

Addressing public health and security challenges with system dynamics: selected papers from the ninth European system dynamics workshop, at National University of Ireland Galway

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Guest Editorial

Addressing Public Health and Security Challenges with System Dynamics

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Guest Editorial

Addressing Public Health and Security Challenges with System Dynamics

Selected papers from the Ninth European System Dynamics Workshop, at National University of Ireland Galway

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INTRODUCTION

This special issue contains papers which use the System Dynamics approach (SD). We are able to be Guest Editors for this issue due to the largesse of the Editor-in-chief, Mike Jackson. Mike is due to stand down from that role in the near future and has revealed to us that in his valedictory editorial he will comment on how the last decade or two has seen a significant increase in the submission of SD paper to this journal. It was not always so.

SD is now six decades old (Forrester, 1958; 1961; 1968) but it draws on older concepts of servo-mechanism theory, digital computing and aircraft simulators. These were then brought together and used to highly practical ends by Jay W. Forrester (Lane, 2007; 2010). SD emerged from a rather different route than most other parts of the Systems Sciences, for a long period being distinctly separate from other approaches and from MS/OR (Lane, 1994). However, the intellectual linkages are carefully laid out by Richardson (1991) and explored in other papers. We are pleased to continue the intermingling of SD and System Science, the locating of the former within the universe of the later.

The papers here derive from the most recent of the 'European System Dynamics Workshop' (EuSDW) series. These are bi-annual workshops which focus on a topic of interest to European (broadly-defined) system dynamicists. In 2019 one was held at National University of Ireland Galway. The papers here are drawn from talks given in Galway last year. They share an interest in using SD to model phenomena broadly related to Public Health and Security.

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THE EUSDW WORKSHOP SERIES

The Galway meeting joins a well-established series. We now think of the very first European System Dynamics Workshop as the event hosted by Peter Milling and Andreas Größler in Mannheim in March 2003. So far the following EuSDWs have taken place:

| Date | Location | Theme |
|-------------|---------------------------------------------------|-----------------------------------------------------------------------------------------------------------|
| 2003 | Universität Mannheim, Germany | Rationality in System Dynamics: Modelling Human and Organizational Decision Making |
| 2005 | Radboud Universiteit Nijmegen, The Netherlands | System Dynamics in Organizational Consultation: Modelling for Intervening in Organizations |
| 2007 | University of St. Gallen, Switzerland | Theory Building with System Dynamics |
| 2009 | Università degli Studi di Palermo, Italy | Public Sector Applications of the System Dynamics Approach |
| 2011 | Frankfurt School of Finance & Management, Germany | Developing Sustainable Strategies with System Dynamics |
| 2013 | Koç Üniversitesi, Istanbul, Turkey | Health, Demographic Change, and Well-being: The European Union's Horizon 2020 Program and System dynamics |
| 2015 | Universitetet i Bergen, Norway | Natural Resource Management: Contributions of System Dynamics to Research, Policy and Implementation |
| 2017 | Universidade NOVA de Lisboa, Portugal | Modelling Sustainability Pathways: Bridging science, policy and society |
| 2019 | National University of Ireland Galway, Ireland | Addressing Public Health and Security Challenges with System Dynamics |

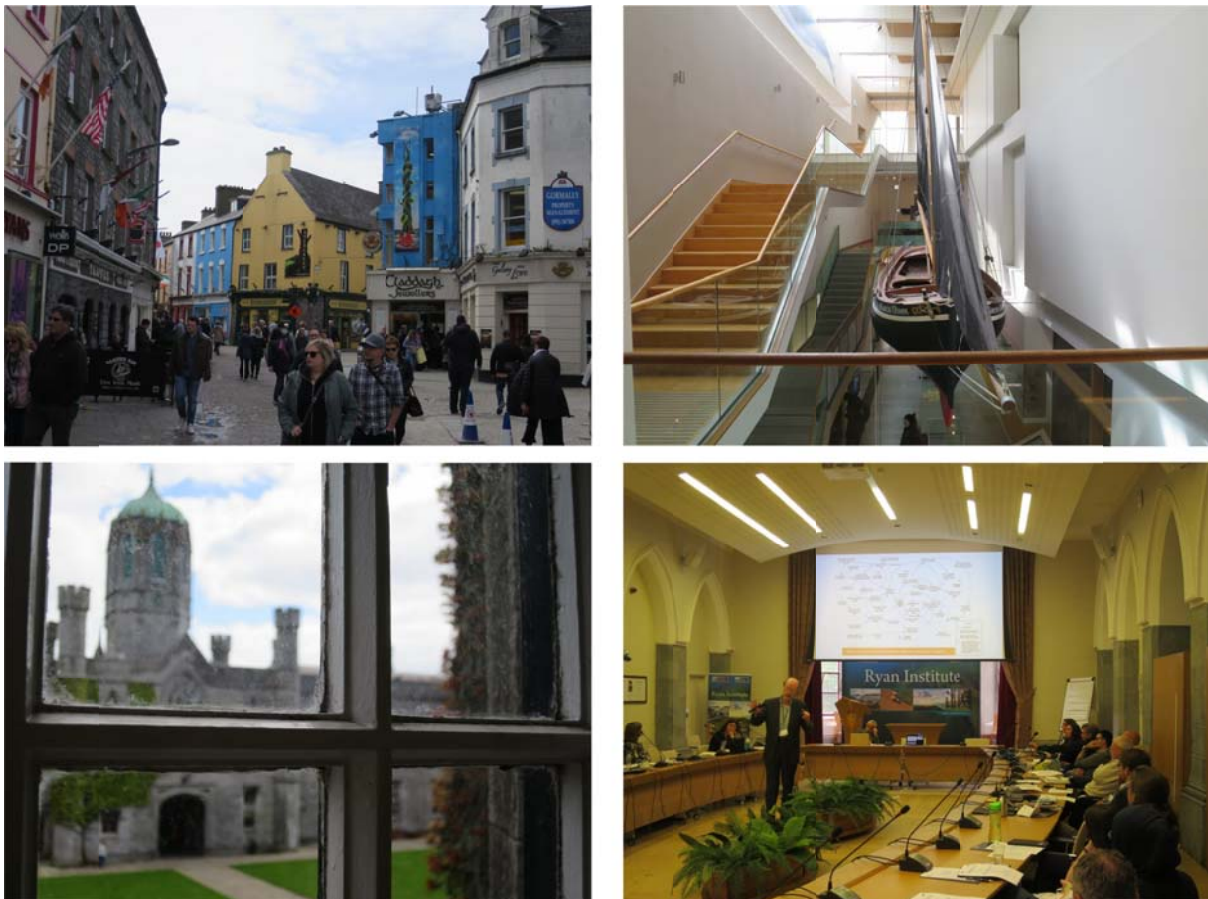
Each of these nine workshops has resulted in a special issue. References to these previous publications are listed at the end of this Guest Editorial, using the citations Lane *et al.* (2004; 2006; 2008; 2010; 2012; 2015; 2017; 2019).

That first workshop launched the reliable and effective approach used in all subsequent meetings. We are very grateful to our hosts in Mannheim 17 years ago and are pleased to follow the path that they created.

A WORKSHOP IN GALWAY – CRAIC WITH A MATHEMATICAL ‘OR’

Galway – *The City of the Tribes* – is located in the West of Ireland, along the River Corrib, which connects Lough Corrib to Galway Bay. The city grew from a fort named Dún Gaillimhe, constructed by the King of Connacht in 1124. During the Middle Ages it was governed by 14 merchant families, with trade links to Spain and France. Galway (population circa 80,000) is widely recognised as a vibrant and cosmopolitan city steeped in culture, rich in folklore and famous for its cobble-stoned streets, quaint shops and charming restaurants. Its international recognitions include: its 2014 designation as a UNESCO City Of Film, one of only eight film cities in the world to achieve this much sought-after status; and for 2020, Galway is the European Capital of Culture. Galway has a spectacular scenic hinterland, including Connemara, with the majestic Twelve Bens mountain range, with peaks that offer panoramic view of the Connemara countryside, as far as the Atlantic Ocean. Connemara is also famous as being the landing location, in June 1919, of Alcock and Brown’s aircraft, following their sixteen hour flight from St. John’s, Newfoundland, the first non-stop aerial crossing of the Atlantic Ocean.

Galway is a beautiful, lovely and welcoming place which wears lightly its rich history and culture (see Figs. 1 & 2).



Figures 1: A Galway workshop (clockwise from top left): a convivial city; a húicéir (Galway hooker) in the Músaem Cathrach na Gaillimh (Galway City Museum); workshop session in full flow in the ‘Aula Maxima’; view of the Quadrangle building. (All photographs are by DCL and are available in colour online.)

The National University of Ireland Galway (NUI Galway) was established in 1845, and opened as Queen's College Galway on 30th October 1849, with a cohort of 68 students. The University was one of three Queen's Colleges, the others located in Cork and Belfast. The original Quadrangle, situated close to the banks of the River Corrib, was built in local limestone in a Tudor Gothic architectural style, and modelled on Christ Church at the University of Oxford. Renamed University College Galway (UCG) in 1908 following the passing of the Irish Universities Act, it was subsequently renamed as NUI Galway as part of the Universities Act in 1997. NUI Galway, with a campus community of over 21,000 students and staff, is counted among the Top 300 universities in the world according to the most prestigious rankings, is a research-led university with a breadth and depth of teaching and research across the sciences, social sciences and humanities, delivered through four Colleges, 19 Schools, five Research Institutes and a range of research centres and clusters.



Figures 2. Workshop scenes from EuSDW-IX. LHS: the NUI Galway campus and the River Corrib. RHS: the workshop dinner showing (top) continuing discussions and (bottom) the view of Galway Bay (All photographs are by DCL and are available in colour online.) For more images from the workshop see Kopainsky (2020).

Across all disciplines, NUI Galway has had memorable moments over its 175 year history. A selection of highlights, from science and engineering, include the following: George Johnston Stoney, Professor of Physics (1852-1857), who coined the term “electron”; Michael O’Shaughnessy, and engineering graduate of 1884, who went on to become Chief Engineer of the city of San Francisco, and oversaw construction of the world famous Golden Gate Bridge; and Alice Perry, who in 1906

became the first female engineering graduate in Europe. From an arts perspective highlights include: Irish actor Siobhán McKenna graduated in Arts in 1943; Lord of the Rings author JRR Tolkien acted as external examiner from 1949-1954; in 1975 graduates Garry Hynes, Marie Mullen and Mick Lally founded the Druid Theatre (Tony Award winner in 1996); and the Galway Arts Festival was founded by the UCG Arts Society and locals arts groups in 1978. In terms of graduates with significant contributions to society, both national and international, include: Michael D. Higgins, President of Ireland, former student and lecturer who left the University to enter politics in 1977, and Dr. Michael Ryan, Executive Director of the World Health Organisation's Emergencies Programme, who graduated with a degree in Medicine from UCG in 1988.

The workshop was hosted by the Ryan Institute - NUI Galway's largest research institute – which is drawn from all four Colleges across NUI Galway. The Martin Ryan Institute was one of the most significant examples of university philanthropy in Ireland, following a significant donation by the late Dr Tony Ryan, founder of Guinness Peat Aviation and Ryanair, in the name of his father, Martin Ryan. The Ryan Institute focuses on four thematic research areas, namely (1) Marine & Coastal, (2) Energy & Climate Change, (3) Agriculture & BioEconomy, and (4) Environment & Health. The Ryan Institute is comprised of 12 research clusters spanning these four themes, and the *Modelling and Informatics Cluster* – led by Jim Duggan - explores interdisciplinary applications of modelling and machine learning approaches to these areas.

The workshop registered a total of 32 participants. The evening before the formal start, all were invited to a reception in the Músaem Cathrach na Gaillimh (Galway City Museum) on Spanish Parade. For this enjoyable event attendees were greeted by PhD student Gilles Dupouy playing the Irish harp and, amongst other exhibits, were able to view an example of a húicéir (Galway hooker), a type of traditional fishing boat widely used on the West coast of Ireland (see Figs. 1).

Formal sessions started the next day and were held over a day and a half, on May 2nd- 3rd, 2019. These took place in the impressive 'Aula Maxima' in 'the Quadrangle' (See Figs. 1). As stated earlier, the Quadrangle was based on the buildings that surround Tom Quad of Christ Church, Oxford, including Tom Tower designed by Christopher Wren. In a happy resonance, Christ Church is where workshop series organisers David Lane and Elke Husemann first met. It is notable, however, that whilst Tom Quad was never fully completed, its Irish counterpart has no such quirk, sporting, for example, an elegant covered cloister.

The workshop was opened by Prof Ciarán Ó hÓgartaigh, the President of NUI Galway, who graciously welcomed the participants and spoke warmly of the international range of interests hosted at the university and which he saw reflected in the workshop itself.

The Galway workshop used the general model of the series. Invited authors first gave a talk on their research project or topic, these having been invited on the basis that they contributed to the broader theme of the workshop, their papers having been circulated to invitees some weeks previously. A designated Discussant then responded with remarks to critique, support, or add further perspective. In open session, all participants then posed questions and contributed comments. A total of eight talk-pairs, across four sessions were presented in this way. The workshop included contributions by Paulo Gonçalves, Yaman Barlas, Andreas Größler, Els Van Daalen, Kim Warren, Birgit Kopainsky, Florian Kapmeier, Gönenç Yücel, Jim Duggan, Inge Bleijenbergh, Nicole Zimmermann, Erik Pruyt, Carmine Bianchi, Erling Moxnes, and David Lane. Étienne Rouwette gave his paper from The Netherlands over the internet, a portent of the strange world that COVID-19 has now imposed on us as we complete this special issue (October 2020).

The first full day featured sessions on ‘Health Supply Networks and Security Challenges’ and ‘Public Health Challenges.’ A brief pause allowed a group photograph (see Kopainsky, 2020). In tune with the workshop organizers’ wish to refresh and play variants on the core structure, a new element was introduced for the conclusion of the first day: ‘5 Talks, 5 Slides, 5 Minutes’. In this interactive one-hour session of five rapid talks on emerging system dynamics research across a range of public health, sustainability and security themes, Caroline Brennan, Merla Kubli, Martina Curran, Anaely Aguiar and Jair Andrade rose to the challenge of having the workshop include in its discussions work in progress.

An evening meal on Thursday May 2nd took place at O’Grady’s on the Pier, an award-winning restaurant situated at the gateway to Connemara, in Barna village on the outskirts of Galway City. This allowed further discussions, illuminated by the exquisite views of Galway Bay, and the limestone hills of *The Burren*, a region located in northwestern County Clare (See Figs. 2)

Further talks made for a busy second day, with sessions on ‘Behavioural Models and Facilitated Modelling’ and ‘SD Challenges and Linking with other Fields’. Local host Jim Duggan closed the formal proceedings by thanking all attendees for their contribution. A response was provided by Birgit Kopainsky, at that time the incoming President of the System Dynamics Society, who thanked the organisers for creating a superb event.

Lunch followed but the Irish interest in Craic – a variant on the Scottish and English word ‘crack’, meaning fun, discussion, or any enjoyable activity – held firm, with many participants taking part in a biodiversity walking tour of the lovely area around the University (see Kopainsky, 2020).

Participants left Galway with fond memories of flowing water, fascinating history, the sound of voices raised in enjoyment or intellectual engagement (the ‘or’ is a mathematical one), the beauty of the country of Ireland and the generous welcome that they had experienced.

Each workshops in the series is created to have specific aims as an event in itself. However, here we can make available some of the themes and topics discussed at EuSDW-IX. These pieces were developed further, partly in response to discussion in Galway but also deriving from the journal’s refereeing processes. To record a sense of the interplay of ideas at the workshop and to offer readers different perspectives on the papers, we also make space for papers by the respective workshop ‘discussants’. Finally, a whole new feature is short pieces that capture some of the ‘5 Talks, 5 Slides, 5 Minutes’ sessions.

PUBLIC HEALTH AND SECURITY CHALLENGES

The theme of the 2019 EuSDW was “Addressing Public Health and Security Challenges with System Dynamics”. The SD approach is well suited to address the dynamic complexity that characterises many aspects of public health , and has been applied to a wide range of healthcare problems, including the prevalence of major diseases (infectious and noninfectious), and the performance of healthcare delivery systems . With the area of security, the impact of the SD method can also be observed through studies such as flood security and water resource security , as a means to facilitate resilience planning for food security in rural communities with ever-increasing climatic pressures, as an exploratory method to investigate modern counter-insurgency theory, and as a means to generate and explore plausible dynamics of radicalization under deep uncertainty . The opportunities for SD within these areas are evident through an emerging field of practice termed *public health emergency management* (PHEM), , which draws on specific sets of knowledge,

techniques, and organizing principles necessary for the effective management of complex health events, including: the design of policies, plans, procedures, and partnerships; systems for surveillance and control; best practice for crisis and emergency risk communication; optimal use of facilities, management, and operations; and support systems for training, exercising, and evaluation. The workshop's public health and security perspective was also informed from continuing research at NUI Galway that addresses public health challenges through dynamic modelling and data science methods. This research is informed by interdisciplinary teams involving public health experts, and technical expertise in SD, data science and software design. To date, research outputs from these collaborations include: a systematic review of how digital data sources, and specifically sources available on the internet, have impacted the field of public health surveillance; a systematic review of to examine the effectiveness of currently available mobile health (mHealth) technology tools in reducing suicide-specific outcomes (Melia *et al.*, 2018; Melia *et al.*, 2020); designing robust time series and machine learning models to integrate search query and unemployment data for suicide risk forecasting in Ireland; exploring how social media disease mentions in airport and hospital geolocations expose dominance of news events for disease concerns ; and, the design of a mobile app to facilitate service users' access to mental health support and safety planning .

The integrated theme of public health and security was further informed through NUI Galway's role in the project titled *Pandemic Risk and Emergency Management (PANDEM)* project, funded through the EU Horizon 2020 Secure Societies programme of research and innovation, whose purpose was to identify viable innovative concepts to strengthen capacity building for pandemic risk management in the EU. A pandemic is defined as an epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people . The PANDEM project was coordinated by NUI Galway, with partners including the World Health Organisation (WHO) Regional Office for Europe, the London School of Tropical Medicine and Hygiene, Swedish Defence Research Agency, Public Health Agency of Sweden, and Université catholique de Louvain and IGS Strategic Communications. Following the outbreak of the COVID-19 pandemic in early 2020, two NUI Galway members of the PANDEM team, Prof Jim Duggan and Prof Maire Connolly, were invited onto the *COVID-19 Irish Epidemiological Modelling Advisory Group (IEMAG)*, which reports in an advisory capacity into Ireland's National Public Health Emergency Team (NPHE). A key objective of IEMAG is to expand mathematical modelling capacity using a range of modelling and statistical methods (including system dynamics), and to develop and deliver epidemiological models of outbreak dynamics, healthcare capacity, demand and resourcing models, in order to inform operational and policy decision making on how best to respond to COVID-19.

The PANDEM project deployed a range of methodologies (systematic reviews, expert-led workshops, SD modelling, rapid prototyping software development), and as its final output, recommended that the European Commission should move on to a larger phase II research project to further develop innovative solutions across three key pillars of public health and infectious disease preparedness and response, namely: (1) *Governance, Planning and Communications* – through advance planning and community engagement to build trust and societal resilience; (2) *Situational Awareness and Decision Support* – with state of the art surveillance, detection and prediction tools, based on system dynamics and machine learning approaches, to support effective decision-making; and (3) *Workforce Capacity, Training and Networking* – relying on enhanced knowledge-sharing and immersive multi-sectoral learning, cross-sectoral simulation exercises and networking to maximise operational preparedness and response. Convinced by the project outputs, the European Commission launched

a follow-on major funding call in August 2019, SU-DRS05-2019: *Demonstration of novel concepts for the management of pandemic crises*, with an award value of €10M, to generate demonstrations in support of cross-border emergency approaches to strengthen preparedness and response to pandemics. A new 20-partner consortium (PANDEM-2), led by NUI Galway, was a successful applicant in this project call, and research work will start in early 2021 on a new integrated project that has a number of key work areas, including (1) Surveillance, (2) Situational Awareness, (3) Pandemic Planning, (4) Pandemic Communications, and (5) Demonstration, Training and Networking.

In summary, based on the wider perspective of SD research in the areas of public health and security, and on the public health focus of research in NUI Galway, the overall workshop objective was to explore how SD can be used to help strengthen and secure public health and security systems, and to better protect communities from naturally occurring and human-caused threats.

CONTENTS OF THE SPECIAL ISSUE

A range of pieces relating to the workshop's main topic are presented in this special issue. Whilst the core is the Research Papers, each of these has a Discussant's Comment which aims to add to the coverage of the topic. We also have a new element. The special issue therefore proceeds as follows:

1. The issue opens with four short pieces reporting work that was still in development at the time of the workshop: Caroline Brennan and Owen Molloy on a pilot study which used SD to communicate sustainability issues to the public; Merla Kubli describes the use of conjoint analysis to reduce uncertainty in energy consumer modelling; Martina Curran, Enda Howley and Jim Duggan outline visualisation experiments with students dealing with stock/flow effects; and Anaely Aguiar explores the contribution that systematic reviews can make to work in the area of SD.
2. These are followed by a Research Paper by Andreas Größler. Using a simulation example he contributes to the ideas of system resilience and anti-fragility. The Discussant's Comments by Els van Daalen explore further the application to supply chains of Größler's ideas.
3. The second paper is by Birgit Kopainsky. She considers how an understanding of the interaction of agriculture, the environment, and human health can be used to support diets in Switzerland which are both healthy and sustainable. Florian Kapmeier's Discussant's Comments probe further into the meat of these issues.
4. The third Research Paper comes from Mert Edali and Gönenç Yücel. They show how a random forest meta-model approach can be used to construct SD models, illustrating this with a flu epidemic model. In his Discussant's Comments Jim Duggan explores further this use of using machine learning.
5. An Afterword by Birgit Kopainsky – the current President of the System Dynamics Society - provides some personal reflections on (and further photographs from) the 2019 meeting itself and comments on the importance of such events for scholarly communication.

As guest editors we hope that this collection will be of interest to researchers and practitioners in System Dynamics, Systems Science, sustainability science, OR/MS, and all others interested in understanding complex dynamic systems and in tackling problems in the real world.

ACKNOWLEDGEMENTS

In our role as Guest Editors we would like to offer our thanks to everyone who made this special edition possible:-

All those who organised the 2019 EuSDW-IX workshop and who ensured that it ran so well, in particular Jim Duggan, Suzanne Nolan (Ryan Institute), Mary Gannon (Ryan Institute) and Tina Earls (School of Computer Science).

Funding support from the Ryan Institute, and the School of Computer Science.

The referees for this special edition. When finding anonymous referees the Guest Editors drew on the global communities of systems scientists, operational researchers and system dynamicists; their contribution to the issue was vital.

Lesley Fitton of the Department of Greek and Roman Antiquities, and Janet Larkin of the Department of Coin and Medals, both of the British Museum, London, who provided the image from which the symbol used for the workshop series was derived. The owl is taken from the reverse side of a silver *tetradrachm* made in Athens around 480 BC. CM 1906-11-3-2591. Copyright British Museum, London. The symbol for the series of European System Dynamics Workshops was created by David Lane.

Finally, Amanda Gregory and Mike Jackson for inviting us to guest edit this special issue – but also for their steadfast support for the European System Dynamics workshops.

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