Institution:
University of Cambridge

Unit of Assessment:
UoA15

Title of case study:
Supporting the development of public policy and company strategy through generalised technology roadmapping

1. Summary of the impact (indicative maximum 100 words)

Research undertaken at the University of Cambridge Department of Engineering (DoEng) since 1998 on strategic technology management resulted in a principled and generalised method of creating roadmaps for technology and innovation management. This research was developed into a complete toolkit through case studies and consulting by the DoEng's wholly-owned subsidiary Institute for Manufacturing Education and Consulting Services Ltd (IfM ECS). Organisations in 26 countries commissioned over 115 consulting projects during 2008-13, benefiting through improved business performance and practices, the adoption of new technologies or processes and the better alignment of technology strategies with policy and commercial imperatives. IfM ECS's revenue from consulting, publications and events based on the research findings was GBP 3,479,758 in the period.

2. Underpinning research (indicative maximum 500 words)

David Probert (Lecturer, University of Cambridge Department of Engineering (DoEng), 1994-2000, Senior Lecturer to 2004, then Reader in Technology Management) led the underpinning research throughout, supported by a small team from 1998, when he appointed Dr Robert Phaal and Clare Farrukh as Senior Research Associates. Phaal became a Principal Research Associate with full Principal Investigator (PI) status in 2010. Dr Clive Kerr joined the team as a Research Associate in 2004.

As PI for an EPSRC grant [a] on "Strategic technology management – linking technology resources to company objectives" (1998-2001), Probert studied the use of technology roadmapping in industry to support strategic planning and to help companies survive in turbulent environments. The team's research highlighted a key gap in the existing literature – a robust generalised process for technology roadmapping – and proposed methods for filling this gap using innovative techniques designed in collaboration with industry co-sponsors. [1]

Approximately GBP500k of further funding for this research was provided by the EPSRC Innovative Manufacturing Research Centre and Cambridge Manufacturing and Technology Centre Grants (2001-12) [b] and [c] for which Professor Sir Mike Gregory (joined DoEng 1976, appointed Professor 1994) was the PI and Probert was a Co-Investigator. The DoEng team's distinctive contribution was to create robust generalised approaches and well-founded agile and practical methods, and to explore how these could be applied to integrated strategic technology management in industry. The key steps in the research, and the insights and findings leading to impact, were:

- firstly, Probert and his team defined the principles by which technology roadmapping could be configured for particular strategic contexts – e.g. sector, technology type & maturity, firm size, strategic decision types – and used these to derive a general-purpose framework for roadmapping as a platform for strategic technology and innovation management [1,2]
- secondly, they designed efficient and effective facilitation techniques for the rapid application of roadmapping, applicable at all scales (from SMEs to corporations and entire industrial sectors), based around large-scale workshops with multifunctional and multi-organisation participation [3,4]
- thirdly, they generated a deeper understanding of the nature of technology management tools (in terms of structure, visual format and integration), in order to support their design, configuration, combination and application within integrated practical toolsets. [5]

Through these steps, the research elucidated how the structured graphical representation provided by roadmaps draws together a range of theoretical perspectives – including strategy and innovation, system and industry dynamics, visual science (particularly for managing cognitive load

in collaborative environments), decision support and psychosocial processes – and acts as a platform for practically integrating tools and techniques for strategy development into a single customisable toolkit.

Using action research methodology, the team tested the theory and underlying concepts of their generalised roadmapping approach in applications including support for new product and service strategy development, business and corporate strategy development, sector-level foresight and exploitation strategies for emerging and disruptive technologies. These activities helped to evaluate the practical applicability of the underpinning research, and to develop pathways for dissemination and direct impact, as described in section 4.

3. References to the research (indicative maximum of six references)

*[1] Phaal, R., Farrukh, C.J.P. & Probert, D.R. (2004), 'Technology roadmapping – a planning framework for evolution and revolution', Technological Forecasting & Social Change, 71(1-2), pp. 5-26. DOI: 10.1016/S0040-1625(03)00072-6

[2] Phaal, R., Farrukh, C.J.P. & Probert, D.R. (2004), 'Customizing roadmapping', Research Technology Management, 47(2), pp. 26-37. DOI: 10.1109/EMR.2004.25111

[3] Phaal, R., Farrukh, C.J.P. & Probert, D.R. (2007), 'Strategic roadmapping: a workshop-based approach for identifying and exploring innovation issues and opportunities', Engineering Management Journal, 19(1), pp. 16-24. www.asem.org

*[4] Kerr, C., Phaal, R. & Probert, D.R. (2012), 'Cogitate, articulate, communicate: the psychosocial reality of technology roadmapping and roadmaps', R&D Management, 42(1), pp. 1-13. DOI 10.1111/j.1467-9310.2011.00658.x

*[5] Phaal, R., Farrukh, C.J.P. & Probert, D.R. (2006), 'Technology management tools: concept, development and application', Technovation, 26(3), pp. 336-344. DOI: 10.1016/j.technovation.2005.02.001

Grants:

[a] EPSRC GR/L62900, 'Strategic technology management – linking technology resources to company objectives' (1998-2001) with D. Probert as PI: GBP272k+60k company contributions http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=GR/L62900/01

[b] EPSRC GR/R64919/01, Cambridge Manufacturing and Technology Centre (2001-06) with M. Gregory as PI and [c] EPSRC EP/E001769/1, Innovative Manufacturing Research Centre (IMRC) (2006-12) with M. Gregory as PI: relevant projects (Investigator D. Probert) 'Business appraisal of technology potentials', 2004-06, GBP250k+50k company contributions; 'Marketing technology – a process guide to making the business case', 2006-08, GBP96k+41k company contributions; 'Technology-based emerging industries – managing creation and transitions', 2009-12, GBP173k http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=GR/R64919/01 and http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/E001769/1

* Research outputs that best represent the quality of the research.

4. Details of the impact (indicative maximum 750 words)

The DoEng's wholly-owned subsidiary, IfM ECS, has been the main vehicle for dissemination of the research results to industry, through publication, training and consultancy. In the period from January 2008 to July 2013, IfM ECS has used the research results to:

- undertake **more than 115 consulting projects** both in the UK and in 26 countries around the world, for organisations such as: AkzoNobel, AstraZeneca, BAE Systems, BASF, BOC Linde, BP, BT, Caterpillar, GE Healthcare, Henkel, Mars, PPG, Proton, Rolls Royce, Royal Mail, Rexam, Sulzer, Syngenta, Unilever, and the UK government (Department for Transport, Ministry of Defence and Technology Strategy Board [TSB])
- run **training courses for over 350 delegates** from the public and private sectors in 24 countries (all the courses being led by Phaal, supported by other researchers)
- publish the second of two **books on roadmapping techniques** (co-authored by Phaal, Farrukh and Probert), to disseminate the research-based findings to practitioners who can then apply the techniques within their own organisations; versions have already been produced that are tailored for Japanese, German and Brazilian markets.[6]

The main impact of the research, realised through these dissemination activities, has accrued in terms of the improved business performance, changed practices, and the adoption of new or changed technologies or processes in the companies and public sector organisations which have benefited directly from consultancy and training drawing on this research. The details of the construction and benefits of strategic roadmaps in major organisations are nearly always kept confidential because such work is inevitably commercially sensitive, but the following examples illustrate the benefits gained by organisations and the scale of decisions influenced:

- In 2012 the roadmapping methodologies were used to run workshops for 70 participants representing key interest groups across synthetic biology. The roadmapping considered the entire synthetic biology landscape, covering key trends and drivers that could affect outcomes at various stages. Drawing upon this work, '*A synthetic biology roadmap for the UK'* was published in July 2012. The Chairman of the UK Synthetic Biology Roadmap Coordination Group, commented: "*The roadmapping workshops were valuable to us in many ways. They enabled the effective sharing of understanding across the constituent biological, engineering and social science disciplines, demonstrating the value of pooling multidisciplinary expertise. They illustrated the breadth of issues that must be addressed now to ensure the benefits to the UK envisaged from this sector can be delivered in the short and long term. Furthermore, they enabled us to take important first steps in establishing an enthusiastically engaged community aligned behind a shared vision of the future. The UK is now well placed to develop synthetic biology towards its goal of becoming a GBP 1bn industry, delivering important benefits in key areas such as medicine, renewables and underpinning technologies.*"[7] The roadmap was cited by Rt Hon David Willetts as the basis for government policy and investment strategy in January 2013, when he announced a GBP160m investment "*to support implementation of key recommendations from the UK Synthetic Biology roadmap, including establishing multidisciplinary research centres as well as a seed fund to support start-up companies.*"[8]

- In 2009 IfM ECS used the strategic roadmapping approach with BAE Systems (the global defence, aerospace & security company with annual sales of GBP17.8bn and a UK workforce of 33,000) to support the development of its UK-wide skills programme. Over 50 structured interviews and an external review of the skills market fed into a roadmapping event attended by 30 senior leaders from across the business; the findings provided the basis of the company's 'Skills 2020' strategy, launched in 2010. Follow-up work in 2013 will include applying the roadmapping approach to strategic workforce planning, a key element of the Skills 2020 recommendations. The Education Director and Head of Early Career Programmes, commented: "*Skills 2020 is a co-ordinated skills and education programme which touches every part of our UK business and on which we spend GBP79 million annually. The findings from IfM's strategic road mapping exercise directly informed our strategy for attracting, developing and retaining the flexible and customer-oriented workforce that we and other UK manufacturers need in this critically important decade.*"[9]

- In 2011-12 IfM ECS used the roadmapping approach with the TSB to support the development of its High Value Manufacturing Catapult strategy (creating technology & innovation centres where the UK's businesses, scientists and engineers can collaborate to generate economic growth) through workshops with a wide range of government, industrial and academic collaborators. The framework informed the roll-out of the Catapult strategy which represents sustained public funding of GBP140m over 6 years with the aim of transforming the UK's innovation capability. The approach was also applied to a number of sector 'deep dives' (including the pharmaceutical and biopharmaceutical sectors), and the terminologies and themes identified are becoming a 'common currency' across TSB, BIS and EPSRC in the building of manufacturing strategy. The Lead Technologist at TSB commented: "*The output from the study was very significant in establishing the TSB HVM Catapult strategy, and provides the framework for an additional GBP25m/year investment by the TSB in economic growth through funded innovation projects in manufacturing.*"[10]

- In 2009/10 IfM ECS used the technology roadmapping approach with the Australian Cooperative Research Centre for Advanced Automotive Technology (AutoCRC) in partnership

with the Australian National University and the Commonwealth Scientific and Industrial Research Organisation on behalf of the Australian Industry Ministry. Workshops, surveys and interviews with approximately 220 individuals from 160 organisations enabled the Australian Government to develop a clearly articulated strategy for the automotive industry, and to set investment priorities for the AUD1.3 billion Green Car Innovation Fund. A Lecturer at Australian National University, in his capacity as Project Manager of Automotive Australia 2020, commented: "*The Australian automotive manufacturing industry is a significant contributor to the Australian economy, exporting in excess of AUD3 billion in components and vehicles, while providing more than 50,000 jobs. As the global automotive industry evolves, Australian vehicle manufacturing must transform to remain competitive and internationally relevant. IfM ECS delivered the roadmapping architecture critical to defining the future direction of this key industry, and bringing industry and research together to realise key research objectives in lightweighting, gaseous fuels, and electrification of vehicles. Funding has included AUD25m from the Australian government with matching funding from industry.*"[11]

The research has also led directly to GBP 3,479,758 in consultancy, training, events and publication revenue for IfM ECS in the assessment period.[12]

5. Sources to corroborate the impact (indicative maximum of 10 references)

[6] Phaal, R., Farrukh, C. & Probert, D.R. 'Roadmapping for Strategy and Innovation' (2010) ISBN 978-1-902546-82-7
[7] Statement received from Chairman, UK Synthetic Biology Roadmap Coordination Group
[8] David Willetts, https://www.gov.uk/government/speeches/eight-great-technologies
[9] Statement received from Education Director and Head of Early Career Programmes, BAE Systems
[10] Statement received from Lead Technologist, Technology Strategy Board
[11] Statement received from Lecturer, Australian National University
[12] Statement received from Chief Finance and Operations Office, Institute for Manufacturing Education & Consulting Services Ltd