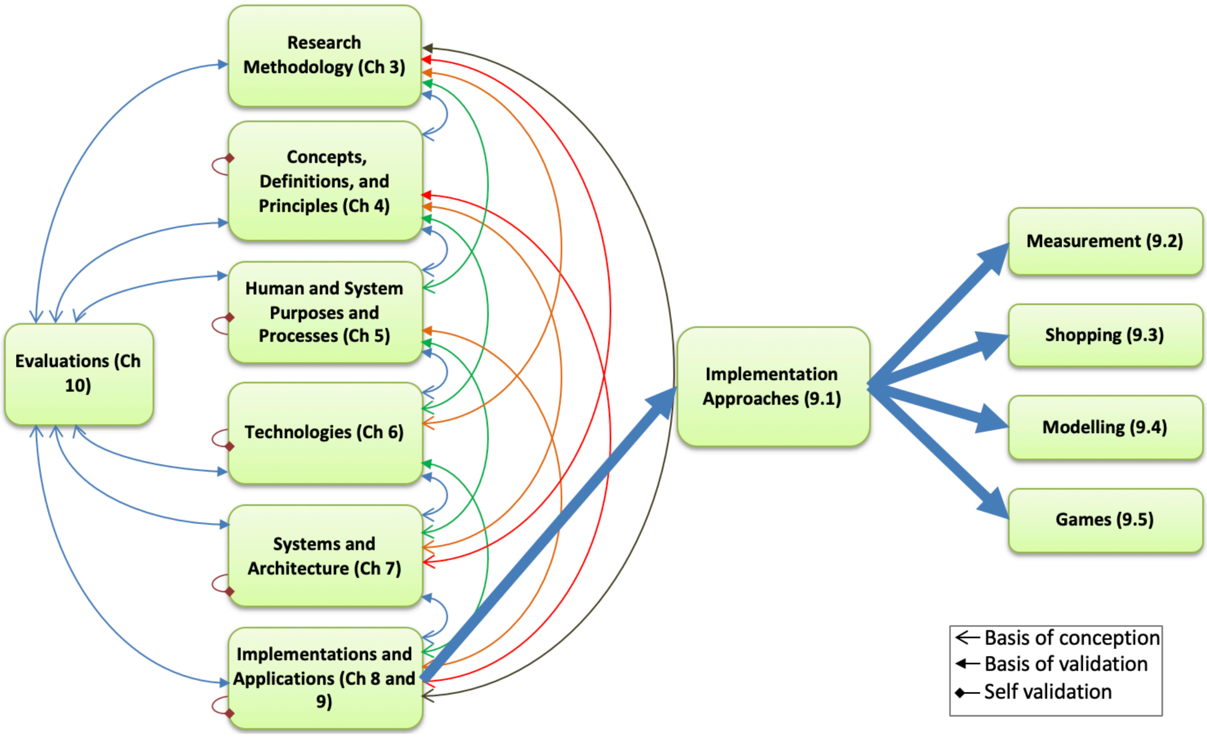


FIGURE 83. CHAPTER 9 STRUCTURE AND RELATIONSHIPS

9.1 Implementation Approaches

To validate concepts, processes, and frameworks that this research has proposed in previous chapters, four prototypical SSHARRPPP systems have been implemented. In this section, this research will explain the background of implementing SSHARRPPP systems.

SSHARRPPP systems have been implemented based on the multi-methodological approach. As discussed in Chapter 3, the multi-methodological approach is useful for identifying unknown system requirements and refining system features. Based on this approach, this research has gone through several implementation iterations. For example, several games with different game logics have been developed to find the best way to educate users. In each iteration, the researcher has attained feedback from both professionals and users of systems to refine the proposed concepts, processes, artefacts, and systems.

In the context of system prototype development, there are two development approaches: a vertical prototype and a horizontal prototype (Nielsen, 1993). The vertical prototype focuses on the detailed functionality implementation of core features of the systems. On the other hand, the horizontal prototype tries to implement different feature sets that the full systems offer (Figure 84).

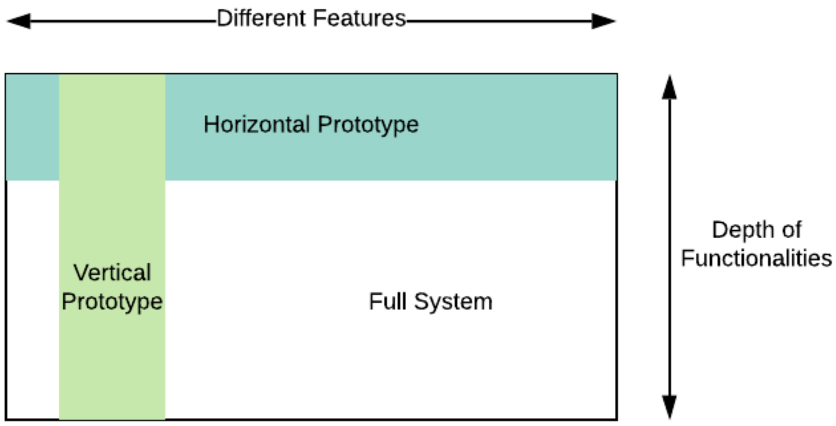
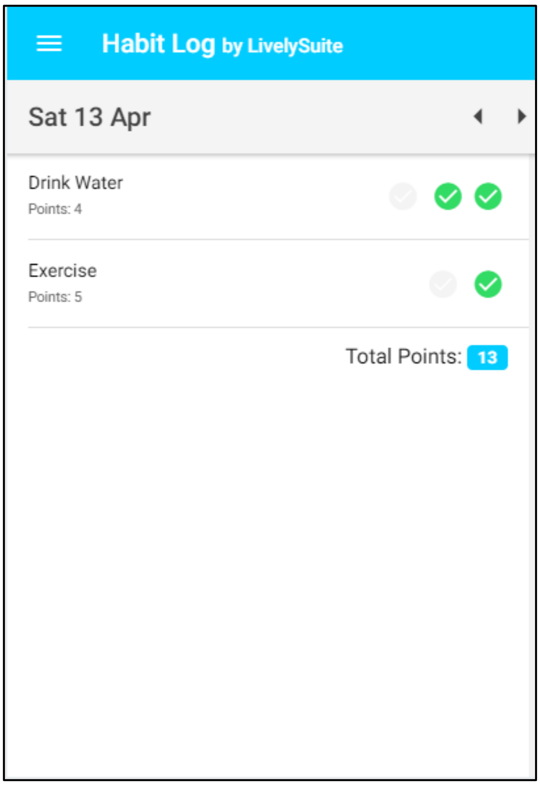


FIGURE 84. IMPLEMENTATION APPROACHES, ADAPTED FROM (NIELSEN, 1993)

This research has adopted the vertical prototypes for our implementations. The vertical prototype implementation is a useful approach when resources and time are limited. Therefore, each of SSHARRPPP systems is implemented to show its main features particularly. After several development attempts, the research has designed and implemented four systems, namely SSHARRPPP Measurement, SSHARRPPP Shopping, SSHARRPPP Modelling, and SSHARRPPP Games.

9.2 Measurement

This prototypical app initially has been developed based on the Android platform using JavaScript. A focus of the Android version is that the users can customise and configure activities to log based on their needs and intentions. It is a flexible logging app to capture holistic aspects of life (Figure 85). The need for this functionality was discussed in 8.2.1. However, this app only collects user-entered data and does not have real-time activity sensing functionality. Therefore, the researcher implemented the second version of measurement app that has both flexible activity logging and real-time activity sensing features together. The second version was developed based on objective-oriented concepts, objective-oriented database management systems and objective-oriented programming languages. The app has been implemented based on the iOS platform, using Swift and Xcode. Overview of these functionalities is discussed in the following section.



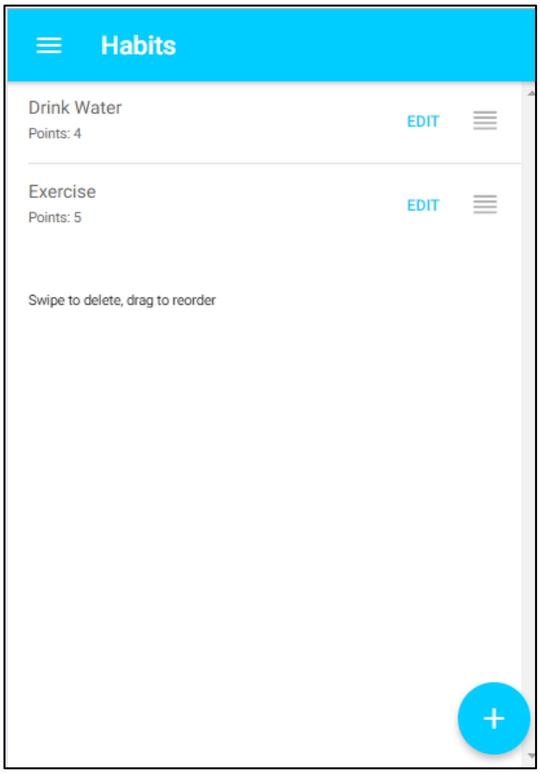


FIGURE 85. ANDROID VERSION OF SSHARRPPP MEASUREMENT

9.2.1 Overview of SSHARRPPP Measurement Functionalities

SSHARRPPP Measurement supports the user's decision-making and habit-formation or destruction while it delivers its main system functionalities. As explained previously, the app follows Sense–Interpret–Respond–Transform (SIRT) processes to provide useful data, information, and knowledge for the user's decision-making and habit formation/destruction supports.

The app senses the user's activities and behaviours and then interprets the data to information. These processes can be done by using data/profile manager and benchmarking manager in the application layer. The system then responds to users with the analysis and progress results by applying appropriate visualisations or benchmarking information. The persuasive and motivational features will be sent by lifestyle and entertainment managers. These features encourage users to take a desired action continuously, so the habit can be formed or destroyed and ultimately transform their lives.

	Functionalities	SIRT	Decision	Habit	Components
SSHARRPPP Measurement	Create sensor-based logs	Sense	Choice	Cue	Real-time and -world ubiquitous systems
	Track and update a user's logs (e.g. status or activity)	Interpret	Intelligence	Routine	Data/Profile Manager & Modelling Manager
	Track remaining activity to achieve the goal	Interpret/Transform	Intelligence/Choice	Routine	Benchmarking/Knowledge Manager & Lifestyle Manager
	Save logs	Interpret		Routine	Data/Profile Manager
	Analyse the saved logs (e.g. the best performance)	Interpret	Intelligence	Routine	Benchmarking/Knowledge Manager
	Show the activity progress for reflection	Respond	Design	Routine	Modelling Manager
	Present current progress	Respond	Intelligence	Reward	Data/Profile Manager & Benchmarking/Knowledge Manager
	Award badges for achievement	Transform	Choice	Reward	Entertainment Manager

TABLE 5. EXAMPLES OF SSHARRPPP MEASUREMENT FUNCTIONALITIES

While the SSHARRPPP Measurement performs sustainable transformation (SIRT) processes, it also supports the users' decision-making. This is because the insights produced from the app make users understand themselves better and choose the best options for their lives. Table 5 shows some functionality examples, which performed through sustainable transformation (SIRT) processes and the related components, support users' decision-making and habit- formation/destruction.

The users can transform their lives sustainably by using SSHARRPPP Measurement. Measuring and quantifying activities and behaviours can be the most persuasive step to make the real-world behaviour change possible. For example, when Apple introduced "Screen Time", a feature that logs how long people are using their phone with which apps, this shocked many iPhone users. This was because that simple measurement let people realise how many hours they spent with their phone per a day (Griffin, 2018). One tech journalist reported that he could conquer his Instagram addiction in a week by utilising data and information provided by "Screen Time" (Paez, 2018). As such, when people have a quantified data, they can understand the true situations and take actions on them.

SSHARRPPP Measurement allows users to log their status and activity data directly through the user interface and/or import data from the real time/real world ubiquitous systems. The collected data from both methods are stored in the component layer. The system then provides a result in many ways. For example, the system can show the gamified results after processing data through solvers and algorithms then handling the processed data through the entertainment manager and present them to the user with a gamified way.

SSHARRPPP Measurement collects real-time and real-world data through the various channels to get precise information. Also, it collects and handles the user's profile data through the data/profile manager in the application layer. The profile data and the precise information is processed together to provide personalised results. These results can be also shared socially with peers to get continuous motivations.

SSHARRPPP Measurement is a configurable mobile application. Therefore, users can log multiple activities to strengthen positive habits and to discourage negative ones. Later the users can compare various activities and understand the holistic relationship among their activities. Through this highly personalised and holistic configuration, users adapt themselves to a new lifestyle.

As explained here, it is essential to provide various ways of logging and sensing user's activities for achieving sustainable transformation. Next section will explain how these functionalities are implemented in SSHARRPPP Measurement.

9.2.2 Implementation

This section explains the implementation of the iOS version of SSHARRPPP Measurement based on the following main functionalities:

- Flexible status and activity logging (manual)
- Real time status and activity sensing (automatic)
- Performance/Progress results and Motivating features

Application of these features were explained in 8.2.

9.2.2.1 *Flexible Status and Activity Logging (Manual)*

SSHARRPPP Measurement uses two ways to log the user's activity and behaviour. Initially the system provides direct input from the user. In this case, the user can create his/her own log into the system. The following methods show how the system handles this direct entry and saves in the database. The direct data entry feature provides the flexibility.

SSHARRPPP Measurement prototype uses Core Data provided by Apple in the macOS and iOS operating systems. Core Data supports permanent data saving for offline use and temporary data cache (Apple Inc, 2019). The below codes (Figure 86) show that the fields are defined as text field. Due to this setting, the user can type anything that they would like to enter at the interface layer. The entered data will be saved into the database called "HabitLogCoreData". This method supports a flexible logging feature of SSHARRPPP Measurement to capture various activities in holistic way.

```
@IBOutlet weak var habitNameTextField: UITextField!
@IBOutlet weak var habitLogImportantSwitch: UISwitch!
@IBOutlet weak var habitLogDateTime: UITextField!
```

FIGURE 86. CODE SEGMENT FOR TEXT FIELDS

The following method handles saving of the entered data.

```
@IBAction func habitLogSaveButtonTapped(_ sender: Any) {


    if let habitLogContext = (UIApplication.shared.delegate as? AppDelegate)?.persistentContainer.viewContext {
        let habitLog = HabitLogCoreData(entity: HabitLogCoreData.entity(), insertInto: habitLogContext)

        if let habitLogTitle = habitNameTextField.text {
            habitLog.name = habitLogTitle
            habitLog.important = habitLogImportantSwitch.isOn
        }
        try? habitLogContext.save()
        navigationController?.popViewController(animated: true)
    }
}
```

FIGURE 87. CODE SEGMENT FOR SAVING DATA

Once the data is saved, it is showed back to the user. The following method shows how the app handles the logged status or activities in table view.

```
override func tableView(_ tableView: UITableView, cellForRowAt indexPath: IndexPath) -> UITableViewCell {
    let cell = tableView.dequeueReusableCell(withIdentifier: "habitLogIdentifier", for: indexPath)
    let habitLog = habitLogs[indexPath.row]

    if let name = habitLog.name {
        if habitLog.important {
            cell.textLabel?.text = "❗️" + name
        } else {
            cell.textLabel?.text = habitLog.name
        }
    }

    return cell
}
```

FIGURE 88. CODE SEGMENT FOR TABLE VIEW

The logged status/activity can be deleted if the user wishes to do so. The deletion of logged status/activity is handled by the following codes.

```
class CompleteHabitLogViewController: UIViewController {

    var habitLogTVC = HabitLogTableViewController()
    var selectedHabitLog : HabitLogCoreData?

    @IBOutlet weak var habitTitleLabel: UILabel!


    override func viewDidLoad() {
        super.viewDidLoad()
        habitTitleLabel.text = selectedHabitLog?.name

        self.view.addGestureRecognizer(UITapGestureRecognizer(target: self.view, action: #selector(UIView.endEditing(_:))))
        // Do any additional setup after loading the view.
    }

    override func didReceiveMemoryWarning() {
        super.didReceiveMemoryWarning()
        // Dispose of any resources that can be recreated.
    }

    @IBAction func completeButtonTapped(_ sender: Any) {

        if let habitLogContext = (UIApplication.shared.delegate as? AppDelegate)?.persistentContainer.viewContext {
            if let theHabitLog = selectedHabitLog {
                habitLogContext.delete(theHabitLog)
                navigationController?.popViewController(animated: true)
            }
        }
    }

}
```

FIGURE 89. CODE SEGMENT FOR DELETION OF LOGGED STATUS/ACTIVITY

9.2.2.2 Real-time Status and Activity Sensing (Automatic)

SSHARRPPP Measurement is designed to show the user's progress and keep motivating him/her to form good habits or lose bad ones. To prove this idea, a movement sensing app has been implemented in SSHARRPPP Measurement. The workflow of this feature has been explained in chapter 8.

The method (Figure 90) shows that distance, duration and time data are captured in real-time and stored in the database. Also, it is capturing latitude and longitude of running location, so the app can show the user's real-world path on the map.

```
private func saveRun() {
    let newRun = Run(context: CoreDataStack.context)
    newRun.distance = distance.value
    newRun.duration = Int16(seconds)
    newRun.timestamp = Date()

    for location in locationList {
        let locationObject = Location(context: CoreDataStack.context)
        locationObject.timestamp = location.timestamp
        locationObject.latitude = location.coordinate.latitude
        locationObject.longitude = location.coordinate.longitude
        newRun.addToLocations(locationObject)
    }

    CoreDataStack.saveContext()

    run = newRun
}
```

FIGURE 90. CODE SEGMENT FOR REAL-TIME DATA AND STORED IN THE DATABASE

9.2.2.3 Performance/Progress Results and Motivating Features

The following method presents the user's progress (running in this example) in the results page. The running data is stored in the "Run" table.

```
private func getRuns() -> [Run] {
    let fetchRequest: NSFetchRequest<Run> = Run.fetchRequest()
    let sortDescriptor = NSSortDescriptor(key: #keyPath(Run.timestamp), ascending: true)
    fetchRequest.sortDescriptors = [sortDescriptor]
    do {
        return try CoreDataStack.context.fetch(fetchRequest)
    } catch {
        return []
    }
}
```

FIGURE 91. CODE SEGMENT FOR THE USER'S PROGRESS

While the user is running, the app shows how much distance is left to achieve the next badge. As each second passes, the method updates distance, time and pace. Then it checks whether the next goal is met or not. If the goal is met, then the app plays the success sound to let users know their accomplishment.

```
private func checkNextBadge() {
    let nextBadge = Badge.next(for: distance.value)
    if upcomingBadge != nextBadge {
        badgeImageView.image = UIImage(named: nextBadge.imageName)
        upcomingBadge = nextBadge
        successSound.play()
        AudioServicesPlaySystemSound(kSystemSoundID_Vibrate)
    }
}

func eachSecond() {
    seconds += 1
    checkNextBadge()
    updateDisplay()
}

private func updateDisplay() {
    let formattedDistance = FormatDisplay.distance(distance)
    let formattedTime = FormatDisplay.time(seconds)
    let formattedPace = FormatDisplay.pace(distance: distance,
                                           seconds: seconds,
                                           outputUnit: UnitSpeed.minutesPerKilometer)

    distanceLabel.text = "Distance:  \(formattedDistance)"
    timeLabel.text = "Time:  \(formattedTime)"
    paceLabel.text = "Pace:  \(formattedPace)"
    let distanceRemaining = upcomingBadge.distance - distance.value
    let formattedDistanceRemaining = FormatDisplay.distance(distanceRemaining)
    badgeInfoLabel.text = "\(formattedDistanceRemaining) until \(upcomingBadge.name)"
}

private func startLocationUpdates() {
    locationManager.delegate = self
    locationManager.activityType = .fitness
    locationManager.distanceFilter = 10
    locationManager.startUpdatingLocation()
}
```

FIGURE 92. CODE SEGMENT FOR SHOWING DISTANCE LEFT TO THE NEXT BADGE

Once the run has finished, the results are saved. When the user reaches a new record, the app issues performance badges for further motivation. The following method handles badges based on the user's performance. To provide a guidance to other researchers and developers who want to design and implement information systems for individual and family sustainability, all methods that have been used to implement SSHARRPPP Measurement prototype will be listed in the appendices at the back of this thesis.

Next section, the thesis will explain how SSHARRPPP Shopping prototype was designed and implemented for measuring multiple life dimensions and family level of activities.

```
override func viewDidLoad() {
    super.viewDidLoad()
    let badgeRotation = CGAffineTransform(rotationAngle: .pi / 8)

    badgeImageView.image = UIImage(named: status.badge.imageName)
    nameLabel.text = status.badge.name
    distanceLabel.text = FormatDisplay.distance(status.badge.distance)
    let earnedDate = FormatDisplay.date(status.earned?.timestamp)
    earnedLabel.text = "Reached on \(earnedDate)"

    let bestDistance = Measurement(value: status.best!.distance, unit: UnitLength.meters)
    let bestPace = FormatDisplay.pace(distance: bestDistance,
                                      seconds: Int(status.best!.duration),
                                      outputUnit: UnitSpeed.minutesPerKilometer)
    let bestDate = FormatDisplay.date(status.earned?.timestamp)
    bestLabel.text = "Best: \(bestPace), \(bestDate)"

    let earnedDistance = Measurement(value: status.earned!.distance, unit: UnitLength.meters)
    let earnedDuration = Int(status.earned!.duration)

    if let silver = status.silver {
        silverImageView.transform = badgeRotation
        silverImageView.alpha = 1
        let silverDate = FormatDisplay.date(silver.timestamp)
        silverLabel.text = "Earned on \(silverDate)"
    } else {
        silverImageView.alpha = 0
        let silverDistance = earnedDistance * BadgeStatus.silverMultiplier
        let pace = FormatDisplay.pace(distance: silverDistance,
                                      seconds: earnedDuration,
                                      outputUnit: UnitSpeed.minutesPerKilometer)
        silverLabel.text = "Pace < \(pace) for silver!"
    }

    if let gold = status.gold {
        goldImageView.transform = badgeRotation
        goldImageView.alpha = 1
        let goldDate = FormatDisplay.date(gold.timestamp)
        goldLabel.text = "Earned on \(goldDate)"
    } else {
        goldImageView.alpha = 0
        let goldDistance = earnedDistance * BadgeStatus.goldMultiplier
        let pace = FormatDisplay.pace(distance: goldDistance,
                                      seconds: earnedDuration,
                                      outputUnit: UnitSpeed.minutesPerKilometer)
        goldLabel.text = "Pace < \(pace) for gold!"
```

FIGURE 93. CODE SEGMENT FOR HANDLING BADGES

9.3 Shopping

SSHARRPPP Shopping prototype was implemented in the context of a New Zealand online retailer. The project opportunity came to the researcher as the company was about to design a new online shopping site. SSHARRPPP Shopping has been proposed as a conceptual prototype to the company and it was developed using Objective-C programming language on iOS environment. The site has been designed for mobile devices like tablets, pads and smart phones.

Our suggestions to the company were: (1) providing insightful shopping information to support customers' better shopping decisions, (2) capturing and analysing customers' shopping data and multi-dimensional lifestyle information, (3) recommending personalised shopping options, and (4) motivating customers to form positive shopping habits through benchmarking and social features.

Some of these functionalities were proposed through the prototypical SSHARRPPP Shopping system. These functionalities are explained in the following section.

9.3.1 Overview of SSHARRPPP Shopping Functionalities

SSHARRPPP Shopping can provide information on three life dimensions (financial, health and environmental aspects) in an integrated manner. In the shopping process, the systems also suggest customised shopping options based on shoppers' multi-dimensional lifestyle information from their profiles and previous shopping data. Then, the system provides shopping analytics which are various types of benchmarking (internal, external, historical, and theoretical) as well as historical trends, comparative and causal-effect analyses that allow individuals and families to be motivated and transformed (Boxwell, 1994). Furthermore, the system provides a social feature to make transformation easier and enjoyable by sharing shopping knowledge with a similar group of people.

For personalised recommendations, the data layer of SSHARRPPP Shopping stores customer data, shopping transaction data, product data, and knowledge. Customer data in the system is very important as it stores detailed user profile and preferences, which will be used for personalised recommendations. Transaction data stores all information related to the shopping, such as purchased items, quantities, prices, and so on. Product data has product descriptions, nutrition and sustainability information. This information will help customers to make better purchase decisions. Also, SSHARRPPP Shopping provides knowledge that is scientific information from formal studies and heuristics. For example, the glycaemic index (GI) is useful information for diabetic patients because it is a relative ranking of carbohydrate in foods according to how they affect blood glucose levels. Therefore, it helps diabetic patients to choose foods with appropriate GI for their diet. In other word, the food that is suggested to a pre-diabetic person may not be suitable for a customer who has type 1 diabetes. The knowledge and product data can be sourced from external social media and collaborative knowledge, but they should be used after the moderation process. As such, all relevant data is utilised for generating personalised recommendations.

Providing benchmarking information is another feature that makes SSHARRPPP Shopping distinguishable to other online shopping cart systems. To provide insightful shopping information, the benchmark manager also accesses all data and knowledge in the data layer as well as external data from social media. The internal benchmarking approach provides self-comparison information such as overall shopping results for healthy products or eco-friendly products. External and competitive approaches provide comparison information with other customers. For example, SSHARRPPP Shopping provides shopping cart comparison information with other customers who have similar situations and preferences. Thus, the customer can reflect upon his/her shopping and can improve the future shopping experiences. A generic (theoretical) approach compares the customer's shopping information with widely accepted standards.

SSHARRPPP Shopping was proposed as the prototype that demonstrates these functionalities. As the researcher was involved in the design phase of the prototype implementation, the next section will explain how the researcher designed two main functionalities for the prototypical system.

9.3.2 Implementation

This section will explain the implementations of two main functionalities below:

- Providing insightful shopping information
- Motivating positive habits through social features

SSHARRPPP Shopping has been implemented in a conceptual prototype to provide the look and feel to the New Zealand online retailer. Therefore, the implementation has been done in ways to prove concepts that we have been suggested to the company.

9.3.2.1 *Providing Insightful Information*

SSHARRPPP Shopping has been designed to provide insightful shopping information that supports shopping decisions to customers. The information includes not only the price and details of product but also, the shopper is presented with multi-dimensional sustainability information. Information for each life dimension will be provided by benchmarked information, commonly adopted methods and government regulations (Figure 94).

FIGURE 94. SSHARRPPP SHOPPING PRODUCT DETAIL PAGE

For example, health information will be presented in traffic lights (green, amber and red) manner as the Department of Health (UK) (2013) has suggested be done. A financial graph will provide information on whether a chosen product is cheaper than other options, and the amount saved or overspent will be shown. Lastly, environmental information will be shown based on ecological footprint standards (https://www.footprintnetwork.org/). Having information on three vital life dimensions on one page and providing an intuitive graphical presentation while they are making a purchase decision will enable consumers to have a holistic perspective on their decisions.

To provide personalised insightful information to the customers, the system database has been designed to provide detailed information to its customers. Figure 95 is a partial database design for SSHARRPPP Shopping. This database explains how the Shopping system handles three life dimensional information and makes recommendations based on customer profile with the predefined product lists. As the design shows, the recommendations can be changed every session that the user accesses to the system.

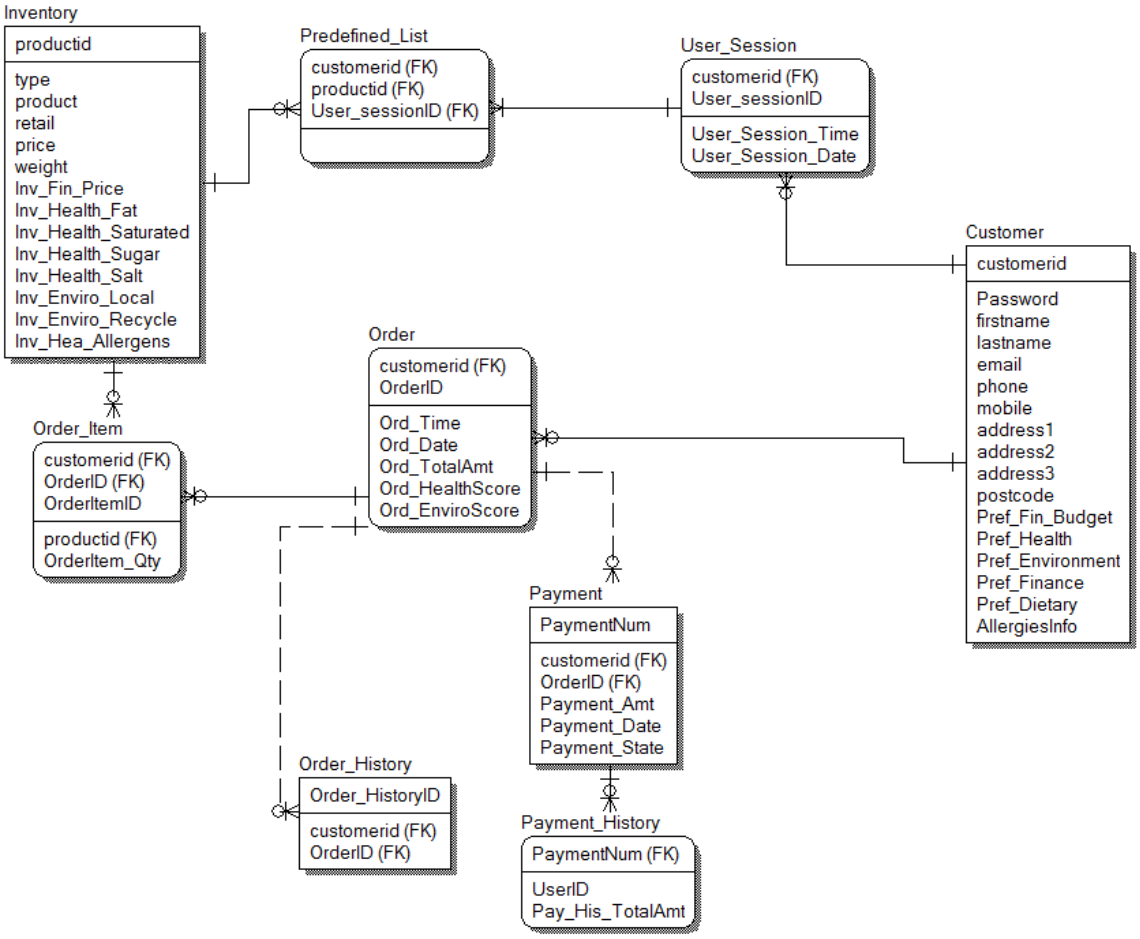


FIGURE 95. DATABASE DESIGN FOR SSHARRPPP SHOPPING

Also, when the customer orders products, SSHARRPPP Shopping shows the customer's total scores for each life dimensional information in this shopping. In this example, the customer gets "total amount money spent", "total health score", and "total environmental score" for supporting decision making.

As such, SSHARRPPP Shopping has been implemented to provide rich information on key life dimensions and recommendations that matches the customer's profile for supporting the sustainable life transformation of individuals and families.

9.3.2.2 Motivating Positive Habits through Social Features

In shopping, social dynamics should be understood well because they play an important role when customers make purchase decisions. Social science researchers often see shopping as a social behaviour (Goodwin, 2018) that is normally influenced by three different groups of people. The first membership group is people we form tight relationships with, like family, friends, co-workers and so on. People in this group are important sources of information for what customers purchase and consume. This group also can pressure customers to conform to group norms or practices. The second is a reference group where customers compare themselves with people in this group. This group provides customers with benchmarking information for comparison and evaluation (Thompson, Hickey, & Thompson, 2016). The last is an aspirational group which customers would like to belong to. Therefore, people often buy things to behave like people from this group. This explains how shopping can represent one's lifestyle and social values.

To support this, the research suggests implementing a social interaction feature in SSHARRPPP Shopping. It means that customers can share their shopping items or carts with their social groups and can get some feedback from them. In recent years, social shopping has gained attention rapidly as it encourages people to share opinions on similar interests (Pfeiffer & Benbasat, 2012). To provide a social shopping experience, SSHARRPPP Shopping provides social media connections on various pages. Therefore, customers can get peers' opinions on chosen products at any point of their shopping.

So far, this research has discussed two systems that sense the various life data at individual and family levels. The following section will discuss how these data can be used for modelling and simulations by SSHARRPPP Modelling.

9.4 Modelling

SSHARRPPP Modelling is used to support the user's decision-making. The system uses data the values are entered through the user interface, or the user data is extracted from the data storage. The entered values are interpreted by equations used in models. The calculated results are responded to through simulations using appropriate formats such as tables, graphs, or graphics to users. As SSHARRPPP Modelling provides a "running what-if" simulation to test output based on the different inputs, it supports the life transformation of the user. As such, while the system processes SIRT, the user can get support on his/her decision-making by attaining insightful information through various simulations.

9.4.1 Overview of SSHARRPPP Modelling Functionalities

SSHARRPPP Modelling is designed based on SSHARRPPP principles. The overall system is designed to support the vision, sustainable transformation of individuals and families. Users can simulate their lifestyles using real-time data which can be collected and shared by SSHARRPPP Measurement and Shopping. Also, the SSHARRPPP Modelling uses data and knowledge together to produce benchmarking information and educational suggestions from relevant resources including socially produced materials.

The main function of SSHARRPPP Modelling is a simulating feature which allows users to test the situation by inputting different data. Through this, users can adapt themselves to a new lifestyle by learning different outcomes. And users can be persuaded by the simulated outcomes that are personalised to their lives. Also, the system returns the results in real time when users input data. This real time feature can support user's habit formation or destruction. For example, if the system shows a simulation that has a constant peak of glucose levels after consuming a large amount of carbohydrates, users can get educated about what is the cause of diabetic risks and try to change a habit of having a large amount of carbohydrates, or try to consume healthier food for themselves like vegetables.

As everyone has a unique circumstance, SSHARRPPP Modelling should allow users to find a right solution. The modelling manager in the application layer supports holistic and real (virtual) world angles. Simulation models take multiple factors from the real world and virtually construct their relationships in holistic manner. Through this feature, SSHARRPPP Modelling can adapt itself to understand the user's specific situations and provide precise information for him/her.

9.4.2 Implementation

Developing a model and building equations are the most important steps in implementing SSHARRPPP Modelling. As discussed in Chapter 8, the type 2 diabetes case has been used for this research. The system has been implemented using Stella®. For SSHARRPPP Modelling prototype, following models are designed and used for the implementation:

- Causal loop diagram – overall conceptual model of type 2 diabetes and lifestyle effects
- Stock and flow diagram – detailed model of inflow and outflow of glucose and lifestyle effects

In the following sections these are explained in detail.

9.4.2.1 Overall Model - Causal Loop Diagram

Type 2 diabetes is a complicated chronic disease where glucose regulation is not functioning properly due to the inadequate secretion of insulin, a reduction in insulin sensitivity of the target cells for insulin hormone, or both (Farmer et al., 2004; Lim et al., 2011; Musselman et al., 2006; Talbot & Nouwen, 2000). There is no single cause of type 2 diabetes, but evidences suggest that obesity is highly associated with insulin resistance (Kahn et al., 2006) and there is a range of contributing elements including genetic and lifestyle risk factors (Farmer et al., 2004). Therefore, the focus of the model is to have a clear picture about how lifestyle changes can result in different diabetes health outcomes.

To educate diabetic patients and their families, it is important to visualise how lifestyle factors create either negative or positive health outcomes depending on each situation. For this purpose, the relationship between blood glucose homeostasis and obesity is constructed in the model by using the components of our major lifestyle factors: diet (Lim et al., 2011; Zeevi et al., 2015), exercise (American College of Sports Medicine and the American Diabetes Association, 2010; Fox, 1999), rest (sleep) (Mesarwi, Polak, Jun, & Polotsky, 2013), and stress (American Diabetes Association, 2013; Kiecolt-Glaser et al., 2002). The following section will explain how the model has been developed from a simple model to the complicated model by adding each related element step by step.

Glucose Homeostasis

Glucose is the main source of energy for most human organisms (Alberts et al., 2002) and its level in the blood stream should be regulated by insulin and glucagon (Röder, Wu, Liu, & Han, 2016). A causal-loop diagram is given in Figure 96 to demonstrate how an equilibrated blood glucose level is maintained in the human body. The amount of glucose in blood varies with food intake and glycogen breakdown from the liver and, depending on insulin secretion and glucagon release, the blood glucose can be kept at its baseline level (Pedro Dagoberto, Almaguer Navarro, Almaguer Navarro, Almaguer Navarro, & Navarro Vazquez, 2013).

The upper loop represents the case where glucose level rises. Once we eat food, our digestive system breaks the starch and sugar found in food, turning them into glucose and releases them into the blood stream. When the blood glucose level is increased, it stimulates beta cell groups in the pancreas to secrete and release insulin into the blood stream. Insulin lowers the blood glucose level in two ways: (1) it transforms glucose into glycogen and stores it in the liver and (2) it combines with glucose absorbed together by our body cells. In this homeostasis mechanism, beta cell insulin responds, and insulin sensitivity components play critical roles to secrete enough insulin and increase the use of glucose by cells, respectively.

In contrast, the lower loop represents the case when the blood glucose level becomes low which stimulates alpha cells in the pancreas which secretes glucagon, and this makes the liver break down glycogen to glucose and release glucose into our blood stream (Levinson, Kahn, & Accili, 2011). In type 2 diabetes, glucose cannot be used by the body cells due to the impaired insulin sensitivity. With time, this results in beta cell dysfunction causing the inadequate secretion of insulin (Fu, Gilbert, & Liu, 2013).

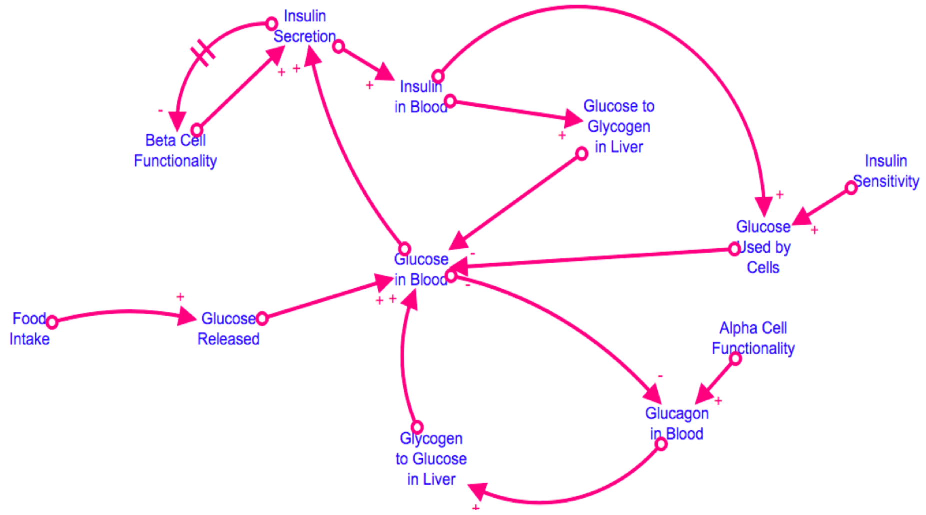


FIGURE 96. GLUCOSE HOMEOSTASIS

According to American Diabetes Association (2018), nutrition therapy (diet), physical activity (exercise), smoking cessation, and psychological care (stress) are the fundamental self-management aspects of diabetes care. In addition to these factors, this research has included sleep into the model as growing body of literature shows an association between sleep disorder and type 2 diabetes incident (Mesarwi et al., 2013). Therefore, diet effect will be discussed in the subsequent section followed by lifestyle (stress, sleep, and exercise) effects.

Diet Effects – Overweight and Obesity

Obesity is associated with an increased risk of developing insulin resistance and type 2 diabetes (Kahn et al., 2006). There are multiple contributing factors of obesity and they are also highly associated with type 2 diabetes. Therefore, the research has introduced the body weight dynamics into this model (Figure 97) and it can be explained by the energy balance mechanism.

The main components considered in this mechanism are diet and exercise. Energy intake increases when people eat food. Energy expenditure increases when our metabolic energy consumption and any physical activities (exercise) are increased. When there is a surplus in energy balance (energy intake > energy expenditure), our body stores the excessive energy in the fat depot (increased in fat mass); thus, it is positively related to obesity. Whereas if energy expenditure is greater than intake, then fat in the storage will break down to meet the energy requirement which negatively associated with the obesity. With time, exercise contributes increasing muscle mass which reduces risk of obesity.

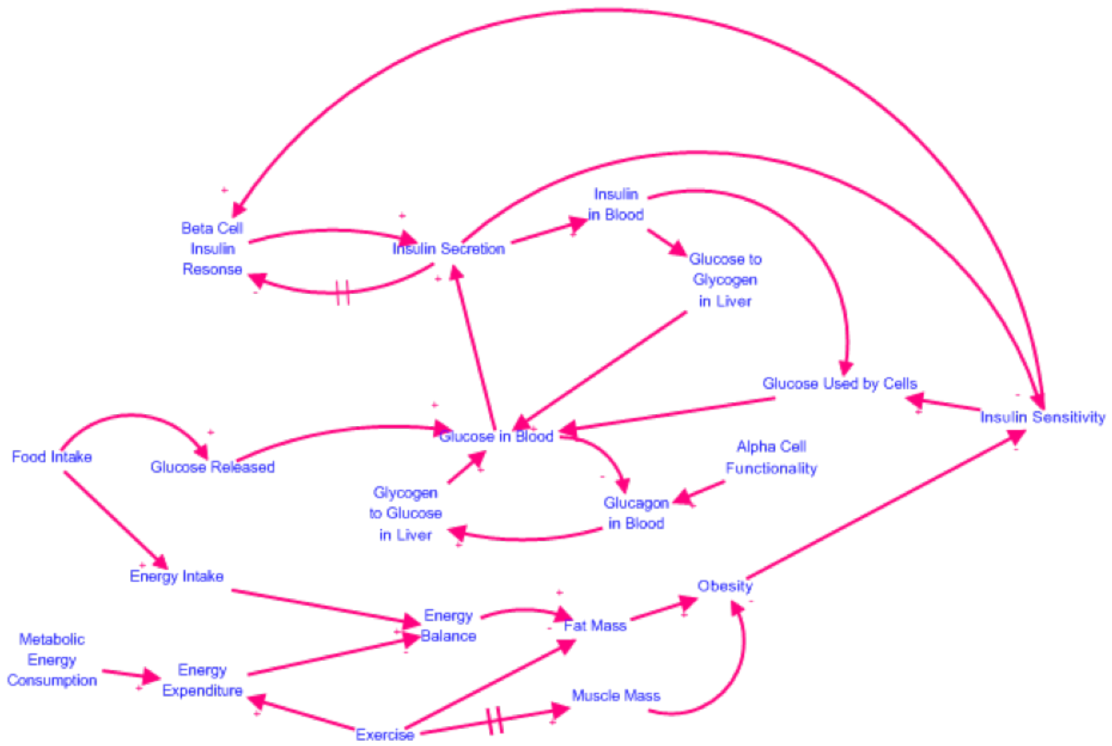


FIGURE 97. DIET EFFECTS – OVERWEIGHT AND OBESITY

Lifestyle Effects – Stress, Sleep, and Exercises

Diet is the first lifestyle factor to add in this model as it is the most influencing factor of the glucose homeostasis and obesity. According to American Diabetes Association (2018), establishing a healthy eating habit is a cornerstone of managing type 2 diabetes. The eating habit is important as it affects not only the amount of glucose released into the blood stream but also the energy intake, which could influence body weight. To represent the individual's eating habit, eating time, food quantity, and food type (GI) are added as variables.

The second lifestyle factor introduced in the model is exercise (Figure 98). Similar to diet, exercise contributes on glucose regulation (Colberg et al., 2010) and weight management (Farmer et al., 2004) based on exercise duration and type. Exercise helps to improve the action of insulin and ultimately increases muscle mass to lower glucose in blood. The model is representing them by connecting exercise to muscle mass and glucose used by cells. Also, muscle mass is connected to glucose in blood and they form a negative relationship.

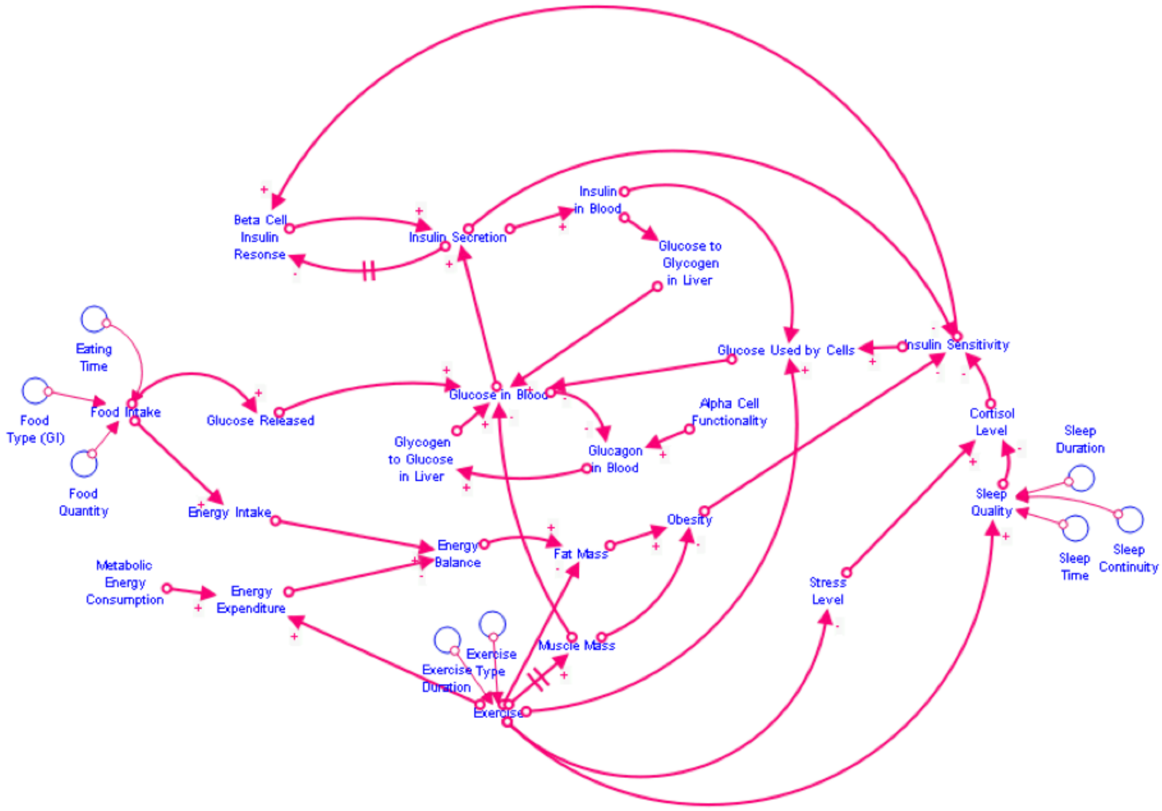


FIGURE 98. LIFESTYLE EFFECTS – STRESS, SLEEP, AND EXERCISES

In this model, exercise is connected to stress level and sleep quality. Various research has conclusively shown that exercise releases hormones and signalling molecules to improve psychological health and sleep quality (Harvard Medical School, 2011).

Stress results when something causes human body to behave as if it were under attack. When stress occurs, the body makes a lot of stored energy – glucose and fat – available to cells. Stress reactions are designed to deal with short-term danger, however if it continues, it can cause long-term high blood glucose level (American Diabetes Association, 2013). Stress can alter blood glucose levels in two ways: (1) increasing cortisol reduces insulin sensitivity and (2) other lifestyle factors get affected in negative ways (i.e. unhealthy diet including excessive use of alcohol, less time to exercise and rest). However, to model the direct causal relationship, this research only has connected the stress level to the cortisol level in this model.

Sleep is another lifestyle factor that is highly associated with the risk of developing type 2 diabetes (Anothaisintawee, Reutrakul, Van Cauter, & Thakkinstian, 2016). When sleep quality is not good, it is like being affected by the stress level: cortisol is increased to reduce insulin sensitivity. Sleep quality is determined by sleep duration, time and continuity. Sleep duration is added as both short and long sleep increases the risk of developing type 2 diabetes (Mesarwi et al., 2013). Sleep time is added as there is evidence that a misalignment of sleep timing with circadian rhythms may be a critical factor for impairing glucose tolerance and beta cell dysfunction (Vetter et al., 2015).

Lastly, the model explains how common type 2 diabetes symptoms make impact back to our lifestyle factors (Figure 99). There are multiple symptoms related type 2 diabetes but the most common symptoms are hunger, fatigue, frequent urinating, and pain in hands and feet (American Diabetes Association, 2015). These symptoms often make patients create a vicious cycle in their lifestyles. As it is modelled in Figure 99, hunger increases food intake, and that can cause, in turn, frequent urinating, which can also negatively influence sleep quality. Pain can cause both reduction in sleep quality and increasing stress level. Then these symptoms are all affecting insulin sensitivity negatively.

Although modelling type 2 diabetes are not simple and straight forward as there are numerous causes, showing interrelationships between glucose level and lifestyle effects can help individuals and families to learn why lifestyle changes are important to manage their current health status. Based on these models, the thesis developed stock and flow diagram, which will be explained in the following subsection.

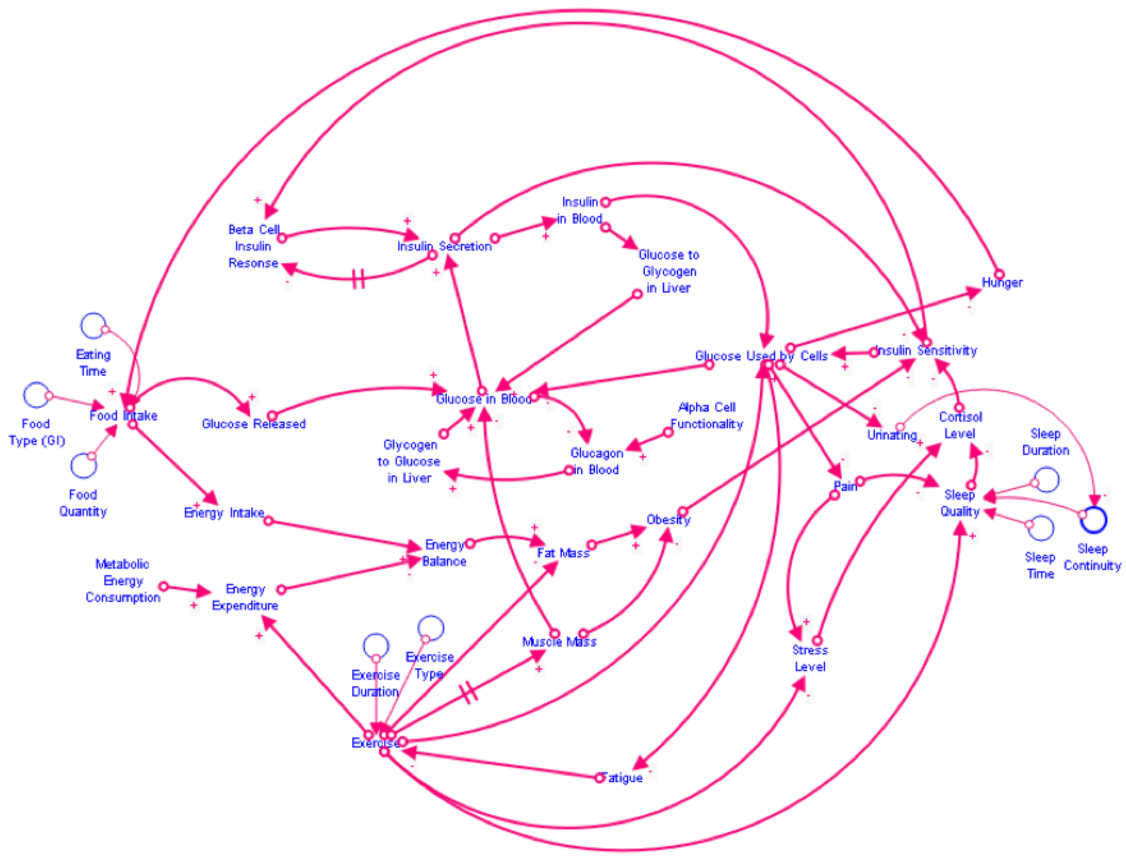


FIGURE 99. LIFESTYLE EFFECTS – DIABETES SYMPTOMS

9.4.2.2 Detailed Models – Stock and Flow Diagram

From the causal loop diagrams, the research has learned that insulin sensitivity is the key element to control type 2 diabetes. However, the knowledge behind the relationship between insulin sensitivity and glucose level can be an overwhelming fact to lay people. The issue of concern in this case is how to manage the glucose level at an optimal level using lifestyle factors effects.

To enhance users' understanding, this research has conceptualised the issue of concern as a two-sector model. The first sector is inflow of glucose and the second sector is outflow of glucose. Then, the user can see the current state of the glucose level in the bloodstream. Equation 1 shows the higher-level equation of the model.

Inflow of Glucose – Outflow of Glucose = Current State of Glucose Level

EQUATION 1. CURRENT STATE OF GLUCOSE LEVEL

Inflow – Accumulative glucose amount after meals

The inflow model is constructed based on the food intake. This model sums carbohydrate consumed in each meal and represents it as glucose level (Figure 100).

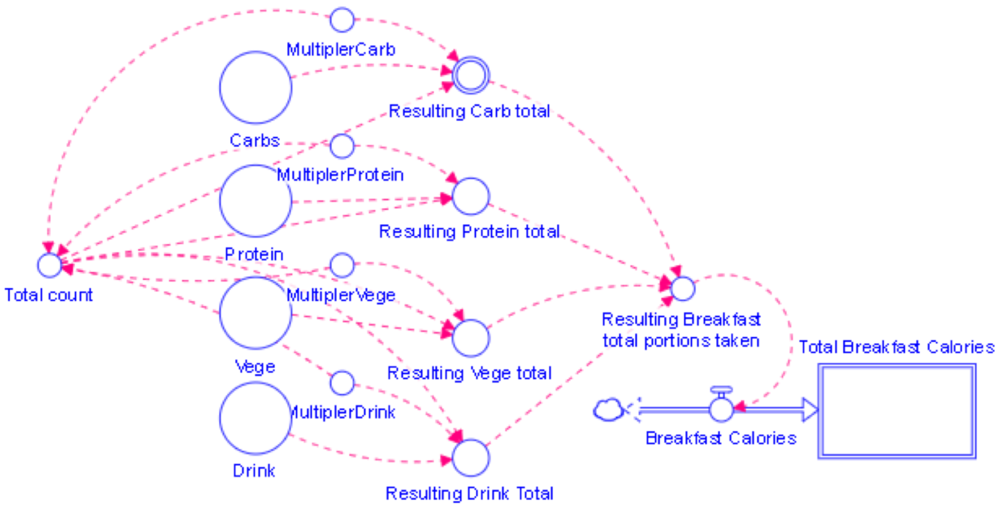


FIGURE 100. INFLOW – ACCUMULATIVE GLUCOSE AMOUNT AFTER MEALS

To show the outcome of irregular and unhealthy eating, the research has plotted four mealtimes per a day. Figure 101 shows the stock and flow model that aggregates glucose from all four meals.

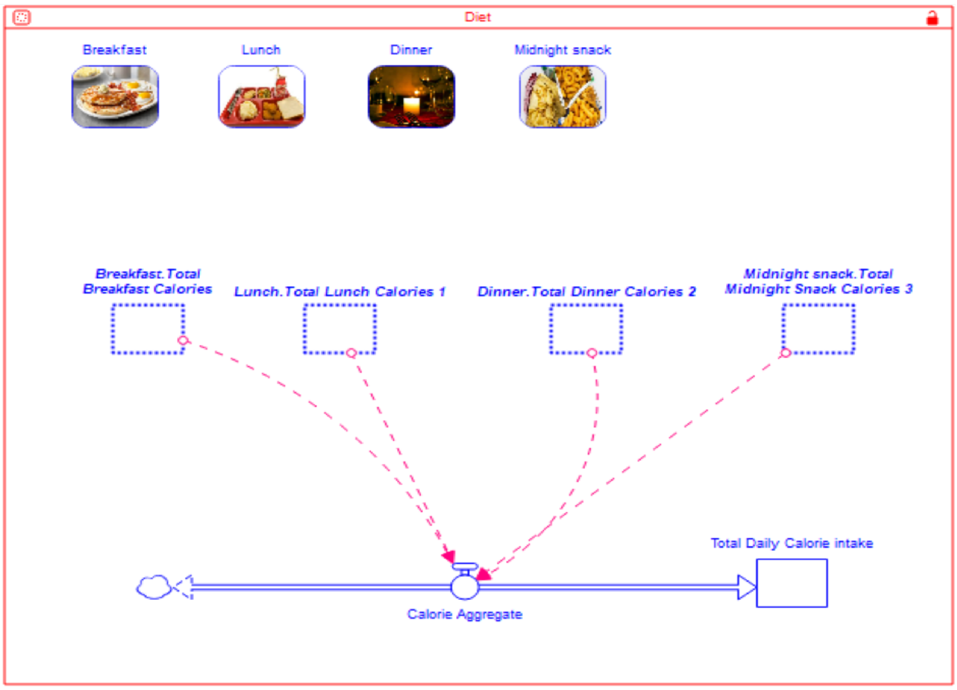


FIGURE 101. STOCK AND FLOW MODEL OF AGGREGATED GLUCOSE

Outflow – Absorption Amount and Lifestyle Factors Effects

Our body uses glucose as energy for body cells. Therefore, it decreases naturally. The glucose absorption varies from one person to another and it even changes based on the person's condition. In addition to this natural phenomenon, the lifestyle factors can affect outflow of glucose. Thus, the outflow equation is:

Outflow of Glucose = Estimated absorption amount + Effects of lifestyle factors

EQUATION 2. OUTFLOW OF GLUCOSE

Insulin sensitivity is an important variable in the diabetes study (Figure 102). When it is at a good rate, glucose in the blood stream is balanced and body cells get enough energy by using glucose. As it is discussed in the causal loop diagram section, lifestyle factors are important in regulating glucose level as they influence the insulin sensitivity. Additive and subtractive multipliers are used to simulate an increase or decrease in lifestyle factors affecting insulin sensitivity. The insulin sensitivity increases when lifestyle factors are in a good range and decreases when lifestyle factors are in a bad range. For example, when the user experiences a very bad stressful event, the insulin sensitivity goes down, so the status of the glucose level is high. Or, when the user has done a reasonable amount and intensity of exercise, the insulin sensitivity goes up to reduce the glucose level in the blood stream.

Current State of Glucose Level

As explained initially, this research has connected the two sectors (inflow and outflow) to see the current state of glucose level (Figure 103).

If the high glucose level persists, it can cause multiple negative health outcomes (Zeevi et al., 2015). The simulated outcomes will be demonstrated in Chapter 8 based on scenarios.

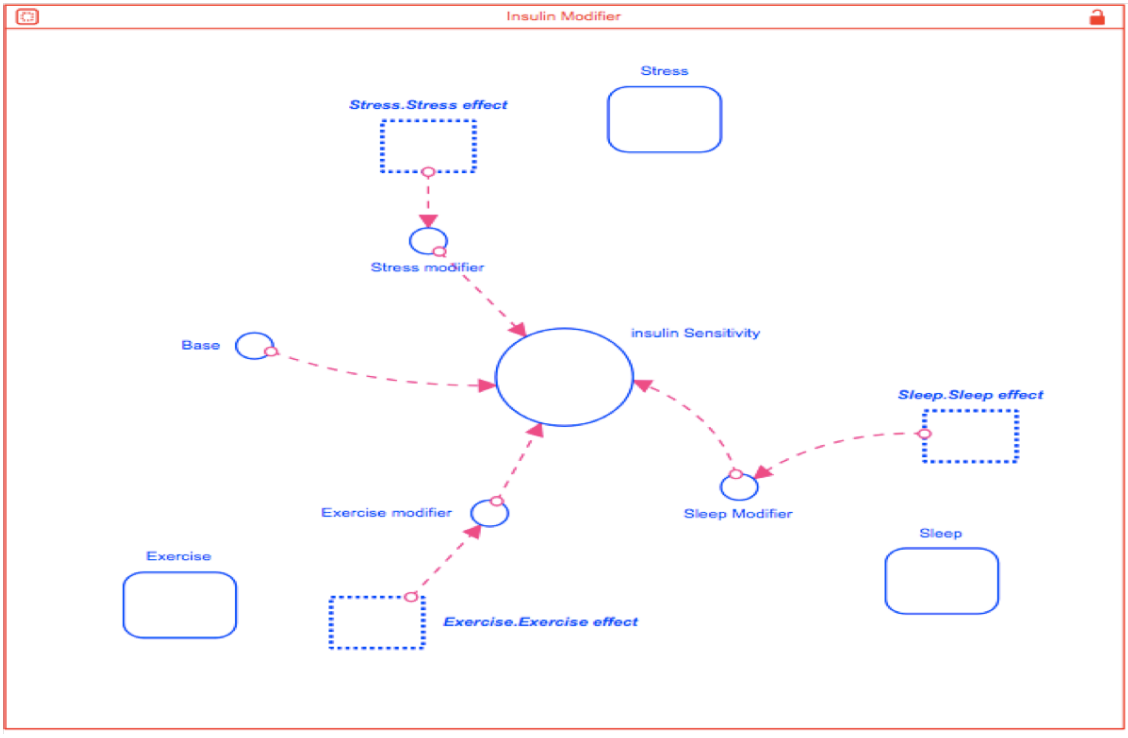


FIGURE 102. MODEL OF LIFESTYLE FACTORS AFFECTING INSULIN SENSITIVITY

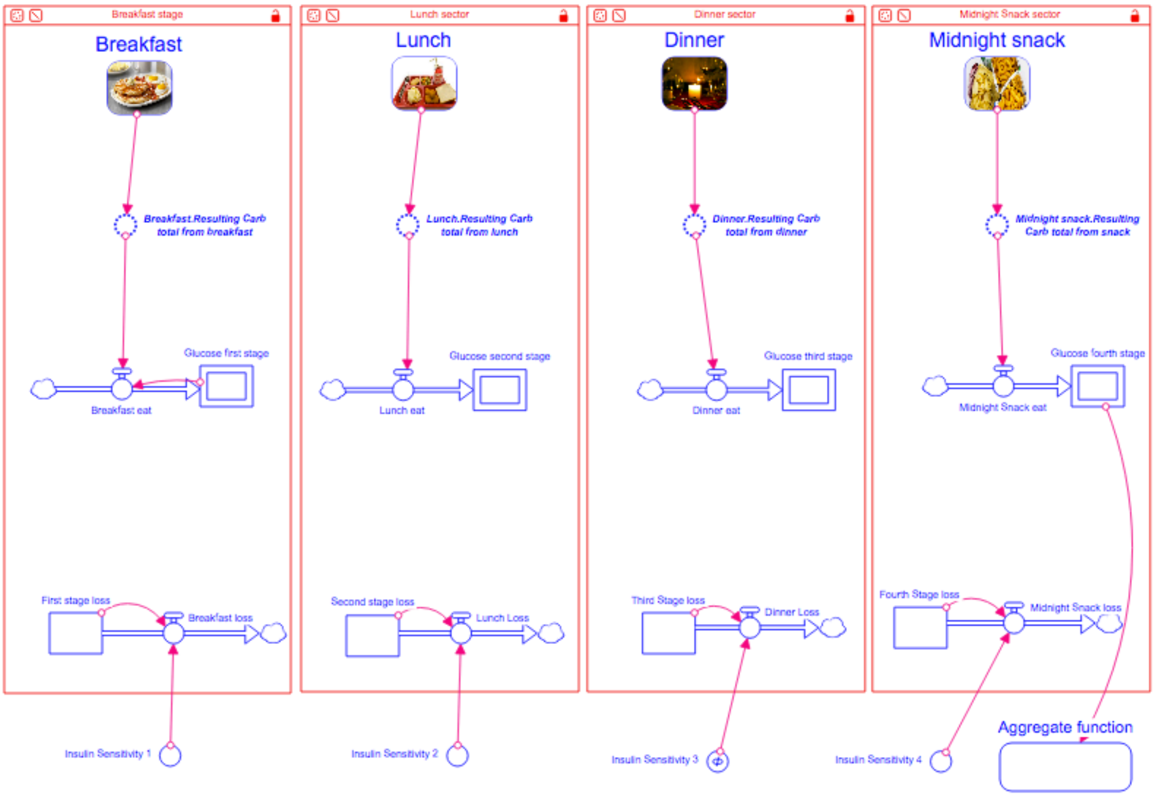


FIGURE 103. CURRENT STATE OF GLUCOSE LEVEL MODEL

As the modelling and simulations are interpreting relationship between life factors and representing the reality to the users, these models can be the input of SSHARRPPP Games that can persuade people to respond and change their behaviours for sustainable transformation. In the following section, the thesis will discuss how SSHARRPPP Games is implemented as the key mechanism to achieve the goals of education and transformation.

9.5 Games

Games are an effective tool to deliver educational contents in playful ways using visual graphics or animations (Van Eck, 2006). The key purpose of SSHARRPPP Games is supporting sustainable education and transformation through entertainment. Users are encouraged to form good habits or destruct bad habits while they are playing multiple games.

The research has attempted several games logics to deliver the educational contents and decided to use a strategy puzzle game for the implemented SSHARRPPP Games. The strategy puzzle games can be the simplest format to problem-solving skills. Usually, problems mean situations where no immediate solutions to reach the goal are existing in the puzzle game (Moursund, 2007). Players must figure out how to solve the problems within the game setting. Therefore, a strategy puzzle game is an ideal game logic to teach lifestyle changes and management within certain settings.

Another reason to choose the strategy puzzle game is its age demographic. One private data insight company found that the age demographic of players of Candy Crush Saga (a global strategy puzzles online game) is wider: 42% of players between the age of 21-35 and almost 40% above age 35 (Newzoo, 2019). As discussed in chapter 8, the researcher developed SSHARRPPP Games to target the audiences who need immediate lifestyle changes due to their chronic conditions. In this case, older adults are target audiences rather than younger children.

In this regard, the researcher designed games for individual and family sustainability. The following sections will explain what functionalities the games have and how they are designed to deliver education and entertainment to the users.

9.5.1 Overview of SSHARRPPP Games Functionalities

The uniqueness of SSHARRPPP games is in its modalities and its interactions. The games have various modalities and interaction mechanisms – from the purely virtual to the completely real and a whole plethora of combinations in between, as illustrated in Figure 104.

In the pure game layer, the games are composed of various worlds, which are representing our life dimensions. For example, the health world has games that educate us to adopt healthy diet, exercise, and rest to managing stressful habits and to discourage the bad lifestyles associate with them. The various worlds also can be integrated together to deliver advanced educational interventions. For example, the finance world and the environment world work together to teach us how to save money and the planet by adopting simple water saving tips.

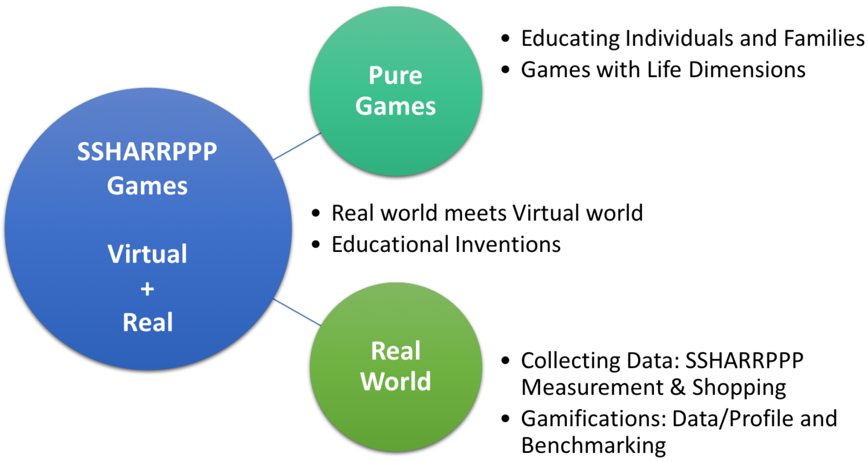


FIGURE 104. SSHARRPPP GAMES FRAMEWORK, ADAPTED FROM THE AUTHORS' CREATION (CHUNG & SUNDARAM, 2018B)

The most interesting habit formation and destruction features are offered in the middle layer between pure game and real-world layers. By converting real-world data to game data, players can play games while they form their desired habits. For example, the players can input their real-world exercise data into the exercise game and play it. For this, the games collect and measure player's activity data in the real-world layer. Also, the games use persuasive gamification features that encourage players to take actions in the real-world. Through these mechanisms, the games can change the user's behaviours and attitudes towards healthy lifestyle through persuasive technologies (Fogg, 1998).

9.5.2 Implementation

SSHARRPPP Games have been implemented on an iOS environment. The objected-oriented programming language, Swift has been used for game development. As it is explained in Chapter 8, multiple games and their levels are implemented to teach lifestyle changes and management for diabetic patients.

To implement educational games with different levels, it is required to think broadly about two things.

- How educational contents should be delivered to players through games
- The most efficient way to implement multiple games

Therefore, in this section, the thesis will explain how SSHARRPPP Games have been implemented to meet these two points.

9.5.2.1 Delivering Educational Content

SSHARRPPP Games have been implemented to deliver two educational contents. Firstly, showing the required activities to manage a diabetics' lifestyle. Secondly, showing what is an expected outcome depending on player's action. The first lesson has been implemented through the game objectives that the player needs to match all the required icons and the second message has been designed to deliver through avatar animation updates (the cat face) based on glucose level.

According to the American Diabetes Association (2018), nutrition therapy (diet), physical activity (exercise), and psychological care (stress) are the fundamental self-management aspects of diabetes care. In addition to these factors, the researcher has included sleep into the Games as a growing body of literature shows an association between sleep disorder and type 2 diabetes incident (Mesarwi et al., 2013).

In each lifestyle requirement, the most important lesson to be learned is "balance". For example, nutrition therapy (diet) teaches to have varied food in a balanced way daily. The objectives of SSHARRPPP Games have been idealised from this perspective. Therefore, players should match (eat) various healthy food in the objective window to win the diet game (as explained in Chapter 8). The codes below show that a thumbs up image will be shown when each matching requirement is met (Figure 105).

```
func updateCompleteImages() {
    if spriteScore1 >= level.targetSpriteScore1 {
        targetSprite1Done.isHidden = false
        targetSprite1Done.image =
        spriteStackView1.isHidden = true
    }
    if spriteScore2 >= level.targetSpriteScore2 {
        targetSprite2Done.isHidden = false
        targetSprite2Done.image =
        spriteStackView2.isHidden = true
    }
    if spriteScore3 >= level.targetSpriteScore3 {
        targetSprite3Done.isHidden = false
        targetSprite3Done.image =
        spriteStackView3.isHidden = true
    }
    if spriteScore4 >= level.targetSpriteScore4 {
        targetSprite4Done.isHidden = false
        targetSprite4Done.image =
        spriteStackView4.isHidden = true
    }
}
```

FIGURE 105. CODE SEGMENT FOR SHOWING THUMBS UP IMAGES

Figure 106 illustrates how the Games show the "thumbs up" images in the objective window area as we have seen in Chapter 8.

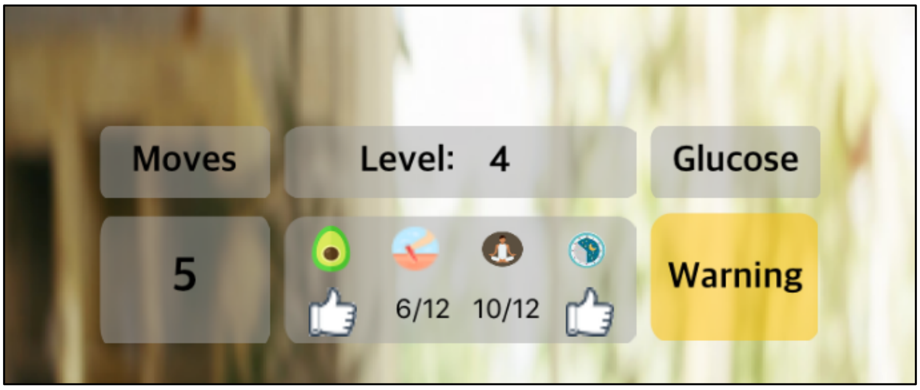


FIGURE 106. THUMBS UP IN SSHARRPPP GAMES

The next code segment shows how the game is designed to win or lose the level (Figure 107). To win the level, player not only needs to match all icons, but also to match them while moves are left, and while sugar is lower than a certain level.

```
func decrementMoves() {
    movesLeft -= 1
    updateLabels()
    updateResultsImages()
    updateCompleteImages()

    /*
     // Use this for Total score scenario
     if score >= level.targetScore {
     gameOverPanel.image = UIImage(named: "WinTheLevel")
     currentLevelNum = currentLevelNum < numLevels ? currentLevelNum + 1 : 1
     showGameOver()
     } else */

    // Use this for Individual food item scenario
    if spriteScore1 >= level.targetSpriteScore1
        && spriteScore2 >= level.targetSpriteScore2
        && spriteScore3 >= level.targetSpriteScore3
        && spriteScore4 >= level.targetSpriteScore4   {

        // Here code should be out of the level
        if currentLevelNumber == numLevels {
        gameOverPanel.image = UIImage(named: "WinTheLevel1")
            gameOverButton.isHidden = false
            // gameOverButton.image = UIImage(named: "BacktoMenu")
            showGameOver()
        } else {
            gameOverPanel.image = UIImage(named: "WinTheLevel")
            currentLevelNumber = currentLevelNumber < numLevels ? currentLevelNumber + 1 : 1
            showGameOver()
        }
    } else if movesLeft == 0 {
        gameOverPanel.image = UIImage(named: "LostTheLevel")
        showGameOver()
    }
    else if sugarLevel >= 11 {
        gameOverPanel.image = UIImage(named: "LostTheLevel")
        showGameOver()
    }
}
```

FIGURE 107. CODE SEGMENT FOR WIN OR LOSE

9.5.2.2 *Game View Controller Structure*

From a developer's perspective, delivering multiple educational message through games can be challenging. For this we have used the Model – View – Controller (MVC) framework for game development. this is because the MVC is a design pattern that decouples important components and is useful for code reuse (Codecademy, 2019). As

SSHARRPPP Games are composed of multiple worlds and levels, MVC framework has provided an easier environment for game development.

Figure 108 shows the implemented structure of SSHARRPPP Games for this research. The left picture shows file structure and, if “Main.storyboard” is clicked on, the right picture is shown. This is the view controller structure for the games. In the file structure, it is an example of how level files and source files for each game are organised. Other games have same file structure. With this file structure, common file can be shared and reused across the games.

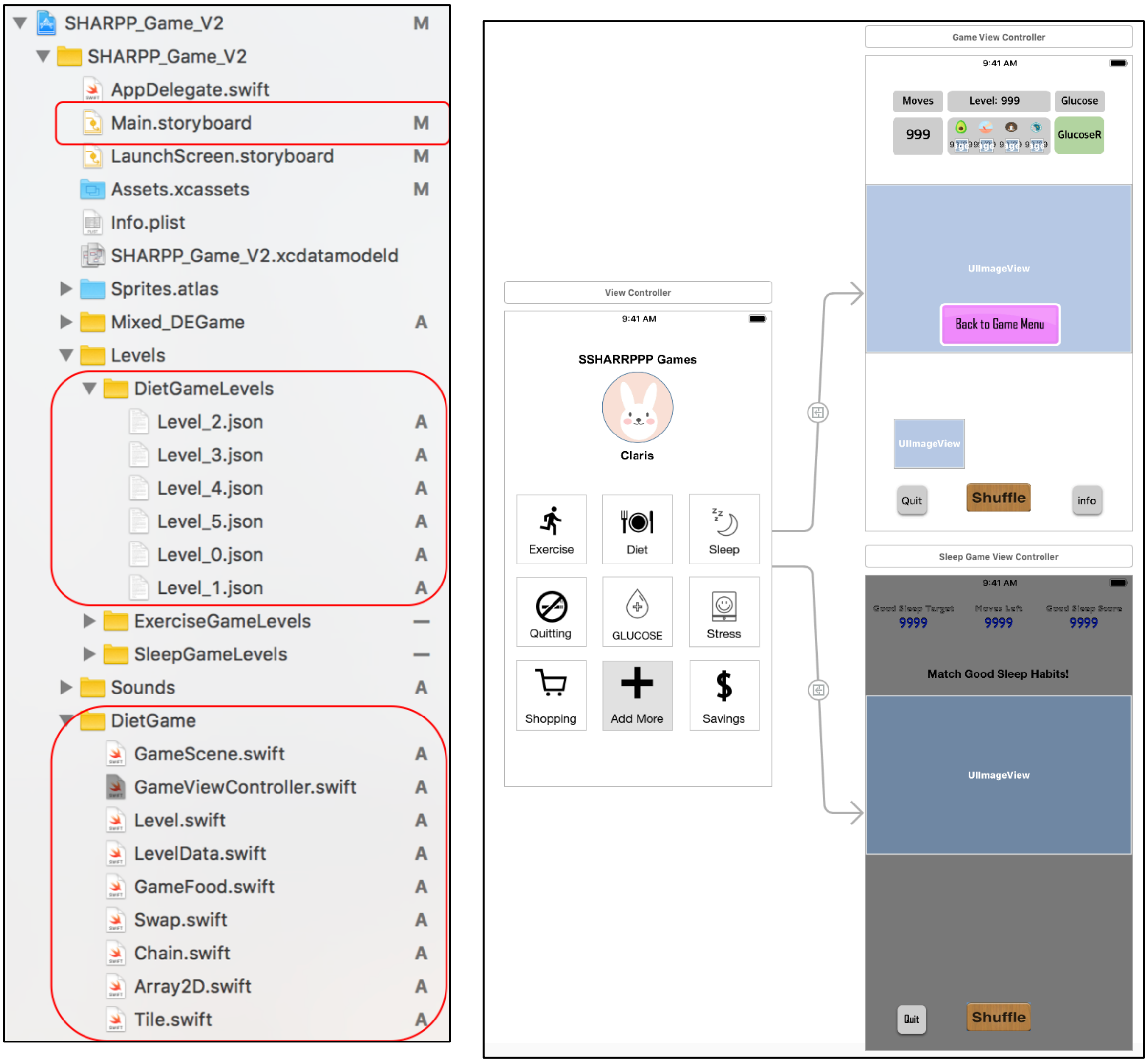


FIGURE 108. THE IMPLEMENTED STRUCTURE OF SSHARRPPP GAMES

There are two view controllers designed to accommodate four different games. Although each game has slightly different objectives and levels, we can use simple and consistent UI composition for multiple games because of the MVC model.

The game window has three areas: information area, play area, and control area. The information areas are above and below the play area. This area shows the winning objectives (icons with score), the game constraint (moves), the level of game playing (level), and the player's current status (score, glucose level, and fitness level). The play area has 7x7 icons where players can find and match three or more icons. This area is in the middle and, as the level goes up, the shape of the area can be changed to increase the challenge of the level. The control area has three buttons: quit, shuffle, and info. By clicking the quit button, the player can stop game playing and return to the first page. The shuffle button allows players to shuffle icons when there are no possible matching three icons. The info button provides useful information about the game.

Levels are loaded from JSON files (Figure 109). Again, each level must have same data structure as shown in the picture to follow MVC model.

```
{
    "tiles" : [[0, 1, 1, 1, 1, 1, 0 ],
               [1, 1, 1, 1, 1, 1, 1 ],
               [1, 1, 1, 1, 1, 1, 1 ],
               [0, 1, 1, 1, 1, 1, 0 ],
               [1, 1, 1, 1, 1, 1, 1 ],
               [1, 1, 1, 1, 1, 1, 1 ],
               [0, 1, 1, 1, 1, 1, 0 ]],


  "targetScore": 50,
  "moves" : 15,
  "targetSpriteScore1" : 3,
  "targetSpriteScore2" : 3,
  "targetSpriteScore3" : 3,
  "targetSpriteScore4" : 3,
}
```

FIGURE 109. JSON CODE SEGMENT FOR CREATING LEVELS

SSHARRPPP Games can be composed of multiple games. Having these modalities and mechanisms in mind, the SSHARRPPP games have been designed and structured to offer support transformation features for sustainable transformation of individuals and families.

9.6 Summary

The design and implementation of prototypical system artefacts is at the core of the design science research and the iteration of this cycle can refine the artefacts to be relevant to the application domains and contribute to the knowledge base (Hevner, 2007). System artefacts are called 'proof of concepts' which imply this is the most important process of evaluating the conceptual, procedural, and technological responses that have been argued and defined for the research.

In this chapter, the thesis has illustrated different and various ways of researcher's involvements in designing and implementing SSHARRPPP systems. The four systems have been developed based on the vertical implementation approach, and each system took several iterations in the development process. This ensures the system refinement. Most systems are developed in the iOS environment. The implementation of key functionalities was introduced in this chapter for the better and focused presentation of the research journey in the development of proof of concepts. The rest of the system development details will be displayed in the appendices at the end of this thesis.

10 Evaluation of Research Artefacts

In the study of multimethodological design science, evaluation is a very important step to check whether the research is rigorous enough to answer the proposed research objectives (Prat, Comyn-Wattiau, & Akoka, 2014). To conduct rigorous research, the researcher used various evaluation methods to test, validate, and refine the artefacts.

Therefore, the following questions are asked in this chapter:

- How has this thesis approached evaluating research artefacts?
- What are the research artefacts and how have these artefacts been evaluated?

And to answer these questions, the research will:

- Illustrate the roadmap of research artefacts and the structure of the thesis that establishes logical arguments to answer the research questions and validate the artefacts in consecutive order in section 10.1.
- Explain how Hevner et al.'s (2004) design science evaluation methods are used to validate artefacts in section 10.2. Tables are used to show the relationship between artefacts and methods.
- Explain conceptual, procedural, technological, and system artefacts that have been developed for this research from 10.3 to 10.6. In these sections, we will describe how evaluation methods are applied to the artefacts and how the artefacts are refined or validated.

Also, as explained throughout at the beginning of each chapter, the thesis is organised to show how chapters have been formed mutual relationships as the basis of conceptualisation and evaluation. Finally, all chapters are linked to this evaluation of research artefacts (Figure 110).

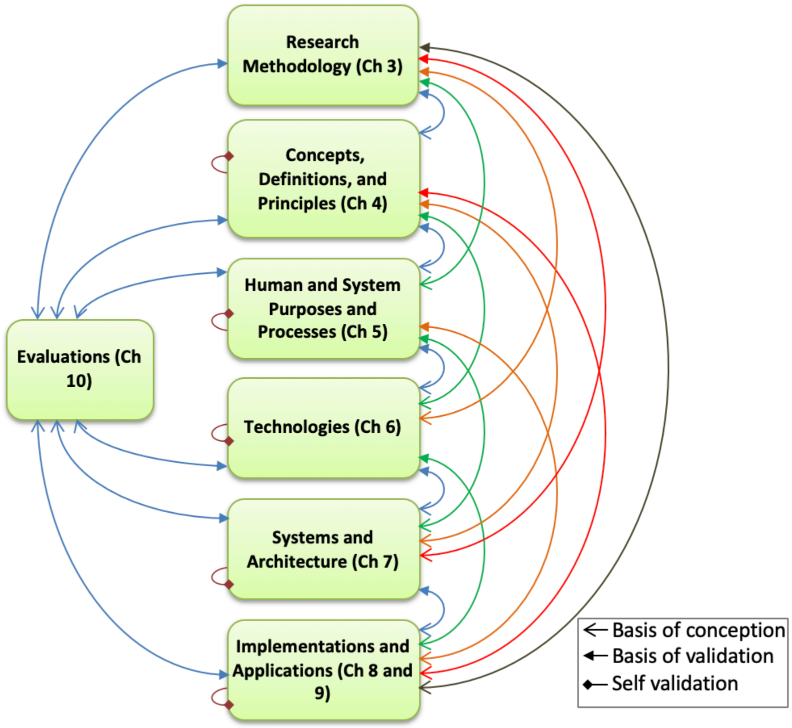


FIGURE 110. CHAPTER STRUCTURE AND RELATIONSHIPS (ALSO PRESENTED AS FIGURE 2 IN CHAPTER 1)

10.1 Roadmap of Artefacts

The motivation of this PhD research began from two simple questions: (1) How can people live sustainably and pursue happiness in their lives? and (2) How should systems be designed and implemented to support that sustainable life transformation? To answer these questions, the research established various arguments and produced various artefacts. A journey of our research has been discussed and explained through this thesis so far.

The journey started from defining a conceptual foundation (Chapter 4) to finding applicable transformation processes and mechanisms (Chapter 5) to suggesting suitable technologies (Chapter 6) to designing and implementing SSHARRPPP systems (Chapter 7, 8 and 9). Figure 111 is a representation of the journey and the structure of the thesis. The inverted triangle represents the landscape of each chapter in the thesis, which means that the earlier chapter covers the wider research domains. The developed arguments in the earlier chapters guide the development of artefacts in the following chapters. In similar but reversed fashion, the artefacts in the later chapters validate the logic and arguments of the preceding chapters.

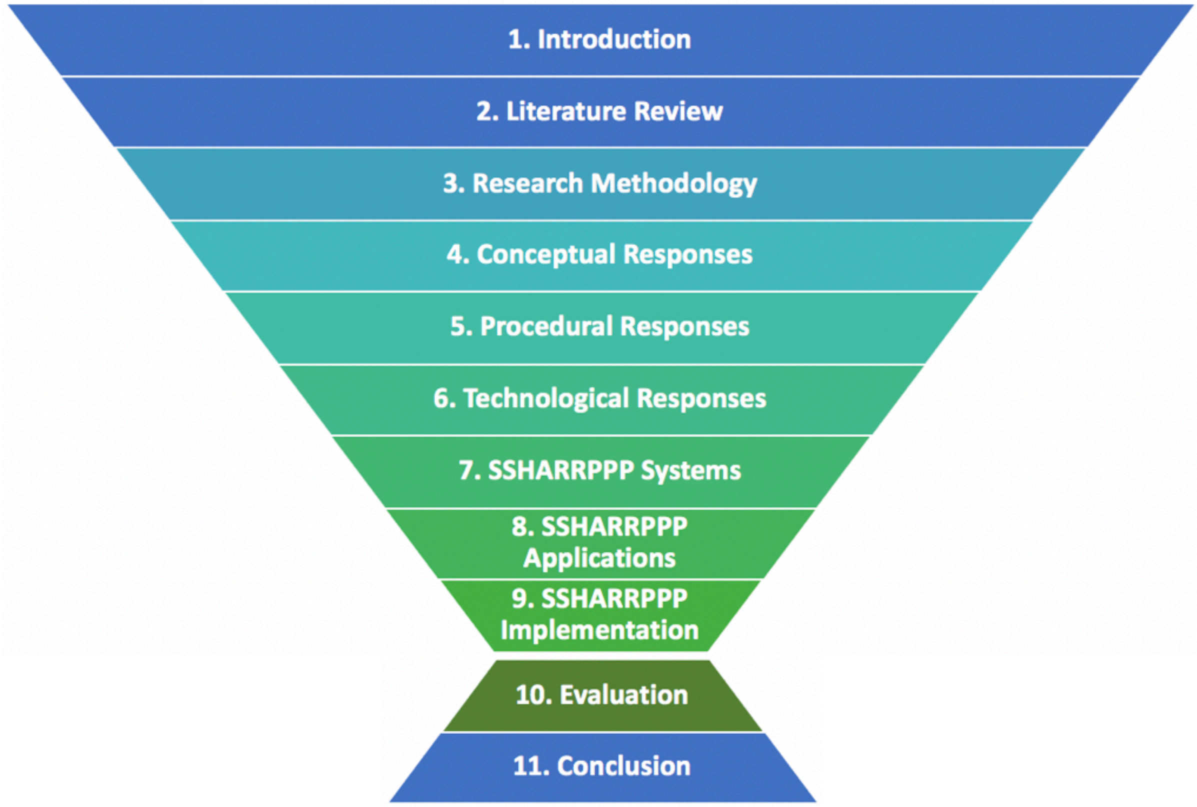


FIGURE 111. THESIS STRUCTURE

For example, the proposed SSHARRPPP systems in Chapter 7 guide what are the key and ideal functionalities that should be implemented for the appropriate situations in Chapter 8 and 9. Mutually, the implemented key features in Chapter 9 validate the proposed systems in Chapter 7. Therefore, the thesis is written in a way that the preceding artefacts guide formation of the subsequent artefacts. The subsequent artefacts also serve a role as an evaluating method of the preceding artefacts.

Furthermore, this thesis journey followed the V-model (Sheffield, 2005), as it was discussed in 3.3.3. The introduction explains why pursuing this research topic adds values to the knowledge base. Literature Review helps us to identify research opportunities and objectives. Research methodology lets us plan how the research should be conducted. Then chapters on conceptual, procedural, and technological responses provide a constructive foundation for SSHARRPPP System implementation. SSHARRPPP systems and Evaluation chapters are the results of this thesis journey and provide evidence that the research objectives have been fulfilled. The conclusion will explain what the payoff from this thesis is.

In the following sections, all artefacts which are introduced and explained in preceding chapters are validated using different evaluation methods. Also, the thesis will discuss the evaluation methods that we have adopted for this research and the processes that we have gone through for the research outcomes.

10.2 Evaluation Methods

This research has used various methods for evaluating the research outcomes and artefacts. Figure 112 provides a summary of research outcomes and their matching evaluation methods. As this thesis is structured, the left column shows the evaluated conceptual, procedural, technological, and system artefacts.

The research has mainly adopted Hevner et al.'s (2004) evaluation methods. Due to the research objectives and goals, the thesis has used a multi-perspective evaluation approach based on five categories of methods: analytical, experimental, testing, descriptive, and dissemination. Analytical methods are used to analyse all research artefacts from static, dynamic, and/or architectural perspectives. Experimental methods, simulations and prototyping, were used the robustness of research outcomes. Functional and structural testing methods were used to test mainly system responses. Throughout the whole research journey, the researcher established arguments, testes research outcomes against scenarios, and applied feedback from expert evaluations (descriptive methods). Also, from the beginning to the end of the research, the researcher has been continuously published and presented her ideas and research outcomes to the top tier peer reviewed conferences and seminars.

Also, for conceptual, procedural and technological artefacts, the researcher has established valid arguments against an *informed argument* first, then analysed and assessed them through *architecture analysis*, *simulations*, and *prototyping*. At the same time, *expert evaluation and academic opinions* are collected and applied through *publications*, *presentations*, and *seminars*. For system artefacts, the research has developed proof-of-concept *prototypes* first, then tested and assessed them through *scenarios*, *simulations*, *technical analysis* and *testing*. Again, *expert evaluation and academic opinions* are used to refine and validate the systems.

Evaluated Artefacts	Static Analysis	Architecture Anaysis	Dynamic Analysis	Simulation	Prototyping	Functional	Structural	Informed Argument	Scenarios	Expert Evaluations	Publications	Presentations
	Analytical			Experimental		Testing		Descriptive			Dissemination	
Conceptual Responses												
Definition of Individual and Family Susntainability		✓		✓	✓			✓	✓	✓	✓	✓
SSHARRPPP Principles		✓		✓	✓			✓	✓	✓	✓	✓
Procedural Responses												
Sustainable Transformation Framework		✓		✓	✓			✓		✓	✓	✓
Individual and Family Mechanisms				✓	✓			✓		✓	✓	✓
System Purposes and Processes		✓	✓	✓	✓			✓		✓	✓	✓
Sustainable Transformation (SIRT) Process		✓	✓	✓	✓			✓		✓	✓	✓
Technological Responses												
to support System Purposes and Processes		✓	✓		✓			✓	✓	✓	✓	✓
to support Sustainable Transformation Process		✓	✓		✓			✓	✓	✓	✓	✓
Overall SSHARRPPP Architecture and Framework		✓	✓		✓			✓		✓		✓
System Responses												
SSHARRPPP Measurement	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SSHARRPPP Shopping	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SSHARRPPP Modelling	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
SSHARRPPP Games	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

FIGURE 112. SUMMARY OF RESEARCH OUTCOMES AND EVALUATION METHODS

Analytical Evaluation

- **Static Analysis**: looks at how well fundamental features are designed. For example, an alignment of user interface components should be consistent throughout the whole system to ensure easy usability. In our evaluation process, we have used static analysis tools provided in the development software (e.g. Xcode).
- **Architecture Analysis**: evaluates whether the artefact has been designed, organised, and constructed properly. Architecture analysis is not only reserved to evaluate technological and system artefacts, but also to check whether conceptual and procedural artefacts can be embedded into the systems.
- **Dynamic Analysis**: looks at whether systems perform the way systems should. For example, the overall resource usage of systems should be checked during system development process and ensure the system can be operated smoothly while it is at the user's side. For this analysis, we have used not only tools built into the development software but also written codes to check the behaviours of systems.

Experimental Evaluation

- **Simulation**: checks key functionalities of systems with synthetic data. This method is used to test system artefacts' performances. Also, we have used simulation method to check that system artefacts deliver concepts like SSHARRPPP Principles or follow the proposed processes.
- **Prototyping**: validates the proposed conceptual, procedural, and technological responses that have been developed in this research. By implementing the proof-of-concept prototypical systems, our research was able to validate one of the research questions, "how the system can support sustainable life transformation."

Evaluation through Testing

- **Functional Testing**: discovers failures and defects of system functionalities. By executing systems or applications, we can check whether the implemented functionalities are working correctly or not. We have tested system functionalities through the designated devices, such as web browser, smart phone, and tablets.

- **Structural Testing**: checks the internal structure of the artefacts. This testing has been performed against the storage and flows of information and data, independent programming paths, and error handling paths. We have used the internal structural testing tools that are built in Xcode.

Descriptive Evaluation

- **Informed Argument**: establishes convincing arguments about the background and generalisability of all research outcomes. Literature reviews in various disciplines provide relevant factors and information to evaluate the proposed and developed conceptual, procedural, technological, and system artefacts.
- **Scenarios**: test research artefacts under the constructed circumstances. We have used type 2 diabetes patients and their families' cases to test SSHARRPPP systems and some of conceptual and technological artefacts were also tested while systems have been tested using scenarios. For this, we have identified the key functionalities that the system should provide to support the sustainable life transformation of individuals and families.
- **Expert Evaluations**: help us to attain artefact evaluation from various viewpoints. For example, SSHARRPPP Shopping was presented to the online shopping company who wanted to build a shopping system that can provide better and unique shopping experiences to its customers. Opinions and feedback from

Evaluation through Dissemination

- **Publications and Presentations:** provide opportunities to attain academic and related stakeholders' comments and feedback. Adopting the feedback from the academics, the presentation of findings, and the publication of research outcomes are critical processes for establishing the generalisability of the study outcomes and the identification of their limitations. Therefore, the researcher has published and presented the findings in top tier Information Systems, Computer Science, and System Sciences conferences (A ranked according to CORE - www.core.edu.au/conference-portal) during the PhD. Feedback collected from various sources has been used for both formative evaluations to develop a particular artefact in any part of the development cycle (Venable, Pries-Heje, & Baskerville, 2016). Table 6 and Table 7 highlights the presentations and publications in which we have disseminated research outcomes during the PhD journey.

Also, the researcher closely engages with the latest research ideas and fellow scholars in sustainable transformation subject by actively serving mini-track chair roles in the top tier conferences. These conferences are the Hawaii International Conference on System Sciences (HICSS) 2020 and the Americas Conference on Information Systems (AMCIS) 2020.

As such, this research and its outcomes were tested and validated holistically from various perspectives and methods. In these regards, the thesis will detail how each research artefact was evaluated with what evaluation methods in the following sections.

		Conceptual		Procedural				Technological			System			
Year	Publications	Definition of Individual and Family Sunstainability	SSHARRPP Principles	Sustainable Transformation Framework	Individual and Family Mechanisms	System Purposes and Processes	Sustainable Transformation (SIRT) Process	Key Technologies	Overall SSHARRPP Framework	Overall SSHARRPP Architecture	SSHARRPP Measurement	SSHARRPP Shopping	SSHARRPP Modelling	SSHARRPP Games
2014	'Sustainable Social Shopping Systems' (Chung et al., 2014)	✓	✓	✓	✓			✓				✓		
	'Sustainable social shopping systems: Concept and implementation' (Chung et al., 2014)	✓						✓				✓		
2015	'Design and Implementation of Sustainable Social Shopping System' (Chung et al., 2015)	✓						✓				✓		
	'Design and Implementation of Individual Sustainability Systems' (Chung et al., 2015)	✓						✓			✓	✓		
2016	'Sustainable, Holistic, Adaptable, Real-time, and Precise (SHARP) Approach towards Developing Health and Wellness Systems' (Mirza et al., 2016)	✓	✓					✓	✓					
2018	'SHARPP Games for the Education Prevention and Reversion of Chronic Diseases' (Chung et al., 2018)	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓
	'Persuasive Serious Social Health Games for Managing Diabetes' (Goundar et al., 2018)	✓	✓	✓			✓	✓						✓
2019	'Individual and Family Sustainability: The Measure Model Entertain Transform Approach' (Chung et al., 2019)	✓	✓	✓		✓	✓	✓	✓				✓	

TABLE 6. SUMMARY OF RESEARCH PUBLICATIONS

		Conceptual		Procedural				Technological			System			
Year	Presentations	Definition of Individual and Family Sunstainability	SSHARRPPP Principles	Sustainable Transformation Framework	Individual and Family Mechanisms	System Purposes and Processes	Sustainable Transformation (SIRT) Process	Key Technologies	Overall SSHARRPPP Framework	Overall SSHARRPPP Architecture	SSHARRPPP Measurement	SSHARRPPP Shopping	SSHARRPPP Modelling	SSHARRPPP Games
2014	NZ Information Systems Doctoral Conference, Dunedin	✓	✓		✓						✓	✓		✓
	The 20th Americas Conference on Information Systems	✓			✓			✓				✓		
	The 6th International Conference on Computational Collective Intelligence	✓	✓		✓			✓			✓	✓		
	The 2nd International Conference on Nature of Computation and Communication	✓		✓	✓			✓			✓	✓		
	The 3rd International Conference on Context-Aware Systems and Applications	✓		✓	✓			✓			✓	✓		
2015	The University of Auckland Department of ISOM Seminar	✓	✓		✓			✓			✓	✓		
2016	the 2nd International Conference on Future Network Systems and Security		✓	✓				✓	✓					
2017	NZ Information Systems Doctoral Conference, Wellington	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓
	The University of Auckland Business School PhD Conference	✓	✓	✓	✓	✓	✓	✓						✓
2018	The 51st Hawaii International Conference on System Sciences	✓	✓	✓	✓		✓	✓	✓	✓				✓
	The 22nd Pacific Asia Conference on Information Systems	✓	✓	✓				✓						✓
2019	Sustainability Seminar for Postgraduate Students	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	The 25th Americas Conference on Information Systems	✓	✓	✓		✓	✓	✓					✓	

Table 7. Summary of Research Presentation

10.3 Conceptual Artefacts

In Chapter 4, the thesis discussed the conceptual research responses, which serve the theoretical foundation of research. Two main concepts have been developed for the research: individual and family sustainability and SSHARRPPP principles. To support these conceptual responses, the research has defined individual and family sustainability, discussed life dimensions and values for individual and family purposes, justified why sustainability is important by suggesting a vision and approaches to achieve individual and family sustainability.

The conceptual responses are validated through informed arguments, publications, architecture analysis and presentations. In what follows, the thesis will discuss how these concepts were produced, proposed, and presented for evaluations.

10.3.1 Definition of Individual and Family Sustainability

Although sustainability has been a business buzzword for decades, the concept of individual and family sustainability is still a relatively new concept to scholars. Therefore, discussions around their interests are scattered and there is no conventionally agreed definition of individual and family sustainability. To set a boundary for the research, defining the individual and family sustainability concept was necessary. The validation methods for the concept were architecture analysis, simulation, prototyping, informed argument, scenarios, expert evaluations, publications and presentations.

The concept has been defined after a thorough literature review. Then the initial concept was presented in the New Zealand Information Systems Doctoral Conference (NZISDC) in 2014. The feedback was from academics of Information Systems in New Zealand universities. In the presentation, the concept of individual and family sustainability was endorsed by many professors because of its maturity and necessity. By taking all constructive feedback, the concept has gradually been refined over time and validated by multiple publications and presentations (Table 6 and Table 7).

While the concept has been endorsed, practical ways of implementing the concept into the system (prototyping) became our next research focus. This is because developing systems for assisting individuals and families involves not only a system performance (technical) perspective but also a system usability (socio-technical) perspective (Hevner & Chatterjee, 2010). Therefore, the individual and family sustainability has become a fundamental concept, scenario, and simulation foundation while the researcher was developing architectures as well as SSHARRPPP systems. Also, the concept has been applied to check the robustness of the system architectures and system functionalities (i.e. whether the systems are designed to deliver functionalities that support the individual and family sustainability).

10.3.2 SSHARRPPP Principles

When the research topic involves multiple disciplines, as in this research, applying various sources or forms of knowledge to design, implement, and evaluate systems can be a complicated task. To meet this requirement, this research proposed the "SSHARRPPP" principles as a guide to operationalise our vision and purposes. It also helps to identify processes and mechanisms, and design and implement certain systems that support individual and family sustainability. To evaluate the principles, we have used architecture analysis, simulation, prototyping, informed argument, scenarios, expert evaluations, publications and presentations.

For the initial principles, "SHARP", was proposed in a conference paper that suggested a new development approach for healthcare systems (Mirza et al., 2016). The paper was co-authored with multiple academics whose specialities are in health informatics, decision support systems, software engineering, and adaptive systems. Then the concept has been expanded to "SHARPP: Sustainable, Holistic, Adaptive, Real-time, Precise, and Persuasive" and applied to design serious health games for chronic patients. Publishing and presenting the paper at the HICSS 2018 (The Hawaii International Conference on System Sciences) validated that the expanded principles are applicable to system development for individual and family sustainability (Chung & Sundaram, 2018). The SSHARRPPP principles, were finalised based on valuable feedback and suggestions from the conference, as well as through a series of seminars and internal discussions based on the informed arguments with the thorough literature review.

The principles have also been presented to a group that has 12 postgraduate students who were majoring in information systems and operations management and two academics. During the presentation, two questions were asked to confirm the comprehensiveness of the final principles. The first question was whether the participants agree that the SSHARRPPP principles help individuals and families to transform their lives or not. The second question asked whether there is any principle to add or remove. For the first question, most participants agreed that the SSHARRPPP principles can help individuals and families to transform their lives. Among the 7 scales (1 for disagree to 7 for agree), the average score was 6.08.

From the technical point of view, designing, developing, and implementing SSHARRPPP systems as proof-of-concept are the major evaluation processes in this research. As the research developed sequentially from concepts and processes to technologies, systems should be implemented to embrace all previously developed artefacts including their particular functionalities. Therefore, SSHARRPPP principles have been validated through the SSHARRPPP systems, architectures, scenarios and simulation of functionalities. For example, the overall SSHARRPPP architecture has been explained against SSHARRPPP principles, system purposes and processes, and sustainable transformation (SIRT) processes in Chapter 6.3.

10.4 Procedural Artefacts

Conceptual responses answers what is individual and family sustainability and why it is important to us. Procedural responses then answer what are the relevant processes to achieve a sustainable and better life. Therefore, the research started to answer by looking at the individual and family transformational processes and mechanisms. Then, the researcher studied and suggested how the system should deliver these procedural ways for achieving the sustainable life transformation. As such, procedural responses are studied with two different viewpoints. One is understanding and suggesting human processes that people adopt to change, improve, and transform their lives. The other is designing system processes which understand human processes and support them to change, improve, and transform their lives.

In what follows, the thesis will discuss how these procedural responses have been suggested, progressed, and evaluated for their validations and how they have contributed to the further creation and development of subsequent artefacts.

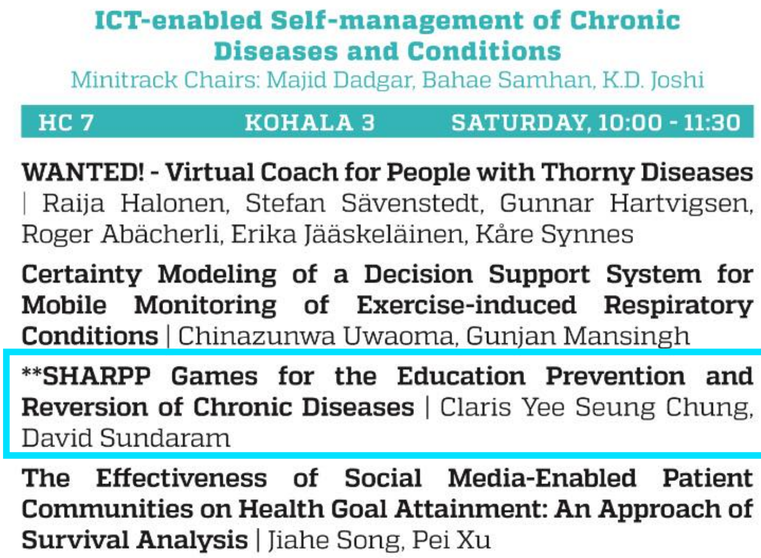
10.4.1 Sustainable Transformation Framework

The sustainable transformation framework guides the design and implementation of SSHARRPPP systems to support decision-making on individuals and families' lives involving various life dimensions. It provides a theoretical and procedural foundation of one of the research questions, "How systems should be designed and implemented to support that sustainable life transformation?" This high-level transformation framework is validated through informed argument, prototyping, and peer academic feedback, such as presentations and publications. The validation methods for this framework were architecture analysis, simulation, prototyping, informed argument, expert evaluations, publications and presentations.

Among these validation methods, informed argument was the initial method to develop and validate the sustainable transformation framework. The framework has been suggested and refined based on various literature on behaviour science and self-management programmes for chronic patients as the behaviour and lifestyle changes comprise vital parts in the journey of transforming one's life. Therefore, changing behaviours, habits, and lifestyles have naturally been chosen as individual and family sustainable transforming mechanisms and the processes have been developed in alignment with behaviour, attitude, and habit change processes.

The sustainable transformation framework also has been validated by presentations and publications. It was presented at the University of Auckland Business School PhD Conference in 2017 and further detailed at HICSS 2018. The audiences in the University of Auckland Business School PhD Conference were from various disciplines, so the feedback from various viewpoints was obtained. Most of the fellow academics agreed that the processes have been modelled and designed to support sustainable transformation. One of the valuable feedbacks was that we should have considered different pathways of sustainable transformation depending on a user's circumstances and situations. This feedback has helped us to refine the process and add prevention and reversion pathways of sustainable transformation within the educational pathway.

The refined and improved sustainable transformation framework then had been presented at the HICSS 2018 whose audiences are peer academics and experts in IS, IT and computer science fields. This presentation was based on a published conference proceeding titled "SHARPP Games for the Education Prevention and Reversion of Chronic Diseases". In this paper, the processes have been applied as a procedural foundation of self-management games for chronic disease patients and their families (Chung & Sundaram, 2018). The paper discussed whether transformation support should be provided at different levels with different purposes (prevention or reversion) depending on the user's situation and family circumstances. One of the mini-track chairs commented that the proposed framework was practically developed and conceptually mature. Also, this paper has been nominated for the best paper award in HICSS 2018 (Figure 113).


ICT-enabled Self-management of Chronic Diseases and Conditions
Minitrack Chairs: Majid Dadgar, Bahae Samhan, K.D. Joshi

HC 7 KOHALA 3 SATURDAY, 10:00 - 11:30

WANTED! - Virtual Coach for People with Thorny Diseases | Raija Halonen, Stefan Sävenstedt, Gunnar Hartvigsen, Roger Abächerli, Erika Jääskeläinen, Kåre Synnes

Certainty Modeling of a Decision Support System for Mobile Monitoring of Exercise-induced Respiratory Conditions | Chinazunwa Uwaoma, Gunjan Mansingh

****SHARPP Games for the Education Prevention and Reversion of Chronic Diseases** | Claris Yee Seung Chung, David Sundaram

The Effectiveness of Social Media-Enabled Patient Communities on Health Goal Attainment: An Approach of Survival Analysis | Jiahe Song, Pei Xu

FIGURE 113. EXCERPT FROM HICSS 2018 PROGRAM (BEST PAPER NOMINATION INDICATED BY ASTERISKS)

10.4.2 Individual and Family Mechanisms

The core element in the sustainable transformation framework is education, which is one of the main pillars of human development and behavioural science (Havighurst, 1953). People learn how to improve or change their lives through education and transform them by applying what they have learned into their behaviours and activities and forming appropriate habits. This is the reason why the thesis has chosen behaviour and attitude changes as the individual and family mechanisms for sustainable transformation. The mechanisms and processes are designed, developed, and validated together in similar ways but the thesis has focused more on the interrelationships between our behaviours and activities.

The focus on individual and family mechanisms has been used as a core implementation concept and processes for all the SSHARRPPP systems. For example, SSHARRPPP Measurement takes running as a keystone habit for type 2 diabetes. SSHARRPPP Shopping considers the shopping process as an inter-dimensional human activity and provides recommendations and rich information to enhance the customer's decision-making. SSHARRPPP Modelling and Games focus on human's fundamental physiological activities as their base applications.

At the HICSS 2018 presentation, holistic interrelationships models of life dimensions and activities (Figure 37 and Figure 38), and habit formation models (Figure 39) were presented to emphasise why a holistic system development for sustainable transformation is important. The peer academics and experts sincerely agreed that life dimensions should be considered holistically to make a life transformation. The individual and family mechanism and sustainable transformation processes have led to conceptualised system purposes and processes. In the following sections, the thesis will discuss the validation of the system perspective of purposes and processes.

10.4.3 System Purposes and Processes, and Sustainable Transformation Processes

Mostly, the purpose of systems varies depending on the area a system covers, but many systems are designed to support certain tasks that human beings carry out, such as decision making, specific analysis, and transactional jobs. SSHARRPPP systems are also designed and implemented with the purpose of supporting sustainable life transformation of individuals and families. Therefore, naturally, the literature about behavioural sciences and human developments have led us to formulate system purposes and relevant processes.

As explained in 5.2.1, the system purposes and processes are measure, model, benchmark, entertain, educate, and transform. These procedural concepts have been used to identify appropriate technologies and system features, and then SSHARRPPP systems have been designed and implemented accordingly. The next question was how the system processes need to be designed to deliver the purposes to the users (individuals and families) effectively and persuasively. Therefore, the research proposed sustainable transformation processes (Sense – Interpret – Respond – Transform) based on the seminal behaviour change theories like Theoretical Model of Change (Prochaska et al., 1992). To validate the system purposes and processes, and sustainable transformation (SIRT) processes, the researcher used architecture analysis, dynamic analysis, simulation, prototyping, informed argument, expert evaluations, publications and presentations.

The most important validating method was implementing the core concepts of purposes and processes into the systems. For this, we have modelled and prototyped SSHARRPPP System interactions and workflows in Chapter 7.1.2. The system interaction model shows how all SSHARRPPP systems are connected and worked together to bring meaningful support to individuals and families under sustainable transformation (SIRT) processes. This model is presented in the AMCIS 2019 and published in the correspondent proceedings.

The model of SIRT processes also have been published and presented at the HICSS 2018. In this paper, the authors explained how the processes could be applied to the game development and how they could benefit chronic disease patients and their families. Two reviewers with health IT background reviewed the paper and given the authors feedback. One of the reviews for the paper mentioned that the proposed model has many thoughtful ideas and is based on theoretical foundations. The reviewer commented that the paper and model present a solid piece of work.

10.5 Technological Responses

The technological responses answer what are the technologies that should be implemented into the system for providing practical supports. In Chapter 6, the thesis discussed various technologies according to system purposes and processes, and sustainable transformation (SIRT) processes, then proposed a general framework and architecture for each SSHARRPPP system. Therefore, the best way of validating technological responses is the prototyping method. Primarily, the proposed, designed, and implemented artefacts are: 1) validating the previous concepts and processes (Figure 111), and 2) mutually validating other technological and system artefacts. For example, sensor-based data collecting technology that has been identified and justified based on the system purposes and processes, have been employed in the SSHARRPPP Measurement development. In the sub-sections, the thesis will explain the validation journey of general system framework and architecture development of SSHARRPPP systems.

10.5.1 Key Technologies to support System Purposes and processes, and Sustainable Transformation Processes

In Chapter 6.1 and 6.2, various technologies were identified based on system purposes and processes, and sustainable transformation (SIRT) processes. To validate the key technologies, the researcher used architecture analysis, dynamic analysis, prototyping, informed argument, scenarios, expert evaluations, publications and presentations.

The identified technologies have justified their feasibility through informed argument. Then the key technologies have mainly been evaluated through the implementation of SSHARRPPP systems. At the end of the section 6.1, the thesis created an interrelationship model of the six system purposes and processes. The model has become the basis for implementing SSHARRPPP Measurement, Shopping, Modelling, and Games. Newell and Simon, (1976, p. 114) argued that:

> *"Each new machine that is built is an experiment. Constructing the machine poses a question to nature; and we listen for the answer by observing the machine in operation and analysing it by all analytical and measurement*

means available. Each new program that is built is an experiment. It poses questions to nature, and its behaviour offers clues to an answer."

As such, the key technologies are evaluated by implementing SSHARRPPP systems and testing the system functionalities using scenarios and dynamic analysis. Also, architecture analysis has been conducted from the overall system architecture to the individual architecture for all SSHARRPPP systems.

The technologies for each system development have been thoroughly discussed through our publications. More importantly, the interrelationship model has been published in the proceedings of AMCIS 2019 (Chung & Sundaram, 2019) and presented in the respective conference.

10.5.2 Overall SSHARRPPP Architecture and Framework

Overall SSHARRPPP architecture and framework were explained in 6.3. The framework showed the mutual relationships among SSHARRPPP Principles, System Purposes and Processes, and Sustainable Transformation (SIRT) Processes. It suggests the overall SSHARRPPP architecture should be designed to provide services and functionalities that support principles, purposes, and processes. Therefore, the validating point of the framework and overall architecture is whether the proposed architecture has been designed to support SSHARRPPP principles, system purposes and processes, and sustainable transformation (SIRT) processes. To validate it, various methods such as informed argument, prototyping, architectural analysis, experts' opinions, and presentation were used.

Firstly, the framework structure was scrutinised through architectural analysis which looked at how well fundamental features were designed in the proposed architecture, then the proposed architecture has been validated through informed argument. In 6.3.2, the thesis justified, proposed and designed technical components using examples of system functionalities against supporting technologies and relevant architectural components (refer Table 4). Later, the research further developed specific system architectures for implementing four SSHARRPPP systems that have become a part of validation.

While the research has progressed, the framework and architecture have been advanced by taking feedback from the various sources such as presentation in seminars and experts' opinions. In the seminars, we asked the audiences whether the proposed architecture effectively support SSHARRPPP principles. The collected answers indicated that many of seminar audiences agreed that the architecture is well and logically structured. The average score was 6.82. One member of the audiences made a comment that "all aspects of the principles are addressed and included in the architecture, so the linkage is very clean."

10.6 System Responses

SSHARRPPP systems consist of four different systems: Measurement, Modelling, Shopping, and Games. To develop rigorous SSHARRPPP systems, we have conceptualised a general system framework first. The framework explains how the overall SSHARRPPP architecture should support principles, purposes, and processes. This means that the proposed system architecture should have all technical components that can deliver services and functionalities. The SSHARRPPP Implementation has been validated through each application using scenarios in Chapter 8.

Initially, the thesis studied various but key technologies, which can make a system to deliver certain purposes to the users. Then the researcher developed a model (refer Figure 53) to explain how these system purposes and processes interact together to help sustainable life transformation of individuals and families. This model is later validated by becoming the foundation of SSHARRPPP system interactions that are explained in 7.1.2.

10.6.1 SSHARRPPP Measurement

As it was explained in the previous chapter, SSHARRPPP Measurement has developed two different platforms: the Android and the iOS. The key feature in the Android version is flexible data entry, which makes the app easily customisable. The iOS version app uses an in-built sensor to capture and display the user's movements and location in real-time on the map.

While the app was being developed, static and dynamic analysis were continuously used to check whether the app does what was expected. Most of time, these validations were carried out through the in-built feature in the developing tool, Xcode. Figure 114 is one of the static analysis features that Xcode provides. This example shows the layout issues that may cause some issues when the app is executed. Some warning signs and the related information are provided, and the tool also indicates where these issues are happening in the layout of the app.

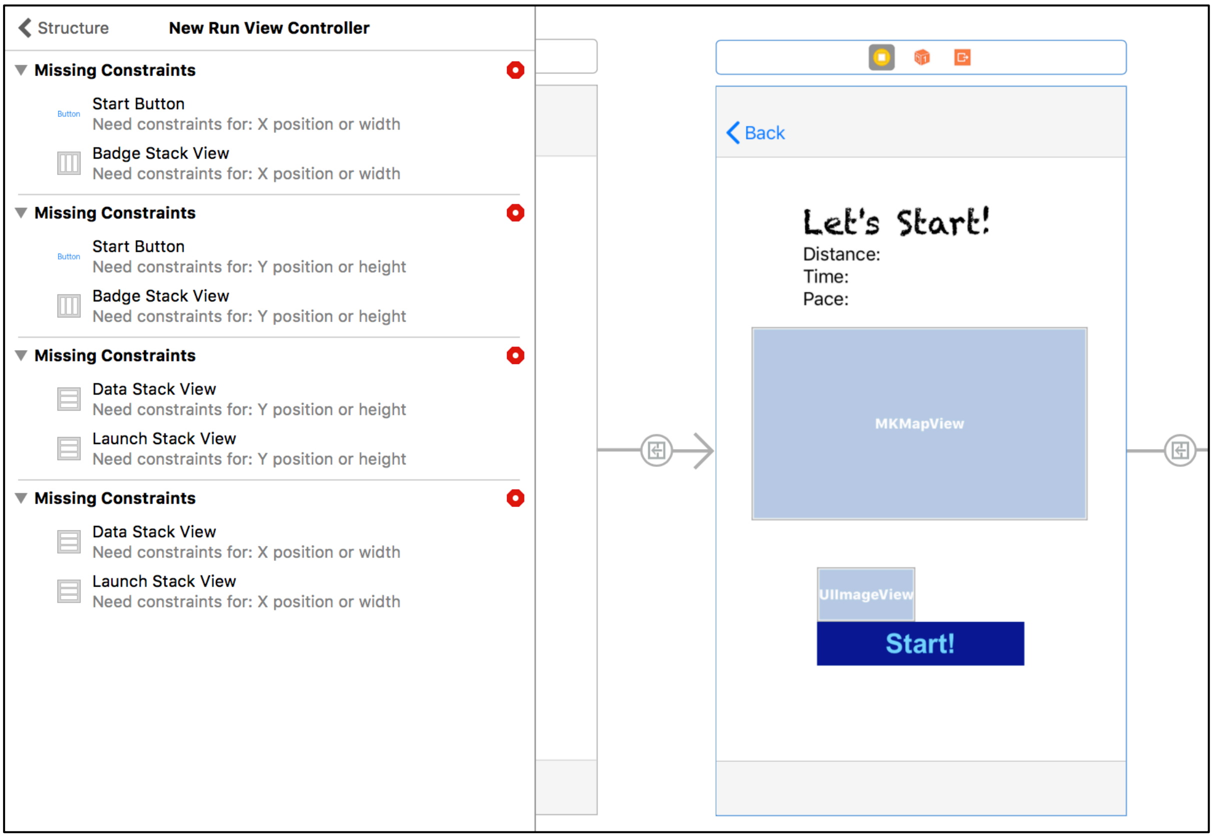


FIGURE 114. EXAMPLE OF STATIC ANALYSIS FEATURES IN XCODE

Also, at each time a block of codes has been completed, the researcher executed and tested the app through “Simulator”. Through this process, the researcher was able to check the app’s behaviours across the variable devices. By simulating the actual usage, the researcher was able to check the estimated resource usage of the app. Also, it went through various testing processes (Figure 115).

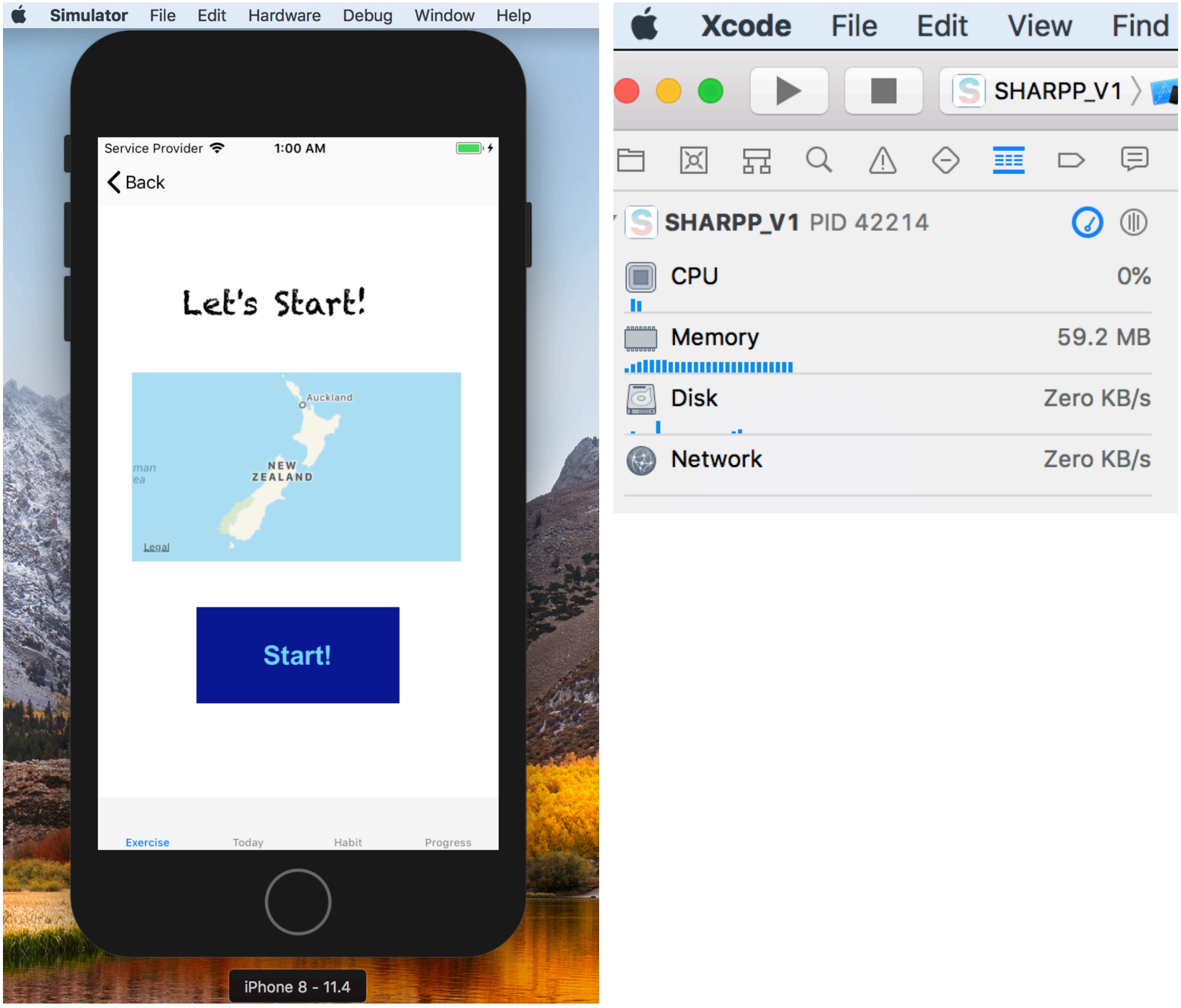


FIGURE 115. XCODE SIMULATOR

Furthermore, this implementation has been presented and published several times to validate it from the user's perspective. In a recent presentation to postgraduate students, the audiences indicated that the app is essential for transformation of individuals and families (scored 6.23/7).

10.6.2 SSHARRPPP Shopping

As previously mentioned, SSHARRPPP Shopping has been developed as proof-of-concept to one of the New Zealand online retailers. There were several meetings and presentations involved from conceptualising the foundational principles to designing and implementing the proof-of-concept prototype.

In the early stage, the researcher suggested the online shopping system concept that helps individuals to be sustainable by considering multiple life dimensions. After several concept meetings, the researcher presented the prototype of the system, which could see UI design, how health, financial and environmental data is presented, and system, and how the system had been framed with a configurable featured front page. The practical feedback was collected from each meeting and tested the idea of online shopping systems that promote sustainable transformation and lifestyle.

The proof-of-concept prototype was designed and built to demonstrate the basic key features. Each key functionality was analysed through an architectural analysis. As the thesis explained in Figure 55 in 7.2.2, the prototype contains all pages that are presented in the customer interface layer and delivers functionalities that can be carried out by executing services in the application and solution layers. This evaluation process was done with several technical testing sessions with the research supervisors and advisors.

The Shopping prototype was also tested through various presentations and publications. The system concepts, frameworks, and key features were tested and validated. Most feedback from the reviewers was that the idea of using shopping systems to support sustainable transformation of individuals and families was interesting. There were also concerns of sharing sensitive information with the shopping systems for recommendation, but it can be moderated if the system lets the users configure their own shopping preferences by deciding the degree of information sharing.

10.6.3 SSHARRPPP Modelling

SSHARRPPP Modelling was developed using a focus group, diabetic patients and their families. There were two stages to implement the Modelling: 1) building causal loop diagrams and stock and flow models and 2) implementing the interfaces for simulations. To build up the causal loop diagrams and stock and flow models, the researcher reviewed a wide range of literature related to diabetes. In this process, the researcher used an informed argument method to test out the logic in the diagrams and models. The causal loop diagrams were developed step by step from the core and internal insulin and glucose relationship to the extended lifestyle relationship to explain how diabetes could develop and what are the effects that lifestyles can make to the patients in terms of their health. Also, the artefacts was presented to peer researchers and stakeholders frequently to check the research findings.

The knowledge gained through this process helped the researcher to organise how simulation should be carried out for the purpose of educating diabetic patients. To make the simulation easy and intuitive to understand, the researcher presented the inflow of glucose by linking one of the most important physiological activities, diet and the outflow of glucose, with three lifestyle aspects: sleep, stress management, and exercise.

Also, the Modelling was presented in seminars to seek the audiences' opinions. Many audiences commented that a good breakdown of factors and the simulation is very informative to help patients to making better decisions. When the researcher asked whether they agreed the SSHARRPPP Modelling would help individuals and families to learn and transform their lives, most of the audience members indicated their agreements (6.02 out of 7).

10.6.4 SSHARRPPP Games

SSHARRPPP Games has been designed and developed for educating individuals and families. Through the entertainment, people can learn things more effectively (Brox et al., 2011; Dondlinger, 2007). Therefore, the researcher spent quite long period of time to find the most suitable format of games for educating sustainable transformation. If any improvement was advised, the game has been iteratively adjusted accordingly. When there were some occasions that a new game logic was suggested, the researcher implemented those into the games.

Initially, the researcher validated the concepts, processes, frameworks, and architecture of the game through publication and presentation. Also, the researcher published the paper that proposed to build games that could support the Sustainable transformation of chronic patients in a holistic and adaptable manner using Real-time, Precise, and Persuasive (SHARPP) principles, processes, systems and technologies (Chung & Sundaram, 2018). In this paper, the authors leveraged wearable information technologies and chronic disease studies to design games that interweave virtual worlds with the real world. It not only supports patients to form healthy habits that prevent and revert chronic diseases but also helps individuals to balance various life dimensions. The paper was presented in the HICSS 2018 and the authors had feedback that the paper's topic is attractive enough to draw scholars' interests.

During the game development process, the researcher adopted diverse methods to evaluate the prototype as its role was critical to validating other research outcomes. To validate the SSHARRPPP Games, static and dynamic analysis was performed to identify issues and errors that the game may have. Particularly, the researcher wrote some code to print the game's behaviours in the debug window. For example, the game should check whether there are possible icon matches first. The highlighted code in Figure 116 detects possible swaps, then prints all possible swaps in the debug window.

FIGURE 116. CODE SEGMENT FOR DEBUGGING

There are several codes that further check users' gestures that the game should/should not allow while they are playing the game and prints them in the debug window also. This method ensures the integrity of the program.

To prove the overall performance of the SSHARRPPP Games, the researcher used simulations using the "Apple Simulator" tool that is complementarily provided by Apple (Apple Inc, 2018). This process helps the researcher to make sure the game is working as it is designed and allows us to check the games' educational purposes with other users and stakeholders. In the seminar to the postgraduate students, the researcher had a session explaining how the game can be played and what the intended purposes behind the game playing are. The audiences agreed that the games can persuade and transform people' lives (scored 6/7). Especially, many audience members expressed interests in using an enjoyable mechanism to persuade individuals and families to learn sustainable lifestyles.

Up to now, the thesis has explained and discussed all research outcomes and artefacts and justified their purposes and objectives. More importantly, these outcomes and artefacts were validated throughout the research journey and valuable feedback was accordingly applied to refine the quality of research outcomes. In the following chapter, the thesis will summarise the details of research, discuss the contributions made by this research, and suggest the future direction of the study by acknowledging its limitations.

11 Conclusion

This research undertook a journey to explore the pivotal issues, challenges, and requirements in the arena of individual and family sustainability. Although sustainability has been a core agenda to be addressed by firms and government, individual and family sustainability has been neglected in the main discussion of it. For this reason, the research had faced a broad range of challenges, some coming from conceptual and procedural perspectives as there are no conventional definitions and sustainable life transformation processes for studying individual and family sustainability. Other challenges came from technological and systems perspectives such as non-holistic, non-systematic, non-personalised, non-adaptive, imprecise, non-contextual approaches to individual and family sustainability.

To find answers for these issues and challenges, the study adopted a multimethodological design science approach (Nunamaker et al., 1991) with the design evaluation methods (Hevner et al., 2004) needed to fulfil research requirements. The research proposes conceptual, procedural, technological, and system responses that would: (1) help capture and transform real-world behaviour that has an impact on individuals, families and society and (2) educate, prevent, and reverse unhealthy lifestyles, and behaviours. These proposals were validated through the design and implementation of four distinct systems, namely SSHARRPPP *Measurement*, *Shopping*, *Modelling*, and *Games*. These systems embrace core concepts from information systems, information technology, computer science, psychology, behavioural science and health science.

To conclude the research, this chapter summarises the study (section 11.1) from the research problems, vision, objectives, approaches, artefacts, to the evaluations. Research processes and artefacts are explained in 11.2. Key contributions are identified in 11.3, and limitations and future directions are discussed in 11.4.

11.1 Summary of Research Gaps and Challenges

To find solutions for individual and family sustainability, the study reviewed sustainability concepts (Kates, Parris, & Leiserowitz, 2005; Slaper & Hall, 2011), levels

(Starik & Kanashiro, 2013; Suzuki, 1996), life dimensions and values of individuals and families (Locke, 1991; Rokeach, 1973), various behavioural theories (Ajzen, 1991; Prochaska et al., 1992; Triandis, 1977), and processes involving technologies and systems. From the review, the researcher identified several research gaps and opportunities to study individual and family sustainability. For better understanding, the researcher classified those gaps and opportunities into four categories: conceptual, procedural, technological, and system issues and problems. The whole study was conducted to find solutions based on these four categories.

The conceptual issues and research gaps in studying individual and family sustainability were caused by a lack of clear definitions and philosophical research guidelines. Although sustainability has been an important concept for decades among scholars, sustainability at the individual and family level was getting relatively less attention from researchers. This lack of interest hindered researchers from having clear concepts of subject and research guidelines and further discouraged them from studying the topic. On the other hand, technologies and system developments to find solutions making human life healthy and well have been developing rapidly. Nevertheless, most of them have developed in a silo fashion without holistic theoretical backgrounds (Swan, 2012). Most of these applications are doing a single task and often showing a neglect of understanding human behaviours and nature (Conroy et al., 2014). As human wellbeing needs a balance of life dimensions and values (Habermas, 1984; Hall & Richter, 1988; Rojas, 2006; Seligman, 2002), individually developed systems and applications have limitations in catering for user's diverse multi-dimensional needs and requirements (Hänsel et al., 2015).

These indentifed problems and issues led the researcher to study various individual and family processes such as behaviour change models (Ajzen, 1991; DiClemente & Prochaska, 1998; Triandis, 1977), habit formation models (Duhigg, 2012), learning processes (Argyris & Schön, 1974; Kolb, 1984), decision-making processes (Langley et al., 1995; Mintzberg et al., 1976; Simon, 1960), and family lifecycles and dynamics (Balswick & Balswick, 2007; Carter & McGoldrick, 1989). A synthesises of the review identified a research opportunity/gap that could be filled through the proposal of sustainable transformation processes for individuals and families. Understanding how people make decisions, learn, and change behaviours further led to the proposal, design, and implementation of technological frameworks, architectures, and systems that would fulfil the research requirements.

11.2 Research Process and Artefacts

To address these research gaps and challenges, the researcher established the research vision and objectives as discussed in section 1.3. Then the research sought conceptual, procedural, technological, and system responses. This research makes use of a multi-methodological research approach consisting of design science methodology suggested by Nunamaker et al. (1991) and Hevner et al. (2004), due to the holistic nature and range of the outlined research objectives. Also, the research synthesised useful components from the two seminal frameworks and develops one multi-methodological framework to conduct individual and family sustainability research. In each chapter, the research started with research questions and structures this study by answering them. Table 8 summarises the research categories, objectives, responses (artefacts), and their evaluations.

As the study involved various research domains, the study defined concepts which were related to individual and family sustainability and proposed SSHARRPPP principles (section 4.2) for the systematic progress of the study. After considering the relationship between individuals and families (Schneider, 1984), and their significant roles in achieving overall sustainability (Kates et al., 2005), the researcher proposed a definition of individual and family sustainability (section 4.1.3). For this, the researcher examined definitions and concepts of sustainability from various organisations and scholars like Brundtland Commission (World Commission on Environment and Development, 1987), Hancock (1993), Pappas et al., (2013), and PRME (2018). The choices with SSHARRPPP principles were made after exploring various life dimensions at the earlier stage of the research. Each principle was chosen after considering problems and issues to achieve sustainability in the context of health. SSHARRPPP principles are like “Pareto analysis (20/80 rule)”, which the selection of a limited number of key principles can produce a significant overall effect for addressing many concerns.

Research Categories	Research Objectives	Research Artefacts	Evaluations
Conceptual	• Define concepts related to individual and family sustainability • Shape guiding principles	• Definition of individual and family sustainability (section 4.1) • SSHARRPPP Principles (section 4.2)	• Analytical, Experimental, Descriptive, & Dissemination (section 10.3)
Procedural	• Develop sustainable transformation process by identifying core human activities and behaviours • Define system purposes and processes that support sustainable transformation	• Sustainable Transformation Framework (section 5.1.1) • System purposes and Processes (section 5.2) • Sustainable Transformation (SIRT) processes (section 5.3)	• Analytical, Experimental, Descriptive, & Dissemination (section 10.4)
Technological	• Identify and explore technologies to serve individual and family • Design system architecture, which show system functionalities and interactions of technologies for system development.	• Key technologies for Human and System Purposes and Processes (section 6.1) • Key technologies for Sustainable Transformation (SIRT) processes (section 6.2) • Overall SSHARRPPP Architecture (section 6.3)	• Analytical, Experimental, Descriptive, & Dissemination (section 10.5)
System	• Design and implement system artefacts that support sustainable transformation of individuals and families	• SSHARRPPP Measurement (section 7.2.1, 8.2, & 9.2) • SSHARRPPP Shopping (7.2.2, 8.3, & 9.3) • SSHARRPPP Modelling (7.2.3, 8.4, & 9.4) • SSHARRPPP Games (7.2.4, 8.5, & 9.5)	• Analytical, Experimental, Testing, Descriptive, & Dissemination (section 10.6)

TABLE 8. SUMMARY OF RESEARCH

Then the researcher suggested sustainable transformation processes (section 5.3) by identifying two key habits: physiological activities and shopping (section 5.1.3). These activities were closely related to sustainable lifestyle transformation (Gilg et al., 2005; Slater & Carlton, 1985), which keep people living healthy and happy lives.

Also, the researcher considered system purposes (section 6.1) and processes (section 6.2) that would be implemented in individual and family sustainability supporting systems. The researcher believed that systems should be able to serve the system purposes, that is: measure (Poslad, 2009; Weiser, 2002), model (Rouse & Morris, 1986), benchmark, educate (Argyris & Schön, 1974), and entertain (De Freitas & Griffiths, 2007; Van Eck, 2006). The researcher proposed sustainable transformation processes that can sense – interpret – respond – transform (SIRT) user's lives sustainably and holistically. The SIRT processes have been designed by synthesising seminal behaviour change theories. This includes Theory of Planned Behaviour (TPB) (Ajzen, 1991), Theory of Interpersonal Behaviour (TIB) (Triandis, 1977), Transtheoretical Model of Change (TMC) (Prochaska et al., 1992) and habit formation process (Duhigg, 2012). Consequently, key technologies were identified to develop key system features that could deliver system purposes and processes by following sustainable transformation (SIRT) processes.

Based on all these precedent research artefacts, the researcher initially developed models that picture the cause and effect relationships of life dimensions (section 9.4.2). From these models, the researcher realised that people could not manage what they did not measure (McAfee & Brynjolfsson, 2012), and people could not understand and transform what they did not model. Hence, measuring individuals and families on various life dimensions and modelling their interactions are at the heart of the sustainable life transformation. Therefore, SSHARRPPP Measurement and Shopping were respectively developed for measuring key activities that are performed by individual and family. SSHARRPPP Modelling was developed to educate individuals and families about the interrelationships and impacts between life dimensions, so they could make sustainable decisions and ultimately transform their lives. Then, the researcher further branched out the idea that, even when people could measure and model, if they could not be persuaded to change their behaviours and adapt into new lifestyles through entertainment, education would be of no avail and transformation would not occur. Thus, the researcher proposed serious games and gamification as the third and critical step leading to education and transformation. SSHARRPPP Games were developed to help people maintain their sustainable lives by making their transformation journey enjoyable.

The four systems (SSHARRPPP systems) were particularly implemented to transform two key habits, physiological activities and shopping, with health in mind. The researcher believes that these key habits are the enablers of individual and family sustainability (Gilg et al., 2005; Maslow, 1954; Slater & Carlton, 1985). SSHARRPPP systems work together to support sustainable life transformation of individuals and families by following the measure – model – entertain – transform processes. SSHARRPPP Measurement measures individual activities and behaviour data, whereas SSHARRPPP Shopping measures family level data. SSHARRPPP Modelling can take the data from Measurement and Shopping to model the interpreted information. Finally, SSHARRPPP Games can import models from SSHARRPPP Modelling that represent the realities to persuade people to transform their lives by providing entertainment. The four SSHARRPPP systems can be configured to support and transform other key habits as well as going beyond the physiological and shopping.

As explained in the evaluation chapter (Chapter 10), SSHARRPPP systems are the main proof-of-concept of this research. When these systems were designed, developed, and implemented, the concepts, processes, and technologies, which were formulated, suggested, and proposed by the researcher, could also be validated by testing each system. All research artefacts have been validated mainly the methods suggested by Hevner et al. (2004). However, the research undertook scholarly peer review-based validation through continuous publications and presentations. Each milestone of the research has been published and presented locally, nationally, and internationally to solicit feedback from experts and academics. The valuable feedback was subsequently incorporated into the research through constructive discussions and deeper studies.

11.3 Research Contributions

This research has proposed and developed multiple research artefacts in the journey of finding answers for individual and family sustainability. Various challenges have been encountered during the research, due to its fast changing and developing technological nature and multiple research domain interdependencies. However, the researcher carried on the study as she saw clear research opportunities and benefits in studying individual and family sustainability.

This study uniquely contributes to the fields of individual and family sustainability in three key dimensions. Firstly, it has outlined SSHARRPPP principles that support individual and family sustainability. SSHARRPPP principles offer various perspectives to integrate different worlds we live in. As discussed in 4.1.2, Habermas's (1984) posited that human life consists of the material, the personal, and the social worlds. To make our lives sustainable, these multiple worlds should be balanced and aligned to people’s life values. Holistic perspective embraces all these worlds and enables our lives to be balanced (Howes et al., 2017). Precisely measured real-time data can help us to adapt the desired lifestyles into our real worlds (Alfian et al., 2018; Bentley & Tollmar, 2013). Furthermore, using personalised recommendations and social mechanisms can persuade people (Fiske, 2014; Fogg, 2003) to transform their lives better and easier. As such, SSHARRPPP principles offer prescriptions transforming people’s lives in a sustainable manner.

Secondly, the research has taken is inspired by two fundamental philosophies. The first “You can’t *manage*, what you don’t *measure*” from McAfee and Brynjolfsson's (2012, p. 4) article in Harvard Business Review. The researcher extended this to “you can’t *transform* what you don’t *model*”. Measurement and modelling became the twin pillars of the research. The SSHARRPPP principles and the twin pillars were realised through four distinct yet interwoven approaches, namely (a) measurement (b) shopping (c) modelling and (d) games.

a. *Measurement* supports sustainable, adapt, real-time, real-world, precise, and personalised perspectives from SSHARRPPP principles. Measurement approach enables people to capture real-time and real-world data, so that can provide precise and personalised recommendations (Anke & Sundaram, 2006). Through the measurement and recommendations, people can reflect their activities then they can adapt sustainable lifestyles. Measurement approach is vital in achieving individual and family sustainability as it makes our lives manageable (Chung et al., 2018; Chung & Sundaram, 2015).

b. *Shopping* supports all principles as it involves multiple dimensions in our lives. This unique approach can collect not only real-time and real-world data but also family level activity data. This provides holistic views to provide precise and personalised recommendations (Chung, Proskuryakov, & Sundaram, 2014, 2015). Also, it uses a social mechanism to persuade people to adapt new choices for their sustainable lives (Sommer et al., 1992).

c. *Modelling* also supports all principles (Chung & Sundaram, 2019). Real-time and real-world data are modelled precisely to show holistic relationships among life factors (Richardson, 2013; Rouse & Morris, 1986). Therefore, people can see the causal effect relationships of their lives and be able to identify root issues. Furthermore, the links shown in models often persuade people to adapt new lifestyles for their sustainability. Also, social mechanisms can be used in modelling to enhance the persuasion.

d. *Games* and gamification support all principles as modelled relationships can be designed as games to make sustainable transformation processes easier and enjoyable. As discussed in 9.5.1, games have multiple modalities that interweave real and virtual worlds. Games can reflect our real-world life by utilising measured data in real-time. Then, holistically modelled relationships among life dimensions can be implemented as games (Chung & Sundaram, 2018). By playing games, people can learn various ways to adapt their lives to achieve sustainability (Groh, 2012). Also, games can help people to transform their lives. Personalised games with precise perspective (appropriate data and game mechanism at the right time) can persuade people to take real-world actions without resistance (Hamari et al., 2014). Furthermore, the social mechanism encourages people to engage with the world and games better.

Lastly, the research has developed conceptual, procedural, technological, and system artefacts that support SSHARRPPP principles, the twin pillars and the four approaches. These artefacts include concepts (definition of individual and family sustainability, technologies to support system purposes and sustainable transformation processes), models (individual and family mechanisms), processes (system purposes and processes, sustainable transformation processes), framework (sustainable transformation framework, overall SSHARRPPP framework), architectures (overall SSHARRPPP architecture, individual system architectures), and systems (SSHARRPPP Measurement, Shopping, Modelling, and Games). These artefacts were identified, defined, designed, and implemented to realise the twin pillars and four approaches to support individual and family sustainability.

The research outcomes can also assist various people, academic disciplines, and industries for diverse purposes. Figure 117 summarises the research contribution based on the proposed and developed research artefacts. In the following sections, the thesis will explain these contributions in detail.

11.3.1 Researchers

This research mainly benefits researchers in the discipline of information systems and sustainability, particularly those who would like to research sustainability at individual and family levels. Initially, this research suggests a definition of individual and family sustainability that can help researchers to understand the relative concepts and scope their research areas. For this, the research has justified why individuals and families are important in achieving overall sustainability (Kickbusch, 2010; Rockström & Sukhdev, 2016), and why a holistic and balanced approach is necessary by explaining various life dimensions and values (Habermas, 1984; Loewe et al., 2014; Rojas, 2006; Rokeach, 1973). Also, the research has proposed SSHARRPPP Principles that guide researchers to have a holistic perspective on the topic.

The principles allow researchers to have a philosophical understanding, as well as practical perceptions when they approach and evaluate the topic. For example, the principle of sustainability lets researchers have a research vision and overarching goal, whereas the principle of real-time allows them to think about how information should be delivered to make an impact on the sustainable life transformation of individuals and families. From the procedural responses, researchers now should be able to see an example of developing sustainable transformation process from multiple seminal individual and family processes.

Research Artefacts	Researchers: Information Systems	Researchers: Sustainability	Researchers: Health and Self-Management	Users: Individuals	Users: Families	Industry: Companies - Online Retailers	Industry: System Developers
Conceptual Responses							
Definition of Individual and Family Susntainability	✓	✓	✓	✓	✓	✓	✓
SSHARRPPP Principles	✓	✓	✓	✓	✓	✓	✓
Procedural Responses							
Sustainable Transformation Framework	✓	✓	✓	✓	✓	✓	✓
Individual and Family Mechanisms	✓	✓	✓	✓	✓	✓	✓
System Purposes and Processes	✓			✓	✓	✓	✓
Sustainable Transformation (SIRT) Process	✓			✓	✓	✓	✓
Technological Responses							
to support System Purposes and Processes	✓					✓	✓
to support Sustainable Transformation Process	✓					✓	✓
Overall SSHARRPPP Architecture and Framework	✓					✓	✓
System Responses							
SSHARRPPP Measurement	✓	✓	✓	✓	✓	✓	✓
SSHARRPPP Shopping	✓	✓	✓	✓	✓	✓	✓
SSHARRPPP Modelling	✓	✓	✓	✓	✓	✓	✓
SSHARRPPP Games	✓	✓	✓	✓	✓	✓	✓

FIGURE 117. SUMMARY OF RESEARCH CONTRIBUTIONS

Furthermore, the process is used to develop system purposes and processes, which embrace human processes of behaviour changes (Prochaska et al., 1992), decision-making (Langley et al., 1995; Mintzberg et al., 1976; Simon, 1960), and habit formations (Duhigg, 2012). Subsequently, researchers can identify technologies based on these system purposes and processes for their studies. Finally, SSHARRPPP systems (Measurement, Shopping, Modelling, and Games) show how systems should be integrated and implemented to work mutually to support individual and family sustainability to researchers.

This research also has a potential to benefit researchers and practitioners who are in the health and self-management disciplines. The research has applied a health management scenario for chronic disease patients as a case of SSHARRPPP systems. The whole of the systems was implemented with a health focus. SSHARRPPP Measurement was mainly developed to collect individual daily activities to form healthy habits, SSHARRPPP Shopping provides extra health information unlike the usual online shopping systems. Particularly, models and equations for SSHARRPPP Modelling have been developed for educational purpose for diabetes patients. Therefore, this can fuel practical ideas to researchers who would like to find answers through technological and system supports. Also, through SSHARRPPP Games, they can test out how persuasive intervention can make a difference compared to simple interventions like text reminders.

11.3.2 Individuals and Families

The ultimate beneficiaries of this research are individuals and families who want to transform their lives sustainably. The research has designed and implemented four prototypical systems that accommodate a holistic view of life dimensions and values, utilise humans as social beings to motivate behaviour changes (Fiske, 2014; Lett et al., 2007), and provide personalised services in persuasive ways to educate and transform lives of individuals and families sustainably.

SSHARRPPP systems collect their real-world data in real-time by minimising inconveniences, analysing people's lifestyles, guiding them to make right decisions for their lives, and assisting them to transform their lives sustainably. For example, SSHARRPPP Measurement collects data automatically using sensors most of the time. Therefore, users do not have much burden in collecting their activity data (Neuringer, 1981). SSHARRPPP Shopping uses benchmarking techniques to allow users to understand their shopping habits and compare them with others. Also, users can understand dynamics and influences between family members through data from Shopping (Boxwell, 1994). SSHARRPPP Modelling allows users to experience health consequences indirectly, so they can take actions to prevent undesirable outcomes. This can be a good learning tool as they can see a causal relationship without paying serious costs related to their health (Rouse & Morris, 1986). SSHARRPPP Games utilises fun strategy and gamification to make users maintain the intended behaviour and habits, and so support them to form desired habits for their sustainable lifestyle.

11.3.3 Industries and Developers of Systems

The whole research can be a reference point for industries and developers of systems for individual and family sustainability. Especially, the research artefacts that are suggested in Chapters 4 to 9 can help them to develop systems that meet the users' needs and requirements for sustainable life transformation.

For example, like the research that has been conducted, developers can identify user's requirements for sustainable transformation. Each principle provides core points of system processes, functionalities, relevant technologies, and so on. Also, SSHARRPPP Principles can be used to evaluate whether their systems are fulfilling requirements against the system architectures and implementations. As the research provides both general and specific architectures for SSHARRPPP systems (section 6.3 and section 7.2), developers can reference how system processes, functionalities and technologies can be integrated to deliver efficient services for sustainable transformation. Furthermore, the interaction and workflow model can provide clear pictures of purposes and roles of SSHARRPPP systems (section 7.1). Especially, developers can foresee practical benefits of systems as the research provides applications of systems using the case of diabetes. Lastly, industries and developers can reference the actual source codes provided in Chapter 9 and appendices.

11.4 Limitations and Future Research

Every research has its limitations and those become an agenda for future research. This research has covered broad interdisciplinary research areas from philosophical and procedural topics like human values, purposes, various processes and dynamics, to actual system implementation with technological discussions. Each issue has answered the questions of what, why and how. However, the researcher identified that there were some limitations to this research, and some could be left for future research.

The first agenda item for furture research should be implementing the full functioning SSHARRPPP systems. As it is explained in section 9.1, our systems are taking a vertical prototype approach to validate concepts, processes, models, and frameworks that the research has proposed. Although core system functionalities have been checked through academics, experts, and potential users, partially functioning systems are limited to present the real benefits of SSHARRPPP systems in sustainable life transformation. The best way of overcoming this limitation is by implementing full system functionalities that are required for sustainable transformation.

The second agenda item for future research should be the integration of individual and family sustainability models. Although family dynamics and concepts were considered and incorporated into the design and implementation of all research artefacts, the Modelling system was designed and implemented predominantly with a focus on individual sustainability. For future research, the researcher has begun to extend the current individual sustainability model (Figure 99) and is in the process of integrating it with a family sustainability model through a holistic consideration of lifestyle dimension. Figure 118 illustrates these extensions and integrations between the individual and the family. The new model places family lifestyle, family wealth, family health, and family support at the core of family sustainability and illustrates how these elements are related to individual sustainability. This extended model is specilised to the diabetes use case and shows direct and mutual impacts through individual and family lifestyles and family support. Family support (Delamater et al., 2001; Griffith, Field, & Lustman, 1990) and family lifestyle (Epple, Wright, Joish, & Bauer, 2003) are direct factors that play important roles in the management of diabetes.

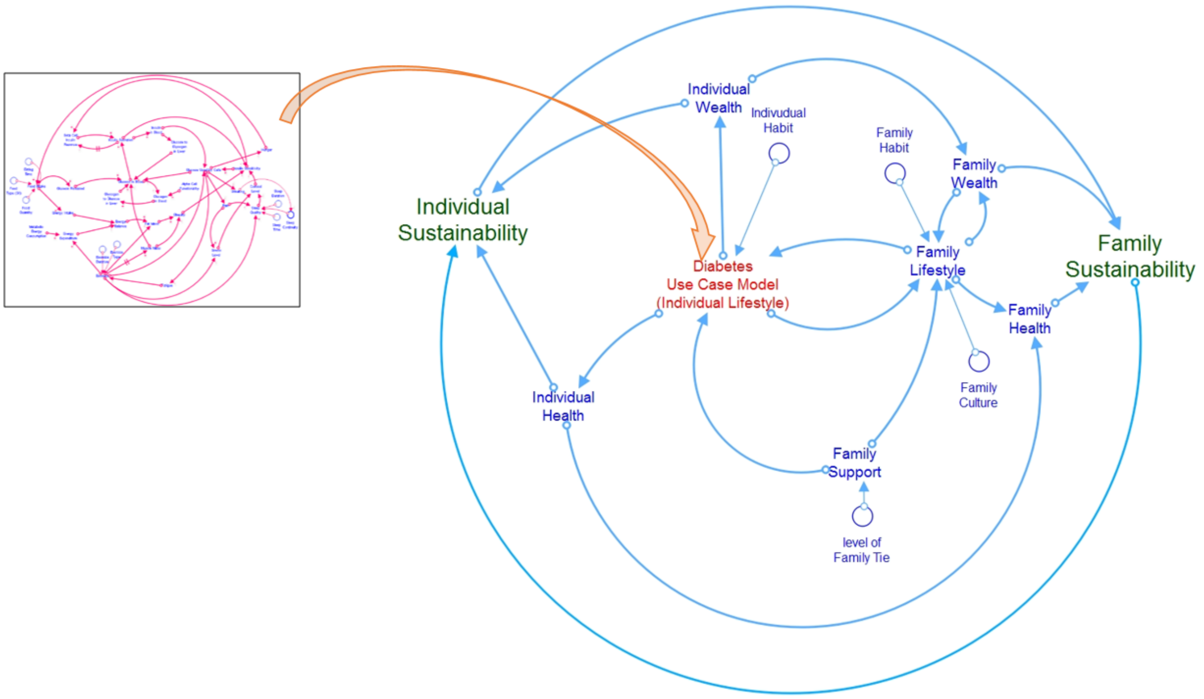


FIGURE 118. INTEGRATED MODEL OF INDIVIDUAL AND FAMILY SUSTAINABILITY

The third agenda item for future research should be full integration of the four SSHARRPPP systems. As the researcher implemented partially functioning systems, SSHARRPPP systems were developed independently and not integrated together. For system integration, the future research needs to consider ways of aggregating heterogeneous data streams and handling various real-time data in the system (Hasselbring, 2000). This can be a huge future research opportunity, as, although numerous activity tracking applications and smart home systems have been developed, they have yet to be connected all together to provide a cohesive experience to consumers.

Finally, the researcher would like to deploy fully functioning SSHARRPPP systems to the public and get them evaluated by real users. Again, the concepts, models, and prototypes of SSHARRPPP systems are validated through various evaluation methods, and it is essential to make systems usable by real users and support their sustainable transformation. It is hoped that the research can be an impetus for making human lives well, happy, and sustainable.

Appendices

This research proposed concepts, models, processes, frameworks, and architectures of SSHARRPPP systems. Prototypical SSHARRPPP systems were implemented based on the proposed system architectures to validate these artefacts. The implementation details of the essential building blocks of the prototype are presented here. As SSHARRPPP Shopping and Modelling were implemented with certain developers, the researcher's contributions on designing these systems were discussed and detailed in 9.3.2 and 9.4.2. SSHARRPPP Measurement and Games prototypes were implemented by the researcher, thus all code segments are presented in this section. Figure 119 shows where you can find the details of each implementation.

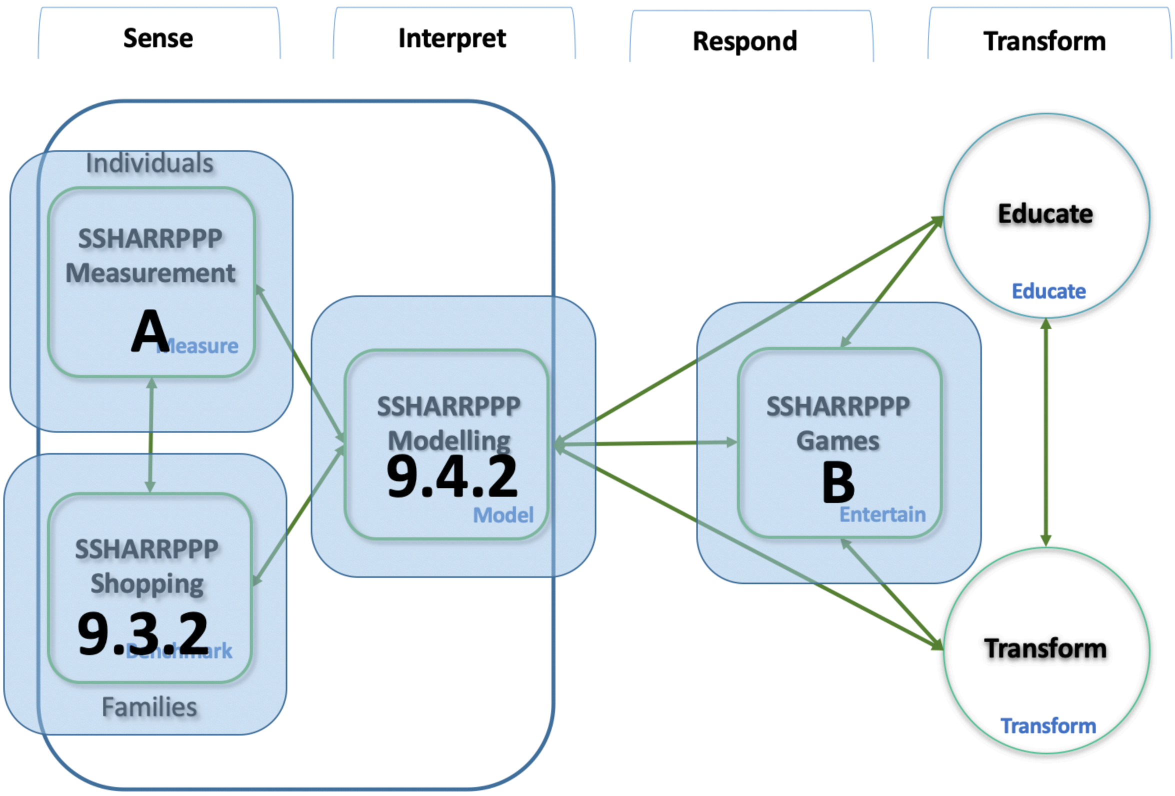


FIGURE 119. INDEX OF IMPLEMENTATION DETAILS

Also, a questionnaire which was used for "Sustainability Seminar for Postgraduate Students" is also presented at the section C.

A. SSHARRPPP Measurement

LogInViewController.swift

```
import UIKit

class LogInViewController: UIViewController
{

    @IBOutlet weak var userNameTextField:
UITextField!
    @IBOutlet weak var userPasswordText-
Field: UITextField!

    override func viewDidLoad() {
        super.viewDidLoad()
        self.view.addGestureRecog-
nizer(UITapGestureRecognizer(target:
self.view, action: #selec-
tor(UIView.endEditing(_:))))

        // Do any additional setup after
loading the view.
    }

    override func didReceiveMemoryWarning()
{
        super.didReceiveMemoryWarning()
        // Dispose of any resources that
can be recreated.
    }

    @IBAction func logInButtonTapped(_
sender: Any) {

        print("Login")

        let userName = userNameText-
Field.text
        let userPassword = userPass-
wordTextField.text

        if (userNameTextField.text?.is-
Empty)! ||
            (userPasswordText-
Field.text?.isEmpty)!
        {
            print("User Name \(String(de-
scribing: userName!)) or Password
\(String(describing: userPassword!)) is
empty." )

            displayMessage(userMes-
sage:"User Name or Password is missing.")
            return
        } else {
            let mainTabBarViewController =
                self.storyboard?.instanti-
ateViewController(withIdentifier: "MainTab-
BarViewController") as!
            MainTabBarViewController

            self.present(mainTabBarViewCon-
troller, animated: false)
        }

    }

    @IBAction func registerButtonTapped(_
sender: Any) {
        print("register in login")

        let registerUserViewController =
            self.storyboard?.instantiat-
eViewController(withIdentifier: "Regis-
terUserViewController") as!
        RegisterUserViewController

        self.present(registerUserViewCon-
troller, animated: true)
    }

    func removeActivityIndicator(activity-
Indicator: UIActivityIndicatorView)
    {
        DispatchQueue.main.async
            {
                activityIndicator.stopAn-
imating()
                activityIndicator.remove-
FromSuperview()
            }
    }
    func displayMessage(userMessage:
String) -> Void {
        DispatchQueue.main.async {
            let alertController = UIAl-
ertController(title: "Alert", message: us-
erMessage, preferredStyle: .alert)

            let OKAction = UIAlertAc-
tion(title: "Okay", style: .default)
            {
                (action: UIAlertAction!) in

                print("Okay tapped")
                DispatchQueue.main.async {
                    let logInViewController
=
                        self.story-
board?.instantiateViewController(withIden-
tifier: "LogInViewController") as!
                    LogInViewController

                    self.present(logInView-
Controller, animated: false)
                }
            }
            alertController.addAction(OKAc-
tion)
            self.present(alertController,
animated: true, completion: nil)
        }
    }
}
```

RegisterUserViewController.swift

```
import UIKit

class RegisterUserViewController: UIView-
Controller {

    @IBOutlet weak var firstNameTextField:
UITextField!
```

```
    @IBOutlet weak var lastNameTextField:
UITextField!
    @IBOutlet weak var emailAddressText-
Field: UITextField!
    @IBOutlet weak var passwordTextField:
UITextField!
    @IBOutlet weak var confirmPasswordText-
Field: UITextField!


    override func viewDidLoad() {
        super.viewDidLoad()
        self.view.addGestureRecog-
nizer(UITapGestureRecognizer(target:
self.view, action: #selec-
tor(UIView.endEditing(_:))))

        // Do any additional setup after
loading the view.
    }

    override func didReceiveMemoryWarning()
{
        super.didReceiveMemoryWarning()
        // Dispose of any resources that
can be recreated.
    }

    @IBAction func cancelButtonTapped(_
sender: Any) {
        print("cancel")
        let logInViewController =
            self.storyboard?.instantiat-
eViewController(withIdentifier: "LogInView-
Controller") as!
        LogInViewController

        self.present(logInViewController,
animated: true)
        // self.dismiss(animated: true,
completion: nil)
    }
    @IBAction func registerMeButtonTapped(_
sender: Any) {

        /*
         let todayPageViewController =
         self.storyboard?.instantiateView-
Controller(withIdentifier: "TodayPageView-
Controller") as!
         TodayPageViewController

         self.present(todayPageViewControl-
ler, animated: true)
         */

        print("register me")

        // Checking all required fields are
filled
        if (firstNameTextField.text?.is-
Empty)! ||
            (lastNameTextField.text?.is-
Empty)! ||
            (emailAddressText-
Field.text?.isEmpty)! ||
            (passwordTextField.text?.is-
Empty)!
        {
            displayMessage(userMessage:
"All fileds are required")
            return
        } else {
            let mainTabBarViewController =
                self.storyboard?.instanti-
ateViewController(withIdentifier: "MainTab-
BarViewController") as!
            MainTabBarViewController
            self.present(mainTabBarViewCon-
troller, animated: false)
        }
        // Checking passwords are matched
        if
            ((passwordTextField.text?.ele-
mentsEqual(confirmPasswordText-
Field.text!))! != true)
        {
            displayMessage(userMessage:
"Passwords are not matched")
            return
        } else {
            let mainTabBarViewController =
                self.storyboard?.instanti-
ateViewController(withIdentifier: "MainTab-
BarViewController") as!
            MainTabBarViewController
            self.present(mainTabBarViewCon-
troller, animated: false)
        }
            }


    func removeActivityIndicator(activity-
Indicator: UIActivityIndicatorView)
    {
        DispatchQueue.main.async
            {
                activityIndicator.stopAn-
imating()
                activityIndicator.remove-
FromSuperview()

        }
    }

    func displayMessage(userMessage:
String) -> Void {
        DispatchQueue.main.async {
            let alertController = UIAl-
ertController(title: "Alert", message: us-
erMessage, preferredStyle: .alert)

            let OKAction = UIAlertAc-
tion(title: "Okay", style: .default)
            {
                (action: UIAlertAction!) in

                print("Okay tapped")
                DispatchQueue.main.async {
                    let registerUserView-
Controller =
                        self.story-
board?.instantiateViewController(withIden-
tifier: "RegisterUserViewController") as!
                    RegisterUserViewCon-
troller


                    self.present(regis-
terUserViewController, animated: false)
                }
            }
            alertController.addAction(OKAc-
tion)
            self.present(alertController,
animated: true, completion: nil)
        }
    }
```

```
}
```

TodayPageViewController.swift

```
import UIKit

class TodayPageViewController: UIViewCon-
troller {

    @IBOutlet weak var userFullNameLabel:
UILabel!

    override func viewDidLoad() {
        super.viewDidLoad()
        self.view.addGestureRecog-
nizer(UITapGestureRecognizer(target:
self.view, action: #selec-
tor(UIView.endEditing(_:))))

        // Do any additional setup after
loading the view.
    }

    override func didReceiveMemoryWarning()
{
        super.didReceiveMemoryWarning()
        // Dispose of any resources that
can be recreated.
    }


    @IBAction func signOutButtonTapped(_
sender: Any) {
        print("sign out")
        //self.dismiss(animated: true, com-
pletion: nil)
        let logInViewController =
            self.storyboard?.instantiat-
eViewController(withIdentifier: "LogInView-
Controller") as!
        LogInViewController

        self.present(logInViewController,
animated: true)
    }

    @IBAction func loadProfileBut-
tonTapped(_ sender: Any) {
        print("load profile")
    }
}
```

HabitLogTableViewControl-ler.swift

```
import UIKit

class HabitLogTableViewController: UITa-
bleViewController {

    var habitLogs : [HabitLog] = []


    override func viewDidLoad() {
        super.viewDidLoad()
        habitLogs = createHabitLogs()
    }

    func createHabitLogs() -> [HabitLog] {

        let running = HabitLog()
        running.name = "Running"
        running.important = true

        let situp = HabitLog()
        situp.name = "Sit Up"


        let weight = HabitLog()
        weight.name = "Weight Training"
        weight.important = false

        return [running, situp, weight]
    }


    override func tableView(_ tableView:
UITableView, numberOfRowsInSection section:
Int) -> Int {
        return habitLogs.count

    }

    override func tableView(_ tableView:
UITableView, cellForRowAt indexPath: Index-
Path) -> UITableViewCell {
        let cell = tableView.dequeueReusa-
bleCell(withIdentifier: "habitLogIdenti-
fier", for: indexPath)
        let habitLog = habitLogs[index-
Path.row]
        if habitLog.important {
            cell.textLabel?.text = "❗" +
habitLog.name
        } else {
            cell.textLabel?.text = habit-
Log.name
        }
        return cell
    }


    override func tableView(_ tableView:
UITableView, didSelectRowAt indexPath: In-
dexPath) {
        let habitLog = habitLogs[index-
Path.row]
        performSegue(withIdentifier: "mov-
eToCompleteHabitLog", sender: habitLog)
    }



    override func prepare(for segue: UISto-
ryboardSegue, sender: Any?) {
        if let addHabitLogVC = segue.desti-
nation as? AddHabitLogViewController {
            addHabitLogVC.habitLogTVC =
self
        }


        if let completeHabitLogVC = se-
gue.destination as? CompleteHabitLogView-
Controller {
            if let habitLog = sender as?
HabitLog {
```

```
                completeHabitLogVC.select-
edHabitLog = habitLog
                completeHabitLogVC.habit-
LogTVC = self
            }

        }
    }

}
```

HabitLogViewController.swift

```
import UIKit

class HabitLogViewController: UIViewCon-
troller, UITableViewDelegate {




    override func viewDidLoad() {
        super.viewDidLoad()
        self.view.addGestureRecog-
nizer(UITapGestureRecognizer(target:
self.view, action: #selec-
tor(UIView.endEditing(_:))))
        // Do any additional setup after
loading the view.
    }

    override func didReceiveMemoryWarning()
{
        super.didReceiveMemoryWarning()
        // Dispose of any resources that
can be recreated.
    }
}
```

HabitLogNavigationViewControl-ler.swift

```
import UIKit

class HabitLogNavigationViewController:
UINavigationController {

    override func viewDidLoad() {
        super.viewDidLoad()

        // Do any additional setup after
loading the view.
    }

    override func didReceiveMemoryWarning()
{
        super.didReceiveMemoryWarning()
        // Dispose of any resources that
can be recreated.
    }
}
```

AddHabitLogViewControl-ler.swift

```
import UIKit

class AddHabitLogViewController: UIViewCon-
troller {

    var habitLogTVC = HabitLogTableViewCon-
troller()


    @IBOutlet weak var habitNameTextField:
UITextField!
    @IBOutlet weak var habit-
LogImportantSwitch: UISwitch!


    override func viewDidLoad() {
        super.viewDidLoad()
        self.view.addGestureRecog-
nizer(UITapGestureRecognizer(target:
self.view, action: #selec-
tor(UIView.endEditing(_:))))
        // Do any additional setup after
loading the view.
    }

    override func didReceiveMemoryWarning()
{
        super.didReceiveMemoryWarning()
        // Dispose of any resources that
can be recreated.
    }

    @IBAction func habitLogSaveBut-
tonTapped(_ sender: Any) {
        let habitLog = HabitLog()

        if let habitLogTitle = habitNam-
eTextField.text {
            habitLog.name = habitLogTitle
            habitLog.important = habit-
LogImportantSwitch.isOn

            habitLogTVC.habitLogs.ap-
pend(habitLog)
            habitLogTVC.tableView.reload-
Data()

            navigationController?.popView-
Controller(animated: true)
        }
    }
}
```

CompleteHabitLogViewControl-ler.swift

```
import UIKit

class CompleteHabitLogViewController:
UIViewController {

    var habitLogTVC = HabitLogTableViewCon-
troller()
```

```
    var selectedHabitLog = HabitLog()

    @IBOutlet weak var habitTitleLabel: UI-
Label!


    override func viewDidLoad() {
        super.viewDidLoad()
        habitTitleLabel.text = select-
edHabitLog.name

        self.view.addGestureRecog-
nizer(UITapGestureRecognizer(target:
self.view, action: #selec-
tor(UIView.endEditing(_:))))
        // Do any additional setup after
loading the view.
    }

    override func didReceiveMemoryWarning()
{
        super.didReceiveMemoryWarning()
        // Dispose of any resources that
can be recreated.
    }

    @IBAction func completeButtonTapped(_
sender: Any) {


        /*

         if let habitLogContext = (UIAppli-
cation.shared.delegate as? AppDele-
gate)?.persistentContainer.viewContext {
         if let theHabitLog = select-
edHabitLog {
         habitLogContext.delete(theHabit-
Log)
         navigationController?.popViewCon-
troller(animated: true)
         }
         }
         }
         */
        var index = 0
        for habitLog in habitLogTVC.habit-
Logs {
            if habitLog.name == select-
edHabitLog.name {
                habitLogTVC.habitLogs.re-
move(at: index)
                habitLogTVC.tableView.re-
loadData()
                navigationControl-
ler?.popViewController(animated: true)
                break
            }
            index += 1
        }
    }
}
```

B. SSHARRPPP Games

Diet Game

GameScene.swift

```
import SpriteKit
import GameplayKit

class GameScene: SKScene {

    var level: Level!
    var swipeHandler: ((Swap) -> Void)?

    private var swipeFromColumn: Int?
    private var swipeFromRow: Int?

    let tileWidth: CGFloat = 41.0
    let tileHeight: CGFloat = 46.0

    let gameLayer = SKNode()
    let gameFoodsLayer = SKNode()
    let tilesLayer = SKNode()
    let cropLayer = SKCropNode()
    let maskLayer = SKNode()

    // Sound FX
    let swapSound = SKAction.playSoundFile-
Named("Chomp.wav", waitForCompletion:
false)
    let invalidSwapSound = SKAc-
tion.playSoundFileNamed("Error.wav", wait-
ForCompletion: false)
    let matchSound = SKAction.playSound-
FileNamed("Ka-Ching.wav", waitForComple-
tion: false)
    let fallingGameFoodSound = SKAc-
tion.playSoundFileNamed("Scrape.wav", wait-
ForCompletion: false)
    let addGameFoodSound = SKAc-
tion.playSoundFileNamed("Drip.wav", wait-
ForCompletion: false)

    required init?(coder aDecoder: NSCoder)
{
        fatalError("init(coder) is not used
in this app")
    }

    override init(size: CGSize) {
        super.init(size: size)

        anchorPoint = CGPoint(x: 0.5, y:
0.5)

        let background = SKSprite-
Node(imageNamed: "background_diet")
        background.size = size
        addChild(background)

        addChild(gameLayer)
        gameLayer.isHidden = true

        let layerPosition = CGPoint(
            x: -tileWidth * CGFloat(numCol-
umns) / 2,
            y: -tileHeight * CGFloat(num-
Rows) / 2)

        tilesLayer.position = layerPosition
        maskLayer.position = layerPosition
        cropLayer.maskNode = maskLayer
        gameLayer.addChild(tilesLayer)
        gameLayer.addChild(cropLayer)

        gameFoodsLayer.position = layerPo-
sition
        cropLayer.addChild(gameFoodsLayer)
```

```
        // Animate sugar label for each
match - decide later
        let _ = SKLabelNode(fontNamed:
"GillSans-BoldItalic")
    }

    func addTiles() {
        // 1
        for row in 0..<numRows {
            for column in 0..<numColumns {
                if level.tileAt(column:
column, row: row) != nil {
                    let tileNode =
SKSpriteNode(imageNamed: "MaskTile")
                    tileNode.size =
CGSize(width: tileWidth, height: tile-
Height)
                    tileNode.position =
pointFor(column: column, row: row)
                    maskLayer.add-
Child(tileNode)
                }
            }
        }

        // 2
        for row in 0...numRows {
            for column in 0...numColumns {
                let topLeft     = (column >
0) && (row < numRows)
                    && level.tileAt(column:
column - 1, row: row) != nil
                let bottomLeft  = (column >
0) && (row > 0)
                    && level.tileAt(column:
column - 1, row: row - 1) != nil
                let topRight    = (column <
numColumns) && (row < numRows)
                    && level.tileAt(column:
column, row: row) != nil
                let bottomRight = (column <
numColumns) && (row > 0)
                    && level.tileAt(column:
column, row: row - 1) != nil

                var value = topLeft.hash-
Value
                value = value | to-
pRight.hashValue << 1
                value = value | bottom-
Left.hashValue << 2
                value = value | bottom-
Right.hashValue << 3

                // Values 0 (no tiles), 6
and 9 (two opposite tiles) are not drawn.
                if value != 0 && value != 6
&& value != 9 {
                    let name = String(for-
mat: "Tile_%ld", value)
                    let tileNode =
SKSpriteNode(imageNamed: name)
                    tileNode.size =
CGSize(width: tileWidth, height: tile-
Height)
                    var point = point-
For(column: column, row: row)
                    point.x -= tileWidth /
2
                    point.y -= tileHeight /
2
                    tileNode.position =
point
                    tilesLayer.add-
Child(tileNode)
                }
            }
        }
    }

    func addSprites(for gameFoods:
Set<GameFood>) {
        for gameFood in gameFoods {
            let sprite = SKSprite-
Node(imageNamed: gameFood.game-
FoodType.spriteName)
            sprite.size = CGSize(width:
tileWidth, height: tileHeight)
            sprite.position = pointFor(col-
umn: gameFood.column, row: gameFood.row)
            gameFoodsLayer.addChild(sprite)
            gameFood.sprite = sprite

            // Give each gamefood sprite a
small, random delay. Then fade them in.
            sprite.alpha = 0
            sprite.xScale = 0.5
            sprite.yScale = 0.5

            sprite.run(
                SKAction.sequence([
                    SKAction.wait(forDura-
tion: 0.25, withRange: 0.5),
                    SKAction.group([
                        SKAc-
tion.fadeIn(withDuration: 0.25),
                        SKAction.scale(to:
1.0, duration: 0.25)
                        ])
                    ]))
        }
    }

    private func pointFor(column: Int, row:
Int) -> CGPoint {
        return CGPoint(
            x: CGFloat(column) * tileWidth
+ tileWidth / 2,
            y: CGFloat(row) * tileHeight +
tileHeight / 2)
    }

    private func convertPoint(_ point:
CGPoint) -> (success: Bool, column: Int,
row: Int) {
        if point.x >= 0 && point.x <
CGFloat(numColumns) * tileWidth &&
            point.y >= 0 && point.y <
CGFloat(numRows) * tileHeight {
            return (true, Int(point.x /
tileWidth), Int(point.y / tileHeight))
        } else {
            return (false, 0, 0)  // inva-
lid location
        }
    }

    override func touchesBegan(_ touches:
Set<UITouch>, with event: UIEvent?) {
        // 1
        guard let touch = touches.first
else { return }
        let location = touch.location(in:
gameFoodsLayer)
        // 2
        let (success, column, row) = con-
vertPoint(location)
```

```
        if success {
            // 3
            if let gameFood = level.game-
Food(atColumn: column, row: row) {
                // 4
                swipeFromColumn = column
                swipeFromRow = row
            }
        }
    }

    override func touchesMoved(_ touches:
Set<UITouch>, with event: UIEvent?) {
        // 1
        guard swipeFromColumn != nil else {
return }

        // 2
        guard let touch = touches.first
else { return }
        let location = touch.location(in:
gameFoodsLayer)

        let (success, column, row) = con-
vertPoint(location)
        if success {

            // 3
            var horizontalDelta = 0, verti-
calDelta = 0
            if column < swipeFromColumn! {
// swipe left
                horizontalDelta = -1
            } else if column > swipe-
FromColumn! {   // swipe right
                horizontalDelta = 1
            } else if row < swipeFromRow! {
// swipe down
                verticalDelta = -1
            } else if row > swipeFromRow! {
// swipe up
                verticalDelta = 1
            }

            // 4
            if horizontalDelta != 0 || ver-
ticalDelta != 0 {
                trySwap(horizontalDelta:
horizontalDelta, verticalDelta: verti-
calDelta)

                // 5
                swipeFromColumn = nil
            }
        }
    }

    private func trySwap(horizontalDelta:
Int, verticalDelta: Int) {
        // 1
        let toColumn = swipeFromColumn! +
horizontalDelta
        let toRow = swipeFromRow! + verti-
calDelta
        // 2
        guard toColumn >= 0 && toColumn <
numColumns else { return }
        guard toRow >= 0 && toRow < numRows
else { return }
        // 3
        if let toGameFood = level.game-
Food(atColumn: toColumn, row: toRow),
            let fromGameFood = level.game-
Food(atColumn: swipeFromColumn!, row:
swipeFromRow!) {
            // 4
            print("*** swapping \(fromGame-
Food) with \(toGameFood)")

            if let handler = swipeHandler {
                let swap = Swap(gameFoodA:
fromGameFood, gameFoodB: toGameFood)
                handler(swap)
            }
        }
    }

    func animate(_ swap: Swap, completion:
@escaping () -> Void) {
        let spriteA = swap.game-
FoodA.sprite!
        let spriteB = swap.game-
FoodB.sprite!

        spriteA.zPosition = 100
        spriteB.zPosition = 90

        let duration: TimeInterval = 0.3

        let moveA = SKAction.move(to:
spriteB.position, duration: duration)
        moveA.timingMode = .easeOut
        spriteA.run(moveA, completion: com-
pletion)

        let moveB = SKAction.move(to:
spriteA.position, duration: duration)
        moveB.timingMode = .easeOut
        spriteB.run(moveB)

        run(swapSound)
    }

    func animateInvalidSwap(_ swap: Swap,
completion: @escaping () -> Void) {
        let spriteA = swap.game-
FoodA.sprite!
        let spriteB = swap.game-
FoodB.sprite!

        spriteA.zPosition = 100
        spriteB.zPosition = 90

        let duration: TimeInterval = 0.2

        let moveA = SKAction.move(to:
spriteB.position, duration: duration)
        moveA.timingMode = .easeOut

        let moveB = SKAction.move(to:
spriteA.position, duration: duration)
        moveB.timingMode = .easeOut

        spriteA.run(SKAction.se-
quence([moveA, moveB]), completion: comple-
tion)
        spriteB.run(SKAction.se-
quence([moveB, moveA]))

        run(invalidSwapSound)
    }

    func animateMatchedGameFood(for chains:
Set<Chain>, completion: @escaping () ->
Void) {
        for chain in chains {
```

```
            // Animate sugar label for each
match - decide later
            animateSugarLevel(for: chain)
            for gameFood in chain.gameFoods
{
                if let sprite = game-
Food.sprite {
                    if sprite.ac-
tion(forKey: "removing") == nil {
                        let scaleAction =
SKAction.scale(to: 0.1, duration: 0.3)
                        scaleAction.tim-
ingMode = .easeOut
                        sprite.run(SKAc-
tion.sequence([scaleAction, SKAction.re-
moveFromParent()]),
                                   withKey:
"removing")
                    }
                }
            }
        }
        run(matchSound)
        run(SKAction.wait(forDuration:
0.3), completion: completion)
    }

    func animateFallingGameFood(in columns:
[[GameFood]], completion: @escaping () ->
Void) {
        // 1
        var longestDuration: TimeInterval =
0
        for array in columns {
            for (index, gameFood) in ar-
ray.enumerated() {
                let newPosition = point-
For(column: gameFood.column, row: game-
Food.row)
                // 2
                let delay = 0.05 + 0.15 *
TimeInterval(index)
                // 3
                let sprite = game-
Food.sprite!   // sprite always exists at
this point
                let duration = TimeInter-
val(((sprite.position.y - newPosition.y) /
tileHeight) * 0.1)
                // 4
                longestDuration = max(long-
estDuration, duration + delay)
                // 5
                let moveAction = SKAc-
tion.move(to: newPosition, duration: dura-
tion)
                moveAction.timingMode =
.easeOut
                sprite.run(
                    SKAction.sequence([
                        SKAction.wait(for-
Duration: delay),
                        SKAc-
tion.group([moveAction, fallingGameFood-
Sound])]))
            }
        }
        // 6
        run(SKAction.wait(forDuration:
longestDuration), completion: completion)
    }

    func animateNewGameFood(in columns:
[[GameFood]], completion: @escaping () ->
Void) {
        // 1
        var longestDuration: TimeInterval =
0

        for array in columns {
            // 2
            let startRow = array[0].row + 1

            for (index, gameFood) in ar-
ray.enumerated() {
                // 3
                let sprite = SKSprite-
Node(imageNamed: gameFood.game-
FoodType.spriteName)
                sprite.size = CGSize(width:
tileWidth, height: tileHeight)
                sprite.position = point-
For(column: gameFood.column, row: startRow)
                gameFoodsLayer.add-
Child(sprite)
                gameFood.sprite = sprite
                // 4
                let delay = 0.1 + 0.2 *
TimeInterval(array.count - index - 1)
                // 5
                let duration = TimeInter-
val(startRow - gameFood.row) * 0.1
                longestDuration = max(long-
estDuration, duration + delay)
                // 6
                let newPosition = point-
For(column: gameFood.column, row: game-
Food.row)
                let moveAction = SKAc-
tion.move(to: newPosition, duration: dura-
tion)
                moveAction.timingMode =
.easeOut
                sprite.alpha = 0
                sprite.run(
                    SKAction.sequence([
                        SKAction.wait(for-
Duration: delay),
                        SKAction.group([
                            SKAc-
tion.fadeIn(withDuration: 0.05),
                            moveAction,
                            addGameFood-
Sound])
                        ]))
            }
        }
        // 7
        run(SKAction.wait(forDuration:
longestDuration), completion: completion)
    }

    // Animate sugar label for each match -
decide later
    func animateSugarLevel(for chain:
Chain) {
        // Figure out what the midpoint of
the chain is.
        let firstSprite = chain.firstGame-
Food().sprite!
        let lastSprite = chain.lastGame-
Food().sprite!
        let centerPosition = CGPoint(
            x: (firstSprite.position.x +
lastSprite.position.x)/2,
```

```
        y: (firstSprite.position.y +
lastSprite.position.y)/2 - 8)

        // Add a label for the score that
slowly floats up.
        let sugarLevelLabel = SKLa-
belNode(fontNamed: "GillSans-BoldItalic")
        sugarLevelLabel.fontSize = 16
        sugarLevelLabel.fontColor = UI-
Color.yellow
        sugarLevelLabel.text = String(for-
mat: "%ld", chain.sugarLevel)
        sugarLevelLabel.position = center-
Position
        sugarLevelLabel.zPosition = 300
        gameFoodsLayer.add-
Child(sugarLevelLabel)

        let moveAction = SKAction.move(by:
CGVector(dx: 0, dy: 3), duration: 0.7)
        moveAction.timingMode = .easeOut
        sugarLevelLabel.run(SKAction.se-
quence([moveAction, SKAction.removeFromPar-
ent()]))
        // spriteScore1Label.run(SKAc-
tion.sequence([moveAction, SKAction.remove-
FromParent()]))
    }

    func animateGameOver(_ completion: @es-
caping () -> Void) {
        let action = SKAction.move(by:
CGVector(dx: 0, dy: -size.height), dura-
tion: 0.3)
        action.timingMode = .easeIn
        gameLayer.run(action, completion:
completion)
    }

    func animateBeginGame(_ completion:
@escaping () -> Void) {
        gameLayer.isHidden = false
        gameLayer.position = CGPoint(x: 0,
y: size.height)
        let action = SKAction.move(by:
CGVector(dx: 0, dy: -size.height), dura-
tion: 0.3)
        action.timingMode = .easeOut
        gameLayer.run(action, completion:
completion)
    }

    func removeAllGameFoodSprites() {
        gameFoodsLayer.removeAllChildren()
    }

    override func touchesEnded(_ touches:
Set<UITouch>, with event: UIEvent?) {
        swipeFromColumn = nil
        swipeFromRow = nil
    }

    override func touchesCancelled(_
touches: Set<UITouch>, with event:
UIEvent?) {
        touchesEnded(touches, with: event)
    }
}
```

GameViewController.swift

```
import UIKit
import SpriteKit
import AVFoundation

class GameViewController: UIViewController
{

    // MARK: Properties
    var level: Level!
    var tapGestureRecognizer: UITapGes-
tureRecognizer!

    // The scene draws the tiles and cookie
sprites, and handles swipes.
    var scene: GameScene!

    var currentLevelNumber = 1
    var movesLeft = 0
    var score = 0
    var sugarLevel = 0

    var spriteScore1 = 0
    var spriteScore2 = 0
    var spriteScore3 = 0
    var spriteScore4 = 0

    lazy var backgroundMusic: AVAudio-
Player? = {
        guard let url = Bun-
dle.main.url(forResource: "Mining by Moon-
light", withExtension: "mp3") else {
            return nil
        }
        do {
            let player = try AVAudio-
Player(contentsOf: url)
            player.numberOfLoops = -1
            return player
        } catch {
            return nil
        }
    }()

    // Add outlets here
    @IBOutlet weak var movesLabel: UILabel!
    @IBOutlet weak var leverNumberLabel:
UILabel!

    @IBOutlet weak var targetSpriteImage1:
UIImageView!
    @IBOutlet weak var targetSpriteImage2:
UIImageView!
    @IBOutlet weak var targetSpriteImage3:
UIImageView!
    @IBOutlet weak var targetSpriteImage4:
UIImageView!

    @IBOutlet weak var spriteScoreLabel1:
UILabel!
    @IBOutlet weak var spriteScoreLabel2:
UILabel!
    @IBOutlet weak var spriteScoreLabel3:
UILabel!
    @IBOutlet weak var spriteScoreLabel4:
UILabel!

    @IBOutlet weak var slash1: UILabel!
    @IBOutlet weak var slash2: UILabel!
    @IBOutlet weak var slash3: UILabel!
    @IBOutlet weak var slash4: UILabel!

    @IBOutlet weak var spriteStackView1:
UIStackView!
    @IBOutlet weak var spriteStackView2:
UIStackView!
```

```
    @IBOutlet weak var spriteStackView3:
UIStackView!
    @IBOutlet weak var spriteStackView4:
UIStackView!

    @IBOutlet weak var targetSpriteScoreLa-
bel1: UILabel!
    @IBOutlet weak var targetSpriteScoreLa-
bel2: UILabel!
    @IBOutlet weak var targetSpriteScoreLa-
bel3: UILabel!
    @IBOutlet weak var targetSpriteScoreLa-
bel4: UILabel!

    @IBOutlet weak var targetSprite1Done:
UIImageView!
    @IBOutlet weak var targetSprite2Done:
UIImageView!
    @IBOutlet weak var targetSprite3Done:
UIImageView!
    @IBOutlet weak var targetSprite4Done:
UIImageView!


    @IBOutlet weak var glucoseColourImage:
UIImageView!
    @IBOutlet weak var gluco-
seResultTextLabel: UILabel!
    @IBOutlet weak var avatarImage:
UIImageView!

    @IBOutlet weak var quitGameButton:
UIButton!
    @IBOutlet weak var shuffleButton:
UIButton!
    @IBOutlet weak var gameInfoButton:
UIButton!

    @IBOutlet weak var gameOverPanel:
UIImageView!
    @IBOutlet weak var gameOverButton:
UIButton!



    override func viewDidLoad() {
        super.viewDidLoad()
        setupLevel(number: currentLevel-
Number)
        backgroundMusic?.play()

    }

    func setupLevel(number levelNumber:
Int) {
        // Configure the view
        let skView = view as! SKView
        skView.isMultipleTouchEnabled =
false

        // Create and configure the scene.
        scene = GameScene(size:
skView.bounds.size)
        scene.scaleMode = .aspectFill

        // Level settings are here
        level = Level(filename:
"Level_\(levelNumber)")
        scene.level = level

        scene.addTiles()
        scene.swipeHandler = handleSwipe

        gameOverPanel.isHidden = true
        shuffleButton.isHidden = true
        gameOverButton.isHidden = true

        // Present the scene.
        skView.presentScene(scene)

        // Start the game
        beginGame()
    }

    // Add button actions here

    @IBAction func shuffleButtonPressed(_:
AnyObject) {
        shuffle()
        decrementMoves()
    }

    @IBAction func quitGameButtonPressed(_:
AnyObject) {
        dismiss(animated: true, completion:
nil)
        backgroundMusic?.stop()
    }

    @IBAction func gameInfoButtonPressed(_:
AnyObject) {

    }

    @IBAction func gameOverButtonPressed(_:
AnyObject) {
        dismiss(animated: true, completion:
nil)
        backgroundMusic?.stop()
    }

    // MARK: View Controller Functions
    override var prefersStatusBarHidden:
Bool {
        return true
    }

    override var shouldAutorotate: Bool {
        return true
    }

    override var supportedInterfaceOrienta-
tions: UIInterfaceOrientationMask {
        return [.portrait, .portraitUp-
sideDown]
    }

    func beginGame() {

        movesLeft = level.maximumMoves
        score = 0
        sugarLevel = 0

        spriteScore1 = 0
        spriteScore2 = 0
        spriteScore3 = 0
        spriteScore4 = 0

        updateLabels()
        updateResultsImages()
        updateCompleteImages()
        scene.animateBeginGame {

            // Think about how to make
shuffle automatically later
            self.shuffleButton.isHidden =
false
        }
```

```
        level.resetComboMultiplier()
        shuffle()
    }

    func shuffle() {
        scene.removeAllGameFoodSprites()
        let newGameFoods = level.shuffle()
        scene.addSprites(for: newGameFoods)
    }

    func handleSwipe(_ swap: Swap) {
        view.isUserInteractionEnabled =
false

        if level.isPossibleSwap(swap) {
            level.performSwap(swap)
            scene.animate(swap, completion:
handleMatches)

        } else {
            scene.animateInvalidSwap(swap)
{
                self.view.isUserInterac-
tionEnabled = true
            }
        }
    }

    func handleMatches() {
        let chains = level.removeMatches()

        if chains.count == 0 {
            beginNextTurn()
            return
        }

        // TODO: do something with the
chains set
        scene.animateMatchedGameFood(for:
chains) {
            for chain in chains {

                self.score += chain.score
                self.sugarLevel +=
chain.sugarLevel

                self.spriteScore1 +=
chain.spriteScore1
                self.spriteScore2 +=
chain.spriteScore2
                self.spriteScore3 +=
chain.spriteScore3
                self.spriteScore4 +=
chain.spriteScore4
            }
            self.updateLabels()
            self.updateResultsImages()
            self.updateCompleteImages()

            let columns = self.level.fill-
Holes()
            self.scene.animateFallingGame-
Food(in: columns){
                let columns =
self.level.topUpGameFood()
                self.scene.animateNewGame-
Food(in: columns) {
                    self.handleMatches()
                }
            }
        }
    }

    func beginNextTurn() {
        level.resetComboMultiplier()
        level.detectPossibleSwaps()
        updateCompleteImages()
        view.isUserInteractionEnabled =
true
        decrementMoves()
    }

    func updateLabels() {
        // targetLabel.text = String(for-
mat: "%ld", level.targetScore)
        // scoreLabel.text = String(format:
"%ld", score)

        leverNumberLabel.text = String(for-
mat: "%ld", currentLevelNumber)

        targetSpriteScoreLabel1.text =
String(format: "%ld", level.tar-
getSpriteScore1)
        targetSpriteScoreLabel2.text =
String(format: "%ld", level.tar-
getSpriteScore2)
        targetSpriteScoreLabel3.text =
String(format: "%ld", level.tar-
getSpriteScore3)
        targetSpriteScoreLabel4.text =
String(format: "%ld", level.tar-
getSpriteScore4)

        spriteScoreLabel1.text =
String(format: "%ld", spriteScore1)
        spriteScoreLabel2.text =
String(format: "%ld", spriteScore2)
        spriteScoreLabel3.text =
String(format: "%ld", spriteScore3)
        spriteScoreLabel4.text =
String(format: "%ld", spriteScore4)

        movesLabel.text = String(format:
"%ld", movesLeft)


    }

    func updateResultsImages() {

        if sugarLevel < 0 {
            avatarImage.image =
UIImage(named: "cat_1")
            glucoseColourImage.image =
UIImage(named: "Glucose_Green")
            glucoseResultTextLabel.text =
"Good"
        }
        else if sugarLevel <= 4 {
            avatarImage.image =
UIImage(named: "cat_2")
            glucoseColourImage.image =
UIImage(named: "Glucose_Green")
            glucoseResultTextLabel.text =
"Normal"
        }
        else if sugarLevel <= 7 {
            avatarImage.image =
UIImage(named: "cat_3")
            glucoseColourImage.image =
UIImage(named: "Glucose_Yellow")
            glucoseResultTextLabel.text =
"Warning"

        }
        else if sugarLevel <= 10 {
```

```
            avatarImage.image =
UIImage(named: "cat_4")
            glucoseColourImage.image =
UIImage(named: "Glucose_Yellow")
            glucoseResultTextLabel.text =
"Danger"
        }

        else if sugarLevel > 10 {
            avatarImage.image =
UIImage(named: "cat_5")
            glucoseColourImage.image =
UIImage(named: "Glucose_Red")
            glucoseResultTextLabel.text =
"Died"
        }
    }

    func updateCompleteImages() {
        if spriteScore1 >= level.tar-
getSpriteScore1 {
            targetSprite1Done.isHidden =
false
            targetSprite1Done.image =  im-
ageLiteral(resourceName: "thumbsup")
            spriteStackView1.isHidden =
true
        }
        if spriteScore2 >= level.tar-
getSpriteScore2 {
            targetSprite2Done.isHidden =
false
            targetSprite2Done.image =  im-
ageLiteral(resourceName: "thumbsup")
            spriteStackView2.isHidden =
true
        }
        if spriteScore3 >= level.tar-
getSpriteScore3 {
            targetSprite3Done.isHidden =
false
            targetSprite3Done.image =  im-
ageLiteral(resourceName: "thumbsup")
            spriteStackView3.isHidden =
true
        }
        if spriteScore4 >= level.tar-
getSpriteScore4 {
            targetSprite4Done.isHidden =
false
            targetSprite4Done.image =  im-
ageLiteral(resourceName: "thumbsup")
            spriteStackView4.isHidden =
true
        }
    }
    func decrementMoves() {
        movesLeft -= 1
        updateLabels()
        updateResultsImages()
        updateCompleteImages()

        /*
         // Use this for Total score sce-
nario
         if score >= level.targetScore {
         gameOverPanel.image =
UIImage(named: "WinTheLevel")
         currentLevelNum = currentLevelNum
< numLevels ? currentLevelNum + 1 : 1
         showGameOver()
         } else */

        // Use this for Individual food
item scenario
        if spriteScore1 >= level.tar-
getSpriteScore1
            && spriteScore2 >= level.tar-
getSpriteScore2
            && spriteScore3 >= level.tar-
getSpriteScore3
            && spriteScore4 >= level.tar-
getSpriteScore4   {

            // Here code should be out of
the level
            if currentLevelNumber == num-
Levels {
            gameOverPanel.image =
UIImage(named: "WinTheLevel1")
                gameOverButton.isHidden =
false
                // gameOverButton.image =
UIImage(named: "BacktoMenu")
                showGameOver()
            } else {
                gameOverPanel.image =
UIImage(named: "WinTheLevel")
                currentLevelNumber = cur-
rentLevelNumber < numLevels ? currentLevel-
Number + 1 : 1
                showGameOver()
            }
        } else if movesLeft == 0 {
            gameOverPanel.image =
UIImage(named: "LostTheLevel")
            showGameOver()
        }
        else if sugarLevel >= 11 {
            gameOverPanel.image =
UIImage(named: "LostTheLevel")
            showGameOver()
        }
    }

    func showGameOver() {
        gameOverPanel.isHidden = false
        scene.isUserInteractionEnabled =
false
        shuffleButton.isHidden = true

        scene.animateGameOver {
            self.tapGestureRecognizer =
UITapGestureRecognizer(target: self, ac-
tion: #selector(self.hideGameOver))
            self.view.addGestureRecog-
nizer(self.tapGestureRecognizer)

            self.targetSprite1Done.isHidden
= true
            self.targetSprite2Done.isHidden
= true
            self.targetSprite3Done.isHidden
= true
            self.targetSprite4Done.isHidden
= true

            self.spriteStackView1.isHidden
= false
            self.spriteStackView2.isHidden
= false
            self.spriteStackView3.isHidden
= false
            self.spriteStackView4.isHidden
= false

        }
```

```
    }

    @objc func hideGameOver() {
        view.removeGestureRecog-
nizer(tapGestureRecognizer)
        tapGestureRecognizer = nil

        gameOverPanel.isHidden = true
        gameOverButton.isHidden = true
        scene.isUserInteractionEnabled =
true

        // level changing codes, here code
should be out of the level
        setupLevel(number: currentLevel-
Number)
        //beginGame()
    }
}
```

Level.swift

```
import Foundation

let numColumns = 7
let numRows = 7
let numLevels = 5

class Level {
    private var gameFoods = Array2D<Game-
Food>(columns: numColumns, rows: numRows)
    private var tiles = Array2D<Tile>(col-
umns: numColumns, rows: numRows)
    private var possibleSwaps: Set<Swap> =
[]
    private var comboMultiplier = 0

    var targetScore = 0
    var maximumMoves = 0

    var targetSpriteScore1 = 0
    var targetSpriteScore2 = 0
    var targetSpriteScore3 = 0
    var targetSpriteScore4 = 0


    init(filename: String) {
        // 1
        guard let levelData =
LevelData.loadFrom(file: filename) else {
return }
        // 2
        let tilesArray = levelData.tiles
        // 3
        for (row, rowArray) in tilesAr-
ray.enumerated() {
            // 4
            let tileRow = numRows - row - 1
            // 5
            for (column, value) in ro-
wArray.enumerated() {
                if value == 1 {
                    tiles[column, tileRow]
= Tile()
                }
            }
        }

        targetScore = levelData.targetScore
        maximumMoves = levelData.moves

        targetSpriteScore1 = levelData.tar-
getSpriteScore1
        targetSpriteScore2 = levelData.tar-
getSpriteScore2
        targetSpriteScore3 = levelData.tar-
getSpriteScore3
        targetSpriteScore4 = levelData.tar-
getSpriteScore4

    }



    func gameFood(atColumn column: Int,
row: Int) -> GameFood? {
        precondition(column >= 0 && column
< numColumns)
        precondition(row >= 0 && row < num-
Rows)
        return gameFoods[column, row]
    }

    func tileAt(column: Int, row: Int) ->
Tile? {
        precondition(column >= 0 && column
< numColumns)
        precondition(row >= 0 && row < num-
Rows)
        return tiles[column, row]
    }


    func shuffle() -> Set<GameFood> {
        var set: Set<GameFood>
        repeat {
            set = createInitialGameFoods()
            detectPossibleSwaps()
            print("possible swaps: \(possi-
bleSwaps)")
        } while possibleSwaps.count == 0

        return set
    }



    private func createInitialGameFoods() -
> Set<GameFood> {
        var set: Set<GameFood> = []

        // 1
        for row in 0..<numRows {
            for column in 0..<numColumns {

                // This line is new
                if tiles[column, row] !=
nil {

                    var gameFoodType: Game-
FoodType
                    repeat {
                        gameFoodType =
GameFoodType.random()
                    } while (column >= 2 &&
                        gameFoods[column -
1, row]?.gameFoodType == gameFoodType &&
                        gameFoods[column -
2, row]?.gameFoodType == gameFoodType)
                        || (row >= 2 &&
                            gameFoods[col-
umn, row - 1]?.gameFoodType == gameFoodType
&&
```

```
                            gameFoods[col-
umn, row - 2]?.gameFoodType == game-
FoodType)


                    // 2
                    // let gameFoodType =
GameFoodType.random()

                    // 3
                    let gameFood = Game-
Food(column: column, row: row, game-
FoodType: gameFoodType)
                    gameFoods[column, row]
= gameFood

                    // 4
                    set.insert(gameFood)
                }
            }
        }
        return set
    }

    func isPossibleSwap(_ swap: Swap) ->
Bool {
        return possibleSwaps.contains(swap)
    }

    func performSwap(_ swap: Swap) {
        let columnA = swap.gameFoodA.column
        let rowA = swap.gameFoodA.row
        let columnB = swap.gameFoodB.column
        let rowB = swap.gameFoodB.row

        gameFoods[columnA, rowA] =
swap.gameFoodB
        swap.gameFoodB.column = columnA
        swap.gameFoodB.row = rowA

        gameFoods[columnB, rowB] =
swap.gameFoodA
        swap.gameFoodA.column = columnB
        swap.gameFoodA.row = rowB
    }

    private func detectHorizontalMatches()
-> Set<Chain> {
        // 1
        var set: Set<Chain> = []
        // 2
        for row in 0..<numRows {
            var column = 0
            while column < numColumns-2 {
                // 3
                if let gameFood = game-
Foods[column, row] {
                    let matchType = game-
Food.gameFoodType
                    // 4
                    if gameFoods[column +
1, row]?.gameFoodType == matchType &&
                        gameFoods[column +
2, row]?.gameFoodType == matchType {
                        // 5
                        let chain =
Chain(chainType: .horizontal)
                        repeat {
                            chain.add(game-
Food: gameFoods[column, row]!)
                            column += 1
                        } while column <
numColumns && gameFoods[column, row]?.game-
FoodType == matchType

                        set.insert(chain)
                        continue
                    }
                }
                // 6
                column += 1
            }
        }
        return set
    }

    private func detectVerticalMatches() ->
Set<Chain> {
        var set: Set<Chain> = []

        for column in 0..<numColumns {
            var row = 0
            while row < numRows-2 {
                if let gameFood = game-
Foods[column, row] {
                    let matchType = game-
Food.gameFoodType

                    if gameFoods[column,
row + 1]?.gameFoodType == matchType &&
                        gameFoods[column,
row + 2]?.gameFoodType == matchType {
                        let chain =
Chain(chainType: .vertical)
                        repeat {
                            chain.add(game-
Food: gameFoods[column, row]!)
                            row += 1
                        } while row < num-
Rows && gameFoods[column, row]?.game-
FoodType == matchType

                        set.insert(chain)
                        continue
                    }
                }
                row += 1
            }
        }
        return set
    }

    func removeMatches() -> Set<Chain> {
        let horizontalChains = detectHori-
zontalMatches()
        let verticalChains = detectVerti-
calMatches()

        removeGameFood(in: horizontal-
Chains)
        removeGameFood(in: verticalChains)

        calculateScores(for: horizontal-
Chains)
        calculateScores(for: vertical-
Chains)

        print("Horizontal matches: \(hori-
zontalChains)")
        print("Vertical matches: \(verti-
calChains)")

        return horizontalChains.union(ver-
ticalChains)
    }
```

```
    private func hasChain(atColumn column:
Int, row: Int) -> Bool {
        let gameFoodType = gameFoods[col-
umn, row]!.gameFoodType

        // Horizontal chain check
        var horizontalLength = 1

        // Left
        var i = column - 1
        while i >= 0 && gameFoods[i,
row]?.gameFoodType == gameFoodType {
            i -= 1
            horizontalLength += 1
        }

        // Right
        i = column + 1
        while i < numColumns && game-
Foods[i, row]?.gameFoodType == gameFoodType
{
            i += 1
            horizontalLength += 1
        }
        if horizontalLength >= 3 { return
true }

        // Vertical chain check
        var verticalLength = 1

        // Down
        i = row - 1
        while i >= 0 && gameFoods[column,
i]?.gameFoodType == gameFoodType {
            i -= 1
            verticalLength += 1
        }

        // Up
        i = row + 1
        while i < numRows && gameFoods[col-
umn, i]?.gameFoodType == gameFoodType {
            i += 1
            verticalLength += 1
        }
        return verticalLength >= 3
    }

    func detectPossibleSwaps() {
        var set: Set<Swap> = []

        for row in 0..<numRows {
            for column in 0..<numColumns {
                if let gameFood = game-
Foods[column, row] {

                    // TODO: detection
logic goes here
                    // Have a gameFood in
this spot? If there is no tile, there is no
gameFood.
                    if column < numColumns
- 1,
                        let other = game-
Foods[column + 1, row] {
                        // Swap them
                        gameFoods[column,
row] = other
                        gameFoods[column +
1, row] = gameFood

                        // Is either cookie
now part of a chain?
                        if hasChain(atCol-
umn: column + 1, row: row) ||
                            hasChain(atCol-
umn: column, row: row) {
                            set.in-
sert(Swap(gameFoodA: gameFood, gameFoodB:
other))
                        }

                        // Swap them back
                        gameFoods[column,
row] = gameFood
                        gameFoods[column +
1, row] = other
                    }

                    if row < numRows - 1,
                        let other = game-
Foods[column, row + 1] {
                        gameFoods[column,
row] = other
                        gameFoods[column,
row + 1] = gameFood

                        // Is either cookie
now part of a chain?
                        if hasChain(atCol-
umn: column, row: row + 1) ||
                            hasChain(atCol-
umn: column, row: row) {
                            set.in-
sert(Swap(gameFoodA: gameFood, gameFoodB:
other))
                        }

                        // Swap them back
                        gameFoods[column,
row] = gameFood
                        gameFoods[column,
row + 1] = other
                    }
                }
                else if column == numCol-
umns - 1, let gameFood = gameFoods[column,
row] {
                    if row < numRows - 1,
                        let other = game-
Foods[column, row + 1] {
                        gameFoods[column,
row] = other
                        gameFoods[column,
row + 1] = gameFood

                        // Is either cookie
now part of a chain?
                        if hasChain(atCol-
umn: column, row: row + 1) ||
                            hasChain(atCol-
umn: column, row: row) {
                            set.in-
sert(Swap(gameFoodA: gameFood, gameFoodB:
other))
                        }

                        // Swap them back
                        gameFoods[column,
row] = gameFood
                        gameFoods[column,
row + 1] = other
                    }
                }


            }
```

```
        }

        possibleSwaps = set
    }

    private func removeGameFood(in chains:
Set<Chain>) {
        for chain in chains {
            for gameFood in chain.gameFoods
{
                gameFoods[gameFood.column,
gameFood.row] = nil
            }
        }
    }

    func fillHoles() -> [[GameFood]] {
        var columns: [[GameFood]] = []
        // 1
        for column in 0..<numColumns {
            var array: [GameFood] = []
            for row in 0..<numRows {
                // 2
                if tiles[column, row] !=
nil && gameFoods[column, row] == nil {
                    // 3
                    for lookup in (row +
1)..<numRows {
                        if let gameFood =
gameFoods[column, lookup] {
                            // 4
                            gameFoods[col-
umn, lookup] = nil
                            gameFoods[col-
umn, row] = gameFood
                            gameFood.row =
row
                            // 5
                            array.ap-
pend(gameFood)
                            // 6
                            break
                        }
                    }
                }
            }
            // 7
            if !array.isEmpty {
                columns.append(array)
            }
        }
        return columns
    }

    func topUpGameFood() -> [[GameFood]] {
        var columns: [[GameFood]] = []
        var gameFoodType: GameFoodType =
.unknown

        for column in 0..<numColumns {
            var array: [GameFood] = []

            // 1
            var row = numRows - 1
            while row >= 0 && game-
Foods[column, row] == nil {
                // 2
                if tiles[column, row] !=
nil {
                    // 3
                    var newGameFoodType:
GameFoodType
                    repeat {
```

```
                        newGameFoodType =
GameFoodType.random()
                    } while newGameFoodType
== gameFoodType
                    gameFoodType = newGame-
FoodType
                    // 4
                    let gameFood = Game-
Food(column: column, row: row, game-
FoodType: gameFoodType)
                    gameFoods[column, row]
= gameFood
                    array.append(gameFood)
                }

                row -= 1
            }
            // 5
            if !array.isEmpty {
                columns.append(array)
            }
        }
        return columns
    }

    private func calculateScores(for
chains: Set<Chain>) {
        // 3-chain is 60 pts, 4-chain is
120, 5-chain is 180, and so on

        for chain in chains {
            print("Chians for food  ==
\(chain.gameFoods[0].gameFoodType)")

            // User matches unhealthy food.
Therefore we increase sugarlevel
            if chain.gameFoods[0].game-
FoodType == GameFoodType.workingdesk ||
chain.gameFoods[0].gameFoodType == Game-
FoodType.dounut || chain.gameFoods[0].game-
FoodType == GameFoodType.smartphone {


                chain.score = 1 *
(chain.length)
                comboMultiplier += 1

                // For updating
sugarLevelLabel
                chain.sugarLevel = 1 *
(chain.length)
                comboMultiplier += 1

                /*
                comboMultiplier -= 1
                if comboMultiplier <= 1 {
                    comboMultiplier = 1
                }
                */


            } else if chain.game-
Foods[0].gameFoodType == GameFoodType.avo {
                // increment avo score
                chain.spriteScore1 = 1 *
(chain.length)
                chain.sugarLevel = -(1 *
(chain.length))
                comboMultiplier -= 1
                if comboMultiplier <= 1 {
                    comboMultiplier = 1
                }
```

```
            } else if chain.game-
Foods[0].gameFoodType == GameFoodType.run-
ningicon {
                // increment bro score
                chain.spriteScore2 = 1 *
(chain.length)
                chain.sugarLevel = -(1 *
(chain.length))
                comboMultiplier -= 1
                if comboMultiplier <= 1 {
                    comboMultiplier = 1
                }
            } else if chain.game-
Foods[0].gameFoodType == GameFoodType.medi-
tation {
                // increment tomato score
                chain.spriteScore3 = 1 *
(chain.length)
                chain.sugarLevel = -(1 *
(chain.length))
                comboMultiplier -= 1
                if comboMultiplier <= 1 {
                    comboMultiplier = 1
                }
            } else if chain.game-
Foods[0].gameFoodType == GameFoodType.hour
{
                // increment milk score
                chain.spriteScore4 = 1 *
(chain.length)
                chain.sugarLevel = -(1 *
(chain.length))
                comboMultiplier -= 1
                if comboMultiplier <= 1 {
                    comboMultiplier = 1
                }
            }


            /*
             //we need to subtract scrore
             chain.score = -(2 *
(chain.length - 2) * comboMultiplier)
             comboMultiplier -= 1
             if comboMultiplier <= 1 {
             comboMultiplier = 1

             // we need to increment scores
             chain.score = 2 *
(chain.length - 2) * comboMultiplier
             comboMultiplier += 1
             */

        }
    }

    func resetComboMultiplier() {
        comboMultiplier = 1
    }
}
```

LevelData.swift

```
import Foundation

class LevelData: Codable {
    let tiles: [[Int]]
    let targetScore: Int
    let moves: Int
    let targetSpriteScore1: Int
    let targetSpriteScore2: Int
    let targetSpriteScore3: Int
    let targetSpriteScore4: Int

    static func loadFrom(file filename:
String) -> LevelData? {
        var data: Data
        var levelData: LevelData?

        if let path = Bun-
dle.main.url(forResource: filename, withEx-
tension: "json") {
            do {
                data = try Data(contentsOf:
path)
            }
            catch {
                print("Could not load level
file: \(filename), error: \(error)")
                return nil
            }
            do {
                levelData = try
JSONDecoder().decode(LevelData.self, from:
data)
            }
            catch {
                print("Level file '\(file-
name)' is not valid JSON: \(error)")
                return nil
            }
        }
        return levelData
    }
}
```

GameFood.swift

```
import Foundation
import SpriteKit

// MARK: - GameFoodType
enum GameFoodType: Int {
    case unknown = 0, avo, runningicon,
meditation, hour, workingdesk, dounut,
smartphone

    var spriteName: String {
        let spriteNames = [
            "Avo",
            "Runningicon",
            "Meditation",
            "Hour",
            "Workingdesk",
            "Donut",
            "Smartphone"]

        return spriteNames[rawValue - 1]
    }

    /*
     // Will allow this when highlighted
images are available
    var highlightedSpriteName: String {
        return spriteName + "-Highlighted"
    }
     */

    static func random() -> GameFoodType {
```

```
        return GameFoodType(rawValue:
Int(arc4random_uniform(7)) + 1)!
    }

}

// MARK: - GameFood
class GameFood: CustomStringConvertible,
Hashable {

    var hashValue: Int {
        return row * 10 + column
    }

    static func ==(lhs: GameFood, rhs:
GameFood) -> Bool {
        return lhs.column == rhs.column &&
lhs.row == rhs.row

    }

    var description: String {
        return "type:\(gameFoodType)
square:(\(column),\(row))"
    }

    var column: Int
    var row: Int
    let gameFoodType: GameFoodType
    var sprite: SKSpriteNode?

    init(column: Int, row: Int, game-
FoodType: GameFoodType) {
        self.column = column
        self.row = row
        self.gameFoodType = gameFoodType

    }
}
```

Swap.swift

```
import Foundation

struct Swap: CustomStringConvertible, Hash-
able {
    let gameFoodA: GameFood
    let gameFoodB: GameFood

    var hashValue: Int {
        return gameFoodA.hashValue ^ game-
FoodB.hashValue
    }

    static func ==(lhs: Swap, rhs: Swap) ->
Bool {
        return (lhs.gameFoodA == rhs.game-
FoodA && lhs.gameFoodB == rhs.gameFoodB) ||
            (lhs.gameFoodB == rhs.gameFoodA
&& lhs.gameFoodA == rhs.gameFoodB)
    }

    init(gameFoodA: GameFood, gameFoodB:
GameFood) {
        self.gameFoodA = gameFoodA
        self.gameFoodB = gameFoodB
    }

    var description: String {
        return "swap \(gameFoodA) with
\(gameFoodB)"
    }
}
```

Chain.swift

```
import Foundation

class Chain: Hashable, CustomStringConvert-
ible {
    var gameFoods: [GameFood] = []

    var score = 0
    var sugarLevel = 0

    var spriteScore1 = 0
    var spriteScore2 = 0
    var spriteScore3 = 0
    var spriteScore4 = 0


    enum ChainType: CustomStringConvertible
{
        case horizontal
        case vertical

        var description: String {
            switch self {
            case .horizontal: return "Hori-
zontal"
            case .vertical: return "Verti-
cal"
            }
        }
    }

    var chainType: ChainType

    init(chainType: ChainType) {
        self.chainType = chainType
    }

    func add(gameFood: GameFood) {
        gameFoods.append(gameFood)
    }

    func firstGameFood() -> GameFood {
        return gameFoods[0]
    }

    func lastGameFood() -> GameFood {
        return gameFoods[gameFoods.count -
1]
    }

    var length: Int {
        return gameFoods.count
    }

    var description: String {
        return "type:\(chainType) game-
Foods:\(gameFoods)"
    }

    var hashValue: Int {
        return gameFoods.reduce (0) {
$0.hashValue ^ $1.hashValue }
    }

    static func ==(lhs: Chain, rhs: Chain)
-> Bool {
        return lhs.gameFoods == rhs.game-
Foods
    }
}
```

Array2D.swift

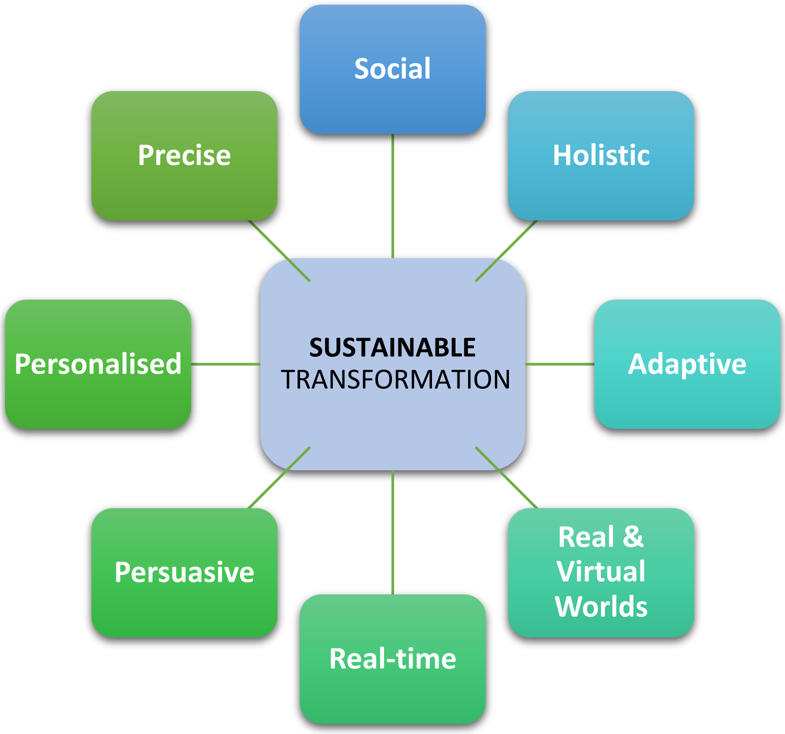
```
struct Array2D<T> {
    let columns: Int
    let rows: Int
    private var array: Array<T?>

    init(columns: Int, rows: Int) {
        self.columns = columns
        self.rows = rows
        array = Array<T?>(repeating: nil,
count: rows*columns)
    }

    subscript(column: Int, row: Int) -> T?
{
        get {
            return array[row*columns + col-
umn]
        }
        set {
            array[row*columns + column] =
newValue
        }
    }
}
```

C. Questionnaire for Sustainability Seminar

SSHARRPPP Principles

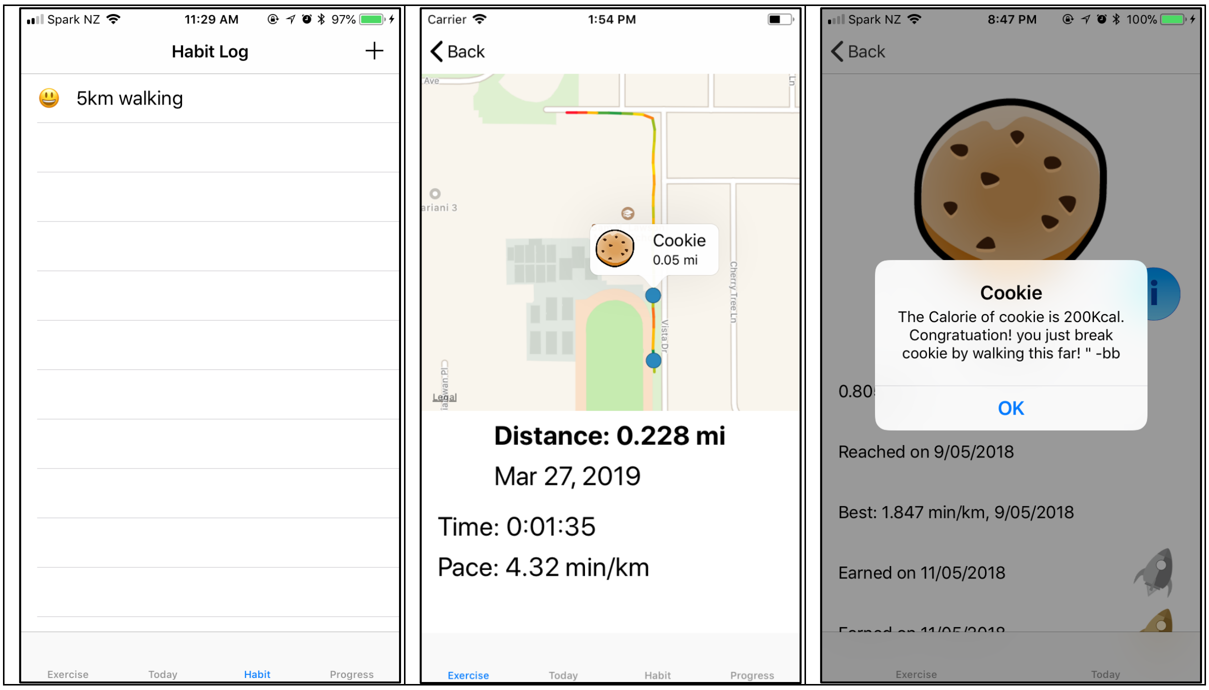


Would the **SSHARRPPP Principles** help individuals and families to transform their lives?

Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Agree**
Why?								

Is there any principle to add or remove? If any, please justify

SSHARRPPP Measurement



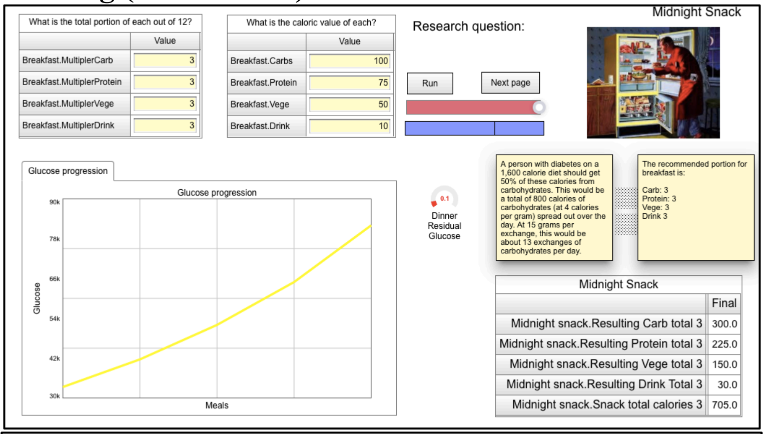
Would the configurable **SSHARRPPP Measurement Apps** essential for transformation of individuals and families?

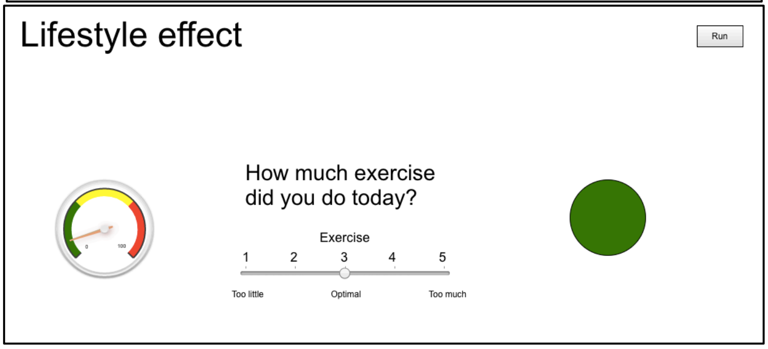
Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Agree**
Why?								

What is (are) the most useful measurement feature(s) to support sustainable transformation and why?

How can we improve it?

SSHARRPPP Modelling (Simulations)



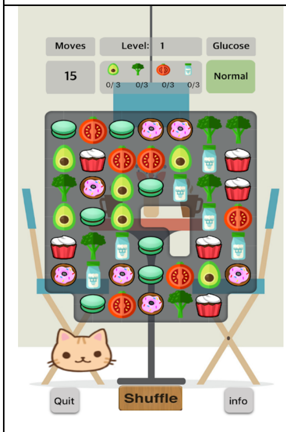
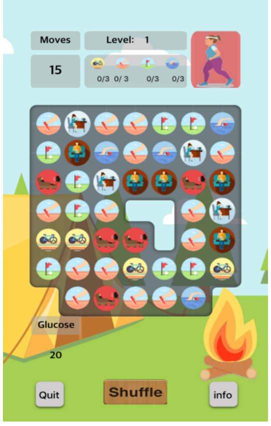
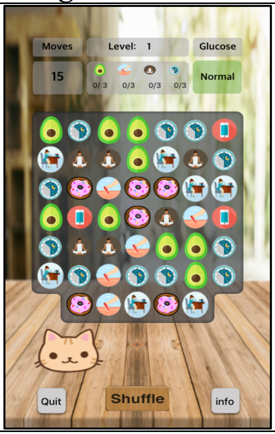


Would the **SSHARRPPP Modelling & Simulation** help individuals and families to learn and transform their lives?

Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Agree**
Why?								

How can we improve it?

SSHARRPPP Games

Diet World	Exercise World	Sleep World	Integrated world
			

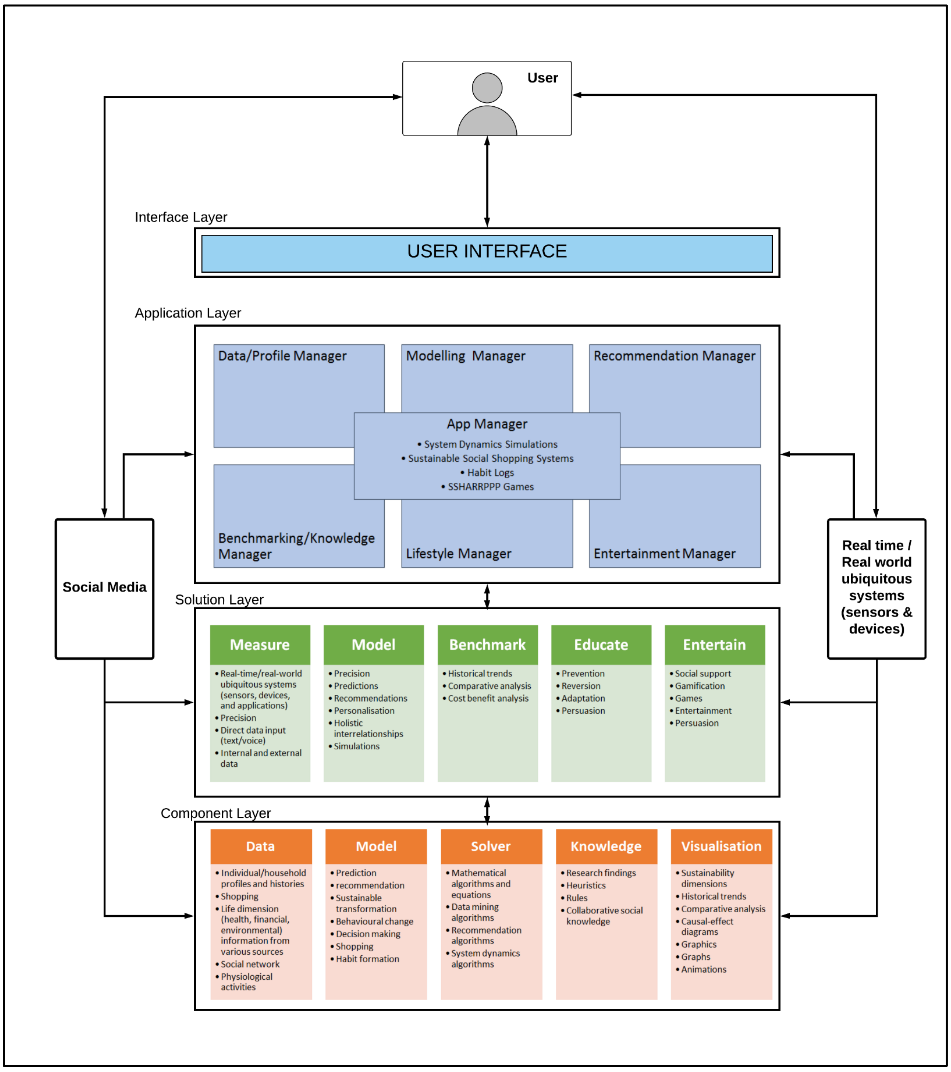
Would combining a popular game with **SSHARRPPP Principles** help individuals and families to persuade and transform their lives?

Disagree	1	2	3	4	5	6	7	Agree
Why?								

What is (are) the most useful feature(s) to support sustainable transformation and why?

How can we improve it?

SSHARRPPP Architecture



Does the **SSHARRPPP Architecture** effectively support SSHARRPPP principles?

Disagree	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Agree**
Why?								

Is there any element and/or interconnection to add or remove? If any, please comment.

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