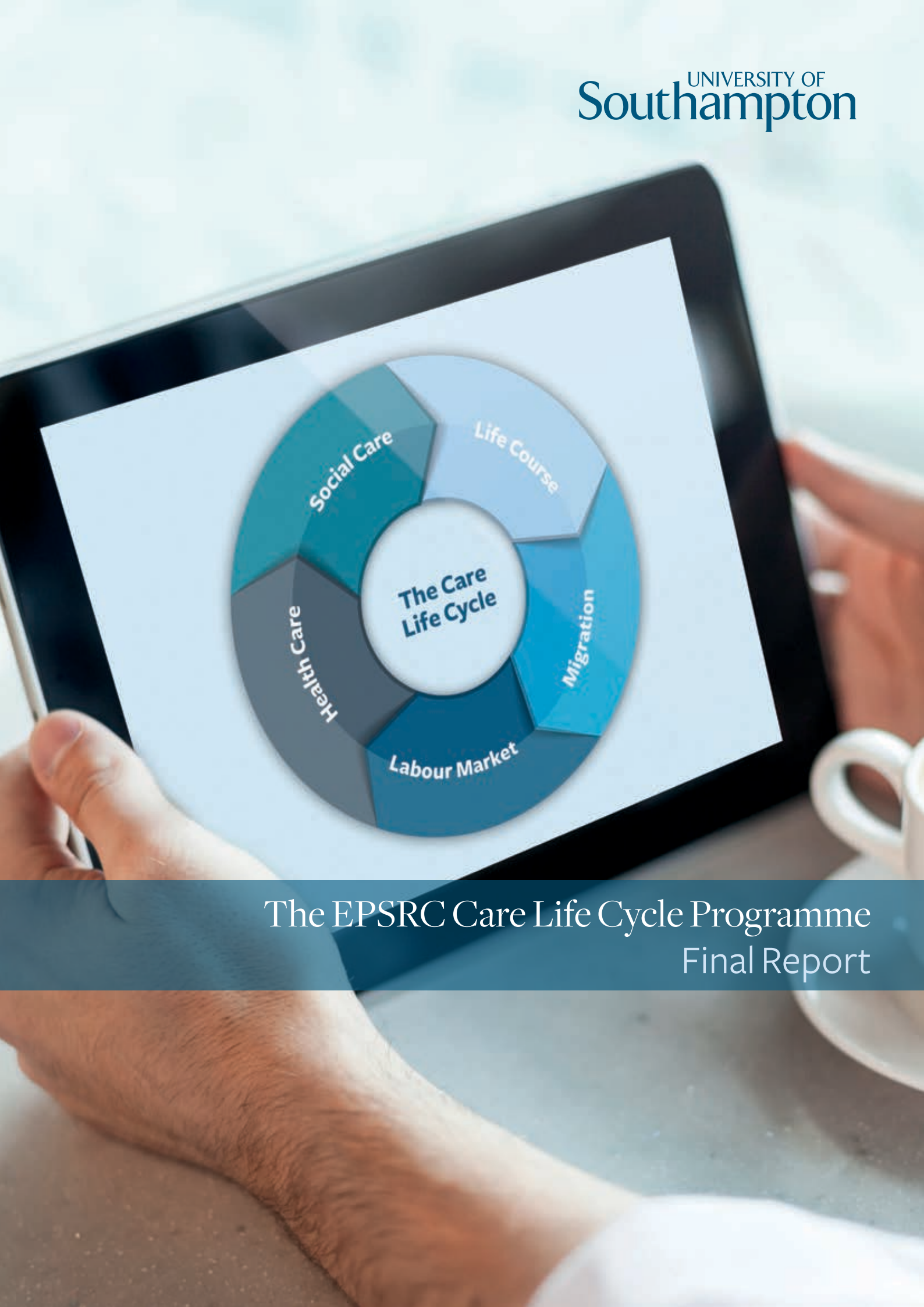
UNIVERSITY OF Southampton



The EPSRC Care Life Cycle Programme
Final Report

Foreword

One of the key demographic changes which is going to face all of us is living in an ageing society in the UK. How will the UK health and social care system cope? What impact will family, work, migration, past and present individual and collective decisions have on how we are cared for as we age?

At the University of Southampton, we have been developing a suite of models looking at how we better address the health and social care needs of an ageing society.

It's my pleasure to introduce this report on the Care Life Cycle Programme which illustrates one of the most exciting and innovative research programmes exploring the demographic challenges ahead.

Our ground-breaking work on modelling approaches can be linked to real world scenarios and practical outcomes, and will help to inform decision makers so that together we can ensure our ageing society is better prepared to meet the challenges ahead.

I would like to thank our funders the Engineering and Physical Sciences Research Council, our partners and our dedicated team for all of their hard work over the past five years.

Professor Jane Falkingham OBE, FAcSS
Principle Investigator, The EPSRC Care Life Cycle Programme

The EPSRC Care Life Cycle

In April 2010, the University of Southampton was awarded over £3 million by the EPSRC (Engineering and Physical Sciences Research Council) under its 'Complexity Science in the Real World' initiative. The purpose was to carry out a five year multidisciplinary research project on the "Care Life Cycle: Responding to the Health and Social Care Needs of an Ageing Society". This research programme brings together teams of researchers from social sciences (gerontology and demography), management science and complexity science to develop a suite of models representing the socio-economic and demographic processes and organisations involved in the UK's health and social care provision. Integral to the project is working with our partners in the public sector and communicating the results of these models to policymakers allowing them to effectively plan for the future.

Society's health and social care needs are determined by a complex set of interacting and interrelated factors, which together may be thought of as the Care Life Cycle (CLC). An individual's need for care is influenced both by their own health and resources as well as by their family circumstances and wider social networks.

Our research programme is split into 3 work streams:

1. **Care Drivers** – exploring the factors affecting the supply and demand for health and social care;
2. **Care Modelling** – developing a suite of models capturing the interactions of these factors;
3. **Care Policy Impact** – ensuring our models are developed in collaboration with stakeholders and policymakers to ensure impact in the real world.

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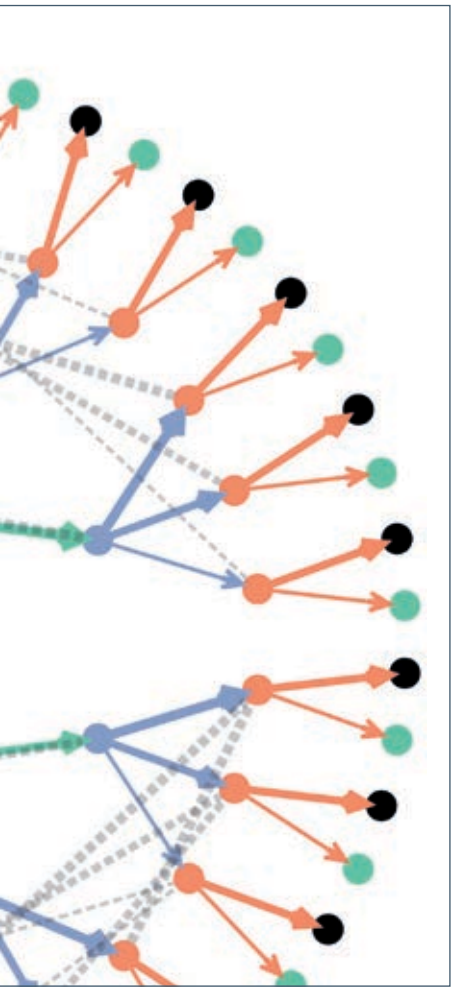

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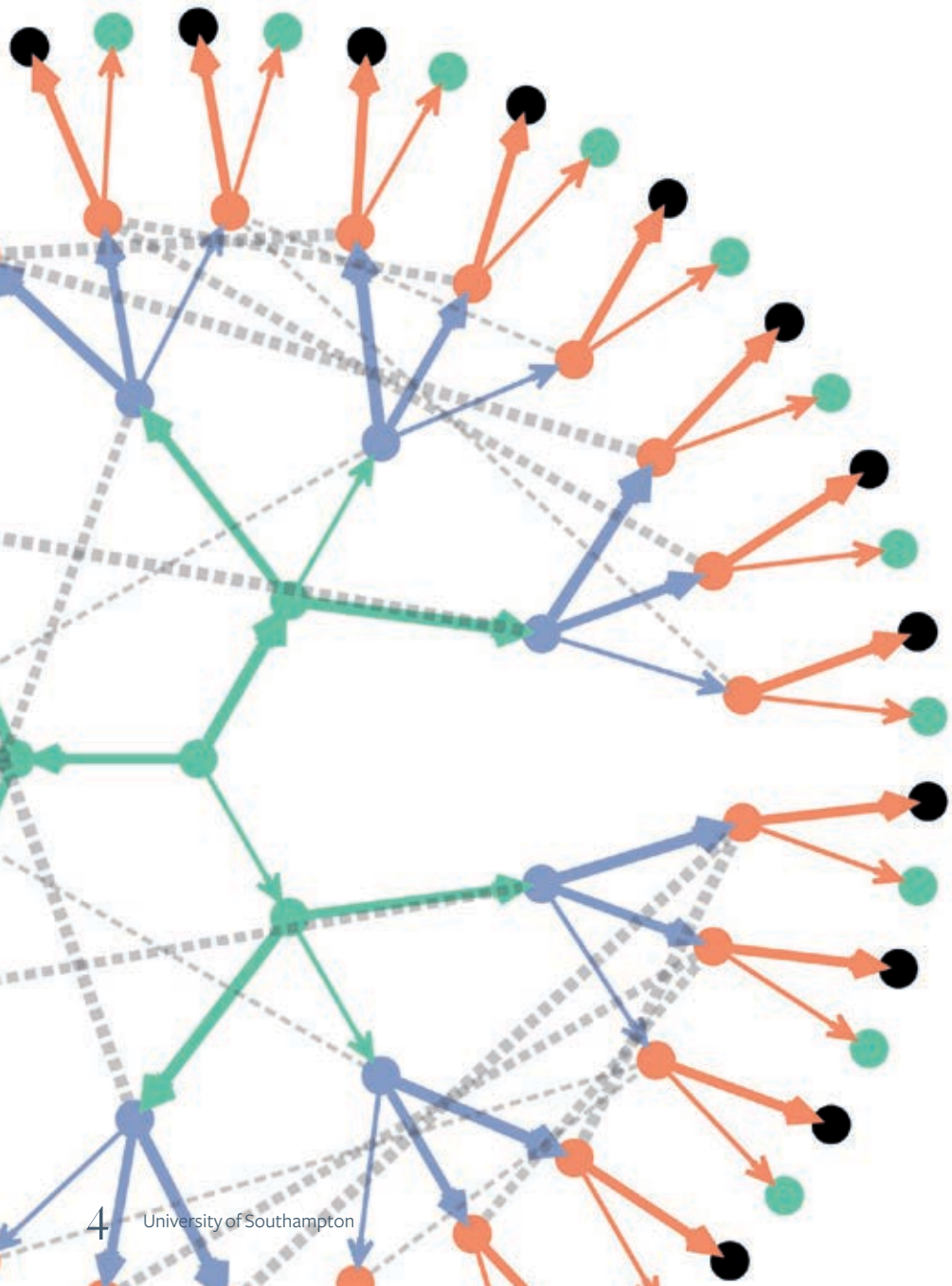
What Is Complexity Science?

In contrast to the twentieth century's huge success in reductionist research programmes epitomised by atomic, genetic and molecular science, this century will see an increasing focus on systemic science and engineering, targeting physical, biological, environmental, social, and technological systems and their interactions.



This move will help us to address questions of system function, organisation, management, stability, resilience, and evolvability.

The current surge in complexity science research is being driven by these pressing real-world challenges, by powerful new theory and modelling tools, and by the opportunity to exploit an unprecedented availability of computational capability and expertise.

Complex systems such as living cells, brains, financial markets, and ecosystems are made up of many interacting parts that together give rise to interesting system-wide 'emergent' behaviours that are hard to predict and explain.

Health care and social care services, and the populations of people that deliver them and make use of them, are important examples of policy-relevant complex systems. Their high-level properties, such as their overall stability, efficiency, and fairness arise from 'low-level', or micro, interactions between the individual people and services involved, in the context of constraints imposed by policies; by the availability of money and resources; and by the behavioural tendencies of people that need care. A complex systems approach allows us to explore how changes in the pattern of these interactions (such as the tendency of people to live near to their older relatives) can lead to changes at the level of the whole system (for example, the pattern of unmet need).

The complex interactions that underpin the behaviour of social systems such as these make them particularly challenging to understand. However, if we care about the cost of the NHS, or the impact of informal social care on the carers that deliver it, or, more generally, about the resilience of the health and social care systems that we all rely upon, then we will have to get much better at dealing with them.

The EPSRC Care Life Cycle in numbers

4 disciplines

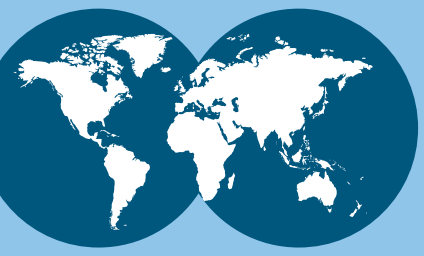
- Complexity
- Gerontology
- Demography
- Management Science

37 publications

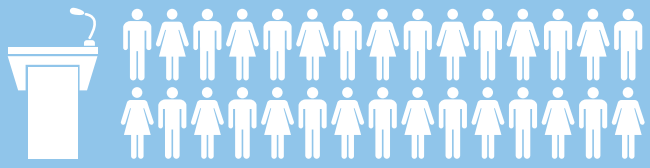
- Journal articles
- Book chapters
- Discussion papers
- Briefing papers
- Conference proceedings
- Book reviews

137 conference presentations by CLC team

across **18** countries



30 seminar speakers



8 international visitors

16 stakeholders

25 team members

5 affiliated student projects

6 international collaborators

A changing landscape. Understanding the drivers of health and social care

Overseen by theme leaders, Professor Jane Falkingham, Professor Maria Evandrou and Dr Athina Vlachantoni, research has focussed on understanding the factors influencing the demand for, and receipt, of social care in later life. Research projects have examined formal and informal care, including moves into sheltered and residential care as well as receipt of care services in the home and the characteristics associated with supplying informal care.

Understanding the need for social care

Health and disability have a major impact upon the individual's need for social care. Research using the English Longitudinal Study of Ageing (ELSA) investigated the key determinants of disability in later life, exploring the extent to which common epidemiological risk factors influence disability independently of pathologies, impairments and functional limitations. Risk factors associated with increased risk of disability included age, being male, heavy drinking, and being in the lowest decile of income. Other risk factors which initially had strong associations with disability, including wealth, education and smoking, were largely accounted for by pathologies, impairments and functional limitations. The research demonstrates that whilst aspects of physical functioning are the strongest determinants of disability, they are not synonymous with disability and other aspects of functioning and the social environment need to be considered.

Changes in the need for social care over time

The provision of state funded social care for older adults in the UK is driven by the concept of 'need', with individuals who have care requirements that surpass a certain threshold being eligible to receive care. A wide range of methods are used to ascertain need, but the ability to conduct simple Activities of Daily Living (ADL), such as bathing and dressing, is often used. However, little is known about how the abilities to conduct these activities change over time, alongside other factors that are associated with changes in care need. Using all five available waves of the English Longitudinal Survey (between 2002 and 2012) the need for social care amongst individuals over the age of 50 was calculated for each time period. ADLs were used to calculate need, which was divided into none, low, intermediate and high. Multistate life tables were then used to estimate the probabilities of transitions between care need states between survey waves, as well as between care need state and death. Life tables were calculated separately by gender, age groups and smoking status and combinations of these factors, providing new insights into the changing levels of need over time.

Measuring unmet need for social care amongst older people

Recent spending cuts in the area of adult social care have given rise to concerns regarding the proportion of older people whose need for social care is not being met. This research explored the concept of 'unmet need' for support in relation to specific Activities of Daily Living (ADLs) and Instrumental Activities of Daily Living (IADLs), using data on the receipt of support (informal, formal state or formal paid) from the General Household Survey, the English Longitudinal Study of Ageing and the British Household Panel Survey. The results show that different kinds of need tend to be supported by particular sources of care, and that there is a significant level of 'unmet need' for certain activities. The research highlights the importance of more precise data in order to effectively measure the level, and understand the nature, of unmet need for social care among older people. As local councils find themselves facing both expenditure cuts and reforms in their assessment and delivery procedures, evidence on unmet need is an essential element of the planning of their future provision.

"The increasing proportion of the population aged over 75 is placing greater pressure on formal and informal systems of care, while changes in living arrangements of older people and their adult children are affecting the supply of informal care. This research provides essential evidence for both improved policy making and informing the CLC models."

Professor Maria Evandrou, theme leader.

The determinants of receiving social care in later life in England

Research examined the relationship between demographic and socio-economic characteristics, and the receipt of support from different sources by older people who report difficulty with daily activities. The research outlines three key results with implications for the future organisation of social care for older people. Firstly, the number of IADLs an older person reports having difficulty with, followed by the number of ADLs, are the strongest determinants of receiving support from any source. Secondly, there are significant gender differences in the factors associated with receiving support from different sources; for example, physical health is a strong determinant of informal support receipt by men, while mental health status is a strong determinant of informal support receipt by women. Finally, the research shows that different kinds of impediments in everyday life are associated with receiving support from different sources. This 'link' between particular types of difficulties and support received from particular sources raises important questions about the way social care provision can or should be organised in the future.

Who cares? Informal caring in England and Wales, stability and transition between 2001 and 2011

Informal caring is of significant and increasing importance in the context of an ageing population, growing pressures on public finances, and increasing life expectancy at older ages. In 2001, for the first time, the United Kingdom Census enquired about provision of informal care, enabling identification of the prevalence of informal care giving at a national level. This research follows up informal carers from the 2001 Census to examine their characteristics and circumstances ten years later using a nationally representative 1% sample of linked Census data for England and Wales, the Office for National Statistics Longitudinal Study. Around a third of informal carers at the 2001 Census were providing care ten years later. Female carers in both 2001 and 2011 were concentrated in mid-life (aged 35 to 54 years) while male carers were concentrated in later life. Carers providing 50 hours or more informal care per week in 2001 were the most likely to be caring also in 2011. The results contribute to our understanding of a particular group of informal carers and provide a more nuanced picture of informal care provision at different stages of the life course.

Moves in residential and sheltered housing

In addition to examining social care, research also investigated factors associated with moves into sheltered and residential care amongst people aged 65 years old and over in England and Wales. Using data from the British Household Panel Survey (BHPS) between 1991 and 2008, the research highlighted significant differences in the factors associated with moving into sheltered and residential care, with transition into residential care being more prevalent at older ages and associated with being widowed and in poor health, whilst moves in sheltered housing occur earlier in old age and are not necessarily associated with poor health but may be part of retirement planning amongst those with the socio-economic resources to do so.

In modelling the future demand for long-term care housing and services, as well as knowing what influences the moves into such care, it is important to also know how long, on average, an older person might expect to spend in residential care. Further work by the team examined the relationship between transitions to residential and sheltered housing and mortality, allowing an assessment of the relationship of preceding moves to a heightened risk of dying. Results show that the mortality risk is highest for

those who have moved into residential housing during the previous 12 months. The results contribute to our understanding of the relationship between ill-health, socioeconomic status, living arrangements and housing transitions and the probability of dying. The study findings have implications for the estimation of older people's mortality risk according to the time they spend in different forms of long-term care accommodation, and can therefore inform the design of social policy in the area of long-term care.

Engaging with Stakeholders

CLC researchers successfully applied to take part in the Office for National Statistics (ONS) 'beta test' scheme to test newly linked 2011 Census data included in the ONS Longitudinal Study database. CLC researchers collaborated with staff from the Population Statistics Division and LS Development Team at the ONS to complete the research. Findings from this research have been presented at numerous UK and European conferences. In addition to academic conferences these have included:

- Conferences and workshops with other dataset users and stakeholders to discuss best practice and considerations in using the data (eg organised by the Centre for Longitudinal Study Information and User Support (CeLSIUS) at University College London)
- Attendance at conferences on use of Census data (eg 'Census Research User Conference' (2013/4); 'Census Applications: Using the UK's population census data' (2015); and discussion about the future of Census data (ONS Beyond 2011 Conference (2014))
- Meeting with Civil Servants to highlight the ability for such data to answer substantive research questions in Government Departments (eg Longitudinal Champions Meeting (2014))

Sharing our research

Research findings presented at UK conferences including:

- Society for Social Medicine in Warwick (2011)
- British Society of Population Studies in York (2011), Swansea (2013), Winchester (2014) and Leeds (2015)
- British Society of Gerontology conference in Plymouth (2011), Oxford (2013) and Newcastle (2015)
- Social Policy Association conference in Sheffield (2013)
- Complexity Science in the Real World Policy Conference at the Royal Society (2014)

They have also been presented to international audiences at

- Gerontological Society of America conferences in Boston (2011), San Diego (2012) and New Orleans (2013)
- European Population Conferences in Sweden (2012) and Hungary (2014)
- International Union for the Scientific Study of Population conference in Korea (2013)
- American Public Health Association Conference in New Orleans (2014)

CLC hosted a seminar by the Aston Research Centre for Healthy Ageing (ARCHA) and Dr Athina Vlachantoni was invited to present research in this area to the researchers within ARCHA.

We were also invited by the Centre for Workforce Intelligence (CfWI) to present our research at their Analysis and Modeller event in Woking in 2014.

The research has been published in a range of academic journals including *Maturitas; Journal of Epidemiology & Community Health; Ageing & Society; Population Trends and Advances in Life Course Research*. Two CLC Discussion paper's and a Briefing paper for a lay audience have also been produced.

Breaking new ground. Modelling health and social care

Overseen by theme leaders, Professors Sally Brailsford and Seth Bullock, this research focussed on developing a suite of models of health and social care on alternative scales using different simulation methods. These ranged from an agent based model of the British population, through to a microsimulation model of social care in England, a system dynamics model of Hampshire, and down to the detailed operation of a local eye clinic.

Social Care Model for England

The CLC team, led by Professors Jane Falkingham and Maria Evandrou, and in collaboration with Graham Stark (Possible Virtual Worlds) and Howard Reed (Landman Economics), are currently developing a microsimulation model which will simulate the costs and distributional effect of changes to the system for paying for social care in England and Wales, for up to 20 years into the future.

The model uses household data from the BHPS/Understanding Society, the Family Resources Survey, the Wealth and Assets survey and the English Longitudinal Study of Ageing (ELSA) and draws on the CLC research reported on pages 6–9 to inform the transition probabilities. The model includes a comprehensive modelling of care needs and the benefit system, explicitly modelling Housing Benefit, Universal Credit/ Family Credit, Income Tax, and NI and other benefits. An enhanced user interface allows users to change key parameters, facilitating exploration of the costs of providing social care under a range of alternative funding scenarios, including those put forward under the Dilnot Commission and subsequent revisions.

A whole-system model for social care in Hampshire

This model was developed in collaboration with the Adult Services Department at Hampshire County Council (HCC). Its aim was to help planners estimate future demand for social care in Hampshire.

Hampshire is a county of contrasts: while it contains many attractive retirement destinations, it also contains some areas of significant socio-economic deprivation. Planning for the future social care of the Hampshire population is therefore a challenging task.

This research uses a simulation modelling approach called System Dynamics to depict changing demand for social care across different categories of care receipt. Some people receive care from Hampshire County Council, whereas others may purchase private care and/or receive 'informal' care from family or neighbours.

People may receive care from a combination of these sources, while many people do not require care at all. In fact, many older people actually provide care rather than receive it.

System Dynamics does not model individual people, but represents the aggregate demand arising from the Hampshire population over time. The model uses a combination of historical data provided by Hampshire County Council, together with data from other sources including the English Longitudinal Study of Ageing and the Office of National Statistics, as well as data derived from other aspects of the CLC project. The model was run for a range of different assumptions and scenarios, to enable Hampshire to explore the consequences of different policy decisions and plan better for the future.

"Working with the University has helped us think differently about how we plan for the future by providing a quantifiable insight into the potential demand for social care services."

Kevin Andrews
Hampshire County Council

Engaging with Stakeholders

The University of Southampton has a long-standing relationship with Hampshire County Council, developed over the years through many collaborative MSc and PhD projects. The CLC project involved regular close contact with Hampshire staff. Other local authorities have expressed an interest in the model, including Wirral Borough Council and Southampton City Council. We have also presented this model to the Department of Health.

Sharing our research

CLC and HCC jointly presented the model to a number of local authorities and academic researchers at an Economic and Social Research Council Impact event at Local Government House in London, and it was selected as a Local Government Knowledge Navigator case study. The research was presented at events in the House of Lords and the Royal Society, as well as numerous academic conferences including the US Winter Simulation Conference. We also produced a Briefing Paper for a lay audience.

Linked Lives: an agent-based approach to modelling partnership and household formation

Over the past two decades there has been a growing recognition of the key contribution made to social care by the unpaid care provided by family, neighbours and friends. In 2001 5.9 million people were providing informal care; by 2011 this had increased to 6.5 million. Increases in the proportion of the population aged 75 and over in England and Wales, combined with continuing local authority budget cuts, means that the provision of unpaid care is, and is likely to remain, a key social policy issue.

The CLC team, led by Dr Jason Noble, has developed an agent-based model of the basic demographic processes that impact upon the supply of, and demand for, social care: namely mortality, fertility, health-status transitions, internal migration, and the formation and dissolution of partnerships and households. The Linked Lives agent-based model allows us to simulate the evolution of kinship networks, capturing how people's lives are connected in many different ways, for example, through being a grandparent, being a half-sibling, being a distant relative, being an ex-partner or a divorced parent. By linking the lives of the agents, we can investigate hypotheses in the social care landscape that are not representable in other modelling approaches.

For example, recent research within the Economic and Social Research Council Centre for Population Change suggests that the propensity of adult children to provide care to their parents in later life might be affected by the timing of parental divorce. If the propensity to care for someone when they are elderly is a function of whether they were a presence during your childhood, it is plausible that a biological parent who left very early in a child's life is less likely to be offered care than a step-parent who was in the household for all 18 years of childhood. The Linked Lives model allows us to build this type of assumption into the model, vary the divorce rate and look at its effect on the projected figures for demand for state-funded social care. In contrast to standard forecasting models, the Linked Lives model provides a tool for policy-oriented scenario generation, providing researchers and policymakers a way of asking creative "what if?" questions.

Sharing our research

The research findings from this project have been presented at national and international conferences including:

- Winter Simulation Conference in Berlin (2012), including publication of research paper in the Conference Proceedings
- World Congress on Social Simulation Conference in Taiwan (2012)
- 27th European Conference on Modelling and Simulation in Norway (2013), including publication of research paper in the Conference Proceedings
- British Society for Population Studies in Swansea (2013)

Seminars have been presented at Keele University and Oxford University.

This research has been shared with policy audiences at events at the Royal Society and House of Lords.

The Linked Lives computer code developed within this project has been used as a case study by researchers at the Max Planck Institute for Demographic Research in Germany, the resulting paper being presented at the Winter Simulation Conference in 2014.

A hybrid simulation model for age-related macular degeneration

This model was developed in collaboration with the Eye Unit at University Hospital Southampton. Its aim was to explore the connections between the health and social care systems.

Age-related macular degeneration (AMD) is a serious but fairly common eye condition which causes sight loss in older people. Until relatively recently AMD was incurable but a treatment is now available which requires monthly hospital outpatient visits. This, in combination with increasing patient numbers due to the ageing population, has placed great strain on hospital outpatient clinics.

The aim of this model was to explore the links between the efficient operation of such clinics and the consequences of sight loss in the older population in terms of future demand for social care. The model combines three different simulation modelling approaches to capture the different aspects of this complex relationship, which illustrates in microcosm much of the thinking behind the Care Life Cycle. The model, which depicts individual patients with AMD, uses a combination of real data collected from the Southampton Eye Unit, together with data from the English Longitudinal Study of Ageing and from the clinical literature.

"It has been interesting to see the model evolve and I hope in the long term it will help us improve clinic flow and our patients' experience. We see over 70,000 people a year in our clinics so critical analysis of our work patterns is essential to cope with this ever increasing demand."

Andrew Lotery
Professor of Ophthalmology,
University Hospital Southampton

Engaging with Stakeholders

It is impossible to develop models like this without direct collaboration with hospital staff. We worked closely with many Eye Unit staff: doctors, nurses and administrators. The key contact and 'champion' for this project was Professor Andrew Lotery, who was involved with the clinical trials for the AMD treatment. In addition we showed the model to (and received useful input from) representatives of the several eyesight charities: the Royal National Institute for the Blind, the Thomas Pocklington Trust and the Macular Society.

Sharing our research

The outputs from this project have been presented nationally at special stakeholder events at the House of Lords and the Royal Society, in addition to national and international academic conferences:

- Winter Simulation Conference in Phoenix (2011), Berlin (2012), Washington (2013) and Savannah (2014)
- annual European conference on Operational Research Applied to Health Services (2011–14)
- invited seminars in Singapore, Toronto and Melbourne as well as numerous UK universities

In return, we have hosted seminars from various relevant external organisations such as the RNIB and the commercial software vendors and consultants Saker Solutions. We also produced a Briefing Paper for a lay audience.

Uncertainty in complex demographic models

Complex models of human populations offer fantastic research possibilities, but their results come with errors. The methodological team led by Dr Jakub Bijak looked into possible ways of dealing with the resulting uncertainty in practice.

Why is uncertainty important?

The future of any social phenomenon is uncertain, and the underlying processes are complex. One of the key challenges for complex modelling of social systems is an assessment of various sources of uncertainty – ideally expressed in the language of probabilities. To analyse the uncertain landscape of model's responses to parameters and policy inputs, specific statistical tools are needed. The ultimate goal is to help the users of complex models make informed decisions under uncertainty.

Uncertainty in complex models

Drawing from the experience of the EPSRC-funded programme *Managing Uncertainty in Complex Models* (MUCM), the CLC team has applied some of the pioneering ideas developed by the MUCM community to demographic questions. Especially promising are the emulators or meta-models – statistical models of the complex models, which link simulation inputs and outputs. Emulators can be used to describe uncertainty, assess the sensitivity of the models to various inputs, and also to help align the model with observed data. In the CLC project, the methods have been successfully tested on two complex demographic models: of marriage formation, and of the care for older people.

Fundamental epistemological questions

The work on uncertainty in complex models is related to the fundamental question about how such models should be constructed – whether starting from hypotheses which are subsequently verified (top-down), or from meticulous observation of reality (bottom-up). The second way is much more challenging, but also offers greater promise with respect to reducing some of the uncertainty in complex modelling. How this could be done in practice is one of the most fascinating questions for future research that has been identified through the work of the CLC methodological team.

"To use complex models properly, we need to know their limits. Analysing and reporting the uncertainty of results is not only a matter of being honest – it also offers the users more information, which can be then used to make more robust decisions."

Dr Jakub Bijak
Theme leader

Engaging with Stakeholders

The CLC methodological team has co-organised, jointly with the ESRC Centre for Population Change and the Probabilistic Population Projection Group at the University of Washington, Seattle, a one-day workshop on the use of probabilistic forecasts, with focus on population applications. The meeting, held on 19 June 2014 at the Royal Statistical Society in London, was aimed at academic and user / practitioner audience.

The team has also organised a session 'Back to the Future: What can we predict, and how to do it?' at a policy conference *Models for Real World Policy*, at the Royal Society, London, on 25 April 2014.
We have also participated and presented at the Eurostat/UNECE Work Session on Demographic Projections in Rome, on 29–31 October 2013 – a biennial gathering, bringing together members of the official statistics community and academia working on population forecasting.

Changing thinking

In 2015, Jakub Bijak was presented the Allianz European Demographer Award, which honours "outstanding research in the field of population studies on demographic change in Europe".
The award was conferred for overall research achievements, which in Dr Bijak's case focused both on methodological and applied work on uncertainty in population sciences. The CLC work has featured prominently in the citation for the award, which was presented by the Chair of the award committee, Professor Francesco Billari, during the ceremony in Berlin on 18 March 2015.

Sharing our research

- **Academic publications:** Four articles in *Demographic Research*, *Journal of Artificial Societies and Social Simulations*, and *Revue Quetelet*, review in Population Studies and *Przegląd Statystyczny* (*Statistical Review*); several papers in conference proceedings from Winter Simulation Conference (WinterSim); International and European Conferences on Artificial Life (ALIFE and ECAL); and others. The CLC work on uncertainty in complex models will also feature in the edited volume *Agent-Based Modelling in Population Studies – Concepts, Methods, and Applications*, edited by J. van Bavel and A. Grow, forthcoming in spring 2016
- **Presentations:** During 2011–2014, the CLC methodological team has given 27 conference and seminar presentations – national, European and international – both at demographic and computer science gatherings
- **Briefing papers:** Two CLC briefing papers, on *Embracing Uncertainty in Complex Models of Social Care* (No. 5), and *New Methodology for Modelling Population Change* (No. 6)
- **Other:** Jason Hilton and Jakub Bijak posted two articles about agent-based modelling and managing uncertainty on the Demotrends blog https://demotrends.wordpress.com

Developing future specialists. PhD Projects

"Combining decision theory with computational social science enables models to capture some of the nuance and sophistication of human decision making."

PhD Supervisor

Jonathan Gray

Jonathan's project explores the nature of decision making in the context of health and social care: Should I let my family know that I need more care? Should I let my midwife know how much I drink? The primary purpose of his work is to explore how the formulation of the decision-making process and assumptions regarding how relevant information spreads through the population impacts on the decisions that people take. Jonathan's research employs agent based models (ABMs), where a population of interacting people are represented by a population of simple interacting software agents, but also uses decision theory, game theory and uncertainty analysis to provide a strong theoretical grounding for modelling the reasoning processes of individuals. His work shows that simple decision rules are sometimes capable of reproducing patterns of real world decision making reported in the literature. For example, the reticence that some women feel about revealing their drinking behaviour early on in their interactions with their midwife.

On the basis of his research, Jonathan was invited to be one of a team of instructors involved in delivering a 10-day course on agent-based modelling and simulation at the Max-Planck Institute for Demographic Research (MPIDR) in Rostock, Germany, a world-leading research centre for demographic modelling. He has given conference presentations at the International conference on Computational Social Science, the Agent Based Models in Population Studies Workshop, and the Student Conference on Complexity Science, and has a chapter accepted in a forthcoming volume on agent-based modelling in demography. His work was also featured alongside that of other scientists and artist Tessa Coe as part of a recent art exhibition: 'Engaging with Complexity'. Jonathan is supervised by Professor Seth Bullock and Dr Jakub Bijak.

"Statistical emulators allow us to systematically explore the behaviour of Agent-Based Models and to calibrate them against empirical data."

PhD Supervisor

Jason Hilton

Jason's research aims to demonstrate how existing techniques in the design and analysis of numerical simulations can be fruitfully applied in agent-based modelling for demography, exploring several possible applications, including the Easterlin hypothesis: does birth cohort size predict social and demographic trends? In particular, Jason's work shows how Gaussian process emulators (which can be used to statistically summarise a simulation model) can be helpful both in analysing more simplistic theoretical agent based models of population process, and for relating more empirically relevant simulations to observations of reality. His work provides an example of how a novel agent based model may be analysed and calibrated using these techniques, bridging between micro-level processes and macro-level patterns, in order to make a substantive contribution to demographic knowledge.

Jason was invited to take a three-month study leave at the Max-Planck Institute for Demographic Research (MPIDR) in Rostock, Germany. He was also one of a team of instructors involved in delivering a 10-day course on agent-based modelling and simulation at the MPIDR in 2014. He has given conference presentations at the CSRW Annual conference, the International Union for the Scientific Study of Population Conference, the Uncertainty in Computer Models Conference, the Student Conference on Complexity Science and the British Society for Population Studies. Jason is supervised by Dr Jakub Bijak and Professor Seth Bullock.

"The model will help determine whether this pilot scheme would be beneficial for patients across Dorset if it were rolled out on a larger scale."

PhD Supervisor

Katherine Penny

Katherine's project focused on telecare for patients with dementia. Her aim was to use simulation to model the capability of technology to enable such patients to live independently and remain in their own homes for longer. For example, if there is a risk that a patient might wander outside their house and get lost, a simple pressure mat by the front door can trigger an alarm to alert a carer or relative. Katherine worked with Dorset County Council to evaluate a pilot scheme for patients with mild dementia who have been recently discharged from hospital. The aim of this scheme was to use telecare for a short period until the patient had either settled back well, or clearly needed additional support such as residential care. Katherine's model depicted the 'pathways' of patients through this scheme and the various potential outcomes.

Katherine won a Gold Award for a poster on this work at Southampton's Postgraduate Research Showcase. She presented her research to a number of local stakeholders in Dorset and Hampshire including: the Wessex Health Innovation and Education Cluster Telecare Workshop; an Assistive Technology Market Place event at Poole's Centre for the Arts; and a national Telemedicine event at the Royal Society of Medicine in London. She has presented her work at the 2013 ORAHS conference in Turkey, and also gave an invited talk at a workshop in Stockholm hosted by the Swedish National Study on Ageing and Care. Katherine is supervised by Professors Sally Brailsford and Maria Evandrou.

"This research will contribute to a better understanding of decision-making about care amongst older people, their families, carers and formal care providers."

PhD Supervisor

Kathryn Wicks

The main focus of Kathryn's research is the examination of the negotiation process that takes place within families and with outside agencies such as local authorities, in relation to the social care support for older kin. The research has conducted in-depth interviews with older people, their families, carers, and formal agencies, to investigate the factors which affect negotiations within families regarding who decides who cares for older relatives; whether factors such as support networks, sense of duty, social capital, and possibility of inheritance, are relevant to family members when making decisions on behalf of older relatives; and how social care resources offered to older people by local authorities (such as Personal Budgets), meet their needs in comparison with other services.

Kathryn, who is supervised by Dr Athina Vlachantoni and Professor Maria Evandrou, has conducted her research in collaboration with AgeUK in Southampton. She has presented her research at the annual Complexity Science in the Real World Conference at Chicheley Hall in 2013 and at the British Society of Gerontology Annual Conference in 2014 where Kathryn was awarded the Stirling Prize for Best Student Poster.

"Your research will make a huge difference to old people like me – I am so pleased I can take part."

Research participant, aged 65–70

Affiliated Student Projects

Dave Evenden

Dave Evenden's PhD project began just as the CLC programme was drawing to a close, but was inspired by the CLC and is closely linked to it. Funded jointly by the University's Vice Chancellor's Award scheme and the Wessex Academic Health Science Network, this multidisciplinary PhD brings together Operational Research, health services research and public health. Wessex covers Hampshire, Dorset, the Isle of Wight and part of Wiltshire. Dave's project is entitled 'New Models for Dementia' and will involve the development of hybrid simulation models with a geospatial element. The model will map the evolution over time and space of the Wessex population with dementia, and will enable policy makers in Wessex to design optimal delivery of services for these patients. Dave is jointly supervised by Sally Brailsford (CORMSIS/CLC), Bronagh Walsh (Health Sciences) and Paul Roderick (Medicine): Paul leads the University's Strategic Research Group in Population Health.

Emma Nelson

What drives people to have only one, or even no children? This question has plagued researchers since fertility rates began to decline across Europe as early as the 1950s. Yet theory that has not been grounded in evidence remains and thus only anecdotal explanations are offered. The aim of Emma Nelson's undergraduate study was to use novel computational techniques to implement highly regarded theory in an empirically grounded simulation. By investigating theory in this way, one can evaluate the hypotheses and determine which should be applied within a given cultural context. Once the mechanisms behind the cause of a phenomenon are understood, nuanced policy interventions can be devised. A large part of the study was explorative, focusing on the question of "how do we study demography?", and discussing the practicalities of implementing new computational methods within the demographic arsenal. Emma is now continuing onto postgraduate study.

Rui Nicola

Rui Nicola is a part-time PhD student in the Centre for Research on Ageing, funded as part of the University of Southampton institutional contribution to the CLC project. In collaboration with a team at the University of Portugal and with his supervisors, Professors Maria Evandrou, Jane Falkingham and Asghar Zaidi, Rui is developing DYNAPOR, a dynamic microsimulation model of the Portuguese population, to investigate the longer term distributional impact of changes in the Portuguese pension system. DYNAPOR uses the Portuguese component of EU-SILC for base dataset and then dynamically ages the individuals through time. Results from the model will inform the debate around pension reform and the equity and efficiency of alternative options.

Yajie (Maggie) Nie

As a linked PhD student, funded as part of the University of Southampton institutional contribution to the CLC project, Yajie (Maggie) Nie has been developing a model of long-term care (LTC) for older people in China. Jointly supervised by Professors Sally Brailsford and Maria Evandrou, her discrete event simulation (DES) model allows users to explore the balance between alternative LTC services, (informal care, institutional care, home-based social services, private and voluntary care) in the face of a growing demand for such care. With a rapidly increasing number of older people and dramatic changes in family structures as a result of the one child policy being in place for over a generation, this model will provide a timely contribution to the evidence base for China's policy makers as they debate how to meet the challenge of the globe's largest ageing society.

Greg Payne

Greg Payne's PhD research interests lie in the interaction of social policy and health. In order to maintain solvency of the state pension system in the face of rapid population ageing, the UK State Pension Age is rising. Jointly funded by the Office for National Statistics and the Economic and Social Research Council, and supervised by Professor Jane Falkingham and Dr Athina Vlachantoni, Greg's research models an individual's ability to work up to and beyond an increasing state pension age. Investigation is conducted primarily through computational simulation methods, namely Microsimulation Modelling and Agent Based Modelling. These methods allow results to be projected into the future, assessing not only current, but also possible future impacts of policy. This research will give improved insight into the link between employment, retirement and health, as well as identify the possible 'winners' and 'losers' across society of this policy change.

Capacity Building / Training

Short training courses

- The CLC project co-organised, jointly with the Max Planck Institute for Demographic Research (MPIDR) and Vienna Institute for Demography, a two-week course on Agent-based Modelling and Simulation, hosted by the MPIDR in Rostock, Germany, 20–30 October 2014. The course featured lectures and computer labs by CLC members: Jakub Bijak, Jonathan Gray and Jason Hilton. The CLC project also funded a bursary for attending the course, which went to a University of Southampton BSc Population and Geography student, Emma Nelson (see p18 for details on Emma's research).
- Jakub Bijak (CLC) gave a guest lecture on the design of computer experiments during the short course on the Introduction to Agent-Based Computational Modelling in Population Studies, Catholic University of Leuven, Belgium, 1–5 June 2015.
- CLC members will also contribute to a course and a workshop on Stochastic Process Approaches to Agent-Based Modelling and Simulation, which will be hosted by the Max Planck Institute for Demographic Research in Rostock, 19–30 October 2015.

Thematic workshops organised

- Workshop on modelling migration; organised on behalf of the Complexity Science in the Real World (CSRW) network, Chilworth Manor, 16 February 2012.
- Workshop 'The decision to emigrate: Agent-based modelling of international migration', organised jointly with the Max Planck Institute for Demographic Research, and held in Rostock 25–27 September 2013.
- Workshop 'The use of probabilistic forecasts, with focus on population applications', organised together with the ESRC Centre for Population Change and the Probabilistic Population Projection Group at the University of Washington, Seattle. Royal Statistical Society, London, 19 June 2014.

International Collaboration

The CLC members have been actively involved in building a vibrant international community of scholars working on computational modelling in demography. The project team has contributed three papers to a milestone workshop on 'Recent Developments and Future Directions in Agent-Based Modelling in Population Studies', organised by the Catholic University of Leuven on 18–19 September 2014. The workshop brought together the leading computational population modellers from Europe and North America. Dr Jakub Bijak is also a founding member of the International Union for the Scientific Study of Populations (IUSSP) Scientific Panel on Microsimulation and Agent-Based Modelling in Demography, led by Professor Frans Willekens from the Max Planck Institute for Demographic Research in Rostock (MPIDR).

Complexity and methodology of demography

The methodological strand of the CLC has involved close collaboration with Professor Daniel Courgeau, emeritus, Institut national d'études démographiques (INED), and Professor Robert Franck emeritus, Université Catholique de Louvain. Together, we have looked at the epistemological questions surrounding agent-based modelling in demography against the broader background of the evolution of scientific thinking and the changing paradigms of demography. The collaboration has yielded two journal articles and four international conference presentations, with more still to come.

Agent-based migration models

Together with the MPIDR team from Rostock, we have been exploring the links between various simulation-based approaches, with special focus on modelling international migration. The CLC has hosted three seminars by the MPIDR team, given by Professor Frans Willekens (on multistate survival analysis), Dr Sabine Zinn (on a multi-level approach in demography) and Dr Anna Klabunde (on life course-based agent-based decision model of migration). A project team member, Jason Hilton, has spent three months in Rostock on study leave, working on agent-based models of migration.

Meta-modelling

The CLC has begun collaboration with the Division of Decision Analysis and Support (DDAS), Warsaw School of Economics, focused on the area of meta-modelling. We have fostered a seminar exchange, where the head of the DDAS, Dr Bogumił Kamiński, gave a talk in Southampton on hypothesis verification for simulation models, and Dr Jakub Bijak (CLC) gave a seminar in Warsaw on the work of the methodological strand (see p. 15). We have also started exploring the EU research funding opportunities through the Horizon 2020 programme.

"A successful cooperation generates new ideas and perspectives. The cooperation with Jakub Bijak and his team in the CLC project has been highly successful. We addressed a fundamental question: How can agent-based modelling create insight in demographic processes and population change?"

Professor Frans Willekens
Max Planck Institute for Demographic Research (MPIDR)

International Visitors' Programme

The following key international experts spent time working with the CLC team, providing invaluable expert advice and guidance:

- Professor Mike Carter, University of Toronto, Canada
- Dr Heather Booth, Australian National University, Australia
- Dr Nic Geard, University of Melbourne, Australia
- Professor Mi Young An, Kookmin University, South Korea
- Professor Michael Wolfson, University of Ottawa, Canada
- Professor Ann Harding, National Centre for Social and Economic Modelling in Australia, Australia
- Lisa Brouwers, Swedish Institute for Infectious Disease Control and Marten Lagergren, Stockholm Gerontology Research Centre

"Our collaboration permitted us to better understand the challenges raised by agent-based models and to try to find some answers to them, even if they are not definite. We should now follow the classical scientific programme, and propose an original way to infer necessary principles from the systematic observation of demographic facts"

Professor Daniel Courgeau
emeritus, Institut national d'études démographiques (INED)

Outreach / Knowledge Exchange

How to get to 100 and enjoy it

We were delighted to support the Centre for Population Change in its UK tour of this unique exhibition exploring the impact of ageing on society.

The exhibition applied interactive technology to showcase cutting edge research to a lay audience. Games, quizzes, interviews and easy to understand texts were used to raise awareness of issues around care, age related illness and intergenerational solidarity.

CLC supported the development of dynamic infographic videos displaying local area statistics which reached over 5,000 visitors in seven UK cities. Comparing local and national demographics, the videos situated each location in a UK context and provided insight into visitors' own lives and neighbourhoods.

The exhibition concluded with CLC Director, Professor Jane Falkingham, giving a series of interviews on BBC Breakfast's live finale of their 'Living Longer' series. Professor Falkingham commented: "We were so pleased that the BBC chose this exhibition to highlight the pressing issues which are starting to arise from people living longer and our ageing society." She added: "Touring the exhibition around the UK has shown us that the public are truly interested in and keen to engage with questions and ideas surrounding population change and what it means for our collective future."

Engaging with policy makers

Central to the CLC research programme has been engaging with policy audiences to help inform the development of social policy in the context of an ageing population.

In April 2014, CLC researchers contributed to a 'Models for Real World Policy' conference held at the Royal Society London. Attended by over 100 policy professionals the event considered how policy making processes can benefit from new tools and thinking emerging from the study of complex social systems. The conference included presentations by Professor Jane Falkingham on research underway within CLC and Professor Bernard Silverman, the Chief Scientific Advisor to the Home Office.

At a Parliamentary reception in the House of Lords, CLC joined with The International Longevity Centre (ILC-UK) to present CLC research to an audience of policy makers, academics and politicians. Two case studies were presented during the event in April 2013. The first examining the demand for local authority social care services, and the second understanding the complex interaction between health and social care using the example of macular degeneration treatment.

Baroness Greengross, Chief Executive of ILC-UK and the host for the event, said:

"If we are to improve health and care in an ageing society we need to ensure that policy makers are informed and working from a strong evidence base. High quality independent academic research plays an important role in both the design and evaluation of effective policy and practice. ILC-UK was delighted to join forces with the University of Southampton to highlight new research that supports and can contribute to meeting the challenge of an ageing population."

> "If we are to improve health and care in an ageing society we need to ensure that policy makers are informed and working from a strong evidence base."
>
> Baroness Greengross
> Chief Executive of ILC-UK

Collaborating Research Centres

This research programme brought together research teams from four of the University's leading international research centres.

Centre for Operational Research, Management Sciences and Information (CORMSIS)

CORMSIS, the University of Southampton's Centre for Operational Research, Management Science and Information Systems, is one of the largest such groups in the UK. It was founded in the mid 1990s although Southampton's expertise in OR/MS dates back to the 1970s. The Centre covers the whole spectrum of current OR/MS/IS from theoretical mathematical developments to problem structuring and knowledge management, and has internationally-renowned expertise in the specific areas of risk, optimisation, finance and health. CORMSIS spans three disciplines (the Business School, Mathematics and Health Sciences) and contains 35 academic staff and over 50 PhD students and post-docs. Five of the academic staff hold joint appointments between Business and Mathematics. Two of the Health Sciences staff belong to Methodological hub of the Wessex CLAHRC (Collaboration for Leadership in Applied Health Research & Care), a £10m NIHR grant in which OR modelling plays a key role.

Centre for Population Change (CPC)

The ESRC Centre for Population Change was established in January 2009. Based jointly at the Universities of Southampton, St. Andrews, Edinburgh, Strathclyde and Stirling, in partnership with the National Records of Scotland and the Office for National Statistics, we aim to improve the understanding of the key drivers and implications of population change.

Our communities are being shaped and re-shaped at unprecedented speed. Changing patterns of migration, fertility, family and household dynamics and ageing all interact to create our society. Understanding the extent, drivers and implications of these changes is essential to develop appropriate policy responses at the national, regional and local level – ranging from provision of services for school children through to the design of pension schemes for today's increasingly mobile population. CPC is undertaking a series of research projects using methods ranging from in-depth qualitative studies, to enable us to discover more about underlying individual demographic behaviour, through to complex statistical and economic modelling.

Centre for Research on Ageing (CRA)

The Centre for Research on Ageing is an international and multi-disciplinary research centre examining key issues in ageing and the lifecourse, informing policy and debate at the national and local level. Through its high quality research, the Centre contributes to a better understanding of the experience of ageing amongst different groups and societies, which will in turn place us in a better strategic position to improve the quality of life of older people. Research in the Centre combines qualitative and quantitative approaches, with a wide range of areas of expertise including: ageing in developing and transitional societies; diversity in later life and ethnic minority ageing; gender and pension reform; income, pensions and inequality; health and social care; paid work and informal caring; retirement prospects of future generations of elders; and social networks and informal support. In addition to research, the Centre contributes to capacity building of future academics and professionals by teaching different postgraduate programmes in Gerontology.

Institute for Complex Systems Simulation (ICSS)

The Institute for Complex Systems Simulation (ICSS) provides a stimulating home for interdisciplinary research that combines complex systems ideas and tools with computational methods to address challenges within key application domains spanning climate, pharma, biosciences, nanoscience, medical and chemical systems, transport, the environment, engineering and computing.

Launched in 2009 the £12m ICSS undertakes world-class simulation and modelling research and runs a flagship doctoral training programme in Complex Systems Simulation. We have recruited over 100 PhD candidates across a broad range of disciplines relating to complexity science. Our PhD students graduate as specialists in their fields, able to analyse, innovate and exploit complex systems models and methodologies to move beyond the current state of the art.

Team Members

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Care Life Cycle Programme

www.southampton.ac.uk/clc

Centre for Operational Research, Management Sciences and Information Systems (CORMSIS)

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Centre for Population Change (CPC)

www.cpc.ac.uk

Centre for Research on Ageing (CRA)

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