Contributions to Management Science

Gabriela Fernandes
Lawrence Dooley
David O'Sullivan
Asbjørn Rolstadås *Editors*

Managing Collaborative R&D Projects

Leveraging Open Innovation Knowledge-Flows for Co-Creation

Springer

Contributions to Management Science

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Gabriela Fernandes • Lawrence Dooley •
David O'Sullivan • Asbjørn Rolstadås
Editors

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Editors
Gabriela Fernandes
University of Coimbra, CEMMPRE
Coimbra, Portugal

Lawrence Dooley
University College Cork
Cork, Ireland

David O'Sullivan
National University of Ireland Galway
Galway, Ireland

Asbjørn Rolstadås
Norwegian University of Science and Technology
Trondheim, Norway

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In Memoriam

Prof Paul Benneworth
1974–2020

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Contents

About the Editors

Gabriela Fernandes is Assistant Professor at the Faculty of Sciences and Technology, University of Coimbra. Her research interests are in organisational project management and innovation management, particularly in university-industry R&D collaborations context. She holds a PhD in Management, MSc in Industrial Engineering—Evaluation and Project Management and Innovation, and Graduation in Industrial Engineering and Management. She spent 10 years in the coordination and management of projects in different industries. Throughout her career, she served as an Executive Director. She developed and taught several project management training courses and, as a consultant, coordinated the implementation of project management systems and project management office structures. She was Director of the PMI Portugal Chapter and is Project Management Professional (PMP)® credential holder. She is a member of the Editorial Board of *International Journal of Project Management* and is author of more than 70 publications.

Lawrence Dooley (MComm, PhD) is a College Lecturer in Enterprise and Innovation at University College Cork (UCC) since 2004. Prior to joining UCC, he was based at the Centre for Enterprise Management in the University of Dundee, Scotland. He undertook his doctoral thesis entitled "*Systems Innovation Management*" at the National University of Ireland, Galway. His core research interests focus on organisational innovation and issues related to interenterprise collaboration and value creation from the SME perspective. Other related interests include knowledge exchange and discovery and the unique demands of lower-tech firms when engaging in innovation. He has published widely over recent years, actively liaises with industry through applied research projects, consultancy, and research seminars and is also Associate Editor of the *R&D Management* journal.

David O'Sullivan is a Professor of Industrial Engineering at the School of Computer Science at the National University of Ireland, Galway. His research interests are in the area of innovation management. His most recent projects include innovation management within SMEs, distributed innovation management across extended enterprises, and the impact of quality assurance in higher education. David has over 150 publications including books—*Applying Innovation* (Sage), *Manufacturing Systems Redesign* (Prentice-Hall); *Reengineering the Enterprise* (Chapman & Hall), and *The Handbook of IS Management* (Auerbach). David works with leading organisations where innovation is a core value including IBM, Thermo King, Fujisawa, Hewlett-Packard, and Boston Scientific.

Asbjørn Rolstadås is Professor Emeritus at the Norwegian University of Science and Technology, Department of Mechanical and Industrial Engineering. His research covers topics like numerical control of machine tools, computer-aided manufacturing systems, productivity measurement and development, computer-aided production planning and control systems, and project management methods and systems. He has published 300 papers and 21 books. Rolstadås is former President of the Norwegian Academy of Technological Sciences and member of the Royal Swedish Academy of Engineering Sciences and the Royal Norwegian Society of Sciences and Letters. He is former President of the International Federation for Information Processing (IFIP) and member of the Academy of Industrial Management (AIM). He has served for 5 years on the Standards Advisory Group of the Project Management Institute (PMI). He serves on the editorial board of a number of journals and is the founding editor of the *International Journal of Production Planning and Control*.

About the Authors

Temitope Akinremi works as a research fellow at the Enterprise Research Centre (ERC) at Warwick Business School. Before this, she earned a PhD in Engineering Management from Coventry University. She has a BSc and an MSc in Chemical Engineering. Her experience also spans across the oil and gas industry and chemical process industry where she worked as a process engineer, process improvement researcher, and business development manager with different companies. Temitope is currently working on an ESRC research grant funded project, which focuses on SMEs, innovation, productivity, and business ecosystems. More specifically, her work examines key practices that contribute to productivity improvements in the foundry and metal component manufacturing industries. She is interested in understanding how productivity can be enhanced in these industry sectors as well as the interactions between them. Temitope is particularly interested in sustainability integration in business models, managing supply chains to enhance profitability whilst minimising the negative impact on sustainability dimensions, project management, management of engineering processes, industrial process improvements, and optimisation.

Gillian Barrett (MSc, PhD) is a College Lecturer in Management and Entrepreneurship at Cork University Business School (CUBS), University College Cork (UCC), since 2016. She completed her PhD entitled "*Open innovation adoption in global high-tech SME firms: a qualitative multiple case study*" in 2017, and her core research interests lie at the intersection of open innovation, the global high-tech SME, and the entrepreneurial founder. Other research interests include entrepreneurial education and business model innovation. She is actively publishing and disseminating her research. Prior to academia, she worked for 15 years in industry in a variety of senior management and leadership roles primarily in innovation and technology management. During this time, she worked with Ireland's largest retailer and wholesaler and managed many strategically important projects in Ireland, the UK, and Spain.

Paul Benneworth was a Professor of Innovation and Regional Development at the Department of Business Administration and Social Sciences at the Western Norway University of Applied Sciences and a Senior Researcher at CHEPS, the Netherlands. Paul's research focused on the dynamics of innovation and societal change and, in particular, the ways in which partnerships of researchers, policymakers, and practitioners use different types of knowledge to stimulate socio-economic development. He led the Working Group on SSH Research Impact in ENRESSH, the COST-funded European Network for Research Evaluation in the Social Sciences and Humanities, and was one of the initiators of the EU-funded training programme, the RUNIN project, which focused on the role of universities in innovation and regional development. He authored more than a hundred of academic publications and several scientific books. Paul passed away on 12th May 2020.

Alencar Bravo is a doctor engineer in eco-design from the University of Quebec at Trois-Rivières, and he is a professor of project management at the same university. He also holds two professional master's degrees in mechanical engineering from the National Institute of Applied Sciences in Lyon (France) and the Technical University of Catalonia (Spain). He has significant experience in the field of industrial research and in development projects of high technical complexity, especially in the automotive and aeronautical fields. Other areas of research interest include eco-design tools, techniques, and methods; life cycle management and total cost of ownership; uncertainty and risk management; customer behaviour; and management and support systems in projects

Christophe N. Bredillet PhD, IPMA Level A, FAPM, is full professor of organisational project management at the Management Department, School of Business, Université du Québec à Trois-Rivières (UQTR). He is Dean of the UQTR School of Business. From 2012 to 2015, he was the Director of the QUT Project Management Academy. Before joining QUT, he was the Dean of Postgraduate Programs and Professor of Strategic Management and Project, Program and Portfolio Management (P3M) at ESC Lille. To date, he has been principal supervisor of 41 doctoral students. Pr. Bredillet's main interests and research activities are in the field of Philosophy of Science and Practice in P3M. He is member of four international editorial boards and was Editor-in-Chief of *Project Management Journal*® between 2004 and 2012. He received the IPMA Research Achievement Award 2016 for the outstanding contribution to project-related knowledge through research and the prestigious Manfred Saynish Foundation for Project Management (MSPM)—Project Management Innovation Award for his contribution to a philosophy of science with respect to complex project management (2012).

Rafaela Escobar Bürger is a PhD student at the Graduation Program in Administration at the Federal University of Santa Catarina/Brazil. She worked as a visiting PhD at the Open University of the Netherlands. She completed her master's by the Graduate Program in Administration at the Federal University of Santa Maria, where she worked as a researcher and extension fellow. Before joining UFSM, for several years she worked as a CEO at Launch Space Systems. She has published numerous articles on entrepreneurship, entrepreneurial education, open innovation, and national innovation systems.

Elena Castro-Martínez was awarded her PhD in 1983. Since 2004, she is a tenured scientist working at INGENIO (a joint institute of the Spanish Council for Scientific Research and Universitat Politècnica de València) in the field of innovation studies and more specifically analysing knowledge transfer and exchange processes. She has more than 10 years of experience in the management of knowledge transfer and more than 15 years as science and innovation policymaker. Usually, she participates and leads R&D projects (financed by regional, national, and European funds), consultancy, and R&D contracts with different international, foreign, and Spanish entities. She has (co-)authored more than 60 scientific articles, 30 book chapters, and 30 reports. She designed and directed a postgraduate course on planning and management of R&D projects (400 hours) which counted with 10 editions between 2008 and 2015.

James A. Cunningham is a Professor of Strategic Management at Newcastle Business School, Northumbria University, UK. His research intersects the fields of strategic management, innovation, and entrepreneurship. His research focuses on strategy issues with respect to scientists as principal investigators, university technology transfer, commercialisation, academic, public sector, and technology entrepreneurship, entrepreneurial universities, and business failure. He has papers published in leading international journals such as *Research Policy*, *Small Business Economics*, *R&D Management*, *Long Range Planning*, *Journal of Small Business Management*, *Journal of Technology Transfer*, and the *Journal of Rural Studies*, among others. He has published several books on the themes of strategy, entrepreneurship, technology transfer, and technology entrepreneurship with leading publishers such as Oxford University Press, Palgrave Macmillan, Springer, and World Scientific Publishing.

Roya Derakhshan has two PhDs in Management, Economics and Industrial Engineering from the Polytechnic University of Milan and Polytechnic University of Madrid. She is a junior lecturer at SDA Bocconi School of Management in Leadership, Organization and Human Resources knowledge group. Her research is focused on the normative and ethical aspects of stakeholder management, stakeholders' perception of organisations, stakeholders' evaluation of organisational legitimacy, and the influence of governance on stakeholder management. She can be contacted at roya.derakhshanalavijeh @sdabocconi.it.

María José Foncubierta-Rodríguez is an Associate Professor of Business Organisation Department at the University of Cádiz. Actually, she is the director of the Faculty of Economic and Business Administration Sciences in Algeciras Bay Campus. Her research interest focuses on professional competences management, intellectual capital of academic researchers, and happiness management. Her work has been published in international peer-reviewed journals and books. She has collaborated in national and international research projects.

Federico Frattini is a Full Professor of Strategic Management and Innovation at the School of Management of Politecnico di Milano (Italy) and Honorary Researcher at the Lancaster University Management School (UK). He is Dean of the MIP Politecnico di Milano Graduate School of Business. His research area is innovation and technology management. On these topics, he has written more than 200 books and papers published in conference proceedings and leading international journals such as *Entrepreneurship Theory and Practice*, *Academy of Management Perspectives*, *California Management Review*, *Journal of Product Innovation Management*, and many others. In 2013, he was nominated among the top 50 authors of innovation and technology management worldwide by IAMOT, the International Association for Management of Technology.

Olof Håkansson (PhD student) is admitted to the third-cycle programme of Industrial Product Realisation within the subject area production systems at the School of Engineering, Jönköping University, Jönköping. He has a master’s degree in product development, specialisation in sustainable building information management, from 2019 and wrote his thesis with a focus on the challenges of assessing the value with BIM. Currently, his research interests concern the challenges of managing and measuring strategic change initiatives of sector-wide and large-scale production systems. He is also one out of the researchers working in the project *Program generic measurement methods*.

Vered Holzmann is a senior lecturer at the School of Management and Economics in the Academic College of Tel Aviv Yaffo where she also serves as a Director for Research, Development and Innovation. Vered teaches at the Faculty of Management, Tel Aviv University, and holds a position of visiting Professor at Università Cattolica del Sacro Cuore in Milan, Italy. Her research topics include innovation and entrepreneurship, project management, and strategy. Vered is a project manager (PMP, SCM) in the IT industry and held various managerial positions in several start-up enterprises.

Mattias Jacobsson (PhD) is an Associate Professor of Management and Organisation at Umeå School of Business, Economics and Statistics (USBE), currently working as a Research fellow at the School of Engineering in Jönköping, Sweden. His main research interests are in projects, practice, and digital technologies, often focused on the construction industry. On four occasions, he was a prize winner at the Emerald Literati Network Awards for Excellence. He has also been awarded the USBE Pedagogical prize and appointed as qualified teacher at Umeå University. His work has been published in a large number of journals, including *Engineering, Construction and Architectural Management, Business Horizons, Management Decision, Project Management Journal®, International Journal of Project*

Management, Creativity and Innovation Management, the International Journal of Managing Projects in Business, and *Construction Management and Economics*. Jacobsson is the corresponding author.

Mengtong Jiang is a PhD student at the School of Economics and Management, Dalian University of Technology, Dalian, China. Her research revolves around the management of exploratory projects, innovation and entrepreneurship projects, the organisational motivation, and knowledge management. She can be reached at dlutjmt@mail.dlut.edu.cn.

Henrik Linderoth (PhD) is Professor in Construction Informatics at the School of Engineering, Jönköping University, Sweden, and received his PhD in Business Administration at Umeå School of Business, Economics and Statistics, Sweden. His primary research interest is technology-induced change processes. His work has appeared in journals such as *Construction Management and Economics, Automation in Construction, Information Systems Frontiers, International Journal of Project Management,* and *International Journal of Healthcare Technology and Management.* Linderoth has been the Project Manager and Principal Investigator of a couple of projects within Smart Built Environment.

Peter Love is a *John Curtin Distinguished Professor* of Infrastructure and Engineering Informatics at Curtin University. He is a Fellow of the Royal Institute of Chartered Surveyors and a Chartered Building Professional. Peter's leadership in research and active engagement with the construction and resources industry was acknowledged in 2010 when he was awarded the inaugural Scopus Young Australian Researcher of the Year Award in 2010 and later in 2012 was a nominee for Australian of the Year. In 2013, he was awarded a *Higher Doctorate of Science* (Sc.D.) by Curtin University in recognition of his substantial and sustained contribution to the field of civil and construction engineering. Peter's impact reaches beyond academia via media engagements, policy advice to governments and multilateral institutions, and consulting with Fortune 500 companies. Peter has a multidisciplinary background and has varied research interests, which include safety and reliability engineering, infrastructure development, and engineering informatics.

Stefano Magistretti is Assistant Professor in design and innovation management at the School of Management, Politecnico di Milano, and a senior researcher in the LEADIN'Lab, the Laboratory of LEAdership, Design, and INnovation. Within the School of Management, he is also a member of the research development platform for the Observatory "*Design Thinking for Business*". He has published journal papers, conference articles, and a chapter in an edited book on the topic of technology innovation, design management, and design thinking.

Mauro Mancini is professor of Project and Program Management in the Department of Management, Economics and Industrial Engineering at Politecnico di Milano (where he teaches in Master of Science, PhD, and specialising master's programmes); he is director of an international master's in project management programme and vice director of MIP Graduate Business School Corporate relations. Mauro is the author of more than 100 international publications in the areas of project management, building information modelling, and megaprojects. He leads national and international research and consultant projects in different industrial sectors including oil and gas, construction, energy, and infrastructures. He can be contacted at mauro.mancini@polimi.

Fernando Martín-Alcazar is a Professor of Business Organisation Department at the University of Cádiz. Actually, he is the director of PhD programme at the University of Cádiz. His research interest is focused on strategic human resources management and in intellectual capital of academic researchers. He is currently the Principal Investigator of HRM research team of the University of Cadiz and has led several funded research projects on HRM strategy formulation process. His work has been published in international peer-reviewed journals such as the *Journal of Intellectual Capital*, *International Journal of Manpower*, *British Journal of Management*, the *Journal of Business Research*, the *European Management Journal*, the *International Journal of Human Resource Management*, *Journal of Organisational Behaviour*, and *Scientometrics*, among others.

Miia Martinsuo (D. Sc., Tech.) is Professor of Industrial Management, especially project and service business at Tampere University, Department of Industrial Engineering and Management. Prof. Martinsuo has over 18 years of academic experience in project and service business and 9 years of industrial experience particularly in organisation and process development in the metal and engineering industry. Her current research interests include project-based organising; steering and selecting product development project portfolios; the autonomy and control of projects; managing manufacturing and process innovations; industrial service innovations and servitisation of manufacturing; and strategic organisational change programmes. She is associate editor of *International Journal of Project Management* and vice president of memberships in the European Academy of Management. Her publications appear e.g. in the *Journal of Product Innovation Management*, *International Journal of Project Management*, *Journal of Service Theory and Practice*, *Journal of Manufacturing Technology Management*, and *Project Management Journal.*

Annika Moscati (PhD) holds a position as senior lecturer at the School of Engineering, Jönköping University, Sweden. Her research interests concern the possibilities to improve information systems for the management and the enhancement of the building heritage integrating geographic information systems (GIS) with architectural information systems and building information modelling (BIM). In addition to being a PhD and senior lecturer, Moscati is a trained architect with several years of work experience. She is also one out of four researchers working in the project *Program generic measurement methods*.

Julia Olmos-Peñuela is an Associate Professor at the Department of Business Management "Juan José Renau Piqueras" at the University of Valencia (UV), Spain. Prior to joining the UV, she was based at the Institute for the Management and Innovation of Knowledge (INGENIO, CSIC-UPV), Spain. Julia's research interests relate to the study of science–society interactions, with a focus on researchers' engagement in knowledge production/transfer and exchange (particularly in the field of management studies and social sciences more generally). She has participated in several R&D projects, and recently she has been Principal Investigator on a regional funded research project exploring the tensions between academic rigour and societal relevance in research (GV/2018/008). Julia has published her findings in a range of academic journals including *Research Policy*, *Research Evaluation*, and *Science and Public Policy* as well as diverse platforms such as *Research Europe* or *LSE Impact Blog*.

Elena Pellizzoni works in Flowe, a Benefit company, pending BCorp and Carbon Neutral, passionate about innovation and sustainability. She works for the Value Ecosystem scouting partners and shaping the ecosystem. She holds a PhD in Management Engineering from the School of Management of Politecnico di Milano where she did research for many years. She has developed extensive research experience at the intersection of innovation management and project management, and she authored several publications appearing in scientific journals and international books. In particular, she has been working on stakeholder engagement in collaborative innovation activities (such as Innovation Contest, Call for Idea, Idea Management System, and Hackathon) and on value creation and appropriation of advanced multistakeholder products-services systems (such as Platform and Ecosystem). Her research also covers project management discipline, mainly focusing on the Agile approach.

José Luis Perea-Vicente is Lecturer in the Business Management Department of the University of Cadiz. Nowadays, he is a PhD student, and his PhD dissertation focuses on the science in the Principal Investigator role. He is member of the HRM research team. His teaching and research interests are focused on human resource management, human capital, and principal investigators.

Rebecca Pinheiro engineer, PhD, is a professor of project management at the University of Quebec in Trois Rivières. She works on ethics in project management in the fields of data analysis and new Internet platforms such as blockchain. A specialist in sober innovation management, she is the author of the book *Sustainable urban planning: management of innovation collectives*, which was published by Presses des Mines

Jeffrey K. Pinto is the Andrew Morrow and Elizabeth Lee Black Chair in the Management of Technology and Professor of Management in the Sam and Irene Black School of Business at Penn State University, the Behrend College. He is the lead faculty member for Penn State's Master of Project Management programme. The author or editor of 28 books and over 150 scientific papers that have appeared in a variety of academic and practitioner journals, books, conference proceedings, video lessons, and technical reports, Dr. Pinto's work has been translated into nine languages. Dr. Pinto is former editor of the *Project Management Journal* and is a two-time recipient of the Distinguished Contribution Award from the Project Management Institute. He received PMI's Research Achievement Award as well as the International Project Management Association's Research Achievement Award for his research career in project management.

Mary Beth Pinto is Professor of Marketing and Discipline Lead for the Marketing Major in the Sam and Irene Black School of Business at Penn State University, the Behrend College. She is the author of numerous book chapters and over 50 scientific papers that have appeared in a variety of academic and practitioner journals, books, conferences, and proceedings. Dr. Pinto is former associate editor of the *International Journal of Pharmaceutical and Health Care Marketing Journal* and is a recipient of Penn State University's Rosemary Schraer Mentoring Award. She is also the recipient of the Black School of Business Advising Award and Learning Innovations Award.

Ronnie Rego is Assistant Professor at the Aeronautics Institute of Technology (ITA), Brazil. He holds a PhD in Aeronautics and Mechanical Engineering from ITA, in cooperation with the Werkzeugmaschinenlabor (WZL) of the RWTH Aachen University, Germany. Since 2011, he is researcher of the Competence Centre in Manufacturing (CCM-ITA), where he coordinates the Gear Innovation Group and the open innovation alliance "*Engrena ITA*". He also performs as Managing Director of the Fraunhofer Project Centre for Advanced Manufacturing at ITA, in cooperation with Fraunhofer IPK, Berlin. He has industrial experience as Drivetrain Engineer of Ford Motor Company, between 2005 and 2011. His research fields of interest are gears and power transmission systems, with a focus on the influence of manufacturing processes over the surface integrity properties.

José Coelho Rodrigues holds a PhD in Industrial Engineering and Management, specialised in technology management on the management of alignment of technologies and interorganisational networks during implementation projects, and a Master in Electrical and Computers Engineering, specialised in optimisation, both from the University of Porto (UPorto). He is currently a Post-Doc researcher at INESC TEC and an invited assistant professor at UPorto. His research interests concern technology management and policy, namely the alignment of technology and organisations in the implementation of technologies, the evolution of business models of technology-based start-ups, and the interactions between policy, technology evolution, and technology adoption. José teaches entrepreneurship courses and general introductory courses of management to engineering students, as well as technology management courses to management students at UPorto, and has supervised several master's dissertations and some PhD theses about technology management topics.

He has also been responsible for workshops on technology management and other management topics in a European project, industrial conferences, and other industry-oriented events. Before joining the PhD course, José has been a functional analyst for a Portuguese clinical software company where he did business process and requirements analysis during the implementation of the software.

Nadine Roijakkers is Director of the Expertise Centre for Education and Full Professor of Open Innovation at the Open University of the Netherlands. Before joining the OU, she worked at several Dutch and Flemish universities such as Maastricht University, Eindhoven University of Technology, and Hasselt University. For several years, she was a strategy consultant at KPMG Consulting. She has published numerous articles on alliance management and open innovation management in among others *Long Range Planning*, *Research Policy*, *British Journal of Management*, *European Management Journal*, *Technological Forecasting and Social Change*, *Small Business Economics*, *California Management Review*, *Journal of Product Innovation Management*, and *R&D Management Journal*. She has served as guest editor for special issues of journals such as *Sustainability*. Furthermore, she is the co-editor of the first edited volume on *Researching Open Innovation in Small- and Medium-sized Enterprises* published by World Scientific and the Routledge edited book on *Sustainable Innovation: Strategy, Network, Process, and Impact*.

Stephen Roper works as Director of the Enterprise Research Centre (ERC) and Professor of Enterprise at Warwick Business School (WBS). Before this Steve was Professor of Business Innovation at Aston Business School, and before that he was Assistant Director of the Northern Ireland Economic Research Centre, Belfast. Stephen holds a BA (Hons) in Economics from the University of Durham, an MPhil in Economics from Oxford University, and a PhD in Economics from the London School of Economics (LSE). He published his first paper on small business growth in 1997 and has subsequently published 12 papers on this theme in 3* and 4* journals. He has been CI and PI on several ESRC projects on the theme of innovation, most recently focusing on the innovation value chain and open innovation. He is also one of the lead partners in the ERSC-funded EREBUS Capacity Building Cluster which focuses on knowledge co-production with SMEs. Stephen has led over 50 externally funded research projects, ran his own consultancy company for some years, and works regularly with the OECD on consultancy assignments relating to small business policy and evaluation. He has also consulted for a range of other private sector and policy organisations. Until the abolition of the RDAs, Stephen was a member of the Advantage West Midlands Enterprise Board and led the regional subgroup on data and strategy. Stephen's recent work with GE Capital on the UK mid-market has been widely reported (Summer 2012). He is a Consulting Editor of the *International Small Business Journal* and a Fellow of the RSA.

Haim Rousso is a former member of the Council of the Israeli Innovation Authority. He spent 40 years in the high-tech industry in Israel in various positions, including CEO of ELOP - Electro-Optics Inc., Executive VP of Elbit Systems for Technology and Engineering Excellence, Chairman of the Board of Taasiyeda, and President of Mofet—Excellence in R&D. Haim is the founder and chairman of two technological incubators. He teaches R&D management courses in MBA programmes at Tel Aviv University and the Technion.

Olle Samuelson (PhD) is an Adjunct Professor at Luleå University of Technology and also working as a strategist of research and innovation at IQ Samhällsbyggnad, a member organisation for companies and organisations in the built environment sector that are interested in R&D. IQ Samhällsbyggnad is host for the programme Smart Built Environment, and Samuelson is its strategic program manager. Samuelson has a long experience working with both research and development (R&D), and as practitioner in the built environment sector.

Ana Correia Simões is researcher at INESC TEC, where she has been working at the Centre of Enterprise of Systems Engineering (CESE). She participates and coordinates several research projects in the areas of Engineering and Technology with emphasis on technology management. She was in charge of the operational team for the creation of the INESC TEC Industry and Innovation Laboratory. She is Invited Professor at University Portucalense Infante D Henrique since 2016, and she was Invited Professor at the University of Minho between 2003 and 2017. Ana teaches operations management, logistics, and supply chain management courses. Ana published 8 conference papers, authored two book-chapter and two papers in peer-reviewed journals (other 2 submitted in peer-reviewed journals), and also participated in several scientific events (conferences and workshops). Ana has supervised several master's students from the University of Porto, in topics related to adoption management, innovation management, and Industry 4.0 technologies. She obtained a PhD in Engineering and Industrial Management at the Faculty of Engineering of the University of Porto (2016) in the area of performance measurement, a master's degree in quantitative methods applied to management at Porto Business School of University of Porto (2003), and a Degree in Engineering and Industrial Management at the University of Aveiro (1998). She has several years of work experience as consultant in operations management and strategic planning in healthcare.

António Lucas Soares is head of research centre at INESCTEC and associate professor at the Department of Informatics Engineering of the Faculty of Engineering—University of Porto. His area of expertise is information systems specialised in applications to collaborative networks and information and knowledge management particularly in industrial organisations. His research interests include socio-technical design, knowledge representation, digital platforms for collaboration, and design science research.

Daniel Trabucchi is Assistant Professor of innovation management at the School of Management of Politecnico di Milano, where he serves as a researcher of LEADIN'Lab, the Laboratory for Leadership, Design and Innovation. His research interests are focused on innovation management. In particular, he has been working on digital two-sided platforms and their peculiarities (focusing on how they can create and capture value and the related data-driven business models); moreover, he focuses on innovation strategy based on the interplay between technology and meaning. His research has been published in peer-reviewed journals such as *Technological Forecasting and Social Change*, *Internet Research*, *Journal of Knowledge Management*, *Research-Technology Management*, *Creativity and Innovation Management*, *Management, Decision, Technology Analysis and Strategic Management,* and *European Journal of Innovation Management*; he is also a reviewer for many of these journals.

Darli Rodrigues Vieira PhD, is a full professor of project management at the University of Quebec in Trois-Rivières (UQTR). He is currently the Head of the Management Department and Director of the Master Program in Project Management at this university. He also holds the Research Chair in Management of Aeronautical Projects. His current research focuses on project management, logistics chain management, strategy and management of operations, and management of MRO.

Derek Walker (PhD, MSc Grad Dip. Mgt Systems) is Emeritus Professor at RMIT University in Melbourne, Australia. He has been actively publishing from his research work in this area. His first book in this area, specifically in the project procurement and delivery field, had its focus on research results from an extensive longitudinal study of the Australian National Museum project which was a first for an Australian institutional building project alliance (Walker and Hampson 2003). That book was followed by Procurement Systems—A Cross Industry Project Management Perspective (Walker and Rowlinson 2008a). In 2015, he co-authored Collaborative Project Procurement Arrangements (Walker and Lloyd-Walker 2015) that reported on a global study of alliancing and related similar project delivery forms. His most recent book publication is *The Routledge Handbook of Integrated Project Delivery* in 2020. He also has collaborated with others writing many book chapters and journal and conference papers. In 2018, he received the 2018 International Project Management Association research excellence lifetime achievement in project management award.

Linzhuo Wang *PhD*, is Postdoctoral Researcher at the School of Economics and Management, Dalian University of Technology, Dalian, China. He has published more than 10 research articles and book chapters within the field of temporary organising. His research focuses on organisational resilience, project governance, and leadership. He can be reached at arrory@hotmail.com

Fangwei Zhu *PhD*, is a Professor and Dean of the School of Economics and Management, Dalian University of Technology, Dalian, China. He is the Director of Institute of Enterprises Management in DUT. He is also the Executive Director of China Management Case Sharing Centre. He conducts researches in organisational project management, network governance, and EPC project management. The results of his studies appeared in more than 60 publications, including 6 books, and 6 Top-100 Chinese Management Cases in six consecutive years.

Managing Collaborative R&D Projects

Gabriela Fernandes, Lawrence Dooley, David O'Sullivan, and Asbjørn Rolstadås

1 Collaborative Innovation

The competitiveness and sustainability of a modern organisation depends on its ability to innovate successfully. Innovation is the combined activity of generating new knowledge and the subsequent successful exploitation of this for benefit (von Stamm 2008; O'Sullivan and Dooley 2008). Innovations rarely involve a single technology or market but instead a requirement to bring a complex bundle of knowledge together into a value-adding configuration. Thus, innovation is not only about accessing and using knowledge about components but also about its integration to solve market needs (Tidd and Bessant 2009). The current perspective of the innovation process views it as an interactive and networked system, spanning independent organisational boundaries to draw on complementary knowledge, experience and capabilities from increasingly diverse sources (Tidd and Bessant 2009; Philpott et al. 2011). Engaging with organisations from other geographic areas (Narula 2004) or cross-industry sectors (Enkel and Heil 2014) can nurture and

G. Fernandes
University of Coimbra, CEMMPRE, Coimbra, Portugal
e-mail: gabriela.fernandes@dem.uc.pt

L. Dooley
University College Cork, Cork, Ireland
e-mail: l.dooley@ucc.ie

D. O'Sullivan (✉)
National University of Ireland Galway, Galway, Ireland
e-mail: dos@nuigalway.ie

A. Rolstadås
Norwegian University of Science and Technology, Trondheim, Norway
e-mail: asbjorn.rolstadas@ntnu.no

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stimulate an organisation's innovation process by exposing firms to new yet complementary capabilities of collaboration partners.

The bringing together of complementary knowledge capability and resources supports the creation of technological competencies (Schoenmakers and Duysters 2006), especially where such resources\capabilities are not internally available or are challenging to obtain efficiently within the market (Das and Teng 2000; Lewis et al. 2010). Organisations that successfully harness external knowledge through inter-organisational relationships will have greater innovation scope and are likely to realise a more significant competitive advantage over those organisations solely relying on internal capabilities (Rothwell 1994; Gratton 2000; Chesbrough 2003; de Faria et al. 2010). Innovation is applied knowledge management (O'Sullivan and Dooley 2008) and understanding the complexity of inter-organisational relationships that underpin effective integration of this 'non-redundant' knowledge is essential for innovation potential. Managing an organisation's knowledge assets within networks and converting it into commercially successful products and services is an intricate and difficult to manage process (Jaffe 1989; Balconi et al. 2004). The collaborative challenges associated with R&D include how to achieve synergistic integration of culture and routines of collaborating organisations (Spekman et al. 1996; de Rond 2003; Dooley et al. 2013), aligning realistic and mutually beneficial objectives (Doz and Hamel 1998), and achieving the synergistic mix of knowledge and network ties (Gubbins and Dooley 2013) that nurtures collective benefit. Barringer and Harrison (2000) also identify challenges such as financial/organisational risk, partner co-dependency, partial loss of decision autonomy, loss of organisational flexibility and anti-trust/anti-competitive implications to this list of collaborative challenges and stress the strategic nature of such decision since '*in the end, the decision to participate in an inter-organisational relationship must be a probabilistic assessment of strategic rather than economic value*' (2000, p 396).

Industry is increasingly reliant on open innovation (Chesbrough 2003) to enhance internal capabilities and develop new trajectories and skillsets. Universities are often the main repository of such exploratory knowledge (Scandura 2016). The increasing competitiveness and the appearance of new science-based industries have decentralised the industrial research activities, where external sources of knowledge (such as universities) have gained importance in the eyes of firms (Sá and Litwin 2011). '*Knowledge and technology transfer between academia and industry is expected to spur innovation, as this kind of collaboration combines not only heterogeneous partners but more importantly, heterogeneous knowledge*' (Rajalo and Vadi 2017, p 42).

Government agencies increasingly promote university–industry collaborations through public funding to stimulate the regional ecosystem (known as triple helix model) and consequently, collaborative research between industry and university is becoming increasingly prevalent (Perkmann et al. 2011). University–industry collaborations are expected to play an important role by the development of innovative products, technologies and processes for industry. They are influenced by both geographical proximity and the quality of these universities. However, industries appear to give preference to the research quality, i.e. existent knowledge, of the university over geographical closeness (Laursen et al. 2011). Yet, collaborative university–industry R&D requires a high commitment of both partners and takes place when the relationship between university and industry is in some way more consolidated (Perkmann et al. 2013).

University-industry R&D collaborations are based on interactive relationships of trust (Plewa et al. 2013) and commitment between partners aiming to create mutual value over time, which allows diffusion of creativity, ideas and skills, hence promoting a bilateral exchange of knowledge (Ankrah et al. 2013). Collaborative university–industry R&D initiatives are usually organised as projects or programmes. They exist to produce new results under pre-defined research objective(s), within several constraints (time, cost and resources), resulting in a set of benefits for both partners. A programme is a set of projects that are somehow related and aimed at achieving a set of significant benefits that are more than just the sum of the projects they consist of (Nieminen and Lehtonen 2008; Pellegrinelli 2011). However, sometimes the concept of the programme is misunderstood, and commonly, programmes are perceived as projects in the context of university–industry R&D collaborations.

Literature research concerning university–industry R&D collaboration has concentrated primarily on the existence and effects of the so-called 'cultural gap'. The factors identified include conflicts over ownership of intellectual property, academic freedom to publish, differences of priorities and time horizons. However, the majority of the problems associated with the 'cultural gap' can be alleviated by good project management (PM) (Barnes et al. 2006). Recently, Huang and Chen (2017) show that the existence of university–industry collaboration management mechanisms has significant effects on the academic innovation performance of universities, namely the presence of a formal, standardised and structured process to manage benefits resultant from these collaborations. This aligns with the perspective of Barnes et al. (2006, p 399), who highlight the importance of a '*project manager to harmonise the differing objectives, perspectives and modes of operation of often diverse organisations*'.

2 Innovating in Practice

The turbulence of the modern world, both economic and societal, demands ever-increasing innovation to meet emerging challenges. While the need for continuous innovation is evident, how to do so effectively remains one of the core challenges to be addressed by researchers and practitioners (Barbosa et al. 2020). Consequently, current perspectives of the innovation process view it as an interactive and networked system that spans organisational boundaries to draw on knowledge, experience and capabilities from diverse sources (Rothwell 1992; Tidd and Bessant 2009). Organisations that are successful in harnessing the potential of external knowledge collaboration for R&D projects have greater scope to undertake complex innovation activity and are likely to realise competitive advantage over organisations relying solely on internal capabilities (Rothwell 1994; Gratton 2000; Chesbrough 2003; de Faria et al. 2010). Innovation research of the past decade has primarily focused on addressing these challenges through '*Open Innovation*' (Chesbrough 2003) and '*Project Management*' (Brocke and Lippe 2015; Barbosa et al. 2020).

The success of innovative ideas developed through inter-organisational collaboration depends as much on the process of open innovation (OI) than of the idea itself (Chesbrough 2004). OI needs to be wisely managed to execute an R&D project effectively and deliver proposed project benefits. According to the Frascati Manual (OECD 2015), for activities to be classified as R&D, they must meet five central criteria: (1) Novel; (2) Creative to advance existing knowledge; (3) Degree of uncertain regarding the outcome, cost and time allocation; (4) Systematic in management and finally (5) Transferable or reproducible. A collaborative R&D project is defined as a temporary organisation with a collaborative work environment, within a specific application context defined, but of interest to all partners engaged. These collaborative projects consist of consortia of heterogeneous, yet synergistic partners (industries, universities and research institutions) with collective responsibilities for the achievement of desired outcomes and, in most cases, with public funding support (Brocke and Lippe 2015). Collaborative R&D is based on the principle of symbiosis, i.e. each partner has a different set of capabilities that enable the leveraging of OI knowledge-flows for co-creation and value appropriation from the collaboration. However, this also brings complexity, which, if not well managed, generates conflicts among partners, hindering innovation and ultimately leading to collaboration failure. There are several reasons behind unsuccessful collaborations, namely: different levels of commitment between partners; lack of a trust bond between partners; different motivations and objectives; unclear requirements; and poor planning and monitoring of progress (Brocke and Lippe 2015; Nsanzumuhire and Groot 2020).

The management of the innovation process, especially in collaborative contexts, requires mastering the capabilities of goal setting, problem-solving, design thinking, project, programme and portfolio management, team building, collaboration and knowledge management (O'Sullivan and Dooley 2008). PM has long been viewed as a key innovation management mechanism for the effective execution of innovation projects (O'Sullivan and Dooley 2008). Although essential, in the context of collaborative R&D projects, this view is simplistic. PM needs to be seen as one of a portfolio of Innovation management tools and techniques that together provide the best opportunity for project success (O'Sullivan and Dooley 2008). Creating and maintaining benefits from collaborative R&D projects requires moving beyond current PM knowledge, and integrate the foundational role of both PM and innovation management in collaborative R&D projects' management process (Midler et al. 2016). PM and innovation management frameworks bring forward different principles, processes, tools and techniques for achieving greater project success (Midler et al. 2016; Mugge and Markham 2013; Müller et al. 2019), that when effectively combined, allows the leveraging of OI knowledge-flows for co-creation.

During the lifetime of collaborative R&D projects, dynamics are created among the organisations involved, namely related to knowledge transfer, which have impacts on the organisations that may go beyond the objectives of the ongoing initiative, resulting, for example, in further projects to explore other ideas (Manning 2017). However, as OI might compromise secrecy, which might be required by some organisations of the consortium, a careful balance between open and closed innovation practices might be needed during the project lifetime (Du et al. 2014). These, and other challenges that emerge in UICs, mainly due to the different nature of the organisations involved, lead to the need for adapting the governance and management approaches used (Du et al. 2014).

3 Book Objectives

This book brings together several multidisciplinary studies around the topic of managing collaborative R&D projects that leverage OI knowledge-flows for co-creation. Seventeen chapters have been developed to present readers with key challenges, case studies and best practices for improving the impact and benefits of collaborative R&D projects. The book is written in an accessible style for managers, decision-makers, principal investigators and project managers in industry, government, universities and research institutes to support the achievement of long-term benefits and societal impact. It is also of interest to university governance boards, funding agencies and corporate and government investors. The ideas and principles outlined in the book apply to any organisation from service to manufacturing and from public sector to private. Features to be found within the chapters of the book include:

- Case studies and real-life examples of OI and project management.
- New approaches to collaboration among established universities and industries.
- New insights into governance and management of collaborative R&D projects.
- Challenges and opportunities within major collaborations.
- Practical roadmaps for more effective OI and project management.
- Critical enablers for delivering project and programme values, benefits and impacts.

4 Book Structure

To guide the reader in accessing key knowledge presented, the chapters have been divided into five parts and their associated chapters. The parts are:

1. Literature Reviews.
2. Industry Collaborations.
3. University–Industry Collaborations.
4. Collaborative Project Management.
5. Collaboration Impact and Value.

4.1 Literature Reviews

Part I of the book presents two detailed reviews of the state-of-the-art literature around OI and PM related to collaborative R&D and the role of managers. In their chapter '*A systematic literature review of open innovation and R&D managers*' Cunningham, Foncubierta-Rodríguez, Martín-Alcázar and Perea-Vicente find that there has been a limited research focus on the role of individual actors and the human side of OI within the literature. They attempt to address this imbalance using a systematic literature review to thematically analyse the R&D leader role. They identify three main themes from the literature: implementation, fear and firm performance. Using these themes, they organise a literature framework and outline future avenues of research. They argue that there is a need to undertake further research on the role of R&D leader to adequately equip and support them in the day-to-day management of collaborative innovation (Cunningham et al. 2020).

The second chapter of this part of the book by Bravo, Vieira, Bredillet and Pinheiro undertakes a '*Review of collaborative project management approaches in R&D projects*'. They find that approaches are as diverse as the collaborative R&D projects they aim to manage, but all share the same goal, i.e. to increase the success and value of projects. Their chapter presents a review of the leading PM approaches based on processes, results, competencies and agility. Each approach, they find, includes one or more parameters and standards. They find that in collaborative projects, common language problems are frequent and highlight the importance of securing collective agreement before starting engagement. The research also highlights that choice of management framework must be intelligent and adaptable, with the necessary investments in place to reinforce long-term collaborative work in terms of both scientific achievements and market-aligned output (Bravo et al. 2020).

4.2 Industry Collaborations

In times of turbulence, the locus of innovation shifts to the network (Powell et al. 1996) as organisations strive to reduce risk exposure and time to market by leveraging the capabilities of other independent organisations rather than develop them internally. This extended resource-based view of the firm has a definite advantage, encompassing linkages with complementary partners including suppliers, intermediaries, complementor and competitor enterprise, universities and even government organisations. While the collective pooling of network resources offers significant potential for knowledge sharing and co-creation, there are multiple challenges in achieving the necessary integration and mutual understanding of objective and value appropriation to achieve the same. Part II of the book focusses on *Industry Collaborations*, consisting of five chapters that explore the complexity of this context and its implications for managing collaborative R&D projects.

In the chapter by Holzmann and Rousso, entitled '*Co-creation of innovation by corporates and start-ups*', the authors continue the focus on the advantage of OI adoption for early-stage SMEs. The chapter highlights the challenges start-ups face when developing new technology and the potential synergies that can be realised from collaborating with established corporates. This research highlights three models to support inter-organisational interaction, namely: the corporate venture model, the corporate incubator model and the corporate shared innovation model. The research discusses the application of these models, highlighting the relative strengths and weaknesses in nurturing start-up-corporate cooperation as well as the potential benefits of pursuing the appropriate co-creation model within the R&D ecosystem (Holzmann and Rousso 2020).

In the second chapter '*Open innovation strategy of an early stage SME*' by Barrett and Dooley, the authors explore the adoption and application of OI practice within the early-stage technology SME context, a research area often neglected within OI research. This chapter focuses on the case of an early-stage medical device SME and their efforts to harness public and private resources through collaboration for the development of disruptive R&D. The analysis highlights that early-stage SMEs are capable of pursuing a beneficial OI strategy to leverage university–industry–government resources and that the breadth of organisational collaborators increases as their capability to manage such collaborative R&D projects develops (Barrett and Dooley 2020).

In the chapter entitled '*Overcoming barriers of systemic innovations in a business network*', Martinsuo explores how systemic innovations expand the development scope of complex solutions when complementary innovations need to occur at the same time. This chapter explores intelligent technologies as a systemic innovation, identifying transformation-related barriers toward open systemic innovation and ways to overcome the same within a business network (Martinsuo 2020).

In their chapter, '*Framework linking open innovation strategic goals with practices*' Trabucchi, Magistretti, Pellizzoni and Frattini, leverage a methodology of systematic literature review to structure the strategic goals and practices of OI. The research strives to assist R&D professionals to better understand the *'right'* OI perspective relative to their specific needs. The findings highlight three strategic goals of OI that impact industry practice, namely (1) identifying new directions, (2) strengthening the market position, and (3) enhancing the innovation process (Trabucchi et al. 2020).

The final chapter of this part of the book is entitled '*The collaboration paradox: Why small firms fail to collaborate for innovation*'. The authors, Akinremi and Roper, explore the paradox of low engagement by a small firm in innovation-focused collaborations, despite the potential for the higher added value of external resources compared with larger-scale enterprise. The research examines the barriers to innovation collaboration in small firms, focusing on three market failures that may limit the extent of collaborative innovation. These are: (1) a firm's inability to recognise the potential benefits of innovative collaboration; (2) a lack of information for assessing the suitability of partners and; (3) difficulty in determining the trustworthiness of a prospective partner. Findings indicate that uncertainty relating to trust and legacy knowledge of the potential partner's capability are key determinants in the collaboration decision (Akinremi and Roper 2020).

4.3 University–Industry Collaborations

University–Industry Collaborations (UICs) are among the most frequent policy instruments put in place by local and national policymakers to foster innovation. The exchange of knowledge between the university and industry is seen as an essential mechanism to enhance innovation and economic growth in which the knowledge produced in universities translates into the industrial environment.

UICs are increasingly being recognised as ways of bringing several benefits to companies, universities and society (Ankrah and Al-Tabbaa 2015). Companies that collaborate with universities tend to introduce more innovations into the market and universities raise the willingness of companies to employ their students and their ability to retain their researchers. Society benefits are realised from UICs through regional/local economic development and technological breakthroughs. The Covid-19 pandemic has brought about an unprecedented number of UICs, and their success has never been more important for society. Yet despite an increasing prevalence of UICs (Galan-Muros and Davey 2017), many fail to meet the stakeholder expectations (Brocke and Lippe 2015; Barnes et al. 2006), a consequence of lack of partner trust; lack of clarity regarding objectives, assigned responsibilities and planning; and lack of flexibility and agility within the governance structure (Rybnicek and Königsgruber 2019; Oliver et al. 2020). A much-needed consolidation of the available knowledge is missing (Brocke and Lippe 2015; Galan-Muros and Davey 2017) and Part III of this book aims to contribute to this.

Part III takes into account both the technical and social aspects of managing UICs. It begins with a chapter on '*Managing a major university–industry collaboration R&D program*' by Fernandes and O'Sullivan. The authors discuss seven main challenges of managing collaborative university–industry R&D within a large case. Most of the challenges found align with the literature, including the *'balancing between creative freedom and control'*, which was addressed by the deployment of a hybrid programme and project management approach, with a set of transversal and contingent PM practices (Fernandes and O'Sullivan 2020).

Love and Walker, in the chapter '*Balancing industry value proposition and researcher academic interests*', address the research question: 'How can academic initiators of collaborative research best shape their value propositions to meet both academic and industry value expectation?' Three key elements emerged from their own experience in UICs: (1) understanding the value propositions of parties involved in a collaboration; (2) building trust and commitment between parties, in fact building trustworthy relations between the collaborating partners is one of the significant challenges of UICs; and finally, (3) adopting a 'best-for-project' alliance mind-set. The authors argue that researchers often take a more transactional view of their relationship with industry rather than an alliancing mindset, which is focused on long-term collaborative commitment (Love and Walker 2020).

'*Emergence of governance structure in collaborative university-industry R&D programs*' by Derakhshan, Fernandes and Mancini discusses the emergence of actors and institutions in a UIC programme, from the strategic planning to the execution and delivery phase. The study investigates the drivers and outcomes of the process of definition and change of roles and relationships during the strategic planning and execution and delivery phases of a significant UIC programme. The study introduces a transitional phase between the two official phases, during which the Program and Project Management Office starts to operate, and the Program Management and Project Teams are shaped. This transitional phase matures the governance structure for the execution and delivery phase to underpin the four governance principles proposed by OECD (2004): accountability, responsibility, transparency and fairness (Derakhshan et al. 2020).

Finally, Rego on the chapter '*Open innovation alliances in technology colonies*' discusses the modus operandi and implementation strategy of an OI alliance in Brazil, consisting of a network of 44 organisations from government, industry and university. The author argues that the basis for defining a *technology colony* is the gap between the academy and the industry, which might be leveraged to increase research initiatives and knowledge dissemination between industry and university partners. Rego shows that the creation of technology colonies are critical to the goal of resource efficiency in converting ideas into innovative projects. He also highlights the strengths, weaknesses, opportunities and threats of implementing an OI alliance in such a technology colony, namely the intensity with which they innovate and the propensity to create patents and introduce new products to the market (Rego 2020).

4.4 Collaborative Project Management

PM is a well-developed field with the research community and integral to the ability of multiple organisations to co-ordinate their collective efforts for R&D. Many commentators claim that PM is a profession and not a science. As practitioners have developed suitable tools and techniques to manage large-scale projects such as construction and ICT applications, research has focused on topics such as success factors, stakeholder analysis and risk management. However, there is significant scope for research in the context of collaborative R&D projects since these projects are amongst the most challenging to plan and manage. In this fourth part of the book, we will scratch the surface of this topic through three significant contributions. R&D projects may differ significantly from construction projects, where PM has been dominant to date. A major difference is in the goal-setting process where goals are fixed and well-defined goals in the construction context and highly dynamic and emergent in the R&D context. There are also some other significant characteristics for a collaborative R&D project that challenge the traditional PM perspective:

- The major stakeholders are often a mix of industry and academia.
- The project setting is global, involving different cultural traditions and exposed to communication problems.
- There is high complexity and uncertainty.
- Many projects are multidisciplinary, with teams working together for the first time.

In the first chapter '*Challenges in managing large scale collaborative R&D projects*', Simões, Rodrigues and Soares identify some important challenges in managing large-scale collaborative R&D projects. Four projects in Portugal have been studied to observe and develop challenges within two crucial processes: collaboration creation and collaboration management. Differences in individual strategies and interests amongst the project partners represent a major challenge in establishing the consortium and defining the goals. To meet the challenges, it is essential to align expectations from and interests of the various types of partners. In the collaboration management process, managing the motivation and expectations of contributors is a significant challenge, as is the management of IP rights associated with developing outputs (Simões et al. 2020).

The second chapter from Pinto and Pinto entitled '*Critical success factors in collaborative R&D projects*' discusses critical success factors (CSFs) in collaborative R&D projects. A CSF is an element of the project which, when addressed by the project stakeholders, increase the probability of success. Some of the most important CSFs in a collaborative R&D project are top management support, clear, realistic goals, a detailed plan kept up to date, excellent communications and user/client involvement (Pinto and Pinto 2020).

Finally, in their chapter '*Developing trust between partners in collaborative R&D projects*', Bürger and Roijakkers discuss the development of trust between partners in a collaborative R&D project. Communication and user involvement (which were identified as key CSFs in the second chapter) will not take place unless there is sufficient trust amongst the partners. This research highlights the central role of social exchange in contributing to trust and success in R&D collaborations (Bürger and Roijakkers 2020).

4.5 Collaboration Impact and Value

Significant numbers of collaborative R&D projects struggle to achieve the promised impact and value to their contributing organisations, mainly because project outputs are not aligned with the organisations' strategy (Musawir et al. 2017). These projects waste scarce resources that could be better used to bring benefits to the organisation (Müller et al. 2019). Collaborative R&D projects need to establish governance systems that will move them from traditional PM methods to strategic methods of work, focused on business value, but without disregarding the processes, of operational programme and project management (Galan-Muros and Davey 2017).

Collaborative R&D projects require a unique set of capabilities (Dooley et al. 2017), focused, for example, on strengthening cultural differences and empowering multicultural teams that improve both business growth and also societal impact (Bornmann 2013). Societal impact are the benefits to the economy, society, culture, public policy or services, health, environment or quality of life, beyond the ones directly involved in the collaboration. A useful approach to understanding the concept of societal impact is presented in the 'logic model' from Kellogg (2004), which defines five steps [Resources/Inputs; Activities; Outputs; Outcomes; Impacts (or benefits)] in a transformation endeavour. However, there is a lack of tools to assess the benefits and societal impact of such collaborations (Perkmann et al. 2011; Brocke and Lippe 2015). Some authors have addressed the appraisal of the socio-economic impacts of research infrastructures within the cost–benefit analysis approach (Florio and Sirtori 2016). Such an approach provides some guidelines that will be useful to assess the impacts of collaborative R&D projects, notably where impact in terms of monetisation is not straightforward (e.g. value of publishing or capability development for future exploitation). Part V completes the book by focusing on the impact and value generated by collaborative R&D management.

In their chapter '*Do academic scientists' perceptions of restrictive effects influence non-academic collaboration*'. Olmos-Peñuela, Benneworth and Castro-Martínez address the recognition of academic research as a potential source of economic growth. They find that policymakers have provided incentives to encourage academics to make their research accessible to wider audiences. Academics typically work as part of collaborative R&D teams to help improve capacity and skillsets, and this engagement introduces social dilemmas and invisible costs or what some call the '*dark side of collaboration*'. This can act as a disincentive to collaboration for some academics that can undermine willingness to exchange ideas and knowledge fully. In this chapter, the authors fully explore the idea of restrictive engagement and provide answers around what determines whether researchers are willing to engage or not (Olmos-Peñuela et al. 2020).

'*Demystifying value co-destruction in collaborative R&D projects*' from Wang, Jiang and Zhu, looks at value co-destruction as it prevails in collaborative R&D projects. The authors investigate the value co-destruction phenomenon and attempt to demystify the underlying paradigms. A comparative case study approach is taken to identify the three dimensions of motivation, behaviours and outcomes of value co-destruction. Following on, the authors discuss the theoretical and practical implications of co-destruction (Wang et al. 2021).

Håkansson, Jacobsson, Linderoth, Moscati and Samuelson close out this final section of the book by discussing the '*Challenges in measuring performance of collaborative R&D projects*'. They begin by acknowledging that although measuring performance is critical for both practitioners and academics, it is rarely straightforward in practice. In their chapter, they present first-hand experience of the performance measurement practice within an extensive, long-term, Swedish innovation programme (*Smart Built Environment*). Backed by three state research agencies, it is one of the largest innovation investments in Sweden. They adopt an auto-ethnography approach utilising the first-hand experience of authors regarding specific measurement initiatives. They describe how the visionary objectives of the programme, related to sustainability, time, cost and business logics, were developed and operationalised in practice. Furthermore, they explain how several emergent challenges were managed, including ambiguity around goal formulation, adaptation to contingencies of moving targets and temporal scope, and development of a multiplicity of assessment methods (Håkansson et al. 2020).

5 Conclusions

This book brings together a set of real-life examples of how to manage and govern R&D collaboration projects for more effective OI. The book provides up-to-date knowledge that investigators, R&D project managers, governance boards and funding officers can use to implement and monitor projects to achieve a more significant impact. Recognised leading authorities with extensive experience in governance and management have been brought together to present new insights that deliver on the promise of OI. The book provides researchers with a basis for future OI management and project management investigations and resource to identify recent and relevant literature for further reading.

The book is a useful compilation of current knowledge, new research and important indications for future research directions in the field. For example, Cunningham et al. (2020) emphasise the need to understand the leadership styles that OI leaders and managers adopt in the management of their initiatives. Wang et al. (2021) highlight the need to study the value co-destruction process and validate it in a broader context, as they focus just on two case studies. Barrett and Dooley (2020) highlight the novel partnerships an SME can engage in across the triple helix model to advance disruptive R&D technologies. Martinsuo (2020) underlines the importance to study how systemic innovations could be promoted, using different levels of analysis concerning the barriers: solution, firm, market and industry and Trabucchi et al. (2020) highlight the need for quantitatively test the relevance and impact of the different OI practices on strategic goals.

There is no one ‘right’ way to how to manage R&D collaborative projects, which suggests that the dominant research philosophy in future studies might be interpretative. Future research on managing OI initiatives must focus on the development of theory based upon actual findings and data. Thus, in parallel with deductive approaches, we strongly recommend exploratory studies, to develop theories based upon the circumstances come across different inter-organisations. The data analysis might be directed primarily by an inductive approach, whereby the collection, examination and process of continual re-examination of data determine the theoretical and practical implications of the conducted research.

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Part I
Literature Reviews

A Systematic Literature Review of Open Innovation and R&D Managers

James A. Cunningham, María José Foncubierta-Rodríguez, Fernando Martín-Alcázar, and José Luis Perea-Vicente

1 Introduction

How best to organise innovation is an on-going challenge for firms. Firms source innovations from inside and outside so that they can maintain and enhance their competitive position. This leads to the creation of multiple relationships that can take several forms such as acquiring knowledge and technology from outside the firms, whether publicly accessible or privately held by other companies, universities or research centres (Fabiano et al. 2020; Skute et al. 2019). These knowledge-intensive organisations contribute more frequently to the creation, development and transfer of knowledge and technology and can provide an array of benefits to individual firms (Cunningham and Link 2015; Scandura 2016; Siegel et al. 2003). As part of companies' knowledge, the firm's R&D functions are an essential organisation function to pursue internal and external sources of innovation (Chesbrough et al. 2006). In the last two decades, there has been a growth in firms in different sectors adopting Open Innovation (OI). The increasing research attention reflects this on various aspects of OI within the innovation domain and cognate fields (see Chesbrough 2017; Chesbrough et al. 2006; Cunningham and Walsh 2019; Bogers et al. 2017; O'Sullivan and Dooley 2008; Enkel et al. 2009; Gassmann et al. 2010; Huizingh 2011). OI represents a means for firms to co-operate with other firms public or private, universities, public research organisations, public bodies, as part of their strategy to sustain a competitive advantage and for value creation purposes (Reed et al. 2012; Rohrbeck et al. 2009). OI means organisations collaborate with

J. A. Cunningham (✉)
Northumbria University, Newcastle Upon Tyne, UK
e-mail: james.cunningham@northumbria.ac.uk

M. J. Foncubierta-Rodríguez · F. Martín-Alcázar · J. L. Perea-Vicente
Universidad de Cádiz, Cádiz, Spain
e-mail: mariajose.foncubierta@uca.es; fernando.martin@uca.es; joseluis.perea@uca.es

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other talented innovators outside their firm (Chesbrough 2003) and adopting OI positively impacts their innovative thinking process (Salter et al. 2015). Competitive advantages can be achieved through the implementation of OI (Vanhaverbeke and Cloodt 2014). The challenge for firms is how best to organise and support OI, so that is aligned with the firm strategy, current and future competitive conditions.

Traditionally, companies use to create research and development (R&D) departments to house their innovation activities and capabilities to improve their productivity and to become more competitive (Grant 1996). The R&D function in a firm has become critical to supporting its long-term competitive sustainability and stability. Moreover, the R&D function is a source and a value-generating factor within a firm (Carpenter et al. 2010), and it is such a particular context that the R&D leader needs a set of specific characteristics (Keller 2017). The R&D leader is a critical role in managing the R&D function that comprises of multidisciplinary knowledge workers and their associated teams. It is a pivotal organisation role in the knowledge transfer and creation processes in R&D environments and is key to achieving the organisations innovative objectives (see Edmondson and Nembhard 2009; Elkins and Keller 2003). Within the literature, there have various definitions of R&D leader role characteristics (Grosse 2007; Keller 2017; Gritzo et al. 2017). For instance, Grosse (2007) emphasised their ability to make their team members work efficiently rather than doing it. Resolving any team members conflict, being respectful and caring, being tolerant to the risk and being accountable are other R&D leader's role characteristics highlighted in the literature (Elkins and Keller 2003; Grosse 2007; Gritzo et al. 2017). R&D leader's role is also to enhance co-operation between the team members and fostering team members to resolve problems (Gumusluoğlu et al. 2017; Lisak et al. 2016). In this sense, Rangus and Černe (2017: 10) demonstrated that leader's behaviours such as: 'mentioning the names of other people who endorse a proposal when asking employees to support it, getting others to explain why they support a proposed activity or change or bringing someone along for support when meeting with employees to make a request or proposal' creates OI relationships. This fosters intra-team collaboration and collaboration between team members and members outside the team, thereby increasing the team's and the company's capacity for innovation and to purse OI.

Against this background of the growth of OI, the role of individual actors in leading and managing OI has been overlooked (see Ahn et al. 2017; Salter et al. 2014). Some studies of OI and leadership highlight the role of top management play in enhancing firm-level OI (Chiaroni et al. 2010; Lee and Shin 2017). However, the role of R&D leaders in leading OI is poorly understood and has not been the focus of much empirical research investigation. Since the R&D function is a singular and unique setting, quite different from other organisational services, managing complex process, people and processes is not an easy undertaking (see Thamhain 2003). It is a very challenging function, and it requires a particular sort of leader (see Gupta and Singh 2015; Zhou et al. 2018).

For this reason, the R&D leader role, managing and leading an OI strategy and the R&D function within the firm needs to be better understood. Using a systematic literature review of key journals in the innovation, strategy, entrepreneurship and leadership fields, the purpose of this chapter is to thematically review and analyse the R&D leader role within an OI R&D environment. Consequently, we begin our chapter with an overview of the methodological approach we undertook for our review, and then we discuss our critical findings before concluding the chapter with our future avenues of research.

2 Methodology

We conducted a systematic literature review to identify and analyse the main themes and streams with respect to R&D leaders and open innovation. Similar to other studies (see Bocconcelli et al. 2018; Henry et al. 2016) we selected crucial high impact and influential journals in the innovation, strategy, entrepreneurship and leadership fields for our study included *Research Policy, Research-Technology Management, California Management Review, R&D Management*, *Technovation*, *Technology Forecasting and Social Change, Journal of Product Innovation Management, Journal of Management, Leadership Quarterly, Organisation Studies, British Journal of Management and Long Range Planning*. Since applying the rigorous methods in identifying, assessing and incorporating research, potential errors and biases are minimised, and the quality of the review is enhanced (Ivarsson and Gorschek 2009). The systematic literature review design comprises different attributes such as, a clear description of the objective to be achieved, a planned methodology, a detailed examination to find those articles that may fit the determined parameters, a selection based on the specification of the criteria and a consistent presentation of the results (Transfield et al. 2003). Its transparency stands out as one of its remarkable strengths as well as its openness to review or critique (Pittaway and Cope 2007).

The primary purpose of this chapter is to determine the pivotal contributions to a growing area of research as OI, related to the specific theme of the R&D leader or manager role within an OI R&D environment. Although the literature on OI research is increasing, the role of R&D leaders in leading OI is still unclear. Therefore, a systematic literature review comprises two phases: the first phase consists of the definition of screening procedures; and the second phase concerns reporting the results (Transfield et al. 2003; Pittaway et al. 2004) (see Fig. 1).

The first phase involves defining the specific questions that need to be addressed, determining the relevant selection criteria and the procedure to include or exclude the papers to be studied (Transfield et al. 2003). For this systematic literature review, the main question to be addressed in this study is to examine the current state of research on the role of R&D leaders in leading and managing OI. Since Chesbrough's work in 2003 on OI, there has been a growing body of research. Hence the period of study is from 2003 to 2019. To obtain the most extensive number of articles related to the specific field of research, the following systematic Boolean keyword search was used: '*Open Innovation*' AND '*R&D leader**' OR '*R&D manager**' OR '*R&D environment*' OR '*leader**' OR '*manager**'. This

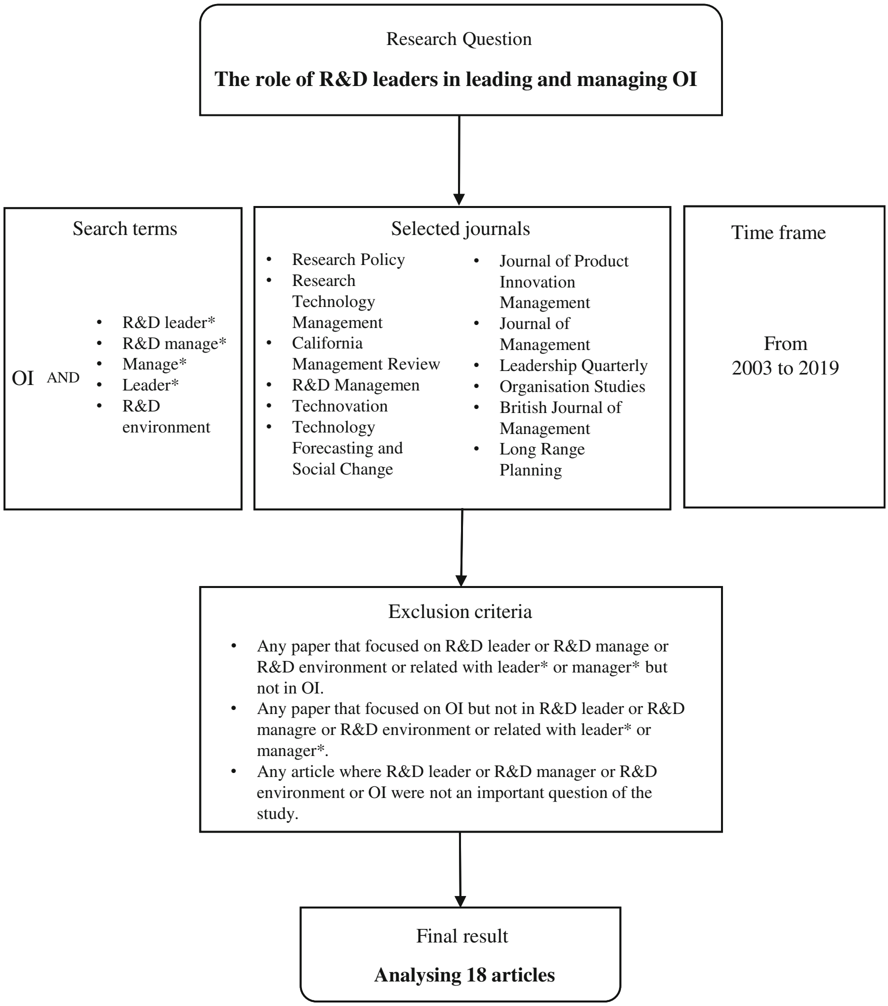

Fig. 1 Systematic review process

process was carried in the title, abstract and/or keywords our selected journals mentioned above. A group of 299 articles were identified through a first analysis of the abstracts (Torraco 2005) from the following journals: *Research Policy, Research Technology Management, California Management Review, R&D Management* and *Technovation.* Using our keyword search surprisingly we did not find any articles publishing in the following journals *Technology Forecasting and Social Change, Journal of Product Innovation Management, Journal of Management, Leadership Quarterly, Organisation Studies, British Journal of Management and Long-Range Planning*.

Our second phase consisted of reading and reviewing each paper concerning fit for OI and R&D managers. The exclusion criteria were applied (Calabrò et al. 2019; Sweeney et al. 2019). The full text, the abstract, title and keywords were analysed of the 299 papers. Those papers that focused on R&D leader or R&D manage or R&D environment or related with leader* or manager* but not in OI, those papers that focused on OI but not in R&D leader or R&D manager or R&D environment or related with leader* or manage* or any article where R&D leader or R&D manage or R&D environment or OI were not an important question of the study was removed from our systematic literature review. After completing this systematic literature review process, a final sample of 18 articles was selected as part of our phase two (see Table 1). We then undertook a comprehensive review of each of the articles to identify and analyse the relevant contributions to our study focus (Table 2).

3 Findings: Key Themes

Based on our systematic literature review, three key themes were identified, namely, OI implementation, fear and firm performance which will be used as the structure for the remainder of this chapter.

3.1 Theme 1: OI Implementation

The traditional R&D model in which discovery, research and development, as well as commercialisation could be managed and developed internally for a firm to be successful can be outdated in some sectors. It is becoming clear that all the competencies needed to innovate are not available within the firm, so pursuing OI becomes essential (Jelinek et al. 2012; Slowinski et al. 2009). For this reason, one of the main themes is determining how the OI implementation process should be within a firm. The main themes from our systematic literature concerning the role of the R&D manager concerning OI implementation included their networks, ability to deal with internal barriers and structures, training programmes and their management of relationships.

One of the challenges for firms is embracing open innovation from a closed innovation environment (Chiaroni et al. 2010). We found some papers focused on understanding successful OI implementation process through exploratory research based on different firms (Slowinski et al. 2009; Sieg et al. 2010; Chiaroni et al. 2010; de Araújo Burcharth et al. 2014), although not always have similar results (Christiansen et al. 2013). For example, Sieg et al. (2010) centred their research on seven firms. Thes firms search for solutions to R&D problems applying OI. The first two phases—problem selection and problem formulation—were conducted inside the firm and R&D department has the primary responsibility. The next two phases—problem posting and problem-solving—are developed outside the firm through an

Table 1 Systematic literature review search results

Keywords	R&D Management	Research Policy	Technovation	Research technology management	California Management review	Total
Open Innovation and R&D leader*	2	1	0	3	2	8
Open Innovation and R&D manager*	19	8	9	8	6	50
Open Innovation and R&D environment	4	3	3	3	0	13
Open Innovation and leader*	9	8	1	4	2	24
Open Innovation and manager*	63	41	42	32	26	204
Total—first analysis	97	61	55	50	36	299
Total—final	6	2	4	5	1	18

Table 2 Comprehensive notes on literature review

Title	Authors	Journal	Year	Purpose	Methodology	Findings
Innovation communities: the role of networks of promotors in OI	Klaus Fichter	R&D Management	2009	This paper introduces a new construct of 'innovation communities' based on promotor theory, which it defines as 'networks of promotors'. It proposes a comprehensive concept of the quality of interaction in innovation communities. (p. 357)	Qualitative method: multiple case-study	Transformational leaders as promotors, and especially their close and informal co-operation across functional and organisational boundaries, play a key role in OI. (p. 357)
Determinants and archetype users of OI	Marcus Matthias KeuppOliver Gassmann	R&D Management	2009	They focus on explaining the externalisation of R&D activities as a result of firm-internal weaknesses to innovate and how this impedes innovation influence in the breadth and depth of OI. (p. 331)	Quantitative method: GLS regression models	They identified four archetypes of firms that differ significantly regarding the breadth and depth of OI and the importance of the impediments. (p. 331)
Firms' OI policies, laboratories' external collaborations, and laboratories' R&D performance	Kazuhiro AsakawaHiroshi NakamuraNaohiro Sawada	R&D Management	2010	This study attempts to measure the impact of firm-level and laboratory-level OI policies and practices on R&D performance. (p. 109)	Quantitative method: structural equation model	The results show how an OI policy can contribute to the laboratory's R&D performance by facilitating external collaborations by the laboratories. It

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Table 2 (continued)

Title	Authors	Journal	Year	Purpose	Methodology	Findings
						demonstrates how these factors affect R&D performance in different ways, depending on the type of R&D tasks. (p. 109)
Identification of competencies for professionals in OI teams	Elise du ChatenierJos A. A. M. VerstegenHarm J. A. BiemansMartin MulderOnno S. W. F Omta	R&D Management	2010	This study examines the competencies that professionals need for working in OI teams (specific but not necessarily unique to OI) and to cope with the challenges they face. (p. 271)	A cluster study and explorative interviews and focus group discussions (qualitative methods)	They proposed a set of competencies professionals need in OI teams.
Unravelling the process from closed to OI: evidence from mature, asset-intensive industries	Davide ChiaroniVittorio ChiesaFederico Frattini	R&D Management	2010	Which changes in a firm's organisational structures and management systems does the shift from closed to OI entail? (p. 222)	Qualitative method: case-study	The results show that the journey from closed to OI involves four main dimensions of the firm's organisation, i.e. inter-organisational networks, organisational structures, evaluation processes and knowledge management systems, along which change could be managed and stimulated. (p. 222)

Managerial challenges in OI: a study of innovation intermediation in the chemical industry	Jan Henrik SiegMartin W. WallinGeorg von Krogh	R&D Management	2010	They investigate the managerial challenges faced by companies working with an innovation intermediary to solve R&D problems. (p. 281)	Qualitative method: case-study	Three challenges were identified: (1) enlisting internal scientists to work with the innovation intermediary; (2) selecting the right problems; and (3) formulating problems so as to enable novel solutions. They explained how these challenges arise out of scientists' different work practices in internal vs. external R&D problem solving and they identified and discussed a number of remedies to these challenges. (p. 281)
Twenty-First-century R&D. New rules and roles for the R&D "lab" of the future	Mariann JelinekAlden S. BeanRichard AntcliffErik Whalen-PedersenApril Cantwell	Research-Technology Management	2012	In May 2007, Richard Antcliff challenged IRI members with a presentation asserting the notion that 'three tsunamis' were about to break upon R&D managers, demanding urgent response. Technological exponentials, global demographic shifts, and the	Brainstorming, online survey, individual interviews and questionnaires	OI, globally dispersed R&D operations, and an emphasis on collaboration suggest that the R&D lab of the future is far less likely to be 'a lab' (especially a single, central corporate lab) than an intricate, dynamic innovation ecosystem. (p. 16)

(continued)

Table 2 (continued)

Title	Authors	Journal	Year	Purpose	Methodology	Findings
				phenomenon of climate change all posed challenges that promised to transform R&D. How are R&D managers responding to the perfect storm created by those tsunamis? (p. 16)		
Effective practices for sourcing innovation	Gene SlowinskiEdward HummelAmitabh GuptaErnest R. Gilmont	Research-Technology Management	2009	Which are the effective practices for OI?	Qualitative method: interviews	Innovation-sourcing practices were identified in three key areas: (1) linking external innovation to strategy, (2) defining what the firm wants to access externally, and (3) leading cultural change. (p. 27)
Improving design with OI A flexible management technology	John K. ChristiansenMarta GasparinClaus J. Varnes	Research-Technology Management	2013	Is it necessary or even possible to apply the management technology of OI to all projects in the same way? (p. 36)	Qualitative method: interviews	Those involved in OI need both a broad knowledge of the various potential elements of an OI effort and a flexible attitude towards their application. (p. 36)
OI at NASA A new business model for advancing human health	Jeffrey R. DavisElizabeth E. RichardKathryn E. Keeton	Research-Technology Management	2015	It describes a new business model for advancing NASA human	Qualitative method: case-study	They describe the strategy execution, including adoption and

and performance innovations				health and performance innovations. (p. 52)		results of OI initiatives, the challenges of culture change, and the development of a knowledge management tool to educate and engage the workforce in the new strategy and promote culture change. (p. 52)
A path to collaborative innovation through internal boundary breaking	Sung-Mahn LeeJuneseuk Shin	Research-Technology Management	2017	It describes LG Chem Research Park's process of transforming a large, closed R&D centre into a collaborative organisation. (p. 26)	Qualitative method: case-study	The internal application of OI tools broke down formal boundaries between individuals and teams. Informal communities allowed researchers to build relationships, thereby breaking informal boundaries. (p. 26)
Towards an open R&D system: Internal R&D investment, external knowledge acquisition and innovative performance	Luca Berchicci	Research Policy	2013	It examines the influence of R&D configuration on innovative performance and the moderating role of a firm's R&D capacity. (p. 117)	Quantitative method: Tobit regression	The findings suggest that firms that increasingly rely on external R&D activities have a better innovative performance, yet up to a point. Beyond this threshold, a greater share of external R&D activities reduces a firm's innovative performance. (p. 117)

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Table 2 (continued)

Title	Authors	Journal	Year	Purpose	Methodology	Findings
Managing OI projects with science-based and market-based partners	Jingshu DuBart LetenWim Vanhaverbeke	Research Policy	2014	This paper examines the relationship between two types of OI partnerships—science-based and market-based partnerships—and the financial performance of R&D projects. (p. 828)	Quantitative method: Tobit regression	The results show that R&D projects with OI partnerships are associated with a better financial performance providing that they are managed in the most suitable way. Market-based partnerships are positively correlated with project performance if a formal project management process is used; however, these partnerships are associated with a lower performance for loosely managed projects. In contrast, science-based partnerships are associated with higher project revenues for loosely managed projects only. (p. 828)
Social media: a tool for OI	Matthew MountMarian Garcia Martinez	California Management Review	2014	How can companies organise for and implement social media for OI. (p. 124)	Qualitative method: multiple case-study	It proposes a range of organisational and technological adaptations that managers can implement to ensure

						they realise the innovative benefits of social media application. (p. 124)
The impact of OI on firm performance: The moderating effects of internal R&D and environmental turbulence	Kuang-Peng HungChristine Chou	Technovation	2013	This study explores the direct and interactive effects of inbound OI and outbound OI on firm performance and further examines the moderation effects of two factors (i.e. internal R&D and environmental turbulence) on those relationships. (p. 368)	Quantitative method: ordinary least square regresion	The result shows that inbound OI positively affects firm performance, whereas outbound OI does not. This study also finds that inbound OI strengthens the relationship between outbound OI and firm performance. Both inbound OI and outbound OI are positively related to firm performance under high internal R&D investment and a turbulent market environment. However, technological turbulence only positively affects the relationship between inbound OI, but not outbound OI, and firm performance. (p. 368)
Research collaboration and R&D outsourcing: different R&D	Peter TeirlinckAndré Spithoven	Technovation	2013	The paper focuses on the different requirements in terms of	Quantitative method: bivariate probit regression	The relation between R&D personnel requirements and

(continued)

Table 2 (continued)

Title	Authors	Journal	Year	Purpose	Methodology	Findings
personnel requirements in SMEs				availability and training of research managers and R&D experts for research co-operation versus R&D outsourcing in SMEs. (p. 142)		research collaboration and R&D outsourcing depends upon the SME size. Very small firms engage significantly less in research co-operation than medium-sized firms and the propensity to engage in research co-operation is positively associated with the share of PhD holders among the research managers and R&D experts. For R&D outsourcing activities both the presence of research managers and R&D experts is important. (p. 142)
Neither invented nor shared here: The impact and management of attitudes for the adoption of OI practices	Ana Luiza de Araújo BurcharthMette Praest KnudsenHelle Alsted Søndergaard	Technovation	2014	This paper focuses on the unwillingness of employees to undertake extra-organisational knowledge transactions in the form of negative attitudes against the sourcing of external	Quantitative method: ordinal regression analyses	By focusing on two attitudinal antecedents to openness, the findings offer an explanation for the problems that firms face in benefiting from inflows and outflows of

				knowledge (the not-invented-here syndrome) and against the external exploitation of knowledge assets (the not-shared-here syndrome). (p. 149)		knowledge and possible guidance as to how managers can disengage such attitudes. (p. 149)
Capturing value from alliance portfolio diversity: the mediating role of R&D human capital in high and low tech industries	Marian Garcia MartinezFerdaous ZouaghiMercedes Sanchez Garcia	Technovation	2017	This paper examines the value of alliance portfolio diversity and whether R&D human capital is the pathway through which alliance portfolio diversity influences innovation novelty. (p. 55)	Quantitative method: generalised structural equation model	Results support the curvilinear (inverted U-shaped) association between alliance portfolio diversity and firm innovation performance reported in studies, suggesting that not only too little, but also too much alliance portfolio diversity may be detrimental to firm innovation performance. (p. 55)

intermediary innovation company. The final phase is developed inside the firm, which is the solution evaluation. They perform the phases that involve OI outside the firm through an intermediary called InnoCentive (Slowinski et al. 2009; Davis et al. 2015; Lee and Shin 2017). Furthermore, Slowinski et al. (2009) refer to additional intermediaries such as YourEncore, Yet2come and NineSigma. The main idea of these intermediaries is quite similar to the process described above, in which those responsible for R&D have to specify which innovation the company needs or will need in the future, and a process of searching will be initiated. The range of external sources will depend on the network of the R&D manager (Slowinski et al. 2009; Sieg et al. 2010). Such studies highlight the role of the R&D manager as a facilitator/ network broker and in some sense, a guardian of the OI processes within firms. This highlights the need for an R&D manager to have an extensive network within the firm outside the R&D department and with outside firms and knowledge intermediaries and brokers.

Based on a longitudinal study of four different Italian firms Chiaroni et al. (2010: 228) asserted that there are three distinctive phases from the closed innovation model to the OI: 'unfreezing, moving and institutionalising'. During the first phase, unfreezing, R&D managers play a fundamental role. R&D managers' social networks provide them access to the essential sources of knowledge and technologies to achieve innovation. Making visible to the rest of the firm the advantages of this new way of innovating is one of the essential functions of the managers of these R&D units. The purpose of this is also to justify all the resources that will be invested in the process of opening up the company to external innovation. Furthermore, the authors proposed beginning by applying the OI techniques in pilot projects, so that later the results can be presented as an example of a better way of innovating. A study undertaken at LG Chem Research Park is used to determine whether the firm can apply OI techniques (Lee and Shin 2017). Throughout the two methods established for the implementation of OI in the firm, Lee and Shin (2017) asserted that R&D managers need to be able to identify any possible internal barriers. Addressing them, they need to be able to overcome them more efficiently, taking advantage of the assets of OI. Also using social media can enhance the positive impact of OI. R&D managers should use it to reduce any internal barrier, to improve the absorptive capacity of external knowledge and the internal knowledge transfer (Mount and Martinez 2014).

A further practice to achieve a successful implementation process of OI is that R&D managers enhance training programmes to overcome any negative attitudes R&D department employees towards OI (de Araújo Burcharth et al. 2014). There are a few studies focused on determining the OI implementation process, as well as there is a lack of sufficient OI practices for success (Brunswicker and Chesbrough 2018). Christiansen et al. (2013) proposed some intellectual property processes and incentives systems, although not always proven to be effective. In fact, among the eight projects they examined, just four turned to be positive. Therefore, R&D managers need to be conscious of the practices that better perform in the OI process, not only at the firm level but also at the department level.

A core tenet of OI is innovation does not have to be developed within a company. Just the opposite. OI is enriched by interactions and relationships with suppliers, customers, research centres, universities and even competitors, to enhance the scope of innovation. Therefore, a competence that R&D managers need for OI is to manage such interactions that take place between scientists belonging to the firm, but also with those outside the firm (see Jelinek et al. 2012; Asakawa et al. 2010).

3.2 Theme 2: Fear

In our second theme, two main aspects emerge concerning fear that OI R&D managers face based on the papers in our study. Inertia from years of experience doing the same thing is difficult to change. Therefore, the idea and practice of sharing information and knowledge with partners outside the firm go against the operating principles and firm culture. Thus, one main fear is sharing knowledge with people outside the firm. The other main fear centres on cultural changes and managing change that is associated with OI.

Undoubtedly, a considerable number of studies that have appeared in this literature review have focused not only on how to deal with the fear of change, but also the fear of sharing knowledge. Building a department that is specifically focused on the implementation of the OI in the company is not enough. There is a need to encourage and foster the new way of innovating by adopting OI such as the internal culture (see Chiaroni et al. 2010; Asakawa et al. 2010; Christiansen et al. 2013).

Implementing OI has many advantages (Chesbrough 2004). However, all these interactions with external actors allow the opportunity to access knowledge and innovations more cost-effectively. The fear also is they may breed future competitors (Jelinek et al. 2012). R&D managers also have to cope with the application of OI techniques and balance this against their misgivings and beliefs about the potential of adopting an OI strategy and associated practices (Sieg et al. 2010; Davis et al. 2015). R&D managers have to consider the consequence of having external innovation—inbound OI—as this can reduce the available financial and human resources (Slowinski et al. 2009). Furthermore, an extremely compartmentalised structure and an absence of communication between the diverse research projects complicate implementation and the organisational culture that is required for OI to thrive (Lee and Shin 2017). Inertia can stifle the adoption of OI and R&D managers need to be mindful of this and the natural fears that arise when collaborating with actors outside their firm.

Conversely, other R&D managers accept the fact that nowadays, innovation takes place globally. As Jelinek et al. (2012: 21) stated: '*innovation has flown from the central R&D lab to the labs of collaborators around the world*'. The strategy to be followed by the R&D department will influence the R&D structure that is created within a firm. In OI contexts R&D managers determine the kinds of problems they deploy OI strategies and the types of knowledge to be shared in the resultant relationships (Chiaroni et al. 2010; Lee and Shin 2017). Furthermore, R&D

managers should be able to understand that with the implementation of OI, not only should they seek solutions to problems, but one of the changes they are facing is that now they also need to seek solutions through knowledge networks or find those who can provide the answer (Sieg et al. 2010; Davis et al. 2015; Lee and Shin 2017). Hence, they have to spend significant amounts of time on it. Therefore, the risk and fear are always that the firms and actor R&D managers finally decide to collaborate with are not the right ones, thus damaging the reputation within their company (Lee and Shin 2017).

One of the conclusions drawn by de Araújo Burcharth et al. (2014) in their paper is that the attitude of the members of the R&D department towards OI is crucial. Unless members support the OI implementation process, they could easily manage that knowledge sharing—inbound OI or outbound OI—ended up becoming a failure. The authors were able to identify two different negative attitudes: the attitude against the acquisition and application in the company of external knowledge, called not-invented-here (NIH); and the attitude against exporting the internal knowledge available in the company, called not-shared-here (NSH), for R&D managers are essential to recognise those kinds of negative attitudes among their employees, to mitigate them immediately.

3.3 Theme 3: Firm Performance

It is not surprising that our third theme to emerge from our study is in respect to firm performance and OI R&D management which has been studied with some interest (Asakawa et al. 2010; Berchicci 2013; Hung and Chou 2013; Du et al. 2014). Such studies have demonstrated the positive impact that can be achieved. Hung and Chou (2013) asserted that inbound OI has a positive effect on firm performance. This relationship is positively moderated by internal R&D. Therefore, as the R&D department is more developed, the firm performance will be higher. This is further supported by Berchicci (2013). In his study, he argues that the impact of the OI in the firm performance depends on the '*stock of knowledge*' (p. 125) contained in the R&D department. Both studies reached similar conclusions, with samples from high-tech manufactures, although from different continents: Hung and Chou (2013) carried out their study in Taiwan–Asia and Berchicci (2013) did it in Italy–Europe. The benefit of this 'stock of knowledge' is reflected in the economic side, since it involves fewer costs and less effort. Furthermore, the higher the internal R&D, the fewer the partners with whom the R&D department has to collaborate with to achieve the objectives and only with those who make the company's value increase. Despite both studies reaching similar conclusions, Berchicci (2013) observed the number of external R&D activities undertaken. In his study, he highlights the point at which these external R&D activities can be counterproductive for the firm's innovative performance, as it can be reduced. In essence, the R&D manager's role is to help shape the form of OI adoption and the associated organisation practices and process that contribute to firm-level performance.

R&D managers' attitudes and initiatives promote the use and implementation of OI. Asakawa et al. (2010) suggested that R&D managers should be proactive in the implementation process, not only in the R&D department but across the whole organisation. Also, along with the facilitation of external collaborations, firm performance can be enhanced. Nevertheless, these results may be different depending on the external collaborator. For instance, if the external collaborators are universities or research centres, they will improve the R&D department's research performance.

On the contrary, if they are companies—customers, suppliers, etc.—they will boost the R&D department's development performance. Du et al. (2014) also explore the impact of the OI on firm performance. However, they make a distinction in the type of relationships that R&D managers carry out in the different projects, distinguishing between 'science-based partnerships'—with research centres and universities—and 'market-based partnerships'—with suppliers and clients—(p. 829). Depending on the type of collaboration, how the R&D managers manage the project will have a positive or negative impact on firm performance. In the case of market-based partnerships, the R&D managers should carry out regular control and strictly fulfil the planning initially established to improve firm performance. In contrast, if the R&D managers are less strict and more loosely managing the science-based partnerships, they will also obtain positive results from these relationships. Therefore, the choices that R&D managers make about the type of OI partnership determine firm performance.

4 Conclusions

From this study, it is evident that the human side of OI has received limited empirical attention in the last decade despite the significant research interest and growth of OI empirical studies. Given the growth of OI in practice across different industrial sectors and firms (Dell'Era et al. 2018) we found that journals we had selected that are more focused on leadership and strategy have not published any papers on OI and leadership and management. This begs the question of why given more commonly practised OI strategies that are being adopted by firms are not reflected in academic journals that take a leadership and management focus. Such a focus is essential to advance our understanding of OI (Pellizzoni et al. 2019). Overall, our study highlights the need for future studies to focus on the leaders and managers who have the responsibility for OI processes, structures and strategy. There is a real need to provide OI R&D managers with practical analytical tools, frameworks to support their management of OI underpinned with empirical evidence.

Based on our study, we see several future avenues for research that would advance our understanding of OI and R&D management and leadership that focused on individual managers and leaders (Table 3). Within the fields of leadership (Kaplan et al. 2012; Rajagopalan and Datta 1996), strategy (Cunningham and Harney 2012; Gavetti and Rivkin 2005), and entrepreneurship (Littunen 2000;

Holt et al. 2007) there have been studies that focused on defining the characteristics of individual actors and examining these characteristics concerning such issues as culture and performance. There is a need within the OI field to purse such cross-country studies of OI leadership and management characteristics and to advance how these impact on firm performance, productivity, culture and other related themes. Moreover, there is a need to understand the leadership styles that OI leaders and managers use when they are initiating and managing OI innovation activities across different sectors, firms' sizes and purposes—for-profit and non-profit. Such studies may begin by examining different types of leadership styles—transformation and transactional—(Bass and Avolio 1993; Bass 1999; Kark et al. 2003; Lowe et al. 1996) on how they impact on OI. Also, an interesting strand of research to pursue is what types of leadership approaches and styles OI leaders and managers use during firm turnarounds that build on an existing body of studies (see O'Kane and Cunningham 2012, 2014). Moreover, these studies should also focus on OI leadership diversity issues (see Bogers et al. 2018). Such studies of OI leadership characteristics should pay particular attention to gender (see Wikhamn and Knights 2013), which is an under-researched theme within the OI field.

To further research the human side of OI and R&D managers, we identified some future research avenues organised around the core themes identified in our study (see Table 3).

Our first theme identified limited studies on OI implementation and the role of the R&D manager. These studies form the basis to expand this research stream. There is a need to develop further empirical studies that examine the variety of approaches and processes that OI R&D leaders and managers adopt in managing the day-to-day OI process within a firm. In particular, there is a need to understand more in-depth how the networks of OI innovation managers and leaders influence and shape the OI

Table 3 Future research avenues

OI implementation	Further empirical studies could: • Examine how R&D leaders manage the day-to-day OI process within a firm. • Focus on managerial and leadership approaches and different leadership styles that R&D leaders adopt to remove internal barriers. • Focus on a better understanding of the firms' training programmes developed to prepare the competencies that OI R&D leaders and managers need for successful continual OI implementation.
Fear	Further studies could: • Analyse the tactics that R&D leaders use for inbound and outbound OI and how they scan for potential OI partners. • Focus on the reason that negative cultural attitudes within the firm emerge against OI R&D leaders and managers.
Firm performance	Further studies could: • Investigate large-scale cross country and sector studies for a deeper understanding of the relationship between firm performance and OI R&D leadership style. • Explore the contribution of OI R&D leaders to firm performance and firm-level value creation activities.

strategy adopted by a firm and the day-to-day management of OI. How do OI leaders and managers appropriate knowledge and practices from these networks? How do these translate into adopting new approaches and processes within the firm? When an OI leader and manager leaves a firm, what is the impact on network access and firm-level OI strategy implementation? To advance studies concerning these pertinent and relevant questions researchers could draw, for example, strategy process (Pettigrew 1992) and institutional logics (Thornton et al. 2015) as a theoretical basis to address these questions.

Within this stream, we also identified a stream of research that identifies how OI R&D managers support the removal of internal barriers. To extend this research theme, future studies could focus on what managerial and leadership approaches and leadership styles do OI leaders and managers adopt to remove these barriers? What is the impact on employees, knowledge and management systems within the firm? What managerial and leadership approaches, practices and styles contribute to continual OI implementation success and under what organisational and contextual factors? Drawing on the growing body of studies of middle managers and sensemaking particularly from the strategy field could form the basis to address how OI leaders and managers overcome internal barriers and how they manage and lead (see Balogun and Johnson 2004; Rouleau and Balogun 2011; Rouleau 2005).

Training programmes and individual level competencies were two further themes identified in our study, and these also are worthy of a new study. There is a need to understand better how do firms develop the role preparedness and individual managerial and leadership competencies of OI leaders and managers that are essential for successful continual OI implementation. What are the optimal training and talent management programmes that are necessary for OI role preparation for an OI leadership and managerial role? What specific leadership competencies enhance OI implementation and OI strategy development? For other leadership and managerial roles such as human resources, finance and marketing within firms, we better understand from empirical research and practice how to prepare individuals for these roles. We lack this clarity and evidence base from empirical studies and practice to develop the appropriate competencies and to also provide the necessary training for future OI leaders and managers to prepare them for the role better. Within human resources literature the growing body of studies on talent management (see Al Ariss et al. 2014; Collings and Mellahi 2009), job competencies and management development (see Akkermans et al. 2013; Jubb and Robotham 1997; Whetten et al. 2007) provide research frames to address the themes of training programmes and individual level competence.

Our second theme we unearthed in this study centred on fear—the fear to share knowledge and cultural change. From the limited studies in our study, it is clear that OI leaders and manager fear not getting the partner selection right and how this will impact on the firm. So, there is a need to more fully understand firstly, the processes and their cognitive thinking concerning partner selection and secondly, what tactics and approaches do they use to prevent partnership failure for OI. Associated with that there is a need for future studies to explore the timing and tactics that OI leaders and managers use for inbound and outbound OI and in particular in how they scan for potential OI partners. Moreover, not all OI pursued by firms will lead to successful outcomes and will fail. The existing literature in the fields of innovation and entrepreneurship has a small body of empirical studies that focuses on different aspects of failure (see D'Este et al. 2016; Link and Wright 2015; Maidique and Zirger 1984; Hu et al. 2015; Walsh and Cunningham 2016 2017; Van der Panne et al. 2003). Researchers taking this focus could examine, for example, how OI leaders and managers manage when OI fails. How do they deal with the stigma of OI failure? How do they learn from OI failure? How do they prevent future OI failure and what organisational processes do they initiate to mitigate against OI failure? What is the physiological impact of OI failure on the individual OI leader or manager, and how do they develop organisational, team and personal resilience to effectively cope and deal with OI failure?

The second related theme to emerge from our study centres on the cultural change and the fear that OI will not work in firms, mainly as employees are not fully bought into the implementation of OI. Therefore, more studies may draw on more extensive change management (see Gill 2002; Herold et al. 2007) literature needs to explore why negative cultural attitudes do emerge against OI leaders and managers. Is this typically focused towards the OI organisational role holder or is it to do with OI as a new process and a way of doing business within a firm? What tactics do OI leaders and managers use to overcome negative employee attitudes? Do incentives—formal and informal—contribute to allaying such negative beliefs and fears?

Firm performance is the final theme to emerge from our study. The existing body of limited empirical studies in the research strand offers some prescriptive advice to OI leaders and managers particularly concerning partner selection and scale, the need for more extensive organisational buy into OI and the importance of their leadership that support effective R&D departments. Existing studies have examined the relationship between R&D and firm performance (see Artz et al. 2010; Belderbos et al. 2004; Falk 2012; Shin et al. 2017), and there is a real need for vast scale cross country and sector studies that can attribute firm performance to OI leadership. In essence, do OI leaders and managers contribute to firm performance and firm-level value creation activities? Acknowledging the challenges associated with such studies, there is a real need if the field is to evolve further and as well as having a practice-based contribution.

In conclusion, there is still a lack of understanding of the influence of OI R&D leaders and managers on the firm performance. Therefore, our study highlights the real need for research to address the human side of OI and in particular, the role of OI leader and managers. Not alone does this further advance this field of study. It provides OI leaders and managers with the requisite knowledge bases, appropriate tools, techniques, tactics and approaches that they can use in an OI leadership and managerial role which is complex given the networks and relationships that need to be managed and maintained. For educators, more knowledge of OI leaders and managers allow them to design and provide the appropriate formal formation experiences to contribute to their OI role preparation so that they can help effectively within firm settings—for-profit and non-profit. This requires embracing different methodological approaches and novel data collection strategies to provide the necessary robustness and rigour that forms the underpinning evidence that can adequately inform practice. For OI to flourish in practice and to be adopted more widely in requires that OI leaders and managers to have a better understanding of their role and that they are equipped with the requisite knowledge to continually be effective concerning OI strategy development and implementation.

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Review of Collaborative Project Management Approaches in R&D Projects

Alencar S. Bravo, Darli R. Vieira, Christophe Bredillet, and Rebecca Pinheiro

1 Introduction

Organisations drive innovation primarily through projects, which is how they create new products or services (Hansen 2015). As a result of the production of innovations and new endeavours, organisations become renowned, and they can continue to thrive in a competitive market, regardless of whether they are academic or industrial (Schwab 2017). Therefore, project management (PM) is a mechanism for prosperity in many fields.

In this chapter, if all projects have stakeholders that collaborate during the project, collaborative projects are understood as a practice in which at least two organisations share the leadership and control of a single project. This involvement is approximately equal in proportion.

Indeed, working on a multi-organisational collaborative project to increase value through collaborative synergy is of interest (Debackere and Veugelers 2005). Collaborative projects are developed to promote the integration of professionals from different organisations based on the same objective, sharing knowledge, and outlining common strategies. For example, the dynamics of universities differ from those of private companies, but productive interaction through collaboration projects between these entities remains possible.

At present, while there are several vastly different PM methodologies, frameworks, and norms, they all have the same goal, i.e. to increase the success of PM. Each framework is distinct in its school of thought and structure, and to date, there is no clear answer as to which approach works best (Joslin and Müller 2015; Muller 2017).

A. S. Bravo (✉) · D. R. Vieira · C. Bredillet · R. Pinheiro
Université du Québec à Trois Rivières, Trois-Rivières, Canada
e-mail: Alencar.Soares.Bravo@uqtr.ca; Darli.Vieira@uqtr.ca; Christophe.Bredillet@uqtr.ca; Rebecca.Pinheiro@uqtr.ca

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In collaborative projects, common language problems are frequent, and even basic terms, such as work breakdown structure (WBS), can be misunderstood in a collaboration that uses different approaches. While PRINCE2 contains a strict decomposition of activities, in the PMI framework, this term refers to the decomposition by-products of the project (Bennet 2017). The bodies of knowledge that serve PM as an academic practice and discipline provide a potentially useful organisational resource. However, coordinating different bodies of knowledge and maintaining pace with changing concepts are challenging, especially in collaborative projects (Delisle and Olson 2004; Kerzner 2019).

This chapter aims to serve as a reference concerning the main approaches currently used in PM based on processes, results, competencies, and agility. Each of these approaches has one or more PM benchmarks and standards. Because there is a vast amount of literature on how to conduct a project according to each approach, it is important to understand the basic structure of each approach before initiating any collaborative project.

This chapter is organised as follows: the first significant section discusses each of the current significant approaches to PM, its system of thought, and its leading benchmark in the market. Then, it offers a discussion regarding the current standards, industries, context, and challenges. Subsequently, it proposes solutions to the deviations in many benchmarks for PM for collaboration in research and development (R&D). Finally, this chapter ends with general conclusions.

2 Review of the Main Approaches to Project Management

2.1 Process-Based Approach

The process-based approach to PM is one of the most commonly used approaches worldwide (PriceWaterhouseCoopers 2013). Processes are similar to projects in the sense that they are mostly a sequence of activities organised to produce a particular result. However, the purpose, treatment, and operation of processes are very different from those of projects.

The central difference between processes and projects is that a project, by definition, aims to produce something new or unique in one way or another (Abyad 2018; Jeston 2014). In this sense, projects cannot be repeated, which has profound implications. For example, because the level of uncertainty in projects is generally high, R&D is usually involved, even if only marginally.

With processes, there is a fundamental difference: they are not intended to be unique; instead, they are meant to be repetitive and, if possible, universal to a certain extent. Low uncertainty and innovation are expected from processes, and in this sense, a process is the opposite of a project.

These two design concepts are very different; however, there is a great deal of interaction between them. The principle of the process-based approach to PM is that to manage a project, an ordered sequence of processes, with defined inputs and

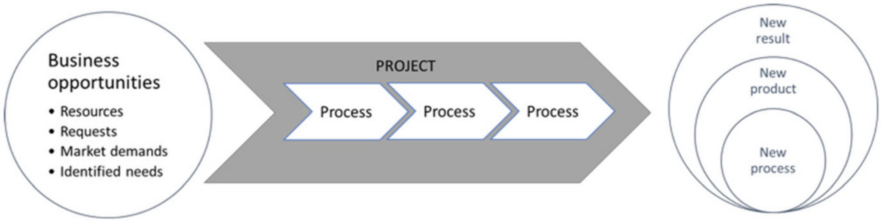

Fig. 1 Illustration of the functioning principle of the process-based approach. Processes are at the centre of projects, and they can result in a new or improved process

outputs, is necessary (Fig. 1). These ordered processes lead to the creation of a new specific result, which can be a physical product, a service, or even another process that can be used or not in another project (Project Management Institute 2017; Su and Chen 2016).

In this case, a project will more successfully advance when mature processes are in place in a structured manner. In this context, benchmarks and standards, such as those in *A Guide to the Project Management Body of Knowledge* (PMBOK Guide) 6th edition from the Project Management Institute (PMI), are very rich in providing not only PM processes but also a large number of resources in the form of techniques and tools. Understanding this process-based structure and having these resources available in the form of best practices attested by the market will, in principle, lead to an increase in speed and quality and reduce the costs of processes due to standardisation. In fact, in highly industrialised regions such as the United States, Canada, Japan, and China, the PMBOK approach is still the market's preferred approach (Abyad 2018).

The formalisation and implementation of processes ensure stable structural bases, with small changes in the level of processes from one project to another. This approach is essentially a predictive method, and the same standardised framework should be used almost universally regardless of the project.

In principle, using this structure to manage collaborative projects between industry and academia is of interest. To arrive at this general basis through processes that can be used in all types of projects, the PMI has repeatedly increased the number and complexity of the processes in this structure up to the 6th edition (Cortés Tapia 2018). To do something in a flexible manner, which is highly necessary for collaborative R&D projects, as a framework, this structure has become to some extent cumbersome.

The PMBOK is useful for ensuring that the interests of all stakeholders are respected and guaranteed due to extensive documentation and even penalty clauses. The problem lies in the nature of research projects, where there are often insufficient guarantees that the desired result can be achieved. R&D projects often encounter far more obstacles than initially anticipated, even after conducting qualitative and quantitative risk analyses, as proposed by the 6th edition framework (Hermano and Martín-Cruz 2019; Project Management Institute 2017). The primary results of the research are often surprising to responsible researchers themselves, and many predictive methods find it difficult to reconcile such results because they are too far from the PM baseline plans.

From a purely scientific perspective, even if a project deviates from the line of reference and obtains novel, unexpected results, it can be considered successful. Regardless of whether the result is market-friendly, it will generally yield publication in a highly renowned journal. This outcome comes at the price of invalidating all the plans that had been extensively developed during the definition and planning phases. This result is not perceived as a market-friendly result as markets attempt to avoid uncertainties. Furthermore, such results can cause costs to increase significantly, and a reduced financial return can, from a financial perspective, invalidate the project. In general, this approach works well in collaborations, in which there are strong possibilities to commercialise the outcomes and where the business side of the collaboration is an essential factor.

2.2 Result-Based Approach

In recent decades, there has been a significant debate over the position of the project manager in contexts that are becoming increasingly specific, technological and complex. Most education and research institutes in PM focus on the subject itself, that is, management. It is understood that management cannot be dissociated from the fact that most discoveries in collaborative projects are extremely technical and highly field-specific. The question arises as to how people with general management training can conduct such technical and complex projects since, concerning their standard training, they do not have the necessary specific technical knowledge to ensure a good interface with management aspects of the project.

The classic proposals for process- or competency-based approaches imply particular specialisations for project manager since responsibility is fundamentally assumed by the project manager, who must make decisions based on information from the project and on consultation and feedback from the technical team. Over time, the project manager will become more aligned with the team and the general theme of the project, and his or her processes and/or competencies will be improved in this specific field.

The proposed result-based approach to PM aims at a management model that reconciles the dialectic of managing diverse technical collaborative projects. The basic idea is that when starting a collaborative project, one of the priorities is to create distinct functions in a new temporal organisation that will lead the project. Thus, the project will not be ambiguous, and the functional limits about what the management team must do and what the technical team must do will be clear. An example of the standard of this school of thought is PRojects IN Controlled Environments (PRINCE2), which is currently managed by AXELOS (Bennet 2017). PRINCE2 is an evolution of the original PRINCE model (which in turn was an evolution of the Project Resource Organisation Management Planning Techniques (PROMPT) model for computer projects), and it is much more flexible

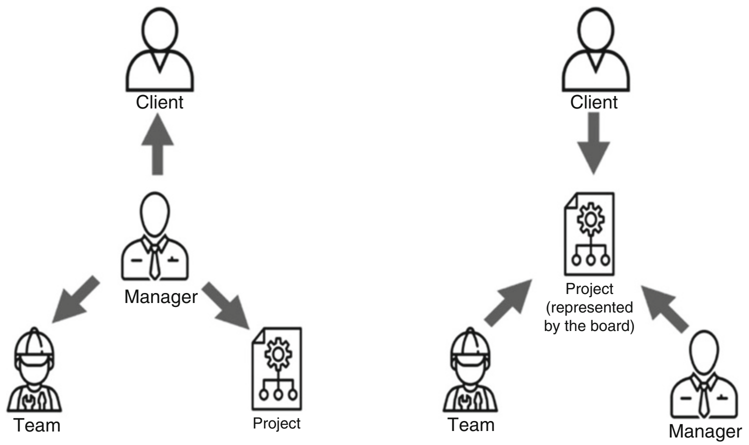

Fig. 2 Comparison between approaches that are not based on results (left) and those where the project results are at the centre (right). In the second case, the project board is at the centre of all decisions

and general than the original version controlled by the UK government (Hinde 2018).

This management model is widely adopted, especially in European countries, Oceania, and parts of Africa and the Middle East; it is also a preferred model for organisations with global reach, such as the United Nations (Jasny 2009; Saadé et al. 2015). The project board is a basic principle and a fundamental part of this approach. This committee (which is composed of the project manager, clients, and suppliers, among others) will be responsible for determining the exact form of the project and all related project decisions. Additionally, this aspect contrasts with the classic assumption in PM that the primary responsibility of the project manager is to address the different stakeholders and direct the project (see Fig. 2). In this case, the project manager will follow the project as agreed upon by the project board (Bentley 2005). While many consider this model to be a product-based approach, the authors of this chapter prefer to use the more comprehensive nomenclature of result-based approach.

Interestingly, in this approach, the client has a more significant involvement in the project and has an essential voice in the decisions made by the project board. Therefore, although project decisions tend to be more assertive and direct, this is due to some loss of speed because of the time needed to create the board itself as well as the time required to organise board meetings.

Notably, in collaborative projects, this lost speed can be somewhat offset because the board ensures that the project continuously allows the interested parties to obtain the advantages stated by the project business case. Consequently, the joint organisation created for the project must be tailored accordingly.

Therefore, if the project does not provide the expected results, the parties will agree in advance to terminate it to avoid further losses. By focusing on results instead of processes, the possibility emerges for a partner initiation that may end with the cancellation of a project in the short term. However, it is still possible for the relationships of the partnership to be preserved, which opens the door for benefits from the possibility of another R&D project in the future. Indeed, the enthusiasm for participation in another project is strong since it is difficult to create the structure of the board in a new collaboration, but this process is accelerated a second time after a first endeavour that ended on good terms (Delmon 2017; Kalkman and de Waard 2017).

2.3 Competence-Based Approach

Due to the large and almost unlimited number of different types of projects and assuming that no two projects (especially in R&D) are the same, it is difficult for the same framework to be efficient and effective in all situations. This reality is very visible with regard to the process-based approach, in which the number of processes increasingly grows over time, with this approach ultimately becoming cumbersome and awkward in many situations. Even a result-based approach cannot be sufficiently generalist. Although forming a well-structured and well-defined organisation with a project board can prove to be effective for large projects, in the case of small projects, this initial requirement can prove to be too large and time-consuming.

In R&D, the major collaborative projects are usually those that receive the most spotlight and publicity so that they can attract the interest of the general population. However, they are not representative of the majority of collaborative projects in R&D between industries and universities (Humphrey 2005; Paasivaara and Lassenius 2003). Many collaborative projects are part of the so-called “*service to the community*” of universities, where several modest projects have a crucial impact on diversifying and increasing the quality of the industrial sector. Additionally, this service is often at the very local (e.g. municipality) level and is fundamental for both economic and social development.

For universities to have this impact on their immediate surroundings and due to the diversity of universities, municipalities, projects, etc., very different contexts require different tools, techniques, and frameworks. Therefore, a pre-conceived set of tools is not the essence of success in many collaborative projects but rather the manager’s competence in selecting the best tool for a given project. This fact makes a great deal of sense in the diverse and dynamic context of collaborative projects, and it is the essence of the competency-based approach.

The greatest exponent of this approach is the Individual Competence Baseline (ICB) from the International Project Management Association (IPMA). Currently in its fourth version, it establishes competencies in three areas: people, perspective, and practice. A manager who fully develops these three competencies due to the acquisition of skills will have the vision to formulate the best strategy for a specific collaborative project situation (Vukomanović et al. 2016). In this sense, because this approach is flexible and well suited for different collaborations, a project manager

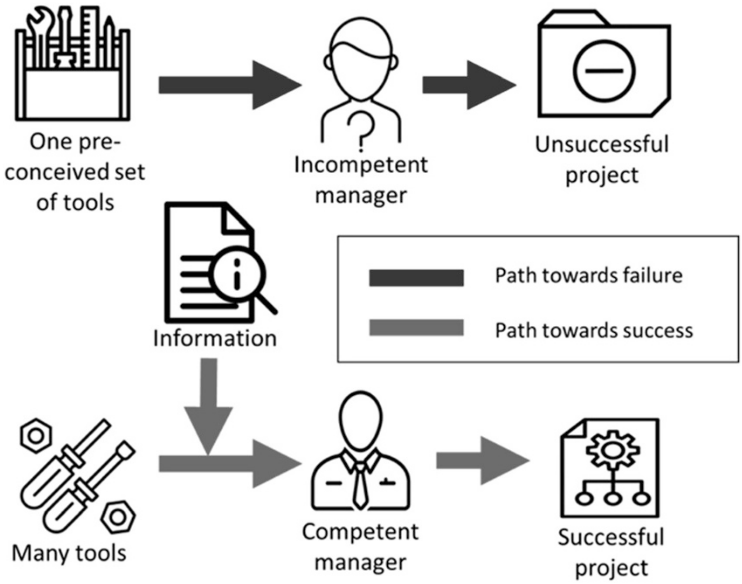

Fig. 3 Schematic illustrating the basis of the competency-based approach: the key is the vision of the manager in gathering information and selecting the most appropriate tools for a successful project

with vision and competence can be considered the key to the success of the project, as presented in Fig. 3.

2.4 Agile-Based Approach

At the beginning of the twenty-first century, 17 representatives from the software industry came together to discuss their frustrations with traditional software development projects. The result was the Agile Manifesto, which triggered a series of PM methods with shared values and principles (Fowler and Highsmith 2001). Notably, "Agile" is an umbrella term referring to a multitude of proposed methodologies. There are many Agile methods, and this section does not intend to analyse a specific methodology. Most importantly, the core of Agile is four essential values (Fowler and Highsmith 2001):

> Individuals and interactions over processes and tools.
> Working software over comprehensive documentation.
> Customer collaboration over contract negotiation.
> Responding to change over following a plan.

The Agile values provide a shift in paradigm, and many principles and methods were derived from these values. Examples of Agile methods include the following: Scrum, Kanban, Scrumban, DevOps, PRINCE2 Agile, SAFe, Praxis, eXtreme Programming, Holocracy, AgileSHIFT, Nexus, Feature-Driven Development, and Crystal. This list is by no mean a comprehensive list of Agile methods. Although each technique has specific practices, to be considered Agile, it must share the values and principles of the manifest.

Therefore, in this section, we do not select a particular framework as a representative of the approach but focus on the common roots of these methods. Agile methods have gained a great deal of ground not only in the software industry but also in other more traditional sectors, such as the airline industry, where classic methods have reigned absolute (Ćirić and Gračanin 2017; Saunders 2018).

To date, the focus has been on finding one or more methodologies to improve the performance of traditional collaborative projects. In the Agile model, this whole paradigm is changed. Traditional methods (in this context, all techniques that are not derived from the Agile values) are also known to be predictive because they are essentially composed of well-defined phases with a very clear result that is expected from the beginning. This approach results in a necessary certain amount of time and a budget to make the business case that justifies the existence of the project. The business case or project charter must be followed to the letter once the project has started; otherwise, it loses its reason for existence.

In the case of R&D projects, the problem lies in this ambition to foresee results. Increasing the degree of collaboration of a project will arguably increase or decrease this uncertainty, but it will also increase the complexity of the project. Therefore, making very accurate long-term timetables or Gantt diagrams for these projects often becomes very unrealistic. As noted above, one of the goals of collaborative R&D projects is to seek and find the unexpected. Therefore, in the face of the inevitable unexpected, the question arises as to which is more critical for the project: continuing to follow the plans or prioritising adaptation, value, and the further development of the collaborative relationship? The second answer reflects the values that are at the heart of the Agile-based approach.

Such a collaboration relationship will be closer and less conventional than that formed through traditional methods. In place of rigid contracts, with little room for manoeuvring because the distrust and penalty clauses are more pronounced, the focus will be on making contracts of a variable scope and working in short cycles to increase the deliveries of small products. The cycle deliverables are chosen from a product log and chosen in an order that will maximise the total value of the partnership. Between each successful delivery, trust in the collaboration increases, the internal performance of the collaboration increases, and the likelihood of developments in other collaborations increase. The differences between the classic approaches and the Agile-based approach are illustrated in Fig. 4. Ultimately, the participants in the collaboration develop a way to function organically rather than in a mechanical and bureaucratic manner.

This type of approach has many advantages for collaborative R&D projects because it treats factors that are generally considered problems as advantages.

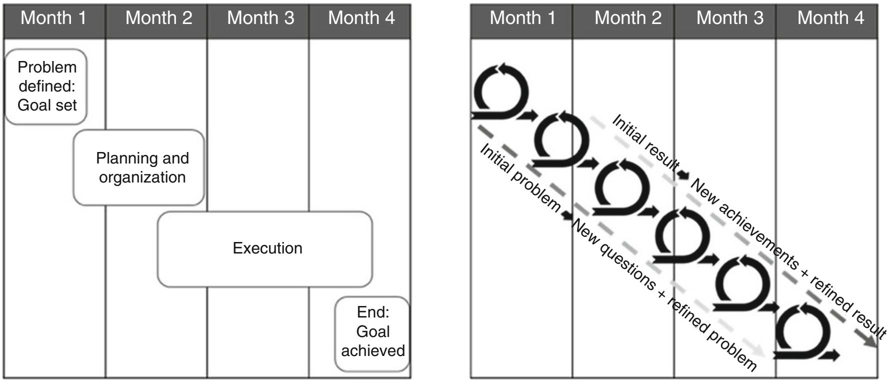

Fig. 4 The contrast between traditional predictive approaches (left) and Agile-based approaches (right)

Here, less importance is attached to which particular method will be used in an interaction; from the last sprint, it will be possible to increase the number of methods. Here, there are much less well-defined hierarchies, processes, and competences. According to the agility-based approach, the key to success is not fixing any of these aspects but setting harmony within the team.

Notably, this approach may seem anarchic, but for Agile methods to work, it is necessary to reduce the size of the structures. For example, teams should be small (no more than ten people), and objectives should be broken down into elements that can be dealt within a maximum of 1 month. This means that in each cycle there are short periods for establishing the problem, the issue, and the delivery deadlines. After each delivery, the collaboration function is improved, which depends entirely on the last result and the revision of the previous cycle.

3 The Contextual Challenges Faced by the Main PM Approaches

Interestingly, some of the frameworks used in PM are more popular than others in different sectors and industries. Most importantly, there is a significant difference in how research projects are generally performed in industry and academia. The former uses PM almost exclusively to focus on tangible results. That is, PM is a technique for solving daily practical problems. Regarding the latter, research results are often more abstract and include new specific knowledge, factors, recommendations, and models (Głodziński and Marciniak 2018). These underlying divergences have profound implications for the type of approach to PM, thus creating significant difficulties for frequently recurring collaborative work.

The review of the previous section shows that there are many best-practice standards in this area, but it also shows that they frequently do not converge. While the use of one of these standards can help collaborative projects achieve better results, in terms of R&D projects, it can also hinder innovation because work is always performed according to a predefined framework.

This fact is more real when considering the case of the more processual school of thought, as is the case of the PMBOK. One of the main criticisms of the PMBOK is its rigidity (Vieira 2016). Because it is extensively used, it is ultimately very bureaucratic, with high inertia. The current sixth edition lists 49 processes that a project will go through during its life cycle. There is an International Organisation for Standardisation (ISO) norm regarding the guidance of PM (ISO21500 2012) inspired by the PMBOK. This norm also functions mainly by processes; however, one can argue that it is less rigid because it defines 39 processes. The norm alone also does not recommend or identify tools and techniques (Calderón et al. 2017).

Departing from mainly procedural frameworks, PRINCE2 is a structured methodology based on principles, themes, and processes, having seven of each. The concept behind PRINCE2 is that a project is a temporary organisation with a defined business case. This temporary organisation created to produce project results is dismantled once a project is completed. PRINCE2 is a suitable framework for result-focused collaborations; nevertheless, it requires the roles of each stakeholder to be defined for optimal project performance (Jamali and Oveisi 2016). Moreover, by requiring a business case to bring forth the project, many collaborative partners can work together towards the same goal and decide when it is time to end the project or update the business case (Bentley 2015).

Many R&D collaborations are structured around a strategic goal of increasing organisational competencies and performance to gain market share and relevance quickly through synergy (Shen 2019). In this case, the most compatible approach to use is that privileged by the ICB standard. This departure from the other schools of thought is still a classic predictive approach to projects; however, it is based on the given competencies that a project manager should have. Because the goal is to enable the vision of the project manager, rather than the use of a pre-conceived set of tools and methods, the collaboration itself can create a vision that can significantly benefit innovation (Vukomanović et al. 2016).

Agile methods go one step further in the negation of scripted frameworks by clearly negating them in order to embrace the uncertainty of projects. Here, the focus is on people over processes and adaptation to provide the speed demanded by business. As Agile methods have revolutionised the computer software industry, applying their philosophy to R&D projects can offer tremendous advantages. At present, many companies are turning to Agile practices to maximise value for the client and time to market (Hoda and Murugesan 2016). If academic institutions use Agile principles in collaborative projects, then they can be instrumental for these institutions to further align themselves with and comply with requests from the industrial sector (Lakemond et al. 2016; Oprins et al. 2019).

On the one hand, Agile methods demand abandoning (or at least minimising the importance of) rigidity, which is the opposite of the process-based approach, bringing the argument full circle. It is not possible to give an unambiguous, clear-cut answer concerning which approach is the most suitable for collaborative projects, which depends on many variables and, most importantly, varies from project to project and from collaboration to collaboration.

There are some elements of convergence in the approaches, for example: all these approaches aim to arrive at an efficient and effective project with the maximum likelihood of full success. On the other hand, it is not possible to arrive at a single model for collaborative projects. Notably, some aspects of some approaches repudiate those of other approaches, considering it as an element that leads to failure. Because all these approaches are formally recognised and used worldwide as references, the decision of which approach to follow is critical, especially in the case of heterogeneous collaborative projects, as in the case of cultures from different countries or widely different sectors.

Thus, why is it necessary to apply an existing and formal standard that can be recognised by everyone in the market if certain aspects of it are better adapted to some scenarios than others? Many large companies create their own "optimal" internal standards. By using this approach, only the parts of each formal standard that are fully compatible with the company are used.

Nevertheless, there are many advantages of working with an already known framework in terms of external interfaces. For example, the models, tools, and conventions that already exist are understood and respected by everyone. Therefore, there is a high increase in time saved when modelling a project and a much lower risk of communication errors, and knowledge quickly becomes available and can be acquired by a collaborator.

If a pre-existing framework is not used, the advantages mentioned above are lost. Projects from other organisations or past projects from the same organisation must be reinterpreted according to the conversion created. Thus, not everyone may understand all elements of the project regardless of whether the collaborator is inside the company or is an external one. Notably, a survey carried out in 400 organisations in different countries by regional sections of the PMI notes that the most common problem in projects is related to communication (PMI 2014).

Therefore, although an optimal internal approach is developed, a problem of external interface compatibility is created, and this newly created problem is significant for collaborative projects. Specifically, with this new problem, a partner entity must comply with a different internal approach that is difficult to learn given that it is not universal; this results in a greater demand for high initial investment in the collaboration. That said, this investment can turn into a considerable loss if the collaboration does not succeed in the long run.

In the case of in-house standards developed by academia and industry, the internal approach can vary drastically. Notably, the academia tends to use very complex methods to conform to scientific standards, including the use of mathematics, statistics, and vocabulary, which do not necessarily form part of the jargon used in the everyday life of many typical industries. The focus of the industry is on quickly delivering functional products and not merely making discoveries. For academia, the more surprising the results are, the more likely they are to be published

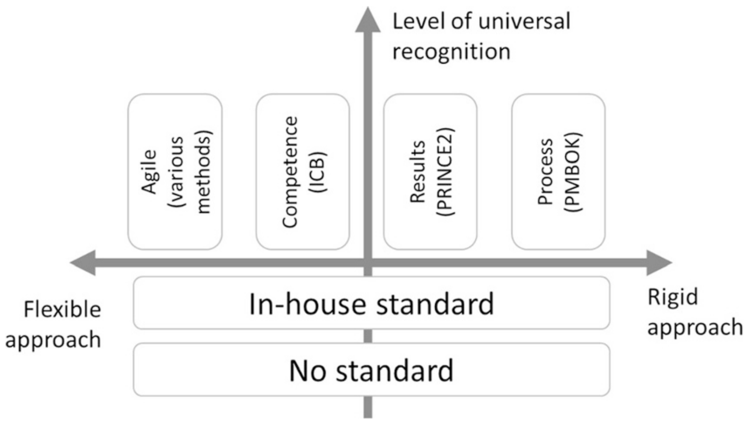

Fig. 5 This graph depicts the level of universality of the current internal PM approaches versus the flexibility or rigidity provided by the approach

in leading journals. For most companies, the predictability of projects is preferable, and the focus is on not only quality but also cost and time savings for optimal market output.

If no standards are applied, there is still a problem with external cooperation, and there is the additional problem of internal cooperation between sectors of the same entity. The best solution for external operations is to prioritise a standard that is already universally known. However, as discussed in this section and as illustrated in Fig. 5, formal approaches vary widely in their structure, meaning that we have now come full circle again. If an industry is already deeply involved in a framework and wants to partner with another industry that is already deeply involved in another approach, this factor can constitute a significant impediment to a partnership.

4 Selection of PM Approaches in Collaborative R&D Projects

Since no standard is better, considering different methods before any collaborative project is of interest (Joseph and Marnewick 2018). Notably, the use of approaches in projects is not all or nothing, and there are several possibilities for hybridisation (PMI 2017). As an example, it is possible to cite a project that is driven mostly by the process-based approach but has a specified phase driven by the competency-based approach. While the opposite is feasible, alternatively, it is still possible to have a project that is managed through a results-based approach with distinct functions and responsibilities and a team that performs project tasks internally using the agility-based approach. Additionally, it is also possible for the two approaches to be applied in parallel with one another or to be applied arbitrarily, creating even a more significant challenge (Blomquist et al. 2018).

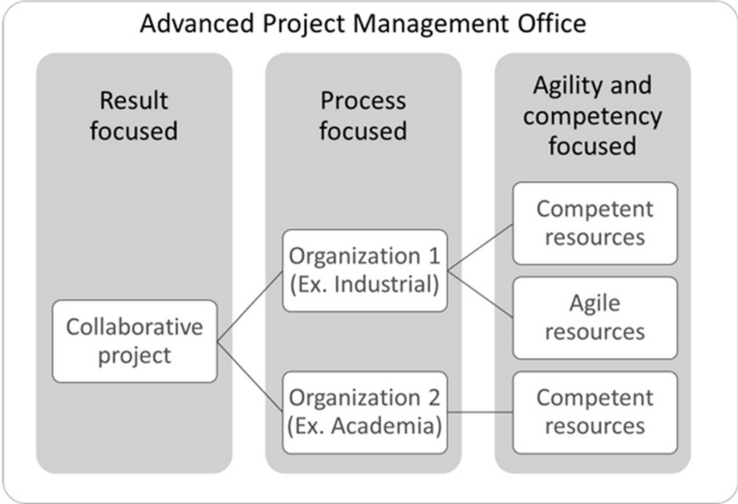

Fig. 6 Example of a depiction of the role of an advanced project management office in arbitrating the approach that will be used at each level of collaboration

In the specific case of an R&D collaborative project, a relationship arbitration unit is required. Importantly, projects evolve, and stakeholders should review possible modifications of the collaboration approach. The solution is to create advanced project management offices with comparative and prospective models of possible approaches so that collaboration agreements can be realised more quickly and more often.

An adaptive answer could be to combine the use of a collaborative project management office with an adaptive framework. This advanced project management office would enable the use of benchmarks in collaborations evolutionarily. An essential area of PM is change management, especially in the case of collaborative environments, due to the increasing complexity of projects and the ever-changing external global scenario. Dedicated offices will help optimally achieve the excellence and maturity of organisational collaborations for each level. An example of the previously discussed possibility of hybridisation is shown in Fig. 6. In this schema, it is possible to observe many layers of the collaboration starting from the top level of the collaboration, which is run mainly by an approach based on results. The following level involves different organisations that are a part of the collaboration. In this example, the organisations work internally by process; nevertheless, at the resource level of each organisation, it is possible to observe approaches according to competence, and even some resources work using Agile principles.

This example is simply an illustrative model of hybridisation in a collaborative project, and an advanced project management office would manage all aspects. From this example, it would be possible to generate a standard template of a hybridised approach to collaborative projects. Nevertheless, it is also essential to consider the dynamicity of collaborations in R&D. Small or profound alterations might be needed to elaborate an optimal hybrid framework from collaboration to collaboration or even within an on-going collaborative project.

The decision regarding the parameters of the hybridisation can become complex very quickly, especially in the uncertain context of R&D. To achieve optimal results, it is recommended for the project management office to explore the use of state-of-the-art techniques. Among these considerations, it is possible to mention the use of artificial intelligence. An artificial intelligence system avoids monocratic decisions based excessively on experience and intuition and considers all alternatives and suggestions for better use using the most significant amount of data available. An additional advantage is that artificial intelligence systems continuously learn; therefore, over time and following each new interaction, the precision of the decisions is improved as the chances of making mistakes decrease. This technology is particularly useful when there is an extensive integrated database of information in the collaboration, and decisions are continuously made throughout the project.

Another example of technology that can be used to assist project office management is blockchain. Blockchain is essentially a distributed database of records or a public ledger of all digital transactions or events that have been performed and shared between participating parties. It is possible to create an organisation without an owner and without a central power that is formed by autonomous individuals but with a status codified in a smart contract. Another possibility is increasing the number of participants in the writing of advanced projects. The technology models the voting rights of each participant as an asset over which he has control, a unique identity, and a digital signature; this expands the possibility to consult members of different communities.

Importantly, the citation of these two tools by an advanced project management office is by no means exhaustive, and many other factors should be considered while making the arbitrating unit. Collecting all factors and state-of-the-art tools and deciding the format of the unit can be as important as the project itself and, in some cases, even more critical. On many occasions, this task is even more difficult because the organisations that are joined in the collaboration have very different core interests or modus operandi. For example, in the case of industrial and academic collaboration, what each sector considers a performance factor is of importance and can be extremely different.

In the industrial world, certifications are created to ensure quality. Due to the diversity of PM methodologies, a genuinely versatile professional will have several certifications listed on his or her curriculum vitae. As previously described, even within one approach, it is possible to have several formal methodologies, especially in the case of the Agile approach. If a professional is comfortable with only one PM methodology, he or she has an additional limitation in participating more actively in collaborations with hybridised approaches.

In the academic field of PM, qualifications are discussed in terms of the ability to publish in journals, especially journals generated by certifying bodies themselves, such as the *IPMA International Journal of Project Management* and the *PMI Project Management Journal.* A compelling case is the *Journal of Modern Project*

Management (JMPM), whose approach aims to bridge the best practices of academia and industry and is compatible with the model described previously.

5 Conclusions

This chapter reviews the main approaches to PM based on processes, results, competencies, and agility. Each of these approaches has one or more parameters and standards in terms of PM. Importantly, in collaborative projects, common language problems are frequent. Therefore, it is necessary to reach a collective agreement before starting a partnership so that the subsequent management and communication are performed on the same basis. Each structure is different in its school of thought and composition, and to date, there is no clear answer as to which method works best.

Many aspects of the formal frameworks of the approaches involve different and sometimes contradictory structures. The possibility of an ideal and formal approach is created when a personalised approach is developed in-house. However, the development of such an approach results in an aggravation of interface problems in collaborative projects. Additionally, it requires a high initial investment, and it may not be successful if the cooperation is not successful in the long run.

Importantly, internal industrial and academic standards also have very different focuses. In the case of industry, the focus is on obtaining a result that is balanced and acceptable from the perspective of the market. In academic terms, scientific methodological rigour and the level of scientific inventiveness are paramount.

It is possible to observe that the reliability of collaborations in R&D projects is complex; thus, the choice of the framework must be intelligent and adaptable. The critical points in the evolution of PM are based on hybrid methods, e.g., the combination of traditional and Agile methods and the management benefits of constant changes in projects.

To that end, an advanced PM office is necessary to use data to determine the most suitable form of collaboration, fully taking advantage of the appropriate approach and level based on recognised standards for universality.

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Part II
Industry Collaborations

Co-creation of Innovation by Corporates and Start-Ups

Vered Holzmann and Haim Rousso

1 Introduction

The current business environment is characterised by rapid technological developments that continuously require implementation and commercialisation of new creative and innovative technologies, and products. One of the most known and utilised practices applied by large companies to extend the existing boundaries to embrace new ideas and technologies is co-creation of innovation (e.g. Chesbrough 2007; Dahlander and Gann 2010; Enkel et al. 2009; Huizingh 2011; Lee et al. 2012; Loureiro et al. 2019; Simanis and Hart 2011; Tekic and Willoughby 2019). This chapter is focused on the co-creation of innovation by R&D corporates based on models of partnership with technological start-ups.

Leading technological companies define innovation as a prioritised strategic goal (Harnoss et al. 2019). The advancements of technology, the changes in markets, and the increased competition necessitate R&D corporates to continuously gain new knowledge, maintain new processes, and introduce highly innovative products (Enkel and Sagmeister 2020; Teece 2007). But, due to their size, complexity, and institutionalised organisational culture, the pace of internal organisation changes is much lower than the pace of technological and market changes (Brinker 2013). Therefore, large technical organisations struggle in their mission to remain leaders in their business domain.

Start-ups and individual entrepreneurs, on the other hand, are flexible, dynamic, and maintain creative culture. However, they work in an uncertain environment (Tomy and Pardede 2018), and most of them do not have the resources, knowledge,

V. Holzmann (✉)
The Academic College of Tel Aviv-Yaffo, Tel Aviv, Israel
e-mail: veredhz@mta.ac.il

H. Rousso
Mofet- Excellence in R&D Ltd, Rehovot, Israel

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and experience to respond to potential risks effectively. Lack of a market need for the new product, lack of sufficient capital, assembly of the wrong team for the project, and superior competition are the main reasons that many start-ups turned out to be unsuccessful (Griffith 2014). To fulfil their vision, start-ups need to prevail over the shortages of limited resources and assets in three main domains: marketing, people, and funds (Marion et al. 2012; Paradkar et al. 2015). Commonly applied approaches to bridge those shortcomings and to encourage entrepreneurs by providing resources, financial support, connections, and mentorship can be in the form of accelerator programmes (Crişan et al. 2019; Drori and Wright 2018) or in the form of incubating programmes (Bruneel et al. 2012; Grimaldi and Grandi 2005). But those are short-term programmes that offer only limited support while achieving the start-up long-term vision requires stable and enduring support.

Models of co-creation of innovation by R&D corporates and technological start-ups create a synergetic long-term framework in which each party exploits its advantages. By presenting, analysing, and reflecting on R&D partnership models that have been developed and applied in recent years, this chapter aims to explore the question *what are the critical success factors and the barriers for successful co-creation of innovation by R&D corporates and technological start-ups*? Specifically, it identifies the pros and cons of three primary structural co-creation models. It also demonstrates the critical issues for synergetic collaboration between large technology companies and start-ups through cases from the innovative Israeli arena. The study contributes to the literature on the co-creation of innovation, thereby extending the open innovation research field in the context of the R&D ecosystem. Furthermore, this study has practical implications for corporates and start-ups in the process of selecting the appropriate co-creation model that will be aligned with their interests.

An explanatory case study research method was applied in the current study to investigate a contemporary phenomenon within a real-life context (Ridder 2019; Yin 2014, 2018). It is based on three in-depth exemplar case studies that have applied co-creation strategies in Israel. Each one of the cases demonstrates the implementation of a different model of co-creation programme and presents the challenges in negotiation between corporates and start-ups in the process of creating non-trivial efforts to create synergetic cooperation. It is an opportunity sampling that has emerged from the researcher's experience, offers the possibility of comparison, and enables to carefully study and explain the phenomenon (Patton 2014; Ridder 2019; Yin 2018) to form a framework to assess successful co-creation of innovation.

Different sources of qualitative data were collected, including internal documents produced in the R&D corporates, mainly minutes of the board of directors' meetings, and through unstructured interviews with the corporates' Chief Technology Officers and with the collaborating start-ups' owners. Inductive content analyses were undertaken for each of the cases to discover emerging themes and categories and to identify similarities and contrasting results (Patton 2014; Ridder 2019) concerning enablers and barriers for successful co-creation of innovation.

2 Models of Co-creation of Innovation

There are numerous models and variations of frameworks for co-creation of innovation in R&D companies that have been developed and investigated throughout the years (Drover et al. 2017; Hill and Georgoulas 2016), including start-up programmes, accelerators, incubators, alliances, and corporate venture capitals (Enkel and Sagmeister 2020). The current chapter is focused on three primary models by which R&D corporates develop innovation through structural collaboration with start-ups. The presentation of each one of the models includes an introduction, review of the advantages and disadvantages for each partner, a description of the processes involved in establishing the partnership, an exemplar case that demonstrates the main challenges and benefits, and a summary.

2.1 The Corporate Venture Model

The corporate venture model suggests that a large company invests funds in start-ups, in return to equity. The established company uses scouting mechanisms aimed at identifying relevant technologies developed outside its boundaries. Once identified, the company exploits its financial power by acquiring all or part of the start-up or by hiring the entrepreneurs to develop further the innovative technology that may lead to a breakthrough (Gompers 2002).

The corporate will apply the venture model not only for financial returns, but also to achieve strategic goals, improve innovation, create long-term value, and reinforce capabilities (Drover et al. 2017; Maas et al. 2020; Rossi et al. 2017). The intentions are to gain new knowledge about emerging technologies and evolving market trends from multiple external start-ups that can be implemented on the programme level (Keil et al. 2016).

The start-up is interested not only in funds, which can be achieved through other channels such as venture capitals but also in supporting infrastructure that encourages innovation and improves performance (Alvarez-Garrido and Dushnitsky 2016; Chemmanur et al. 2014; Weiblen and Chesbrough 2015).

The corporate venture model (Fig. 1) suggests that a corporation acquires a start-up and its knowledge and technology and embrace it into the corporate as an additional asset. In some cases, the start-up will be fully consolidated and absorbed

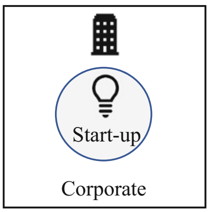

Fig. 1 The corporate venture model

by the corporate R&D department. In other cases, the start-up will continue to operate as a stand-alone company fully, or substantially, owned by the corporate.

Although corporate venture investments serve as a vital force in the R&D market and demonstrate successful results (Drover et al. 2017; Rossi et al. 2017), there is evidence that in the long run, many of them are destined to fail due to misfit of strategic goals, cultural differences and gaps in expectations (Burgelman and Välikangas 2005; Teppo and Wüstenhagen 2009).

The following exemplar case describes an unsuccessful attempt to apply the corporate venture model, where a win-win situation turned into a fail-fail situation. Due to the misalignment of expectations, the entrepreneurs left the company shortly after the investment had been made, and the company lost most of the knowledge that was expected to be gained after substantial financial investment.

Case #1: Corporate Venture

Background

A large company in the field of medical equipment strategically decided to establish a new business unit that will focus on new products based on very advanced and innovative technology. It was clear from the very beginning that such a move requires new competencies both in marketing and technological domains, and luckily a small company with excellent technical capabilities was identified shortly after.

The Process

The parties entered into negotiations. Although the start-up needed funds, the entrepreneurs' main concern was that the intensive involvement of a big company would reduce their agility and flexibility. The company's top managers explained that it is their ultimate interest to keep the start-up work with minimal interventions.

The Agreement

By the end of the year, an agreement was signed. The company paid $6 M in cash for full ownership. However, it was agreed that the start-up would continue to work in its original premises, 50 miles far from the corporate headquarter, and will follow its previous daily procedures.

The Result

Six months later, the corporate's CFO raised the issue of cost duplications derived from the start-up being running at a separate facility (rent, travels, overheads) and VP operation claimed that the different administrative processes generate extra work at the corporate level. Thus, it was decided to apply the corporate procedures in the new start-up. The start-up moved to the leading corporate facilities within 6 months and became an integral part of the R&D department. Despite huge objections to those decisions, most of the start-up employees (8 out of 10) decided to give it a try.

Finally, a year later, all the experts, except one, left the company. A knowledge valued at $6 M vanished. Much worse than that was the fact that the strategic move into the new direction was delayed by more than 3 years.

As the above case demonstrates, the balance between the corporate and the start-up expectations is critical for success. The corporate venture is a favourable model from the corporate perspective. It serves the corporate's objectives, contributes to the company knowledge, extends its capabilities, and enables a high level of control (Anokhin et al. 2016; Dushnitsky and Lenox 2005; Lee and Kang 2015). The corporate has to invest funds to get direct access to knowledge on new technology and marketing trends that will be integrated into its ongoing operation. By embracing the start-up into the corporate, on both strategic and operational levels, the corporate benefits from a high level of coordination, and it can easily manage and control the additional activity as an integrated part of its overall operation.

On the other hand, this model is usually much less attractive to the start-up team. While it gets the funds for further developments, the valuation may be impacted (Röhm et al. 2018). Still, its independence and level of flexibility are vulnerable both in terms of business objectives and organisational culture. The start-up is expected to be aligned with the corporate's strategy, and the team is expected to adopt a culture that may suppress their entrepreneurial spirit.

Since in most cases, when adopting the corporate venture model, the corporate is granted a lot of power, it should be used wisely. The corporate should be very careful about pushing its interests too far, in order not to put the whole deal into risk, and ensure that the start-up team will still have substantial benefits in terms of managerial support, training, and mentorship that will enable the entrepreneurs to keep their entrepreneurial spirit.

2.2 *The Corporate Incubator Model*

In the corporate incubator model, a new independent joint venture, owned by the corporate and the start-up, is established (Gassmann and Becker 2006). The corporate contributes funds, network assets, administrative, and marketing support while the start-up provides knowledge and competencies (Branstad and Saetre 2016). Unlike the traditional incubation models that were ultimately aimed to yield financial profits, this model is designed to create value by improving products through new technologies and developing knowledge about the corporate products and market (Becker and Gassmann 2006).

The corporate extends its technological capabilities through a controlled investment that will yield returns, in a relatively short timeframe, by commercialising external ideas that were initially developed externally (Chesbrough 2006; Gassmann and Becker 2006). Although the new initiative might disrupt the existing business model and organisational processes which may lead to resistance within the company, an array of additional benefits might include external ecosystem development and network-building, creation of new revenue streams, rejuvenation of brand image, speeding-up innovation processes, attracting and retaining talent, and promoting a cultural change (Kruft and Kock 2019).

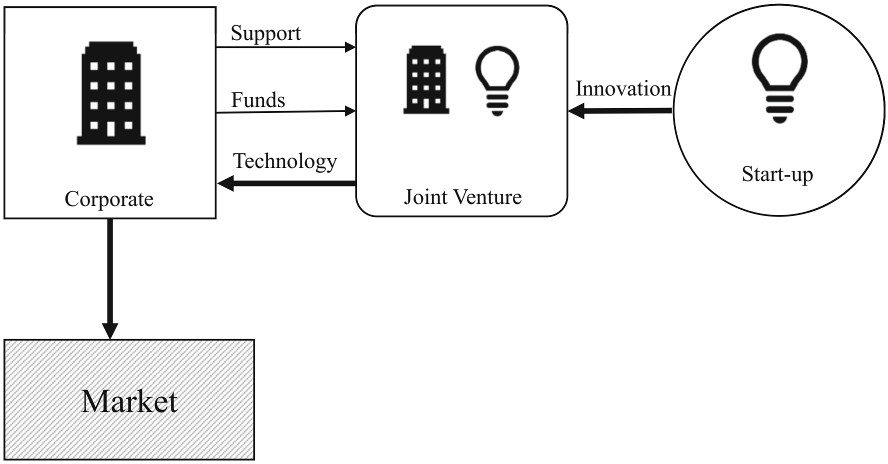

Fig. 2 The corporate incubator model

From the start-up perspective, this model offers solid and reliable resources in the form of funds, office space, and computing resources, as well as intangible assets in the way of mentoring and training, access to market channels, introduction to technological, professional and financial networks, and an active learning environment (Branstad and Saetre 2016; Bruneel et al. 2012; Larkin and O'Halloran 2018). The joint venture remains relatively independent in terms of operational activities. It is involved in decision-making processes and potential future revenues, but those are targeted to the corporate line of business.

The corporate incubator model (Fig. 2) suggests that following the selection, structuring, and involvement stages, the exit stage is either skipped and the joint venture remains as a stand-alone business owned by both parties, and it is replaced by an acquisition of the joint venture by the corporate, which embraces it into its operational infrastructure.

Although many companies currently adopt a technological corporate incubator as a successful approach (Kruft and Kock 2019), it may raise several difficulties, including a dispute over ownership shares (Branstad and Saetre 2016) and conflict of interests related to technology exploitation. On the technology exploitation aspect, there is an imbalance between the entrepreneurs who wish to continuously develop their dream into an array of breakthrough products and markets. In contrast, the hosting company wants to produce specific lines of products in its business domain.

Finding the right balance for the corporate and the start-up on multiple dimensions and ensuring that both parties' current and future interests are met are critical success factors for corporate incubation. This complicated situation is illustrated in the following case description.

Case #2: Corporate Incubator

Background

A worldwide company leader in the field of night-vision equipment, with a wide array of capabilities in design and production of such systems, owns a detector company that supplies all the IR (Infrared) detector needs to develop products in different configurations, technologies, and spectral ranges. The IR detector is based on a very sophisticated technology; its production requires cumbersome infrastructure, and the production costs significantly affect the product price.

One day, the corporate's CTO was approached by an astute and previously successful technology entrepreneur who presented a revolutionary approach to build detectors straightforwardly at a meagre cost. Once the technology is proven, it will have a disruptive effect on the night-vision market.

The Process

The CTO appointed a team of technical experts from different disciplines to evaluate the technology. The team was very sceptical but could not identify any mistakes in the analysis presented by the entrepreneur and reported accordingly to the management.

Based on previous bad experiences with acquisitions of technologies, it was decided to propose an incubation arrangement, based on the establishment of a new joint venture. It will be 51% owned by corporate and 49% by the entrepreneur who will serve as the CEO of the new venture. The corporate will invest in the development of a detector at a configuration that complies with its needs.

However, the entrepreneur insisted on initiating development efforts in a few other configurations to cover the broadest possible market needs. This concept was rejected by the corporate, which declared that it intended to stick to its own market without splitting efforts into other markets. After a few months of negotiations, the entrepreneur decided not to accept the offer and to look for another partner.

The Agreement

No agreement was signed

The Result

The entrepreneur received funds from venture capital and continued the development of the technology. One year later, in a lesson learned process at the corporate, it was concluded that due to inflexibility, the company missed a valuable opportunity to strengthen its position in the market and to expand its line of products.

An examination of the above exemplar case and similar cases leads to a better understanding of the advantages and disadvantages of the corporate incubator model. It is generally balanced in responding to the corporate and the start-up interests, but at the same time, it does not provide a comprehensive solution to either party. By investing funds, the corporate can enhance its knowledge about innovative technologies. Still, the establishment of a joint venture requires additional funds for administrative support and increases the level of managerial efforts. By applying this model of cooperation, the corporate can improve its dynamic capabilities in terms of sensing and seizing technology and market opportunities (Drover et al. 2017). Still, since the new venture operates as an independent unit, the corporate is limited in the level of administrative control and chances to embrace an innovative and entrepreneurial organisational culture.

For the entrepreneurs, this model of cooperation offers much more freedom in the ability to maintain a working environment which is characterised by informal operational processes, usually based on the agile approach. Since the start-up team operates almost independently from the corporate, it gets less managerial mentorship and supervision, but can remain flexible and keep its entrepreneurial spirit. However, the team is mainly involved in technology-related decisions. Still, it has minimal impact on strategic marketing-decisions, since it is bound to the limited business and markets of the corporate. This situation might be frustrating for entrepreneurs with a solid vision about potential business or societal impact.

The corporate venture model is a viable framework that offers valuable benefits to both partners, but to be successful, it should take into consideration not only the entrepreneurs' characteristics and traits (Kerr et al. 2017; Van Weele et al. 2017) but also their vision regarding the impact on society and potential markets.

2.3 The Corporate Shared Innovation Model

Following the previous models, it is clear that the integration of start-ups into complex and established companies is valuable but also challenging. The relatively new corporate shared innovation model (Fig. 3), presented here, builds on the previous frameworks and expands the mechanism for co-creation by expanding the potential markets beyond the corporates business domain.

In this model, a new independent unit, jointly owned by the start-up and the corporate, is established. However, in this case, the new entity is both technology-oriented and business-oriented. It supports the development of new technologies for the benefit of the corporate's market and for the benefit of additional markets that are external to the corporate business domain. The additional market-oriented activities require extra financial investments to materialise the entrepreneur's vision to impact different markets and keep them engaged in the partnership for the long run.

To avoid conflict of interests, the corporate is granted exclusive rights to use the technology for its needs in the defined application areas, and the joint venture retains all technology use rights that are not within the scope of the corporate business. Each party contributes to the shared venture its expertise and assets, and each one of them can exploit the shared resources for the continuous development of new products in relevant markets. Thus, the potential created value can be amplified in more than one market.

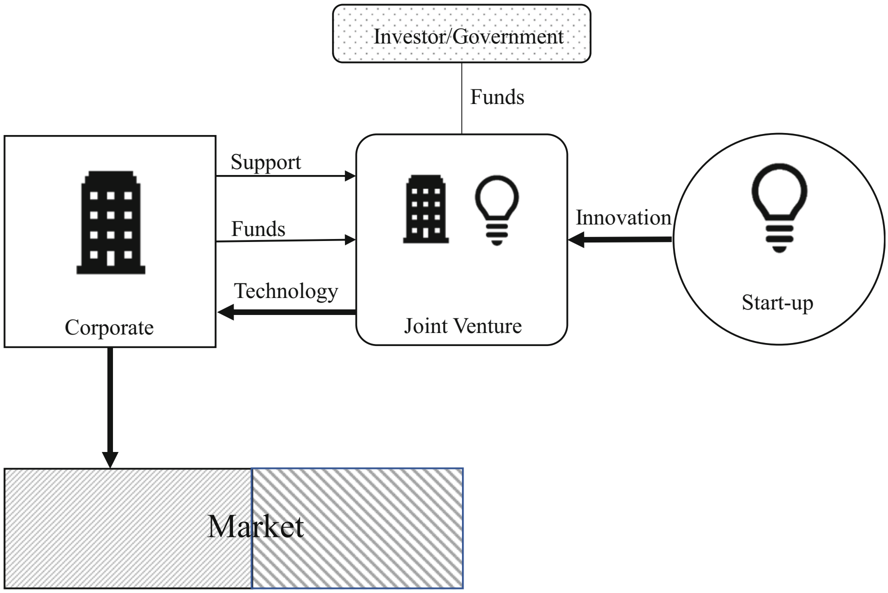

Fig. 3 The corporate shared innovation model

Yet, in some cases, over time, a new tension might evolve since additional funds are needed to expand the marketing activities. Then, the corporate can provide additional funds, or a third party can be introduced and join the venture. In the second option, the third-party involvement will reduce the dependence on corporate funding and therefore, will provide more flexibility and freedom concerning strategic and operational decisions. However, this is not a trivial move, in the early stages, due to the high level of risk that might be intimidating for potential investors and the possible consequential change of priorities. Thus, in certain circumstances, the third-party place will be fulfilled by governmental investment.

As part of a comprehensive national policy to support the R&D ecosystem (Frenkel and Maital 2014), the corporate shared innovation model is applied in Israel, with the support of the government, to ensure maximum exploitation of the newly developed technologies into various markets. The government does not have ownership nor on intellectual propriety neither on the joint venture equity. Studies show that in general there is a national interest in supporting R&D initiatives to strengthen the economy (Antolín-López et al. 2015) and similar programmes are employed in the USA (Mazzucato and Robinson 2018) and India (Surana et al. 2020). In the corporate shared innovation model, after a limited period or whenever a third business partner is interested in the joint venture, the government steps away.

The following case describes a successful partnership based on the corporate shared innovation model, in which a national agency investment was of great importance to enable extensive and comprehensive line of developments and removed potential conflicts between the partners.

Case #3: Corporate shared innovation (with governmental support).
Background

A leading company in the field of security systems has an extensive range of surveillance systems both for indoor and outdoor applications. Various sensors used by the company cover the spectrum from visible to far infrared, and the product portfolio addressed most of the market needs. However, since all the products were based on optical sensing, the need for 'behind the wall' sensing remained unmet. While looking for potential technologies that will be able to bridge this gap, Terahertz (THZ) imaging was found as one of the most promising.

In its scouting efforts, the company identified a small group of entrepreneurs with a solid background in the field of THZ imaging. This group was focused on building a solution to monitor senior citizens in their home without breaching privacy.

The Process

The company offered the entrepreneurs a very attractive acquisition deal, but they refused to accept. The second offer, which was based on joining the corporate incubator, was also rejected by the entrepreneurs. It was clear to them that by accepting, they put their dream to help the elderly population at very high risk, especially since the difference in R&D efforts for each application was quite significant. Since both parties recognised the potential benefits, they continue to negotiate. Still, one issue remained unsolved: what is going to be the leading application and where will the money be spent.

The Agreement

In further discussions, an agreement that follows the shared innovation model was reached. A new legal entity, jointly owned, was established. Both parties agreed that the main priority of the new venture would be the development of a new product for the market of home care, with the support of government funds for the first 2 years. The corporate will fund the additional R&D efforts needed to respond to security applications and will be granted exclusive rights to use the technology for all security applications.

The Result

Three years after reaching the agreement, the results are very positive. The home care product is already in the market, and advanced security products are included in the corporate portfolio. Two years after its inception, a third partner joins the venture while the government stepped away.

The case presented above sheds light on the gains that each partner can take from adopting the corporate shared innovation model and implies to some of the challenges that may be raised. Regarding the synergy of knowledge, enhancement of dynamic capabilities, and required managerial efforts, this model offers the same benefits to the corporate as the corporate incubator model. Still, it differs concerning financial investment and expected returns. In this model, the corporate invests funds not only for R&D and administrative operations, as the previous frameworks suggested, but also for additional significant marketing undertakings. Therefore, it requires a strategic decision that is perceived at high risk for the corporate.

On the other hand, this additional investment is an opportunity for growth in terms of line of business and future expected returns. If the corporate wishes to mitigate the risk that is derived from the additional investment in an unknown market, it can share it with a third party, which is either a business investor or a governmental agency. For start-ups, the corporate shared innovation model is mainly superior to the previous models concerning the exploitation of innovative ideas that will be realised through the developments of products to additional markets. Hence, it empowers the entrepreneurs, keeps them passionate, and enables them to follow their dream to make an impact.

The corporate shared innovation model offers a promising framework for start-ups while retaining most of the benefits for the corporate. The start-up partner contributes knowledge about innovative technologies and receives tangible and intangible resources to exploit technology and target multiple markets. Thus, the start-up team gets the opportunity to follow their vision and keep working in a flexible and creative environment. The corporate contributes funds and resources in return to exclusive use of innovative technologies that enable enhancement of its products and reinforcement of its competitive advantage, and it can also extend its line of business.

3 Conclusions

This chapter aims at exploring structural frameworks for the co-creation of innovation by corporates and start-ups. It presents three primary models, although, in practice, those can be applied in numerous variations. Previous studies have thoroughly discussed co-creation of innovation from the corporate viewpoint (Chemmanur et al. 2014; Chesbrough 2007; Enkel et al. 2009; Tekic and Willoughby 2019), but there is only minimal research on this topic from the start-up perspective (Drover et al. 2017). For a long-term fruitful collaboration, both partners must be able to assess the potential advantages and disadvantages of getting into a collaborative agreement. Therefore, the goals and expectations of both partners are discussed, and insights on critical success factors and barriers to co-creation of innovation are considered.

The necessary fundamental condition to be engaged in a partnership is that the corporate will get access to new technology, and the start-up will get access to funds. However, each partner has additional implicit and explicit expectations from the partnership. The corporate wishes to gain access and control over new technologies and markets, encourage synergy with external teams, get direct or indirect returns on the investment, and in the long run to significantly improve its competitive position. The start-up aspires to boost its technology development efforts, extend its managerial capabilities, market accessibility, and networking while keeping the agile

Table 1 Considerations and expected benefits

Partner	Criteria	Description	Corporate venture	Corporate incubator	Shared innovation
Corporate	Managerial efforts	Alignment with procedures, standards, and organisational processes	High	Medium	Medium
	Dynamic capabilities	Sensing and seizing technology and market opportunities	Medium	High	High
		adopting entrepreneurial and innovative organisational culture	High	Medium	Medium
	Synergy of knowledge	Coordination between corporate and start-up teams to access current knowledge on innovative trends	High	Medium	Medium
	Investment	Level of required funds for R&D, marketing, and administrative support (presented in reverse order)	High	Medium	Low
	Expected returns	Positive financial return on investment	Medium	Medium	High
Start-up	Agility and entrepreneurship	Sustaining informal and flexible operational processes	Low	High	High
	Decision-making	Involvement in and impact on strategic decision-making	Low	Medium	Medium
	Multi-markets	Extending developments to additional markets by development of new ideas	Low	Low	High
	Mentorship	Level of managerial support, training, mentoring, and consulting	High	Medium	Medium
	Develop networking	Connection to technological, professional, and financial networks	Low	Medium	High

mindset and the entrepreneurial spirit of the team and remaining significantly involved in strategic decision-making processes.

Table 1 summarises the primary considerations for engagement and expected benefits for each one of the partners concerning the primary co-creation models: corporate venture, corporate incubator, and shared innovation.

It can be shown that there is no one ideal model for any partner and that the partners' expectations are not entirely aligned. Thus, by adopting any form of partnership, both partners need to compromise. While the corporate venture model gives a higher priority to the corporate expectations, and as the corporate incubator model presents a more balanced approach to meet both partners' expectations, the shared innovation model is perceived as more favourable for the start-up.

In the corporate venture model, the required operational expenses by the corporate are moderate, mainly aimed to support R&D efforts. The corporate and the start-up complement each other knowledge on technological, marketing, and business aspects. But as presented in the first case in this chapter, while the corporate keeps a significant control over the start-up activities, the start-up team has to adapt itself to the organisational processes and culture of the corporate and has only limited possibilities to express its agility and entrepreneurial spirit.

In the corporate incubator model, the establishment of a new joint venture requires more coordination efforts by both partners. Since the new venture is independent, it generates additional expenses for the corporate to provide the necessary resources and to support administrative actions. Although it opens other channels for gaining knowledge on new technologies and market trends, the corporate has less managerial control on the operational activities. The start-up team, in this model, is much more involved in the decision-making processes and can keep its working environment and agile spirit. However, as can be learned from the second case presented earlier, because the new joint venture is a technology-oriented entity, it limits the start-up team to explore opportunities beyond the corporate's business interests.

In the shared innovation model, as described in the third case above, the start-up team gets a complete response to its expectations. In addition to its benefits obtained by the corporate incubator model, the joint venture has the resources to explore business opportunities that are not necessarily correlated with the corporate interests. The corporate has to dedicate more funds to support additional marketing and related R&D efforts but also has the option to strengthen its business. The model variation in which a third party (especially government) contributes to the funding of the new venture, makes the shared innovation model attractive to the corporate, as well.

Since usually, the start-up has less power when entering a negotiation; it is the corporate's responsibility to assure long-term beneficial agreement. Therefore, the shared innovation is perceived as a preferable form for co-creation of innovation, and by introducing third-party investment, this model becomes attractive to both sides.

This chapter provides insights into the multiple considerations related to strategic decisions on co-creation engagements. From a theoretical perspective, it outlines an advanced framework for co-creation of innovation by R&D corporates and start-ups: the corporate shared innovation model. The contribution of the current chapter to literature is on two aspects: motivation and outcomes. First, it adds to the extensive literature that reviews and analyses the corporate's interest in co-creation by examining how each one of the models is also perceived from the start-up viewpoint and what are the potential incentives for the entrepreneurs. It is a significant input that should be identified and analysed, since any successful partnership depends on the level of meeting both parties' expectations. Second, it presents a collaborative design that extends traditional forms of co-creation of innovation by considering not only the exploitation of technology but also opening out additional markets. The new corporate shared innovation model, presented in this chapter, adds to the existing literature a new framework in the context of open innovation. From a practical perspective, the main contribution for R&D corporates and start-ups concerns decision-making process that is based on comparative assessment. The partners can utilise the set of criteria and evaluate the level of response that each model can provide under certain circumstances. The key message is that there is no 'one size fits all' model that is ideal and can be applied on all occasions. There is a need to understand the specific context, the explicit and implicit expectations of each partner in the short and long terms, and to engage in a collaborative structure that will adequately respond to both partners' interests. On a national strategic level, this model can be further studied by policymakers to take actions at specific points to enhance innovation that will lead to economic growth and societal benefits.

This study has limitations and offers opportunities for future research. The main limitation relates to the explanatory research approach, which is associated with subjective interpretation. Although it provides a rich description, it lacks quantitative results that could have provided support to the conclusions. Further field studies that will collect data from multiple cases of implementing co-creation of innovation by R&D corporates and start-ups will be valuable to understand better which specific model is the preferable one in each state-of-affairs. Since this chapter is focused on three main structural models of co-creation, it does not provide explanations to all possible variations of engagement, which a broader investigation into the negotiation process will be able to clarify. Also, increased focus on the dynamic and emergent aspects of innovation in the context of co-creation will shed light on the impact of rational and emotional considerations in the decision-making process conducted by corporates and by start-ups and entrepreneurs.

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Open Innovation Strategy of an Early-Stage SME

Gillian Barrett and Lawrence Dooley

1 Introduction

The model of the triple helix (Etzkowitz and Leydesdorff 2000) recognises the potential benefit for regional development in terms of innovation and venture creation when the stakeholders of University–Industry–Government engage purposively. Similarly, the paradigm of open innovation (OI) has gained prominence within the innovation literature as to how research and development (R&D) can be advanced through harnessing externally controlled resources to complement internal assets (Chesbrough and Bogers 2014). The OI research to date has been particularly skewed towards large-scale enterprises practices (Chesbrough 2003, 2012; Chesbrough and Brunswicker 2013; Viskari et al. 2007; Huston and Sakkab 2007; Mortara and Minshall 2011; Mortara and Minshal 2014), with the efforts of small to medium enterprises (SMEs) being primarily ignored until recently (Kraus et al. 2019). SMEs, especially high-tech early-stage SMEs offer the potential for significant value appropriation and regional development. Yet, little is understood of how the early-stage SME[1] (ESME) category (Greul et al. 2018; Usman and Vanhaverbeke 2017; Brunswicker and van de Vrande 2014; West and Kuk 2016; Eftekhari and Bogers 2015) adopts OI practices to support such technological development. It is within this context that the research is undertaken and is the focus of this chapter.

[1]The term early-stage SME, as opposed to 'start-up', is used as the case study in question is in its early stage of development and is generating revenue. The early-stage implies flat organisation structures, informal innovation processes and planning; individual and entrepreneurial decision-making (Smith, K. G., Mitchell, T. R. & Summer, C. E. 1985. Top level management priorities in different stages of the organisational life cycle. *Academy of Management Journal,* 28**,** 799–820).

G. Barrett (✉) · L. Dooley
University College Cork, Cork, Ireland
e-mail: gillian.barrett@ucc.ie; l.dooley@ucc.ie

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SMEs are an essential segment of the industry base that contributes significantly to economic growth and technological innovation (Acs and Audretsch 1987; Hoffma et al. 1998; Gassmann et al. 2010) and are thus worthy of study (Vanhaverbeke 2012; van de Vrande et al. 2009). Rothwell and Dodgson (1994) describe the innovation advantages of SMEs as mostly behavioural, comprising of flat organisational structures that are fast, reactive and flexible to changing market requirements and where management is fast learning and quick decision-making. Yet despite these advantages, SMEs experience significant resource (human, financial and capital) limitations (Acs and Audretsch 1987; Vossen 1988), and OI would appear a credible SME strategy to pursue given these deficits and the potential impact on the SME's future of the developing innovation (Hagedoorn 1990). OI offers potential benefits to organisations including sharing of R&D costs and risks, opportunity to complement internal knowledge base and revenue generation (Dahlander and Gann 2010; Gassmann 2006). However, these advantages are counter-balanced by challenges such as selecting the right partner, managing the OI process and negotiating and appropriating value (Salter et al. 2014; du Chatenier et al. 2010; Dooley et al. 2016) for the organisation. While these benefits and challenges of OI are theoretically open to all organisations, for early-stage SMEs, such problems may appear impossible due to lack of industrial experience (e.g. academic spin-outs), the relative resource constraints of the venture (Dooley et al. 2017; Prashantham and Birkinshaw 2008), ability to attract suitable partners and the significant length of R&D route to market.

Currently, we know relatively little about *if* and *how* ESMEs adopt OI (Greul et al. 2018; Eftekhari and Bogers 2015; Kraus et al. 2019; Brunswicker and van de Vrande 2014) and how such ESMEs overcome the challenges of OI (Bogers et al. 2017). To address this question, the research considers the case of an Irish ESME (DiagCo), established in the medical device (MD) industry, to develop a complex and potentially disruptive technological platform for the global market. The likelihood of any ESME being capable of developing such products without the leverage of externally controlled resources of public and private entities is low. Yet, these ESMEs may lack the necessary capabilities that prohibit the harnessing of OI's potential. The research findings of DiagCo's development over its first 5 years highlights that such firms can leverage OI not only to access the existing complementary intellectual property (IP) to support R&D advancement but also to underpin co-creation, reputational credibility and even funding of the venture.

A single ESME case study was chosen due to its ability to provide unique insights plus its potential as a *'revelatory case'* (Yin 2009). This case study relied on three data sources, including semi-structured interviews with the ESME founder/chief executive officer (CEO), follow-up emails and phone calls for clarification purposes and secondary data. Substantial desk research was conducted before and after interviews with the founder, which resulted in the collection of significant secondary data to facilitate the triangulation process (Yin 2009). This was followed by a case write-up including the case study narrative and a timeline of the key events in the ESME's history, which the founder/CEO reviewed and commented upon thus facilitating reliability and validity. Data were analysed at the level of the ESME and the individual OI projects (Du et al. 2014; Vanhaverbeke et al. 2014; Bahemia and Squire 2010), which enabled us to unpack the underlying details. Conducting OI research at these different levels of analysis (firm and project level) provides for a more comprehensive understanding of OI (Chesbrough 2006; Randhawa et al. 2016) especially given the short-term, reactive nature that personifies the ESME context. We used a series of tables and matrices to organise the data (Miles et al. 2014), thus going back and forth between theory and data.

The chapter is structured by first outlining the case study and the individual OI projects adopted. It then proceeds to discuss the collaboration partners, the OI mechanisms used (i.e. modes and forms) and the motives. Finally, we then reveal the primary challenges experienced by DiagCo and how these challenges were overcome.

2 Case Study: DiagCo

DiagCo is an Irish medical device ESME, which provides a platform to enable the decentralisation of routine medical testing from central laboratories into general practitioner offices, medical clinics, pharmacies and potentially other test settings. At the time of research, the company was 6 years old and employed 20 people (primarily in R&D) and was still progressing its primary product offering towards market launch and thus is deemed to be in the early stages of enterprise development. The company's founder/CEO was an engineer with significant multinational enterprise (MNE) managerial experience but lacked specific contacts and knowledge of the medical device industry: *'I was prepared to take twelve months out to understand the medical industry .... To ask the stupid questions and to bring a solution from left field for a problem that may or may not exist'*. His engineering knowledge allowed an entrepreneurial opportunity within the MD industry to be identified and cognisant of his knowledge deficit, the founder/CEO deliberately recruited the *'right'* internal team and subsequently *'right'* external partners to address structural holes. Through this approach, DiagCo built a credible, multidisciplinary R&D team, that possessed the absorptive capacity to partner with world-class university research institutes, established global medical device players and both European Union (EU) and national enterprise support agencies to advance their R&D and ensure credibility and compliance in the highly regulated MD industry. Three key challenges facing this ESME development included: first, how to progress their R&D to realise a regulatory aligned, market-ready medical device; second, how to establish credibility with existing industry stakeholders and finally, how to secure the funding streams necessary for the continued growth of the company, especially given the length of development time to market of their innovation. In resolving these challenges, DiagCo's founder/CEO leveraged the capabilities of University–Industry–Government resources through OI practices as a core strategy to develop the R&D and to bring the technological platform to market: '*we would figure out who* [complementary partner] *had the budget and then work at getting an R&D project going with* *them that aligned with our R&D [trajectory]'*. Interestingly, while the purposeful harnessing of complementary resources to overcome internal capability deficits was deliberate, a targeted *entrepreneurial strategy* (Mintzberg and Waters 1985) of the founder/CEO was adopted. This was driven by the management team's strong relational capability and a '*common sense*' approach to OI adoption given the management teams unfamiliarity of the OI paradigm. Irrespective, the ESME, DiagCo, has benefited significantly from its leverage of the capabilities of Government support agencies, University research institutes and industrial partners in advancing the maturity of their R&D and growth of the venture through successful execution of OI related projects (see Table 1 for further project details).

2.1 DiagCo's Development Through Collaborative Projects

DiagCo has spent the last 6 years developing its medical device platform and growing the scale and value of its venture. Since its foundation, a government high potential start-up programme has supported it, where the venture has received both managerial guidance in terms of market entry, sales/partner engagement strategies and mentoring programmes plus also initial access to public funding to support its technical advancement involving vouchers to fund development to solve a specific technical problem. These interactions have also assisted in widening both the industrial and financing sources of the founder/CEO by making initial introductions. The first OI collaboration (Project I) to support this ESME in the development of its R&D occurred during the first 12 months of the firm's existence and was initiated to acquire technology from a leading US university [Uni A] through a licensing-in deal. The benefits derived by the ESME from this collaboration with the 'world-class' University were twofold. First, DiagCo needed access to this background IP and by working with this research partner in the knowledge transfer process, upskilled in the technological domain quickly and achieved access to human resource capability outside the scope of an SME. Second, research collaboration with this internationally renowned University helped establish research credentials and credibility of the firm within their industry. This licensing-in project, the credible IP transferred into the ESME and the relationship with the international University helped to differentiate it from its competitors. It assisted in opening doors to the funding sources required (business angels and venture capital firms (VCs)) to finance the development of the platform. The importance of collaboration with complementary external resources was highlighted in a quote by the founder/CEO, *'[Partnering was] for more strategic reasons if you will. We had ... to entice them to invest in the company. What is also crucial for us ... is credibility; when we go to investors and mention [Partner name], we have credibility straight away'*.

Following the success of Project I, where the acquired technology enabled the ESME to advance their internally developed R&D, the management team began to seek out other potential partners. Reflecting on this, the ESME identified challenges in accessing and securing partnering opportunities, given both the scale of the

Table 1 OI project details (listed in the sequence of adoption by DiagCo)

Project*	OI mechanism (form/mode)	OI partner	Motive—pecuniary/non-pecuniary
I. Sourcing technology	Inbound licensing/ outside-in	International university [Uni—A] Government [Gov—A]	Acquire complementary IP to support technology development. Enhance reputation and credibility in the industry. Enhanced ability to acquire funding to support the venture.
II. Sourcing technology	Inbound licensing/ outside-in	Industry—MNE [MNE—A]	Acquire complementary knowledge (IP and regulatory) to support technology development. Defensive purposes of alignment with the larger-scale company. Enhance reputation and credibility in the industry.
III. Acquisition of specialised resources and knowledge	Co-creation R&D/coupled	National university [Uni—B]	Access specialised resources and equipment of public research centre to build increased research capacity and capabilities aligned with internal R&D trajectory.
IV. Extend the reach of technology into a new market	Co-creation R&D/coupled	EU/government agency [Gov—B]	Access to matched public funds for the extension of the platform to enter a new market. Enhance reputation and credibility in the industry. Increased breadth of network of potential collaborators.
V. Acquisition of specialised resources and knowledge	Co-creation R&D/coupled	Industry—MNE [MNE—B] (participated in a university accelerator programme before embarking on this OI project)	Acquire complementary knowledge (IP and regulatory) to support technology development. Access to funding stream for growth and scale development. Enhance reputation and credibility in the industry.
VI. Extend the reach of technology into a new market	Co-creation R&D/coupled	EU/government Agency [Gov—C]	To access funds for the extension of the platform to enter a new market. Enhance reputation and credibility in the industry.

company and the non-medical device background of the founder/CEO. Despite these constraints, the quality and technological novelty of their R&D, together with the disruptive opportunity of their potential market offering; these were critical factors for initial partner discussions. Likewise, these factors also facilitated the ESME in accessing deeper funding sources to permit more ambitious R&D development. Following a thorough search and 'due diligence' of prospective partners, the company targeted an industrial company that was a global diagnostics player [MNE A] and the founder/CEO commenced a purposeful process of engagement *'it sometimes took 3-4-5-10 referrals to get to the right person, I had to be tenacious at it'*. Following persistent relationship building, DiagCo achieved their second collaboration (Project II), driven by a desire to access a legacy portfolio of unexploited IP held, but unexploited, by MNE A and also to gain industrial credibility of being associated with a global leader. Despite being small in scale, DiagCo deliberately targeted the most advantageous rather than the most accessible collaborative partners, given the strategic importance to venture sustainability of continued R&D development. Reflecting on the experience, the founder/CEO highlighted the importance of time since it is not just about securing access to the *'right'* organisation but also building trust with the '*right'* people to achieve desired objectives and deliver benefits for all parties engaged.

While DiagCo continued to develop its R&D, its limited internal resources constrained its capacity. One such technological objective, which was constrained, was the miniaturisation of their innovative device. This resulted in DiagCo's third collaboration [project III] to facilitate development. Given the ESME limited financial resources, DiagCo sought out suitable EU research funding that they leveraged to achieve this objective through a partnership with a public research centre [Uni B], who possessed both the required specialist equipment and research expertise: *'those items are too expensive for us to invest in …* [Partnering we were able to] *leverage their huge amount of capital, test and simulation equipment'*. This partnership was not only vital in achieving the miniaturising goal but also in facilitating two-way learning within the collaborative context of the project, further enriching DiagCo's internal R&D capability: '*… the PI (primary investigator) had an industry background, understood what we were about, they were learning from us and vice versa'*.

As DiagCo worked through the highs and lows of inter-organisational collaboration to advance its R&D, its capabilities to manage such projects and take on larger scale initiatives increased. Their next collaboration [Project IV] is viewed by the ESME as one of those '*eureka'* moments. While considering the wider application of the device, the question of '*where else might this work'* led to exploratory discussions with the European Space Agency (ESA) for further platform extension. Previous management team connections with the ESA aided the exploration of synergies in objectives and potential funding opportunities for DiagCo. Realising a significant R&D overlap with this public research institution, DiagCo embarked on their next collaborative Project through a matched funding model to advance the R&D frontier: '*This Project was perfectly aligned with our R&D and … they* [ESA] *loved it'*. As with all its collaborations, DiagCo made sure that they maintained IP ownership of emerging technologies within the medical device context, maximising their potential for a future appropriation of value. Over 2 years, the research teams synthesised their collective R&D capability towards their shared objective and enabled further advancement towards the launch of the innovative platform. The non-pecuniary benefit of collaboration with this and past partners has enhanced DiagCo's reputation and enhanced the ESME's ability to attract both new collaborative partners and funding sources.

In the last 2 years, DiagCo has continued to advance its R&D but has had a greater exploitative rather than exploratory focus to its collaboration efforts. First, they partnered with an industrial company (MNE—B) that, globally, has the dominant market share of their target market [Project V]. While DiagCo recognised that the MNE's interest was from a technology scanning perspective: *'they love engaging in these types of projects to vetting the company, to check if this is a technology they want to bring in-house'*, their interest was to gain a more in-depth insight of regulatory/compliance issues that could impede the platform's market adoption. This partnership was yet again a deliberate effort of the founder/CEO to strengthen the credibility and reputation of DiagCo within the industry and enable the leading industrial player '*see what we are doing as disruptive, and they* [could decide if they] *wanted to be part of it and were willing to invest'*. The final collaborative Project to date [Project VI] has been an EU funding initiative, undertaken to extend the platform reach into additional diagnostic capabilities attractive to the market. The targeting of public funding to continue scaling and developing the technology is viewed as advantageous since it allowed the ESME to maintain control over the emerging foreground IP, either through the provision of background IP or contractual 'first right of acquisition' conditions. Another key advantage of this particular project was that it provided access to a wide array of international healthcare providers and research centres, thus helping to raise the profile of DiagCo and undertake market research for its launch.

These OI projects highlight the deliberate and targeted efforts by the ESME founder/CEO and management team to recruit collaborative partners through OI projects. The founder/CEO realised early on the path to establishing a disruptive medical device platform that this ambitious vision was not possible without accumulating external resources, knowledge and capabilities from both public and private research sources through collaborative R&D partnerships. DiagCo adopted OI as an entrepreneurial strategy; engaging in ever increasingly ambitious projects and consistently adding to their internal capability and assets in terms of financial, IP, networks and industrial credibility that nurture the venture along its pathway to growth. Additional to this, the management team has been enhancing the OI maturity of their firm, gaining valuable experience of how to manage more complex inter-organisational collaborations.

2.2 OI Partners and Mechanisms (Forms and Modes)

DiagCo began operations with a relatively small network to draw on given the founder/CEO's lack of medical device experience. However, over the first 6 years of this ESME, the management team has successfully collaborated with a range of partner types, including university research centres, industry companies (MNEs) and European Union/Governmental agencies. Perhaps unsurprisingly, DiagCo commenced OI by collaborating with a university partner, licencing in IP into the venture to complement their internal R&D. Initial targeting of a public institution by the ESME was driven by the IP they possessed and their global reputation as the leading University in the field. While these factors determined the specific partner, it is likely that beginning the OI journey with a heavily transactional knowledge transfer into the embryonic venture and initially partnering with a public rather than commercial partner, provided DiagCo with greater certainty of the outcome and less risk of IP leakage. Importantly, the ESME targeted the 'world's best' to partner with, being consciously aware of the associate benefit of association with such a renowned institution and the potential leverage in attracting future partners. While DiagCo's initial experience was highly positive and while they highlighted a degree of frustration with the perceived lack of urgency by the public institution and getting to the right decision-maker to 'make things happen' it was the basis for further collaborations, including OI project III with University B.

Following the experience of Project I, DiagCo felt encouraged to undertake other collaborations, including those with industrial companies that might be perceived as a threat to the ESME. Again, DiagCo was ambitious with its partner selection, pursuing prestigious partners of high value to their growth trajectory. Aside from the reputational credibility, partnering with these commercial MNEs filled structural holes in the ESME's industry knowledge and provided access to a significantly increased network of professional linkages. While there were reservations at the early stages of industry partner interaction as trust developed, the founder/CEO's past MNE experience and commercial acumen gave DiagCo reassurance of their ability to negotiate and manage the contractual requirement to appropriate value. While the relative scale of the ESME and MNE industrial partners was significant in terms of the power and resources (finance, legal, time duration) they had at their disposal, DiagCo felt comfortable interacting with large companies since they had an industrial reputation to uphold and thus were less likely to behave in an opportunistic manner detrimental to the smaller partner.

The benefits of DiagCo's collaborative engagement has been heavily skewed towards exploitative purposes (i.e. pecuniary) given the necessity for commercialisation of the technology to sustain the venture and the requirement of regulatory approval to access the market. However, critical non-pecuniary motives of research credibility and industrial reputation derived from the OI projects and learning enhancing the ESME's absorptive capacity (Zahra and George 2002; Huang and Rice 2009) have also nurtured the venture development and supported raising of required finance. Overall, DiagCo's decisions to engage in such partnerships were heavily influenced by *strategic factors* towards the development of the venture rather than purely economic or operational necessity considerations (Doz and Hamel 1998). DiagCo primarily used exploitative OI forms (licensing-in and co-operative R&D) within the outside-in OI and coupled modes realising both pecuniary and non-pecuniary motives. Academic research has paid the most attention to the outside-in model of OI (West and Bogers 2013) with both the inside-out and coupled modes of OI remaining less understood (ibid). While DiagCo demonstrates both outward-in and coupled modes of OI knowledge exchange, the absence of activity from the inward-out mode by the ESME may reflect the focused R&D undertaken to date and the lack of any extra or 'redundant' IP within their knowledge store that the venture feels comfortable appropriating value through transfer to another entity.

3 OI Challenges and Management Practices Used to Overcome

The harnessing of external resources by an ESME from stakeholders across the triple helix (i.e. the interaction between private, public and academic sources) is evidently of strategic advantage to the growth of the firm (Etzkowitz and Leydesdorff 2000). However, given that OI is a complex management practice and challenging to execute successfully (van de Vrande et al. 2009), it can pose challenges, particularly for ESMEs collaborating with more significant, more powerful partners (Prashantham and Birkinshaw 2008). Analysing the case of DiagCo highlights two critical challenges that the organisation had to overcome in harnessing the potential of OI to grow their venture (see Table 2).

Table 2 OI challenges and management practices used to overcome

Challenges	Management practices used to overcome these challenges
Selecting and accessing the 'right' partner	Building the 'right' team The deliberate targeting of potential partners Identification of key individuals (i.e. decision-makers—project managers, principal investigators) within potential partners prior managerial experience assisted in these practices
Protection of IP and knowledge	Formal and informal safeguards in place leading to the 'tightly coupled' partnerships Protection of team and knowledge—selectively revealing/paradox of openness Meticulous and personal management of each project by the founder/CEO

3.1 Challenge 1: Selecting and Accessing the 'Right' Partners

The first OI challenge encountered by DiagCo was finding and securing access to the '*right*' partners. DiagCo, like many ESMEs, was a fledgling operation without customers or market-ready products and thus was challenged in attracting the right partner. The resource limitations, both in terms of firm size/age and its internal R&D assets impeded access to collaboration partners (Aldrich and Auster 1986), as did the founder/CEO's lack of industry knowledge, expertise and network linkages. Small firms are strong at seeking opportunities; however, they typically lack resources to appropriate value from these same opportunities due to limited knowledge and market influence (Ketchen et al. 2007; Ireland et al. 2003). It was the disruptive potential of the novel technology, coupled with the entrepreneurial drive of the founder/CEO, that were key factors for DiaCo in overcoming this challenge. The case shows strong evidence of *strategic entrepreneurship* (Ketchen et al. 2007; Hitt et al. 2011) and the central role of the founder/CEO in the strategic trajectory of the ESME. Embedded within this challenge was the hidden problem of finding the '*right'* person within the collaboration partner, with whom to build a relationship. The importance of these '*hands-on and active*' individuals, involved in the operational management of the collaborative projects (Narsalay et al. 2016) was crucial to success, and DiagCo's experience highlights that there is often a time lag from when institutional agreements are signed until practical knowledge benefits flow towards the ESME. The research reveals that while securing access to '*right'* resources is invaluable in advancing ESME R&D [Project III with Uni—A and project IV with Gov—A], it is relational development with the *'right'* individual that facilitates the necessary knowledge flows (Kale et al. 2000).

Reflecting on DiagCo's success in harnessing the potential of collaborative R&D to develop their venture, the analysis highlights three management capabilities/ practices that have enabled their ability to attract the 'right' partner organisations. First, in considering *'how'* to attract suitable partners, the founder/CEO was keen to develop a credible multidisciplinary R&D team with the necessary technical expertise and capabilities as this would help alleviate some of the barriers in selecting and accessing the '*right'* partners. Again, he leveraged his managerial experience and background in attracting and recruiting team members renowned for their technical leadership and capabilities: *'The team is broadly multidisciplinary . . . there is magic if you will that within the team, the fact that it is multidisciplinary and the fact that the platform is being developed and advanced in parallel across all areas'*. This multidisciplinary team provided the necessary foundation and credibility to commence the process of attracting the *'right'* partners.

Second, the founder/CEO deliberately targeted industry leaders and influencing organisations (i.e. Government/EU agencies, global universities) as potential partners. The research revealed a purposeful strategy on the part of the ESME to search for and potentially access partners. This was aided through the participation in a Health Care accelerator programme that provided access to a first professional network. Likewise, DiagCo pursued and won many innovation awards, which brought credibility and positive visibility to the venture. Third, building on this early momentum, the founder/CEO attended leading industry tradeshows and conferences, which assisted in the identification of *key* individuals and budget holders within leading industry organisations. Through active networking and tenacity, the founder/CEO *'courted'* key individuals within these organisations, secured meetings and partnerships through articulating the firm's overall vision, the potential for industry disruption and the team's calibre and expertise. As outlined, this took conscious effort and resilience. These practices were recursive for each collaboration partner, and the founder/CEO was relentless until he secured the all-important initial meeting with the 'right' person. Given his industry background, he knew how MNEs behaved; he understood the norms and practices and knew *how* to work within the MNE organisational structures. Overall, this experience and knowledge proved invaluable in searching for and securing access to the *'right'* collaboration partners.

3.2 Challenge 2: Ensuring Adequate Value Appropriation

The second OI challenge encountered by DiagCo related to its concerns regarding the ability to appropriate value for the ESME from their collaborations. Developing a new medical device is a long, costly, risky and complicated process (Davey et al. 2011; Hogan 2005) and protection of assets and value appropriation is of crucial importance to all stakeholders. DiagCo had secured 30 patents which were the primary organisational assets and thus, IP protection was a significant concern and a considerable challenge when collaborating with commercially savvy MNEs. The analysis of this case highlights three management capabilities/practices that have enabled DiagCo appropriate value from their collaborations.

At the initial stage of each project, DiagCo insisted on formal protection mechanisms and safeguards between the parties: *'in the early stages, we used non-disclosure agreements'*. These initial safeguards provided the ESME with a sense of security to engage in discussions with the external organisation to explore potential synergies. Throughout the process, the founder/CEO led interaction and involved in a strategy of *'selective protection'* and *'selective revealing'* (Henkel 2006) with OI partners as the emerging context for opportunity developed. This strategy encompasses a vital issue of all collaborating organisations but more so when relative scale/power is significant since knowledge exchange is necessary to identify synergistic opportunities and build trust. Still, until trust exists between parties, then the perception of being vulnerable to IP exploitation can impede the knowledge shared. DiagCo's experience highlights the necessity of allowing time to develop relationships to harness opportunity potential, possessing unique complementary resources of interest to the partner and having partners that valued their established reputation assisted in meaningful and worthwhile knowledge exchanges for both parties: *'they don't want to take the chance of us partnering with anybody else'*. This *'paradox of disclosure'* (Arrow 1962) was a challenge to a greater or lesser degree for all DiagCo's OI projects, their deliberate strategy of partial disclosure of elements of proprietary knowledge while controlling and safeguarding access to other factors provided the context for the necessary trust to develop between parties.

Another practice employed by the founder/CEO, in enhancing the ability to appropriate value, was the protection of his R&D team at the early stages of OI projects. The founder/CEO felt a sense of duty to the team and shielded them away from partner interaction until ways of workings were established. Only when the founder/CEO was confident that the partnership opportunity and the underpinning relationship were strong, that the wider R&D team were then introduced: *'I wouldn't give any of these partners access to the team until the relationship is well and truly developed'*. An advantage of this founder/CEO practice was to minimise the likelihood of accidental IP leakage to the partner organisation early on and also to reduce the risk of losing key talent. The founder/CEO worked closely with each partner until the dyad was a tightly coupled partnership (Barringer and Harrison 2000), underpinned by formal agreements and structures. These rules and structures provided a meaningful expectation that others behave in a competent and benevolent way (Nooteboom 2004). They provided a process for knowledge exchange, learning and co-creation to occur.

Overall, the challenge of how-to appropriate value from these collaborations was overcome through the founder/CEO's deliberate and meticulous management of each OI partnership. Their purposeful and skilful management of each project stage, using a combination of formal and informal safeguards, '*selectively revealing'* key proprietary elements and continually developing collaborative relationship trust by reinforcing mutual advantage nurtured an environment of reciprocity where the ESME appropriated value.

4 Conclusions

While research of OI within the SME has gained prominence within the literature in recent years (Kraus et al. 2019), the niche category of ESME OI practice remains underexplored (Criscuolo et al. 2012). ESMEs are important in delivering new innovative and disruptive technologies and for the regional employment that they create. Through case analysis, this chapter explores how ESMEs can provide value from open innovation and harness the R&D potential of public and private resources through various OI modes for venture growth and the development of their technological disruptive R&D.

The research case highlights that the leverage of University–Industry–Government resources through OI adoption is a legitimate and advantageous development strategy for ESMEs to advance its R&D. This research makes two novel contributions. First, exploring OI at the project level highlights an OI adoption path of ESMEs as their collaborative capability and internal R&D develops. The findings reinforce the importance of public research institutions and support agencies in the early stages of the ESME development, validating the potential of collaboration and enabling a maturing of capability for successfully interacting with private organisations and the broader ecosystem. Second, this case study highlights the pivotal role of the ESME founder/CEO in adopting OI. The ESME challenges experienced in terms of selecting and accessing the '*right*' partner and ensuring adequate value appropriation are heavily determined by the founder/CEO's vision, their network and *strategic entrepreneurship*.

Overall, this case study highlights an exemplary strategy of value delivery through OI adoption in the ESME context. ESMEs used partners as strategic investors—universities EU/government agencies and established industry players, not only to advance their internal R&D but also to leverage their development budgets and reputation to acquire the necessary venture financing. Such action achieves R&D co-creation, industry advocates of their disruptive technology and facilitates venture growth as the technology moves closer to the market.

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Overcoming Barriers of Systemic Innovations in a Business Network

Miia Martinsuo

1 Introduction

Firms pursuing radical innovations do not settle merely with product and service innovations, but also seek value innovations that may significantly renew the logic of doing business (Berghman et al. 2012; Matthyssens et al. 2006). For example, manufacturing firms may experiment with intelligent technologies that enable the connectedness of products, equipment and entire processes with each other and related services as a possible means for extending or transforming the firm's business logic (Porter and Heppelman 2014). Such innovations may be systemic, that is, innovations '*whose benefits can be realised only in conjunction with related, complementary innovations*' (Chesbrough and Teece 2002, p. 128). In systemic innovations, development occurs throughout the entire system: it concerns not only technologies, products and processes, but also services, supply chains, business logic and even customers and markets. This chapter focuses on intelligent technologies as systemic innovations and how they are used to transform industrial firms' business.

In the case of systemic innovations, firms cannot drive the innovations alone, but depend on the other members in the business network, even though they cannot necessarily control them (Chesbrough and Teece 2002). The business network includes other organisations, such as suppliers, customers, customers' customers and various third parties, including software suppliers, consultants, service providers and other stakeholders whose involvement is required for the innovation to create value. While previous research on open innovation has focused mainly on collaborative inventing among the actors in the business network, the value creation and capture processes beyond invention deserve further attention (Chesbrough et al.

M. Martinsuo (✉)
Tampere University, Tampere, Finland
e-mail: miia.martinsuo@tuni.fi

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2018). As systemic innovations are particularly complex and require the commitment of the business network, their pathway towards value creation and capture in the market can be particularly challenging.

Radical technology shifts imply business logic changes that may threaten existing business models and, therefore, require completely new ways of working for the entire business network (Tongur and Engwall 2014). New partner firms and collaboration may be needed—even within new industries—to create and capture value from the systemic innovation. Forming the business network and identifying a shared value proposition take place at the front end of the innovation (Reid and De Brentani 2004; Takey and Carvalho 2016); this is when ideas for the innovation are created and experimented with, strategies are formed, and before choosing the final solution concept for implementation. The front end of systemic innovations requires specific attention to identifying and coordinating the business network and preparing for the new type of business model in the network, which takes place before planning for the subsequent process phases (Takey and Carvalho 2016). Previous research has not revealed the barriers and related changes in initiating the systemic innovations sufficiently, and more research has been called for in the domain of intelligent technologies (Tongur and Engwall 2014).

The purpose of this chapter is to explore intelligent technologies as a systemic innovation, particularly in terms of the barriers experienced at the front end of the innovation and ways to overcome them. The idea is to view open innovation from the perspective of value creation and capture (Chesbrough et al. 2018), focus on stakeholders' experiences during the front end of the systemic innovation, and thereby tackle the emergence of new business logic, instead of focusing exclusively on product-related invention and R&D. The systemic approach of creating value is apparent in business networks and ecosystems as different actors bring their specific resources that need to be integrated into the system (Aarikka-Stenroos and Ritala 2017). The goal is an increased understanding of the implementation requirements of systemic innovations, specifically in the case of an intelligent technology to be adopted in a business network. The focus is on two research questions:

1. What kinds of barriers do stakeholders in the business network experience when involved in defining systemic innovation?
2. How (i.e. through what kinds of changes) is the systemic innovation initiated in a business network?

The focus is limited to business-to-business (B2B) settings where manufacturing firms deliver products, services and solutions for customers and may drive systemic innovations, intelligent technologies in particular. This choice is motivated by the topicality of intelligent technologies and the systemic nature of their innovations, specifically in B2B contexts. Thus, consumer businesses are purposely excluded. Attention is directed at complex systemic innovations, i.e. situations where multiple innovations occur in parallel and depend on each other. As a contrast to single-firm innovations and firm–customer dyads, the focus is on business networks where multiple firms need to collaborate to define, complete, share and diffuse the innovation.

The chapter next introduces how intelligent technologies have been considered in earlier research and frames them as systemic innovations requiring the involvement of business networks. Then, a case study on a manufacturer moving towards intelligent materials is introduced. The data collection deals with the early phase of a systemic innovation programme carried out on the firm's engineering and construction business areas. The results reveal barriers on multiple levels concerned with the innovation and change requirements regarding the front end and in anticipation of the back end, of the systemic innovation. The contributions draw attention to the preparations made at the front end of the systemic innovation that already involves the business network actors.

2 Systemic Innovations in a Business Network

2.1 Digitalisation and Systemic Innovations

Through the increasing digitisation in industries, technologies and products are becoming more intelligent; they are '*able to collect, process and produce information and even "think" for themselves*' (Rijsdijk et al. 2007). Companies may use intelligent components in their products (Rijsdijk et al. 2007), for example to acquire information about customers' goals and processes digitally (Weill and Woerner 2015). They may also enhance their value creation processes through remote technologies and increased information technology support (Wünderlich et al. 2013; Momeni and Martinsuo 2018), and enhance or complement their core offerings with smart and digitised services and product-service systems (Barrett et al. 2015; Coreynen et al. 2017; Wünderlich et al. 2013). Typically, intelligent technologies may be discussed through concepts such as smart technologies and services (Ehrenhard et al. 2014; Wünderlich et al. 2013), digital technologies (Pagani and Pardo 2017), digital innovations (Nylén and Holmström 2015) or digitisation (Coreynen et al. 2017).

Irrespective of the terminological differences, intelligent technologies typically deal with software and sensors embedded in technologies (materials, processes, systems or products) as well as the supportive information and communication technologies. They enable the collection, processing and use of technology and customer information through information systems, and subsequently improve value creation for involved stakeholders (Barrett et al. 2015; Porter and Heppelman 2014; Rijsdijk et al. 2007). They also create an opportunity to use multiple business logics and channels to meet the customers' needs (Weill and Woerner 2015). The properties of technology intelligence have been mapped to some extent already, particularly for consumer business (Rijsdijk et al. 2007).

The nature of intelligent technologies is quite all-encompassing—they may deal with the entire business system in a firm. Sensors, information technologies, software, the core manufacturing process, products, and complementary services are inherently connected throughout the system. Therefore, this study considers intelligent technologies as systemic innovations where the benefits of the entire system require parallel development of related additional innovations (in line with Chesbrough and Teece 2002). Intelligent technologies have the potential to radically change how value is created, experienced and captured (Porter and Heppelman 2014), so they may also be considered as value innovations (in line with Berghman et al. 2012; Matthyssens et al. 2006). The systemic nature of the innovations in intelligent technologies draws attention to the need to coordinate work and cooperate throughout the innovation process. This coordination and cooperation become challenging in inter-organisational business networks, particularly with pioneering technologies that do not have established standards (Chesbrough and Teece 2002).

2.2 Involvement of Business Networks in Open Systemic Innovations

With entirely new value constellations and business models, systemic innovations may cannibalise existing businesses and require resources and services from other organisations very early, at the innovation front end (Chesbrough 2003). The involvement of possible partners in the business network could be useful to define, create and deliver the innovation successfully for commercial use. Stakeholders for a manufacturing firm may range from current and future customers; wholesales intermediaries; other material, component, product and service suppliers that offer complementary innovations; and research partners, consultants, and industrial designers, among others. Any of these stakeholders can have their different expectations, goals and contributions (Ritala et al. 2017) in creating the systemic innovation and growing it into a successful business.

The involvement of these kinds of stakeholders is common to open innovation (Chesbrough 2003; West and Bogers 2013), which has traditionally been considered from the perspective of technology invention and R&D (Chesbrough et al. 2018). However, in systemic innovations, it is not sufficient to concentrate on a product or technology—value must be considered more broadly, covering the entire system. Ecosystems emerge and evolve based on the stakeholders' voluntary participation, depending on their competencies and aspirations for value creation (Rohrbeck et al. 2009; Weill and Woerner 2015). Particularly with digital innovations and service-related business logic changes, an ecosystem view with stakeholders' mutual value creation is emphasised (Barrett et al. 2015; Weill and Woerner 2015), meaning that value creation and capture must be considered for the entire product-service system and all stakeholders involved.

Very commonly, such an idea of openness depends on how a particular firm wants to outsource activities, find external partners, use the partners' resources and capabilities and adopt innovations created by others (West and Bogers 2013). The joint effort and proactive involvement of other firms in the business network are less frequently covered in the research. The focal firm's perspective is typically taken, in terms of accessing information from partners in the supply chain (Berghman et al. 2012), the firm's capabilities for networking (Eggers et al. 2014; Reid et al. 2015) and collaborating in inter-organisational relationships (Gemünden et al. 2007). As systemic innovations tend to represent radical transformation both for a focal firm and its broader network, any firms in the network will need to change their assumptions and worldviews (Reid et al. 2015), their 'orientation' and competencies (Herrman et al. 2007; also Talke 2007), and the framing of their search in novel market and technical environments (Bessant et al. 2014). Ritala et al. (2017) emphasise the need to establish good knowledge search and integration mechanisms to resolve network-level tensions that may emerge due to actor-specific knowledge and goals. Behaviours and attitudes among personnel will significantly affect the firm's capacity to carry out and benefit from their radical and systemic innovations (O'Connor and Rice 2013).

As the adoption and implementation of intelligent technologies may transform the way that value is created throughout the business network, different firms, both in the supply chain and more broadly in the business network, need to become part of the transformation. While sometimes intelligent technologies are discussed merely from one focal firm's perspective, this study is more concerned with a broader involvement from the business network. Intelligent technologies and related business networks appear in the consumer sector (Palo and Tähtinen 2013; Rijsdijk et al. 2007; Vendrell-Herrero et al. 2017; Wünderlich et al. 2013) and in the industrial B2B environment that may also be connected with consumer businesses. This study focuses on B2B contexts.

2.3 Challenges in Implementing Intelligent Technologies in Business Networks

Previous research has investigated a variety of systemic innovations, including building information modelling (Alin et al. 2013; Lindgren 2016), wind turbines (Andersen and Drejer 2008), multi-storey timber house-building systems (Lindgren and Emmitt 2017), energy-efficient housing (Mlecnik 2013), electric vehicles (von Pechmann et al. 2015) and renewable energy (Kang and Hwang 2016). These studies mostly agree on the challenges dealing with the implementation of the complex, systemic innovations and the significant effects they may have throughout the supply chains. Attention is drawn, for example, to factors relevant to the diffusion (Lindgren and Emmitt 2017) and scale-up of the innovations (von Pechmann et al. 2015), as well as alignment of interests and sharing of knowledge in the business network (Alin et al. 2013; Andersen and Drejer 2008; Kang and Hwang 2016; Mlecnik 2013). Of these examples, particularly building information modelling contains intelligent technologies in the B2B sector, and in construction in particular. Similar kinds of tensions, challenges of knowledge search, integration and goal alignment have also been identified in R&D networks more generally (Ritala et al. 2017).

Takey and Carvalho (2016) proposed a conceptual framework that sums up the key elements for the front end of systemic innovations. The four main elements in the framework are: mapping of the actors and positions in the network, mechanisms for coordination and collaboration, creation of new business models, and strategic business and venture planning as phases following from the front end. They point out that some practices in the front ends of autonomous innovations may be useful for systemic innovations, too. Concerning intelligent technologies, specifically, previous empirical research aligns reasonably well with the conclusions of Takey and Carvalho (2016), but with slightly different focuses and so far without a specific emphasis on the front end of the innovation. Examples of such empirical research are summarised in Table 1.

The business network transformation regarding intelligent technologies is very strongly tied with the idea of service-oriented business models, and the change of these logics creates strategic challenges for the involved firms. The adoption of intelligent technologies may be quite demanding, as the traditional goods-centric logic may need to be replaced or complemented with the logic of services and may require business-wide service transformations (Coreynen et al. 2017; Eloranta and Turunen 2016; Porter and Heppelman 2014; Tongur and Engwall 2014). In support of these findings in the B2B sector, the service-oriented business logic changes have also been experienced in the consumer sector (Palo and Tähtinen 2013; Vendrell-Herrero et al. 2017).

When companies transform the business model, intelligent technologies will have implications on the configuration of resources (Coreynen et al. 2017) and the use and linkages of digital resources (Pagani and Pardo 2017). In particular, companies may need to consider what kinds of platforms they want to use to leverage the resources from the network (Eloranta and Turunen 2016). Notably, the involvement of the network actors is affected, requiring the identification of the network actors and their activities (Ehrenhard et al. 2014), defining portfolios of activities for network management (Nordin et al. 2018) and coordination of activities between actors (Pagani and Pardo 2017). Thus, both the resource configurations and the network management may be challenging, as individual firms cannot control their network partners or fully know their interests (also Ritala et al. 2017).

The above empirical studies reveal that intelligent technologies (mainly through digitalisation) may take various paths in business networks. The adoption and use of intelligent technologies may be very challenging, mainly due to the business logic change. Network-level management needs to be considered, and barriers are experienced in various ways. However, the studies most frequently view the obstacles and challenges solely from the focal firm's perspective and do not acknowledge the other network actors' viewpoints. In particular, the end-user's adoption of the intelligent technology may face barriers regarding end-user's familiarity with the technology, the lack of standardisation and poor compatibility of technologies and services in the system, the price of the new technology solution, and the lack of support from government and regulations (Ehrenhard et al. 2014). Further knowledge is needed, particularly concerning very complex solutions, mature firms' networks, both intra- and inter-organisational issues and various industries.

Table 1 Examples of previous empirical research concerning the adoption and implementation of intelligent technologies in business networks

Source	Method and context	Finding	Gap, need
Coreynen et al. (2017)	Multi-case study, manufacturing SMEs in Belgium.	Reveals different pathways for digitisation (depending on where it is applied in the value chain) and, consequently, types of servitisation and related resource configurations.	Does not cover complex customer-specific solutions and related value delivery.
Ehrenhard et al. (2014)	Single-case study and exploratory interviews, smart housing	Maps the primary and secondary actors, their roles and activities in the value network; identification of barriers for market adoption of complex multi-stakeholder technologies.	End-user view dominates; barriers not covered more generally in the (industrial) network.
Eloranta and Turunen (2016)	Multi-case study, large manufacturing firms, platforms for service-driven manufacturing	Reveals mechanisms to leverage complexity and three logics for their implementation: connecting actors, sharing resources, integrating systems.	The focus was on platforms dealing with service-driven manufacturing, not necessarily dealing with intelligent technologies.
Nordin et al. (2018)	Single-case study with an SME offering solutions for smart home energy management	Identification of network management capabilities in an emerging smart technology field: context handling, network construction, and network position consolidation	Validation of the framework needed, also in different industries. The focus was on a start-up; network management in established firms may be different.
Pagani and Pardo (2017)	Multi-case study, five B2B industries	Identification of three types of digitalisation (activity links-centred, resource ties-centred, actor bonds-centred)	Validation and extension of the framework needed, also covering intra-organisational issues.
Tongur and Engwall (2014)	Single-case study, automotive industry	Characterisation of the business model dilemma stemming from a technology shift, consequently challenging the firm's entire logic of business.	The relationships between technological innovation, service innovation and business innovation deserve further attention. Also, different technologies and industries should be studied.

3 Case Study

3.1 Intelligent Materials for Construction and Engineering Industries

To enable an in-depth analysis of the sophisticated systemic innovation of intelligent technologies in its specific business context, the case study method was adopted as the research strategy. The case study was carried out with a large, international industrial manufacturer, referred to here as MaterialCo. The firm has sales of over 10 BEUR, more than 15,000 employees, and its headquarters are located in Northern Europe. It manufactures metallic raw materials and components and designs and delivers assembled systems and sophisticated solutions to customers internationally. It has two primary market segments—construction and engineering—each served through a dedicated business area in the firm. The engineering business area covers components, products and systems created from the raw materials for other manufacturing firms, and the construction business area delivers structural components and systems for building and infrastructure construction firms. Due to the international market, the company faces similar kinds of market and institutional conditions as its competitors. At the same time, the Nordic home market has an ongoing trend of digitalisation in industries, which created excellent opportunities for experimenting with new technologies.

MaterialCo has been involved in creating an intelligent material to enable storing and communicating information about the material, product and manufacturing process and distributing this information throughout the supply chain for the full lifetime of the material. In this chapter, this intelligent material is used as an example of systemic innovations since it represents a strategic, radical innovation. It would require complementary innovations and involvement of the business network. Already the front end of the systemic innovation required initiating various development and experimentation projects. The firm expected that the number of projects and involvement of other firms would increase over time, thereby increasing the complexity of the innovation task.

The systemic nature of the solution mainly requires innovating all aspects of the material and information flow throughout the business process. MaterialCo could add intelligent features to component materials by various identifiers (such as sensors or radio frequency identification) and use them to enable technology-supported information flows in the supply chains for both business areas. The use of modern information systems and analytics could enable reading, replicating, updating and using the same information across firms involved in the specific supply chain. Delivering value in the business network would require defining new kinds of commercial offerings, sharing information throughout the supply chain and active cross-firm collaboration.

When data for this study were being collected, MaterialCo was exploring the technologies and partner organisations that could be involved in the future commercial business. Therefore, this study deals with the early phase of systemic innovation.

The firm later proceeded with the innovation in various areas to the design and testing phases, followed by market experimentation.

Data collection took place within the focal firm and its two market segments in the early phase of the systemic innovation. Interviews were held with 27 people, including selected customer and partner firms in the engineering market ($n = 12$) and construction ($n = 11$), and managers within MaterialCo ($n = 4$). Additionally, we organised four workshops with the firms involved in the business network and meetings with the contact person from MaterialCo to validate the results and promote the innovation work. The data collection was carried out in DIMECC's (Digital, Internet, Materials and Engineering Co-Creation ecosystem in Finland) research programme (Future Industrial Services) and is explained in more detail in Martinsuo (2019).

3.2 Front End of the Systemic Innovation

The early phase of the development at MaterialCo included a visionary phase of strategising and starting new projects to develop and experiment with the technologies and to design intelligence into commercial solutions. The process and structure for the systemic innovation were emergent and informal, and only some technology-related and business-design tasks were specified as separate projects. MaterialCo invited some stakeholder firms to collaborate, co-develop and experiment in some projects to enable the application design and market piloting related to the intelligent materials. As MaterialCo is a market leader in its home markets and has a good reputation, it was in a strong position to pique the interest of potential partner firms to get involved in systemic innovation. These companies in the business network participated in the development work as a result of their interest in growing their business and to achieve a first-mover advantage in the field.

The customer and partner firms had some previous experience with intelligent technologies and were eager to voice their requirements and opinions. Even if the front end of innovation proceeded in an unstructured manner, the stakeholders shared the strategic interests concerning intelligent materials: efficient distribution of material-related data over the supply chain; the possibility for automated as well as manual reading of these data; new information system linkages between firms; and the opportunity to monitor the material/component data throughout the solution's lifetime. The interviewees foresaw a possibility to use modern information technologies proactively, develop a shared platform for information sharing and activate new business for all firms in the business network.

The interviewees anticipated that an advanced version of intelligent materials would imply 'self-awareness', increased automation and dynamics in functionalities and processes, and even self-correction capacity. Still, it would take a long time to achieve this. Although the technical readiness was already sufficient, commercialisation of practical solutions would require a lot of development effort. With the slow pace of development in the construction and engineering industries, the requirement of transforming companies' network positions, relations in the supply chain and business models would be risky, not only for MaterialCo and its customers but also for other firms in the business network.

4 Barriers to the Systemic Innovation in the Business Network

Various challenges were discussed concerning the adoption and use of intelligent materials in the business network, mainly dealing with the value creation and capture of intelligent technology. The challenges were first coded inductively with detail and, then categorised into barriers concerning markets, industry, solutions and investments. As can be seen, the identified barriers do not deal with technology or R&D as such. In fact, many interviewees expressed that the majority of technologies for intelligent solutions are already available. Instead of technical challenges, the value creation and capture for different stakeholders causes barriers. Furthermore, other issues were discussed by the interviewees, but only to a lesser extent. Table 2 summarises some examples concerning the identified barriers, which are discussed in further detail below.

Interviewees expressed **various customer and market-related issues** as the most common potential barriers to adopting intelligent materials and related solutions. They emphasised that all customers are different, different markets demand different solutions, and the specific circumstances of customers would need to be adequately understood to design suitable solutions. Customers were described as somehow reluctant or slow to accept and use the intelligent materials (as opposed to a willing and able). Interviewees described this, for instance, by doubting customers' knowledge on what they need, the usefulness of the technologies and ways to benefit from the technologies. Some interviewees described occasions where customers were not able to procure service-enhanced solutions, or they could not utilise the solutions in the right way for their benefit. Customers' actions can even cause problems if they do not understand the interplay between technical systems and the stakeholders involved in the business network, or if they do not communicate and give feedback on time. Some interviewees also discussed various third parties, such as software and service providers, who were not yet ready or willing to use intelligent systems. In a global industry, the market issues become even more complicated, as customers in the different geographic areas may vary in their technological readiness.

The second most apparent barrier relates to **insufficient readiness at the industry level**. When the intelligent technologies are taken into use, and standard solutions do not exist yet, the tradition in the industry meets the future. Interviewees discussed global competition and the difficulty of getting information about competitors' actions. Still, at the same time, they were also concerned about the threat of confidential information flowing to competitors. The reluctance and slowness

Table 2 Example quotes from interviews concerning the barriers to adopting the systemic innovation

Barrier	Link to value	Example quotes
Insufficient market pull	Mechanisms of value capture among customers Perceived threat of (previous) value destruction	'The customer's buyer never emphasises the positive things [about our solutions], but they'd rather say something about what the competitors do better so that they can get a reduced price. In reality, we should get the feedback from the operators and designers and users, technical people [of the customer firm]'. [MaterialCo] 'They [customers] really do not have such capabilities [that would be required for these systems]'. [construction] 'The value [of the intelligent solutions] comes indirectly to the customers when utilising the information. But it is difficult to imagine how they understand the value of knowing where the material has come from'. [engineering] 'I guess we all have some sort of resistance to change and fears toward new things if you do not necessarily know what the change means to you'. [engineering and construction]
Insufficient industry readiness	Competing solutions for creating the same value	'Well, all firms are competitors, I mean, these machine builders, and it is a severe competition. There is no standardisation whatsoever [in a certain domain], nothing matches between competitors. Every firm wants to keep these applications and interfaces to themselves. It would be the customer's benefit to open up these interfaces [but it is not happening, yet]'. [engineering]
	Perceived value of the status quo	'In the construction business, it is often so that "if nobody else does this, why should we." And "this is how we have always operated." And "we are doing quite well like this"'. [construction]
Pervasive character of the solution	Systemic nature of value – the complexity of value creation before value capture	'There are still customers that want [systems operating with a traditional logic], with no intelligence at all. The ocean is full of these, so it is impossible to compare the information from intelligent systems to the manual ones [to motivate broader use]'. [engineering] 'Still today we many times face the situation that these interfaces [requiring different companies' collaboration] are not well enough designed, and then we have

(continued)

Table 2 (continued)

Barrier	Link to value	Example quotes
		to ponder what to do. If the project manager would think about them in advance, it would be much easier'. [construction]
Investment requirement	Cost of the created value	'Of course, it deals with who has the money, who is going to make the investment. Is that firm getting the benefits or extra value?' [construction]
	Separation of benefits and costs to different stakeholders	'Often in these apartment building sites, it is the grandmothers who think what this costs [and make the decisions]'. [construction]

(as opposed to interest and willingness) of stakeholders in the industry to accept and use the systemic innovation deals mainly with the complexity of the network and the deeply rooted habits of the industry. Both engineering and construction industries have their established routines, which may be hard to break in a business network. The attitude of '*this is the way in which we have always operated*' may prevail, and there may be resistance to change. It may even be unclear who should be treated as the customer, and which firms should collaborate to convince customers of intelligent solutions. As all firms have their strategies and expectations, and standardisation has not yet taken place, whose ideas should be followed? Some interviewees described that the complexity of the business network is reflected in structural arrangements within firms in the network. In a new network, it is not clear who within the firm should collaborate together and with a specific partner.

Another actively discussed barrier relates to the **pervasiveness of the solutions** developed based on intelligent systems and their necessary interplay with existing legacy systems. The variety of existing systems is already extensive, and when technologies evolve rapidly, firms may be unwilling to take up new systems before they are standardised and well established. The intelligent technologies imply transformations almost everywhere in the business system, and this overwhelming transformation is not easy to absorb. Interviewees discussed the difficulty of communicating the benefits of the new solutions, the ongoing technological insecurities, the invisibility of indirect earnings and the time required for demonstrating the benefits. Also, the need to connect new solutions with old systems was experienced as a challenge, particularly as there are no interface standards, and the solutions may involve different firms in the business network for each customer. With intelligent technologies, each solution has its business network; thereby, all customer solutions require unique approaches and involve unique risks.

Interviewees pointed out the **investment requirements** for all stakeholders concerning intelligent materials. Due to the front-end phase of the innovation, it was not at all clear who would pay for the required investment and how the costs and income would be shared across the network. Many interviewees discussed that the novel earning logics of solutions would change selling routines, and customers' purchase patterns may not yet acknowledge service-oriented procurement. Customers are typically very price-conscious and may find it challenging to compare traditional goods-centric prices to service-centric prices. Moreover, the provision of services is labour-intensive, calling for human resource-related investments. As it is quite uncertain how intelligent solutions are adopted, this can cause significant risks for suppliers.

Furthermore, various other challenges and barriers were discussed, each to a lesser extent. In particular, the service orientation typical to solutions is worth mentioning. As the business logics change towards services, the interviewees felt that the increased person-dependency and the novel earning models could become barriers for customers and partner firms. The current ways of working, with their long histories, may seem easier and safer, whereas service-oriented logics will require a lot of development and education throughout the business network. Various technical details were also discussed, reflecting the necessity to develop such technical enablers and conditions that make it possible for customers and other stakeholders to benefit from intelligent materials.

5 Network-Related Changes at the Front End of the Systemic Innovation

Most of the required technologies concerning the intelligent materials already exist and primarily need refinement, application development and information solution development to facilitate the novel type of value creation and innovative connections with each other and to be offered as a complete solution. Four themes recurred when discussing network-related changes in initiating the systemic innovation (see Fig. 1): foresight of the solution life cycle, changes in the solution design approach, changes to the earning logics and optimising the performance of the solution for the customers. These themes convey the need for firms to collaborate differently very early on and to anticipate various aspects of the future business over its possible long-life cycle.

Some changes dealt with the use of the solution broadly. A few interviewees pointed out the need to develop **foresight of the solution life cycle** much beyond the solution delivery. This life-cycle view emphasises that various stakeholders have their specific expectations of value, that such value is created and captured differently over the value chain, and that the versatility of expectations needs to be anticipated at the front end of the innovation. According to interviewees, the suppliers cannot just concentrate on delivering the solution as cheaply as possible and then forget about it. In reality, they need to understand and foresee the years or even decades of solution use, as the years of solution use will eventually determine the life-cycle costs and benefits of the solution. As one interviewee explained: '*A lot of this material can be recycled and re-used .... Monitoring of material wear and fatigue in demanding-use contexts will be really useful. And how about material*

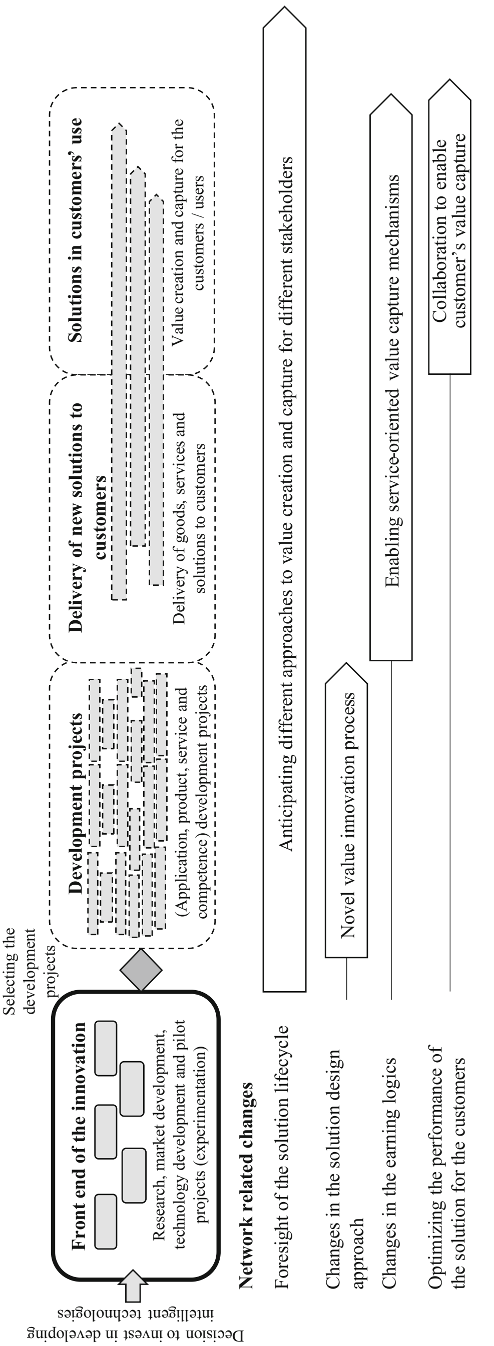

Fig. 1 Overview of network-related changes at the front end of the systemic innovation

sorting and recycling at the end of life? A lot of small firms have their money tied to these materials, so they would benefit if you could control it better' (construction and engineering). The interviewees anticipated that intelligence was relevant not only during the solution use but also for dismantling and recycling of the materials after use.

Some changes dealt directly with developing solutions using intelligent materials. Many interviewees felt that the entire **approach to solution design is changing** and it should no longer deal with technical planning only, but also planning of applications, new processes, use and maintenance for the customer. Solution design occurs right after the front end of innovation, and the specific need is to identify the right value propositions for the right stakeholders. Each development project may require its particular value innovation for the complete systemic innovation to become successful. One service provider explained this through an example from their perspective: '*If we think about these remote solutions, so far it has been very few instances where the maintenance of the solution has been considered during design and construction .... It might be completely new construction, just commissioned, and we [the service provider] start discussing if it is possible to connect this to a remote monitoring system. Then we start to think and invite the contractor back to implement the changes ... This collaboration could happen much earlier*' (construction). Indeed, the solutions that use intelligent materials are not really in the hands of the focal firm alone; customers and their possible other partners need to be involved during solution design.

Solution development would often also imply **changes to the earning logics** of the solutions. It is possible that product-centric pricing and earning is no longer likely with intelligent technologies but, instead, earning takes place over time, through use and availability. This may imply a service-oriented value capture logic and the need to involve completely new kinds of partners in the business network. In particular, the service-provider firms discussed that the system itself '*does not really cost anything*', referring to a very low technology cost. In contrast, the cost of design and installations for remote monitoring, the cost of having unique processes for different customers and alternative costs of on-site monitoring can be substantial. Various firms get involved in such services over time. Interviewees described the possibility of using monthly availability-based pricing or performance-based pricing (e.g. based on energy or material consumption, or based on their reduction due to the remote solution). Still, they also indicated that the company networks create challenges for earning. One service provider offered examples of various stakeholders involved in installing water monitoring systems in construction: '*Everybody knows that the maintenance always costs something. But the system itself does not cost much .... If the customer wants to follow up their water consumption themselves, someone needs to manage the customer information. What if it is a rental flat? There is a property owner, and there is a facility maintenance firm, people move, users change .... This causes certain challenges, legal and other*' (construction).

Attention was given to the customer's view to value, particularly in terms of **optimising the performance of the solution for the customers.** For the systemic innovation to succeed, the business network needs to keep sight of the customer's value capture when the solution is in use. Many interviewees discussed how the customers could utilise the information concerning the intelligent materials and, consequently, optimise their operations for efficiency, flexibility and customer satisfaction. The ability to follow the material flow on-line, anticipate needs and problems and communicate this information to the right stakeholders may be crucial for the customers' business performance. In many cases, intelligent materials would require that many firms are committed to supporting the customer-specific solutions. '*Identification of these materials will be really relevant. It deals with reclamations, the correct use of the material, the location, its history .... Sometimes we find that the complaint concerns another firm's material, not ours*' (MaterialCo). The long-term view to solution use introduces novel uncertainties to the business network, as it is not fully known how technologies, customers' businesses and ways of working will evolve.

Customers have not yet been very active in demanding intelligent solutions. However, their willingness to participate in experimenting with the new technologies is relevant and an early step to promoting customers' solution acceptance. Interviewees offered examples of this kind of experimentation in both market segments. Although customers often want to control the information flows concerning their products and solutions, it is challenging to anticipate what happens concerning intelligent materials in their use. For example, customers may lack the necessary knowledge and capabilities on intelligent materials and, therefore, they will need the support of other firms, particularly during early experimentation. Some interviewees characterised that intelligent materials will transform the industry, in terms of reconfiguring the stakeholders' relationships, network positions and roles and changing the industrial culture. The interviewees discussed various make-or-buy alternatives since it is not clear which firms will eventually orchestrate the business network for intelligent materials. They also pointed out that novel entrepreneurial firms may take essential positions in the network. The interviewees were not sure which firms would take leadership in the change, or how the networks will be configured. Still, they saw that even alternative network configurations are possible, as long as some focal firms dare to drive the transformation.

6 Conclusions

This study has explored intelligent technologies as a systemic innovation, particularly concerning the barriers and required changes at the front end of the innovation. The qualitative investigation of a single case centred on a manufacturing firm that pursues increased intelligence in its offerings, changing many aspects of its offerings and operations, and also requiring its partner firms to revise their practices, services and processes. With this study, the intent was to understand the implementation requirements of systemic innovations, specifically in the case of an intelligent technology to be adopted in a business network. Systemic innovations are particularly interesting for open innovation research as they not only cover product-related invention and R&D but also more generally renew the logic of value creation and capture for many of the stakeholders involved in the innovation.

The first research question asked, '*What kinds of barriers do stakeholders in the business network perceive when involved in defining the systemic innovation?*' Where previous research has identified barriers to adopting intelligent technologies, particularly from the end-user's perspective in consumer business (Ehrenhard et al. 2014), this study added a broader view of the participating business network. It emphasised the supply chain connectedness, also between industrial and consumer businesses. Similar to Ehrenhard et al. (2014), standardisation and compatibility issues emerged as part of the pervasive character of the intelligent solution as a potential barrier. However, in industrial contexts, the legacy and history of systems cause further challenges, as they may slow the diffusion of the novel systems. Also, the findings revealed barriers concerning markets (insufficient and dispersed market pull), industry (insufficient industry readiness) and investments (investment requirement), thereby suggesting that systemic innovations must be seen at multiple levels, each requiring different actions. The barriers at the front end of systemic innovations need to be seen as **issues to be analysed and resolved** through various actions, within single firms and the business network and in the industry more generally. It is not sufficient to respond and react to adoption and diffusion barriers later in the process; instead, businesses must anticipate them proactively at the front end of the systemic innovation.

The second research question inquired, '*How (through what kinds of changes) is the systemic innovation initiated in a business network?*' The findings align with previous research in the need for openness, collaboration and networking (e.g. Eggers et al. 2014; Gemünden et al. 2007; Reid et al. 2015), but as a contrast to the focal firm's perspective (West and Bogers 2013), the attention was drawn to the proactiveness of various actors in the business network (Barrett et al. 2015; Weill and Woerner 2015). While previous research has emphasised the general need to align the network actors' interests (Andersen and Drejer 2008; Mlecnik 2013), this study explains what this alignment might mean when anticipating the life cycle of intelligent solutions. Namely, the four recurring themes concerning the changes of systemic innovations deal with the **business design at the front end** and **anticipation of the back end of the intelligent solution**, particularly in terms of value creation and capture for various stakeholders. Changes in the solution design approach and earning logics are issues typically requiring attention at the innovation front end. For systemic innovations, these are multi-organisational issues instead of issues concerning a focal firm only. The networked approach to designing the systemic innovation will have significant implications on the actual innovation project in terms of specifying the roles and responsibilities within the network, configuring the entire network, specifying the value propositions for each participating stakeholder and cost and profit-sharing. In this way, this study has offered empirical evidence concerning some of the issues covered in the conceptual analysis of Takey and Carvalho (2016).

Foresight of the solution life cycle and optimising the performance of the solution for the customers dealing with the backend of the innovation (i.e. the use of the innovation after the innovation project) need to be anticipated when planning the systemic innovation. These, too, were discussed as networked efforts requiring the joined forces of firms in the business network. As the value creation and capture for stakeholders occurs differently over the solution life cycle, the anticipation of the life cycle draws attention to knowledge availability, search and integration (Ritala et al. 2017). What knowledge is available about the customers' and other stakeholders' operating conditions *in the future*, when the solution is in use*?* While knowledge processes between stakeholders were purposely not investigated in this study, the findings revealed inherent uncertainty concerning the solution life cycle, outlining challenging conditions for the pursued life cycle foresight and inviting future research.

Besides these themes, the findings emphasised that the systemic innovation required the reconfiguration of stakeholders' involvement and relationship, possibly changing the industrial culture and landscape. While previous research has discussed the transformation in the business logic through intelligent technologies in other contexts (Tongur and Engwall 2014), this study offers further insight through the versatile usage options of the intelligent materials without restricting the analysis to a particular industry.

Qualitative single-case studies seek understanding of a selected phenomenon in a specific context. This case study is limited through the choice of the focal firm and its business network, as well as the choice of intelligent materials as an example of systemic innovations. To facilitate learning from the case, an extreme and informative case was purposely chosen, and its background and features have been characterised.

Empirical research concerning systemic innovations, in general, and intelligent technologies, in particular, is still young. This encourages scholars to explore different types of systemic innovations in different contexts more broadly. Forthcoming research should not only cover innovation management and diffusion and network management but also more fine-grained aspects of the innovation process. The findings in this study, for example, draw attention to the design of the systemic innovation and the anticipation of the life cycle of the solution as issues that have not yet been covered sufficiently. This study has also emphasised the different levels of analysis concerning the barriers: solution, firm, market and industry. All of them may open up novel avenues for further research concerning the ways that the barriers can be overcome and how systemic innovations could be promoted.

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Framework Linking Open Innovation Strategic Goals with Practices

Daniel Trabucchi, Stefano Magistretti, Elena Pellizzoni, and Federico Frattini

1 Introduction

Almost 20 years ago, in 2003, Henry Chesbrough approached the management community with his Open Innovation (OI) paradigm (Chesbrough 2003). This perspective suggests that companies stop thinking of the innovation process as something closed and confined within the company's boundaries. He proposed thinking of the innovation process as an open process, where companies have porous borders that let innovations come from the outside or go outwards for a nontraditional path. More broadly, OI is a distributed innovation process that leverages knowledge flows across company boundaries (West and Bogers 2014).

Over the years, researchers in innovation management paid significant attention to this paradigm, making OI the leading model in the innovation field (West and Bogers 2014; Randhawa et al. 2016). A simple search on Scopus, looking for "open innovation" in the title, the abstract, or among the keywords, give more than 5000 results between 2003 and 2019. More than 600 are published just in 2019. The extensive attention received by OI led to the emergence of many heterogeneous cases such as the famous "Connect and Develop" program developed at P&G. This became one of the flagship cases of OI (Dodgson et al. 2006) for the usage of big data to sense and identify innovation directions (Del Vecchio et al. 2018), till B2B collaborations (Bianchi et al. 2011). By presenting different cases that belong to the same broad family of OI, this chapter aims to help R&D Professionals in approaching OI, identifying why they should embrace it and how they could implement it.

D. Trabucchi (✉) · S. Magistretti · E. Pellizzoni · F. Frattini
Politecnico di Milano, Milan, Italy
e-mail: daniel.traucchi@polimi.it; stefano.magistretti@polimi.it; elena.pellizzoni@polimi.it; federico.frattini@polimi.it

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Within this academic debate, two main approaches to OI can be clearly defined: Inbound and Outbound (Enkel et al. 2009; Gassmann and Enkel 2004; Chesbrough and Crowther 2006). Inbound OI is the outside-in process that allows the company to enrich its knowledge by getting in touch with external stimuli, which may be ideas, opportunities, technologies, and so on (Laursen and Salter 2006; Lettl et al. 2006; Piller and Walcher 2006). Typical examples of inbound approaches are the call for ideas or crowdsourcing activities. It is essential to highlight how several sources of external knowledge are found in the empirical literature such as users, suppliers, and competitors (Enkel et al. 2009; Dell'Era et al. 2018). More recently, even user-generated big data has been inserted in this perspective (Trabucchi et al. 2018). Outbound OI is the inside-out process that allows the company to channel its innovations into external markets or different organizations that are better suited to their diffusion and exploitation (Gassmann and Enkel 2004). During the development process, companies may obtain potentially interesting innovations that do not fit the company's ultimate goals, or that cannot be further developed due to the need for specific investments of capabilities. The possibilities of creating spin-offs or finding new markets to commercialize an internally developed innovation are typical outbound practices.

Moreover, it emerges from the research conducted in OI literature that these two approaches are not alternatives but can be orchestrated simultaneously to expect higher performances due to the synergies in inbound and outbound knowledge transferring (Cassiman and Valentini 2016). The coupled approach matches together with the inbound and outbound methods, having knowledge flows both inside- and outside-out regarding the innovation process. This chapter focuses on the pure inbound and outbound practices since coupled approaches tend to match and sum practices coming from the inbound or the outbound approaches.

From a managerial point of view, a lot of work has been done defining the actual managerial practices that may be represented by the broad umbrella of open innovation. Although extensive research has been undertaken in this direction, it is often stated that it is difficult to propose "*a complete list of practices*" (Van de Vrande et al. 2009).

Moreover, several objectives have been indicated to implement the OI practices, proposing to, for example, to import ideas or innovations developed outside the boundaries of companies, as well as to find a new path to establish internally born ideas and opportunities.

This chapter aims to help R&D professionals have a clear overview of the strategic goals they may pursue using OI and the possible OI practices to reach them. This may help R&D professionals get in touch with OI's comprehensive and extensive work through a synthetic framework that facilitates understanding of what they may get through OI and how they can implement it. In other words, we aim to provide a comprehensive framework that can link the strategic goals and practices, providing a reference guide for managers and entrepreneurs approaching the OI paradigm. In more detail, our goal is to provide answers to the following open issues regarding OI: firstly, why R&D managers should use Open Innovation, and secondly how R&D managers can practically implement Open Innovation. To answer these research questions, and to consider the extensive academic research, we relied on a systematic literature review methodology. In doing so, we shed light on the strategic goals that OI can address (i.e., Enhance the innovation process, Strengthen the market position, and Identify new directions) and we divided the OI practices into those relevant for Inbound and those relevant for Outbound. Moreover, we coupled each practice with examples of companies that adopted them. This gives more concreteness to the work and value for the R&D Managers that can practically see how to transfer theory to practices.

2 Search for Concrete Practices

Previous studies that focus on systematic analyses of OI in different ways (e.g., West and Bogers 2014; Randhawa et al. 2016) were essentially academically oriented studies, proposing research agendas to guide further developments of the field. Thus, this chapter offers a managerial vision on the OI paradigm, summarizing the strategic and operational goals that have been pursued. Nevertheless, this research is based on academic rigor both in terms of methodology and data collected, using empirical papers to gather the information needed for this analysis. From a research design point of view, we have leveraged previous studies' recommendations to address this literature review (Tranfield et al. 2003; Magistretti et al. 2020).

First of all, as previously mentioned, we aim to identify OI strategic goals and the practices to implement OI. With this goal, we approached the literature review using the keyword "open innovation" as the starting point in creating our dataset. We searched it in the Scopus database, referring to titles, abstracts, and keywords. The database was selected as generally considered complete for a systematic literature review in the management domain (Santos 2015). This sample was limited in terms of years, searching for contributions published since 2003, due to the publication of Chesbrough's seminal book. To increase congruence, other keywords (such as practices, tools, mode, approaches, instruments, objectives, and goals) have been included, to find only those papers dealing with an empirical exploration of the OI paradigm. The sample was further decreased through filters such as document type (published articles and articles in press), the field (Business, Management, and Accounting), and the language (English).

The resulting sample has been screened through the abstract and the full text searching for elements suggesting the study of precise strategic goals or OI practices. We used a recursive and iterative approach, creating a list of goals emerging from the papers. The list has been discussed by all the authors in order to identify goals that may be merged. Similarly, the practices have been reviewed and clustered together. The result of this process is presented in the following section. We start by showing the three macro strategic goals that emerged from the analysis of the papers. For each of them, we give the detailed goals that appeared in the literature review and then clustered within the three macro categories. Then, we present the OI practices that emerged throughout the study. In particular, relying on the distinction between inbound and outbound practice previously mentioned, we introduce each practice with a brief description.

In the final part of the chapter, we show how the various practices may serve for multiple goals presenting a comprehensive framework that match goals and practices; to do so, we use illustrative examples that may help R&D Professionals in seeing the heterogeneity of applications of Open Innovation.

3 Building the Model

In the following section, we first introduce the strategic goals, clustered in three main typologies, and then practices emerged from the literature review.

3.1 Open Innovation Goals

Open Innovation is recognized as a paradigm with the purpose of expanding companies' perspectives on innovation (Chesbrough 2003). Companies usually embrace OI to promote innovation, but the review of the literature shows how strategic goals may be extremely different.

Companies can leverage the OI by targeting different strategic goals, which requires to work on different aspects of innovation. OI may assist companies in finding new directions to foster innovation, eventually discovering "new environments" in which to operate. Moreover, companies may want to rely on the OI paradigm to strengthen their market position, acting on the environment in which they are working. Finally, companies can implement OI to enhance the innovation process, looking for a more efficient and effective way to approach innovation. As reported in Fig. 1, these three goals can be mapped over the dichotomy of Exploration vs Exploitation (March 1991). Indeed, OI can assist with both exploring new directions and exploiting resources and projects available within the company. These three strategic goals will be further explained, offering the operational goals that can be linked to them.

3.1.1 Identify New Directions

The final set of goals is directly related to the main idea of OI: to foster innovation. Companies may face problems in successfully fostering innovation because they tend to get stuck in old successes and ordinary activities and products (path dependency). The decision to rely on external stimuli to foster innovation may significantly help to overcome this—common—phenomenon by providing different visions and perspectives.

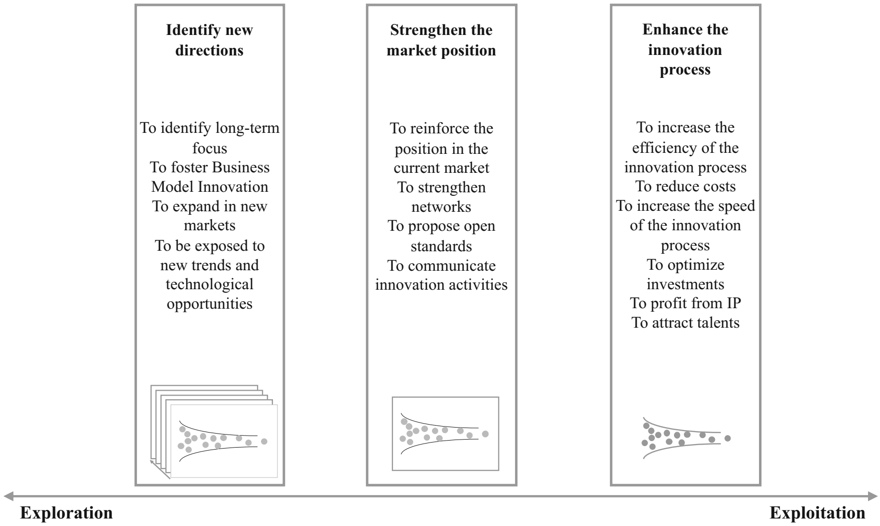

Fig. 1 Open Innovation strategic goals

The radicality of the new direction may vary significantly. OI can be leveraged to identify innovation pathways that can be focused both on the current (more incremental) or new markets (more radical), but that have a long-term focus, aiming to guide the company's strategic direction.

External sources of knowledge and stimuli for innovation can also push the innovation goals a little further. Several companies have been able to strategically leverage OI to foster Business Model innovation (e.g., Chesbrough and Schwartz 2007; Alberti and Garrido 2017). Openness allows companies to get in touch with individuals, established companies, start-ups, and several other sources of ideas and inspiration. All these sources may offer new insights in terms of value creation and value capturing. When the two dimensions get together in innovative ways, the open innovator may even change the underlying business model that was leveraged. Moreover, these changes may offer the possibility to expand in new markets (Pellizzoni et al. 2019), which were not foreseen before the OI adoption. Finally, OI gives the innovator the chance to be exposed to several external stimuli. This includes exposure to new trends and technological opportunities that may incrementally improve the company's products (Trabucchi et al. 2018; Del Vecchio et al. 2018).

3.1.2 Strengthen the Market Position

The possibility to rely on new, fresh external ideas can open opportunities that would not be unveiled through a traditional—closed—innovation approach. By relying on OI approach, companies can strengthen their position in today's market by improving their ability to read what the market is looking for, and listening to new sources of ideas (e.g., van de Vrande et al. 2009; Dell'Era et al. 2018). For example, companies relying on an OI approach can see new opportunities and paths that were previously unidentifiable, this can open the chance to develop innovations with strategic partners by strengthening networks and improving the firm's position on the market (West et al. 2014; Zobel 2017).

Also, empirical research has shown that an open philosophy can help companies lay the foundations for open standards that can be deepened by the market, but that puts the innovator in a stronger position in the market (Llanes 2019). These three sub-goals show how OI offers the opportunity to redefine the company position within the competitive landscape.

In the end, the possibility to communicate to the market initiatives and programs that require external involvement in innovation initiative can reveal a final objective that aims to improve the market position and perception: to communicate innovation activities (e.g., van de Vrande et al. 2009). In this case, an OI approach increases the chances of being perceived as an innovative company during the whole innovation process and not only with the commercialization of (successful) innovations.

3.1.3 Enhance the Innovation Process

Chesbrough, through his seminal work, has challenged the traditional funnel of innovation by eliminating the boundaries of companies. Indeed, the first main goal of OI in the empirical literature is still to enhance the innovation process. Researchers show how OI improves the stages of idea generation by providing access to external knowledge which ultimately leads to a more efficient innovation process (e.g., Chesbrough and Crowther 2006; Enkel et al. 2009; Pellizzoni et al. 2019). This means that OI allows the increase of several KPIs of the innovation process, such as the innovativeness or the number of ideas evaluated.

The possibility of relying on externally generated ideas can reduce costs in the early stages of the innovation process. Also, this can lead to a faster innovation process, as one step is substantially outsourced. Some companies consider the OI philosophy to optimize innovation investments, reduce the risk, or maximize the return on the investments. An OI approach allows companies to make specific investments on external innovations (e.g., start-ups) by building an innovation portfolio that may minimize the overall risk. Finally, regarding the impacts on the innovation processes, OI can increase its overall efficiency by giving a new path to those ideas that otherwise would not reach the end of the funnel (e.g., Bianchi et al. 2011).

In particular, through an OI approach to innovations, companies can consider the possibility to profit from Intellectual Property that has been developed internally but is not exploited within the company's boundaries (Holgersson et al. 2018). Finally, open innovators may have another way to improve their innovation process, based on an open approach. Researchers have shown how OI practices might help companies attract talents that can have a significant impact on the company's overall performance (e.g., Mortara and Minshall 2011; Usai et al. 2018).

The three goals show the broad flexibility of OI in terms of strategic goals. OI may be used to explore where future innovation projects may go, even identifying new directions of where to foster innovation. At the same time, OI can help companies exploit the resources, the projects within the innovation funnel, and the activities in place to make the innovation process more efficient and effective. For R&D Professionals, this shows how OI can be used in very different situations to reach completely different outcomes. The next section will focus on how OI can help in achieving such diverse goals.

3.2 Open Innovation Practices

The brief overview of OI above shows the relevance of the issue for both academics and professionals. It also illustrates how the paradigm is divided into two sub-clusters. These are the Inbound and the Outbound Open Innovation. These two methods to embrace OI are characterized by differences in the adoption of the paradigm by companies, and they influence the practices. A closer analysis of the paradigm reveals a first duality: inbound strategies are related to value creation (search for new ideas and opportunities). In contrast, outbound strategies are mainly linked to value capture (e.g., profit from an innovative project through licensing or search for new markets). Still, when it comes to the implementation of the Open Innovation paradigm, companies use different mechanisms to be successful. Therefore, we are going to provide a synthesis of the most relevant OI practices, emerging from previous research.

3.2.1 Inbound OI Practices

Regarding inbound OI practices, what emerges from the analysis of the papers is that there is significant heterogeneity among them. Some refer to initiatives that companies can put in place to attract and recognize powerful new ideas. Conversely, others contemplate the possibility of collaborating with other players, other firms in fostering joint innovations. Starting with Business Accelerators (e.g., Pauwels et al. 2016; Mian et al. 2016; Hausberg and Korreck 2020), they show the ability of companies to support environment for start-ups and fledgling companies to whom established firms offer intensive coaching/education program, consisting of business advice and product advice. This accelerator is not only dedicated to internal ideas but is more inclined to incubate ideas that are interesting for the company but come from outside. Similarly, the Corporate Venture Capital (Basu et al. 2011; Wadhwa et al. 2016; Gutmann 2019) is the practice where a large company takes shares in a small but innovative private entrepreneurial company.

Scholars refer to crowdsourcing (e.g., Bogers et al. 2010; Foss et al. 2011; Afuah and Tucci 2012; Mazzola et al. 2018; Ghezzi et al. 2018; Elia et al. 2020) as a practice for seeking help from a crowd to solve innovative challenges, and not specific organizational tasks. This attitude helps firms in attracting ideas from the outside and implementing a mechanism of inbound OI. Similarly, the Outside-in Programs (e.g., Piller and Walcher 2006; Mortara et al. 2013) leverage the same assumption: external people can help you in solving problems, but with the notable difference that the problem is not always set ex-ante. So, this practice consists of those initiatives related to open innovation challenges, competitions, hackathons, and tournaments. If in crowdsourcing, the focus is on problems to solve, their programs are more used to call for ideas. Finally, the Open Source (West 2003; Henkel 2006; Dong et al. 2019) is the practice based on allowing users to co-develop on or through a digital product. This can be seen as an inbound OI practice because by collaborating with others, it is possible to collect new ideas and access new solutions proposed by other actors.

The second group of practices refers to the possibility for a company to collaborate with other firms to promote innovation. The first practice that emerges from the analysis in this group is the Coopetition or horizontal alliance (Cassiman and Valentini 2009; Bouncken et al. 2015; Holgersson et al. 2018). It refers to a strategy involving both competition and cooperation. While the term is relatively new, the fact that firms cooperate and compete is widely recognized in the literature. The practice is to enter into an inter-organizational R&D agreement with a company competing in the same market to access complementary knowledge and to exploit synergistic effects aiming at reaching a higher level of innovation. In addition to this company, it can also create alliances.

This is the essential element that brought to the identification of Cross-industry Alliances (Chesbrough and Schwartz 2007; Enkel and Gassmann 2010; Garcia Martinez et al. 2017) as another powerful practice to implement inbound OI. It consists of creating partnerships and alliances between two or more parties that belong to different industries. They are an increasingly effective means of innovating and improving innovation performances, such as cost, time to market, and risk. Unlike these alliances, the Joint Research Alliances (e.g., Rothaermel and Deeds 2004; Callaert et al. 2015; Battaglia et al. 2017) consider in the partnership and collaboration also the universities and other research institutions that can collaborate through interorganizational arrangements to work on research and development activities. If the alliance to foster innovation is set with suppliers, the literature refers to Vertical Alliance practice (Kazemargi et al. 2016; Parker et al. 2016; Dong and Netten 2017). It is widely acknowledged that suppliers are an essential source for product innovations, enabling improvements to product quality and leading to reduced innovation cycle time and lower cost.

Moreover, if the alliance is strong, it could lead to the creation of a different business entity. This is the practice that usually is defined by scholars and practitioners as Joint Venture (Dittrich and Duysters 2007; Zheng et al. 2018; Chesbrough and Brunswicker 2013). Not all the joint ventures are OI, but an inbound OI approach can foster the creation of joint ventures. Finally, the Merger and Acquisitions (Mawson and Brown 2017; Cammarano et al. 2017), as the consolidation of companies, consists of a combination of two companies to form a new one or a purchase of one company by another one. As mentioned above for the joint venture, this practice can be adopted as an open innovation practice in the sense that firms are interested in acquiring innovative start-ups to increase their level of innovativeness.

3.2.2 Outbound OI Practices

Looking at the outbound practices is clear that under this cluster are grouped all the practices and initiatives that allowed the company to channel its innovations to the external market. In particular, the first one that is widely reported in academic research refers to Corporate Incubators (Becker and Gassman 2006; Hausberg and Korreck 2020). These are specialized corporate units that provide the entrepreneurial team with a start-up like environment (e.g., funding, co-location, expertise, and contacts). In this unit, promising internal ideas or technologies that are not always aligned with the holding company's core business can be developed and brought to the market. When the idea has matured enough to address the market, the major company can decide how to launch the solution. Scholars have defined Intellectual Property as out-licensing (e.g., Bianchi et al. 2011; Holgersson et al. 2018) another outbound practice. By licensing the idea and allowing other players to leverage on it, the company supports the channelling of innovation into the end market, which would not be adequately exploited within the company. Finally, the third emerging practice is the Platform Programs (Gawer and Cusumano 2014; Weiblen and Chesbrough 2015; Parker et al. 2016). This practice deals with the creation of a platform connecting other players and allowing others to develop new solutions on it, working as an innovation platform (Cusumano et al. 2019), working as a two or a multi-sided platform (Trabucchi and Buganza 2020). To these are added, the Spin-offs mentioned initially by Chesbrough as the typical example of an outbound approach and later furthered studied (e.g., Van Geenhuizen and Soetanto 2013; Venturini and Verbano 2017). In other words, the company that promotes innovation creates and organizes an ad hoc company to evolve the innovation project and bring it to the market.

As for the Strategic Goals, even OI practices can be mapped on an axis that moves from exploration to exploitation (Fig. 2). Both in the case of inbound and outbound practices, some cases help companies in exploring the innovation domain (e.g., through various shapes of incubators or accelerators, or crowdsourcing activities) as well as to exploit innovation activities (for example through alliances or out-licensing). Again, this underlines the high flexibility of the OI paradigm, teaching R&D Professionals the vast array of ways in which they may implement OI.

4 The Framework

In this section, we propose a comprehensive framework matching OI goals and practices. In particular, we show OI illustrative examples that can inspire R&D Professionals on the way they can orchestrate different practices for reaching different Strategic Goals. We show evidence of how other companies in various sectors leveraged different OI practices—either Inbound or Outbound—for achieving different goals. Doing so, we can share with practitioners what kind of practices

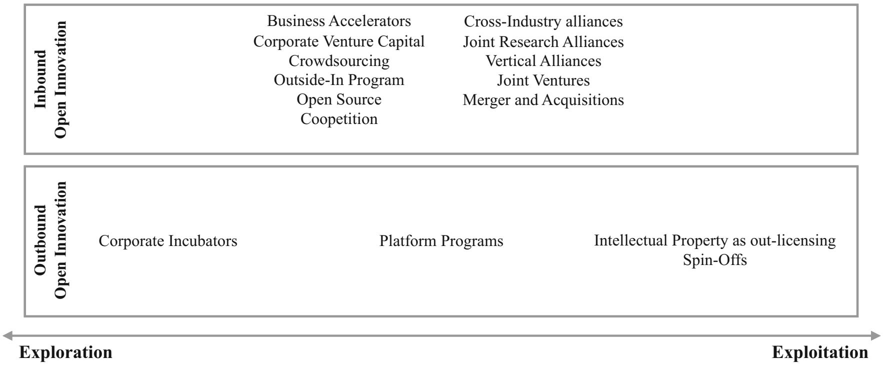

Fig. 2 Open Innovation practices

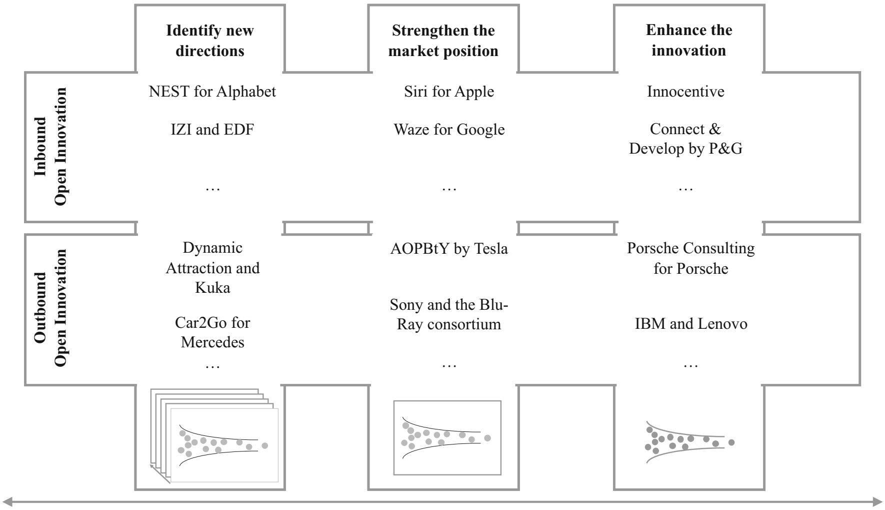

Fig. 3 Summary of the examples

they would need if the goal is to identify new directions, strengthen the market position, or enhance the innovation process.

The two models previously introduced, showing how both the goals and the practices may be mapped in the space between "Exploration" and "Exploitation" (March 1991) offer the chance to sum them. OI provides a wide array of possible matches between goals and practices moving through exploration and exploitation of competence, resources, and people within and outside the firm. In the remainder of the chapter, we are not going to map the practices directly on the goals—even if the Fig. 3 might suggest which of them tends toward exploitation or exploration. Indeed, practices are flexible enough to be used for different purposes, as we will show with the following illustrative examples. Still, even if it is not prescriptive, the framework may help R&D professionals in finding their way through the OI paradigm.

4.1 Inbound: Identify New Directions

Inbound open innovation is an approach that, despite the two previous goals, can also help companies identify new directions. By collaborating with other companies through joint ventures or different types of alliances, companies can ring new skills and know-how that previously resided outside the company into their innovation process (Laursen and Salter 2006). This introduction of new knowledge will increase companies' ability to spot new directions of the new area of business that might prove relevant for future development of the company itself.

Alphabet Inc. shows how the strategic decision to acquire a business entity as NEST helped them in identifying new directions. Indeed, as a software company rooted in providing algorithms and software solutions, such as search engine and mail service, NEST's acquisition in 2014 allowed them to see potential in-home automation and control. In a different industry, i.e., utilities, *EDF*, the French market leader in 2019, acquired IZI, a start-up offering services for home maintenance and small household chores. In particular, the solution provides support not only for energy problems but also for the home environment's needs. This has allowed the utility company to identify new directions for the development of its services.

4.2 Inbound: Strengthen the Market Position

The second strategic goal is to strengthen the market position that companies can pursue by adopting an inbound open innovation paradigm. Companies can absorb knowledge and experiences outside the company's boundaries through Merger and Acquisition (M&A) of start-ups that would bring technological expertise and can support the holding in strengthening its market position. Indeed, through the acquisition of start-ups, companies can enhance their leading position in specific sectors, showing how they are keeping track of innovation and experimentation trends (Piller and Walcher 2006).

Turning to exemplar cases, Apple's 2010 acquisition of the Siri start-up is one of them. In fact, with the acquisition of this start-up that introduced the virtual personal assistant as an independent solution within the apple store, Apple was able to strengthen its position as a market leader in the smartphone industry. The turning point in the inbound strategy came in 2012 when they introduced Siri as a feature inside the new iOS system as one of the first players to do so in the consumer electronics market.

Another compelling case in this direction is the acquisition of Waze, the GPS solutions start-up launched into in 2008, and later acquired by *Google* Inc. Indeed, when Google acquired it through an M&A process in 2013, the application counted more than 20 million active users, and this allowed Google to strengthen the market position by showing to the market that the GPS world was under its control with Google Maps and Waze.

4.3 Inbound: Enhance the Innovation Process

Inbound open innovation is a useful approach to achieve the strategic goal of improving the innovation process. Indeed, by leveraging various inbound practices such as crowdsourcing or in-licensing, companies can absorb technologies and innovations from outside and channel them in their internal processes (Chesbrough and Crowther 2006). This allows them to enhance the innovation process, the support coming from outside is useful to stimulate and support the innovation phases and thus to solve typical problems such as lack of knowledge.

A world-famous case in this direction is the *Procter & Gamble* initiative to transform the Research and Development initiative in Connect and Develop. In fact, by creating the Connect and Develop online platform, the multinational company was able to enhance the innovation process by leveraging the crowdsourcing of ideas for future products and solutions. Likewise, another compelling case that shows how companies can leverage inbound practices to enhance the innovation process is the usage by *Enel*, a utility company, of a crowdsourcing platform like Innocentive. In 2018, Enel began to intensify its collaboration with Innocentive to receive support and set the stage for identifying the solution to 50 technological challenges to achieve the UN's strategic sustainable development goals.

4.4 Outbound: Identify New Directions

Finally, outbound open innovation can help companies achieve their strategic goal of identifying new directions. They can do this by leveraging business incubators or by creating a platform program (Trabucchi and Buganza 2020). In this way, they can propose completely new visions and directions to the market. This can be done by supporting them in envisioning new opportunities and launching products and services on the market that otherwise they would not have been able to manage and control under the same brand of the parent company.

Kuka, the robot company that collaborated with Dynamic Attraction in 2001 to create the RoboCoaster concept, is a vivid example of how outbound open innovation can help companies identify new directions. The expansion of the German robot company to amusement parks, with the RoboCoaster concept, is a clear example of how through a joint venture, the company was able to address a new market with a completely new direction and meaning. A second compelling case is *Car2Go*. Created in 2008 as a Daimler Group spin-off, the start-up was launched to introduce the concept of car sharing in the automotive market. Daimler, the holding company that controls car manufacturers like Mercedes and Smart, was able to identify a new opportunity that is car-sharing thanks to this outbound approach. In doing so, the company identified a new direction of growth that brought them in the world of services, leveraging the sharing economy phenomenon.

4.5 Outbound: Strengthen the Market Position

The second strategic goal is to strengthen the market position that companies can also pursue by adopting an outbound open innovation paradigm. Firms can achieve this strategic goal by leveraging outbound practices like IP out-licensing (Gassmann and Enkel 2004). Companies can show to other players that they can set a standard and identify a novel technology that others may acquire from them. In this way, out-licensing can strengthen its market position.

In 2014, Tesla was able to strengthen its market position as an innovator leader in the technology industry by opening its patent portfolio to out-licensing. In particular, under the motto "*All Our Patent Are Belong to You*," Elon Musk, CEO of the company, was able to strengthen its market position by leveraging the outbound open innovation approach. The second example in this approach is the *Sony* experience with the creation of the Blu-ray disc technology standard. Indeed, by introducing as first this technology, they were able to set the industry standard after the DVD. The outbound approach has been instrumental in strengthening Sony's market position as a leader in entertainment support marketing.

4.6 Outbound: Enhance the Innovation Process

Outbound open innovation is an approach that can support companies in achieving the strategic goal of improving the innovation process. Companies can better channel their innovation investments into creating more market opportunities by leveraging various outbound practices such as corporate incubation or IP out-licensing (Gassmann and Enkel 2004). Indeed, by leveraging these approaches toward outbound open innovation, companies may be able to enhance the innovation process while being confident that no investment will be lost.

One of the most compelling cases of outbound open innovation that has enabled a company to enhance the innovation process is *Porsche* with its consulting service. Indeed, *Porsche* Consulting is a spin-off of the automotive company that was spun off to test the knowledge of other companies and manufacturers and that would have allowed the consulting firm to grow. In fact, by interacting not solely internally, at the Porsche manufacturing plant, the consultants were also able to increase their know-how. *IBM*, which sold its computing division to Lenovo in 2004 to increase internal efficiency and reduce innovation cost in noncore products, is an excellent example of an outbound strategy to enhance the innovation process. In fact, by selling the division, IBM was able to refocus the company on the core vision regarding innovation, computing power, and computing capability.

These illustrative examples (summarized in Fig. 3) show how OI practices may fit different strategic goals. More interestingly, it shows how both inbound and outbound practices may meet the three strategic goals that emerged from the literature analysis.

In other words, these examples are showing how OI may be a very flexible and comprehensive framework. R&D Professionals may leverage the framework through a three steps approach:

Identifying the strategic goal: It is essential to understand the strategic goal in approaching open innovation.

Identifying the value flow: Professionals should understand if expected benefits in approaching OI are related to value creation dynamics (inbound practices) or value capturing dynamics (outbound practices).

Picking the OI practice: Finally, the list of practices may help professionals in identifying the OI practice that better fits their needs.

These three steps may help professionals to approach the wide and complex world of Open Innovation, with a framework that may help them identify the OI nuances that better fit what they are looking for. From a theoretical perspective, this framework, emerging from the literature and the examples used to support it, seems to suggest that both inbound and outbound practices can be suitable for the three strategic goals. This shows the high flexibility of the OI approach, which showed its wide range of applications and purposes over the years. Nevertheless, this study offers a comprehensive view of practices and goals that may help researchers dug in the link between the specific practices and the various goals.

5 Conclusions

Almost 20 years ago, Henry Chesbrough challenged common innovation belief: innovation is not just in R&D offices; but can be everywhere, inside and outside companies (Chesbrough 2003). Years later, we are faced with one of the most successful and sophisticated paradigms in history. Recent contributions aim to highlight the significant peculiarities that OI can have in given contexts, such as in the field of digital technologies (Enkel et al. 2020) or the impact an OI mindset can play on innovation policies (Bogers et al. 2018). In this complex landscape, this chapter is aimed at providing a concise but comprehensive summary of what happened in recent years regarding the emergence of different OI practices. Indeed, Open Innovation is not only a demand for ideas or "openness" of the innovation process; open innovation is not only a label that more and more companies use every day. Open Innovation has become a complex set of practices for achieving different goals.

This chapter proposes a framework that combines the matching of OI goals and practices in the span between exploration and exploitation. Moreover, by also adding to the framework, real cases of companies that adopted the practices for achieving specific goals shed light on how companies can use the framework to make more conscious choices regarding the OI strategy. Thus, this chapter supports managers and R&D professionals in entering the Open Innovation discourse and finding an answer to two possible questions. First, how can managers implement Open Innovation? This question finds its solution in the list of the different 15 Open Innovation practices—divided into two Inbound and Outbound, respectively, 11 and 4 practices identified. Secondly, why should managers use Open Innovation? This question finds its answer in the three strategic goals which emerge from the analysis of the literature: (i) identifying new directions; (ii) strengthening the market position; and (iii) improving the innovation process.

Finally, we show how practices and goals can be combined in a comprehensive framework, showing that Open Innovation is less complicated than it might seem from outside. So, this framework can help managers assess if the practice they are experimenting with is aligned with the company's strategic goal. What also emerges from the framework is the fact that the Inbound and Outbound are not alternative but can be combined to achieve a common strategic goal. Further research might quantitatively test the relevance and impact of the different practices on strategic goals. Indeed, it is evident how OI's field is still eager for more research and evidence as it is highlighted by the massive amount of publication already available.

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The Collaboration Paradox: Why Small Firms Fail to Collaborate for Innovation

Temitope Akinremi and Stephen Roper

1 Introduction

Recent research on firm growth and productivity has highlighted the importance of innovation in creating competitive advantage and increasing productivity. Studies have shown that the development of new technological combinations and knowledge capabilities often leads to improved product quality, reduced time-to-market, and cost reductions. An increasing disparity in productivity between frontier firms and non-frontier firms (OECD 2015), has also led to calls for a shift in the manner in which firms engage in and commercialise innovation, with an increasing emphasis on strategies that promote innovation-focused collaboration with external firms (Chesbrough 2003; West et al. 2014). This innovation model that encourages businesses to collaborate with external firms to bring about the development of new products, processes, markets, and business re-engineering emerged from the Open Innovation (OI) paradigm pioneered by Henry Chesbrough in 2003.

The burgeoning literature on innovation strategies based on collaboration highlights the role of a firm's internal and external knowledge base in deriving the complementarities necessary for generating competitive advantage from the collaboration relationship (Fey and Birkinshaw 2005). A firm with limited internal absorptive capacity and resources may find it difficult to actively innovate to bring about growth, expansion, and diversification. This lack of internal capabilities is most common in smaller firms, compared to their larger counterparts that tend to have the resources, managerial competence, and capacity to engage and derive benefits from innovation. Due to internal and external structural drawbacks, SMEs (Small and Medium Enterprises) are often impaired by resource and managerial capacity constraints, causing such firms to avoid substantial strategic innovation portfolios and

T. Akinremi (✉) · S. Roper
University of Warwick, Coventry, UK
e-mail: Temitope.Akinremi@wbs.ac.uk; Stephen.Roper@wbs.ac.uk

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instead focus on small-scale innovation initiatives; an effect which can be alleviated by the adoption of an innovation collaboration strategy (Iturrioz et al. 2015; Van de Vrande et al. 2009; Laursen and Salter 2014). The rationale being that, such innovation-focused collaborations have the potential of providing SMEs with access to external knowledge, technology, skills, innovation infrastructure, and financial resources (Bigliardi and Galati 2016).

However, despite the significant benefits SMEs stand to gain from collaborative innovation relationships, review articles suggest that firms that engage in such relationships and can effectively appropriate complementary benefits of collaboration are often large firms with high absorptive capacity. This defines the collaboration paradox; '*small firms have more to gain from collaboration but may find collaboration more difficult to implement*'.

Described as the lifeline of the modern economy, SMEs play an integral role in the continuous creation of innovative solutions across the globe (Vrgovic et al. 2012). Despite the continuing relevance of SMEs, studies of innovation collaboration and its adoption in the business environment, particularly in the traditional sector, remain at its infancy (Bigliardi and Galati 2016; Hossain 2015) as this group of firms has only until recently been included in mainstream innovation collaboration discussion. Also, earlier research on SMEs indicates that compared to larger firms, SMEs are often not favourably positioned to access external resources and tend to have fewer technological assets that can be exchanged in innovation collaborations (Xiaobao et al. 2013). Regardless of these limitations, the literature indicates that innovation in SMEs has an external focus and such firms engage in alliances or networks, which are often entrenched in their social and personal ties for developing and extending their technological competencies (Brunswicker and Vanhaverbeke 2015).

Numerous studies have explored collaborative innovation in specific industry sectors (van de Vrande et al. 2009; Lichtenthaler and Ernst 2009; Bigliardi and Galati 2018). These studies suggest that industry characteristics and sectoral structure may act as determining factors for the availability of potential innovation partners and the successful implementation of collaboration. Furthermore, firm-level studies identify the effect of firm size on SMEs' adoption of innovation collaboration. Compared to large firms, smallness in SMEs does have its advantages. As such, scholars have argued that being small may mean that SMEs can derive greater benefits from innovation collaboration, as such firms are often less bureaucratic, respond faster to changing business environment, and are more willing to take risks (Hossain 2015). Smallness in SMEs may also mean that such firms are characterised by high innovation risk due to their often small innovation portfolio, lack of capital and restricted access to commercial lending, a reduced likelihood of taking advantage of market opportunities that require a significant financial commitment, and diminished capacity to learn interactively (Bigliardi and Galati 2016; Van de Vrande et al. 2009). These factors may make small firms less dynamic in adopting innovative practices and engaging in collaborative innovation relationships (Saluja 2012). Many of these SME limitations echo resource and capability constraints that typify SMEs and often slow down productivity and competitive gains that firms can derive from innovative strategies. Challenges which studies have shown can be overcome via innovation collaborations (Gassmann et al. 2010).

Furthermore, limitations related to finding the right partner with synergistic capabilities, risk of opportunistic behaviour by collaboration partners, loss of competitive advantage, and the threat of imitation (Enkel et al. 2009; Gassmann et al. 2010; Teirlinck and Spithoven 2013; Verbano et al. 2015) may mean that SMEs are discouraged from adopting a collaborative strategy. Innovation in vertical value chains under pure market conditions can also be impeded by transaction costs, as investment or heavy reliance on a specific technology may be a risky endeavour if the technology is of low value elsewhere or owned by a rent-seeking monopolist (Tomlinson 2010). A collaborative innovation strategy can ameliorate this situation, the success of which is dependent on the nurturing of trust between collaborating firms (Tomlinson 2010; Dyer and Singh 1998; Iturrioz et al. 2015).

Based on earlier works by Kim et al. (2010) on supply chain partnership and Hewitt-Dundas and Roper (2018) on market failures in innovation collaboration, here we explore three specific market failures that may limit the extent of collaborative innovation in SMEs:

- The inability of firms to identify potential benefits that can be derived from collaborative innovation.
- Lack of information for assessing the capability or suitability of a potential partner.
- Difficulty in assessing the trustworthiness of potential partners, which may result in a reluctance to engage in collaborative innovation.

We test the significance of these market failures by adopting a mixed-methods approach to consider how decision makers in two traditional, SME dominated, manufacturing sectors—metal-forming and metal casting—acquire and evaluate knowledge about the trustworthiness, capabilities, and strategic orientation of potential innovation partners. Survey data from firms in both sectors is combined with evidence from semi-structured interviews to highlight the causes of the collaboration paradox.

The remainder of the chapter is structured as follows. The next section discusses informational market failures and their influence on collaborative innovation, our data and methods, and an overview of the case-study sectors. Section 3 presents our findings on the influence of informational market failures in collaborative innovation in SMEs. Finally, Sect. 4 concludes and discusses the findings for the case-study sectors and SMEs in general.

2 Informational *Market Failures and Collaborative Innovation*

Theoretical perspectives indicate that a firm's inclination to innovate and the strategy adopted towards this purpose is strongly influenced by firm-level factors (Brunswicker and Vanhaverbeke 2015; Varis and Littunen 2010; Crowley and McCann 2018), sectoral structure and appropriation regimes (Verbano et al. 2015), and the availability of potential innovation partners (Iturrioz et al. 2015).

While manufacturing is an attractive sector for innovation adoption, SMEs are often faced with difficulties in building absorptive capacity as they rarely engage in formal R&D (Brunswicker and Vanhaverbeke 2015) and tend to be lacking in the resource and managerial capacities necessary to improve their innovation performance via collaborative innovation (Fernández-Esquinas et al. 2017). These weaknesses may mean that smaller firms may be limited in their ability to recognise, assimilate, and apply new external knowledge (Cohen and Levinthal 1990), characteristics essential to collaborative innovation.

Also, for firms to consider a collaborative strategy, knowledge of the existence of a potential partner with the required capabilities and how to assess these capabilities is important to initiate and forge a beneficial alliance (Martín-de Castro 2015). In supply chain collaborations, Kim et al. (2010) suggest there are four developmental stages: (a) identifying the strategic need for the collaboration; (b) assessing and selecting partner(s); (c) implementing the partnership; and (d) reassessing and reshaping the partnership.

The first stage of partnership development as described by Kim et al. (2010) captures a firm's ability to acknowledge the need for collaboration and the costs and benefits to be derived if undertaken. In the context of collaborative innovation, this may be a determining step to the entire process, as it marks the beginning of the collaboration process and the underpinning uncertainties, risks, and challenges associated with the appropriation of the benefits of the innovation process (Åstebro and Michela 2005). For smaller firms, managerial and absorptive capacity constraints may mean that undertaking this assessment may be difficult, making costs and benefits assessment for the collaboration a daunting task. Thus, the consequence of informational market failures related to potential outcomes may lead to firms underestimating or exaggerating the benefits and costs of the collaboration. Literature, however, indicates that firms tend to underestimate the benefits, resulting in underinvestment in collaborative innovation (Hewitt-Dundas and Roper 2018).

The second stage in the collaboration process reflects a firm's ability to assess and select appropriate partners. This stage can prove difficult for firms, as they search for potential partners with innovation objectives that resonate with the firm's own innovation goals alongside capabilities that complement the firm's knowledge base (Dong and Pourmohamadi 2014; Dyer and Singh 1998; Hosseini et al. 2017; Le Ber and Branzei 2010). Difficulty in assessing this type of knowledge, especially where there are geographical challenges or where potential partners are outside a firm's existing network, may lead to firms obtaining incomplete information on potential partners (Berchicci et al. 2016). Firms searching for collaboration partners may also be faced with the dilemma of revealing some of their technical knowledge or expertise to assess knowledge from a potential collaborator (Laursen and Salter 2014). This may be perceived as a risk, especially where this involves revealing information on a product or technological strength, as a competitor can emulate a firm's market advantage. Thus, making such firms adopt secrecy, legal exclusion right, and selective revealing as avenues for innovation knowledge protection (Henkel et al. 2014). Situations, where information on the capabilities of potential partners is limited or asymmetric, defines a second market failure. This informational limitation can be detrimental to the whole collaboration process as firms are unable to find appropriate partners or end up with inappropriate partners (Le Ber and Branzei 2010).

The third stage in the collaborative development process relates to the implementation of the partnership. In implementing collaborative innovation, there has to be some level of trust between collaborators. How much knowledge a firm is comfortable to allow outside its boundary to a potential collaborator is dependent on the level of trust in the potential partnership. This further determines the mode of governance and the implementation of the collaboration (Hewitt-Dundas and Roper 2018). Trust in inter-firm collaborations relates to the confidence that a collaborator will not perform irrationally to the detriment of the collaborating firms and relationship, but rather, that actions performed are aimed at beneficial outcomes and the fulfilment of obligations of the relationship (Madhok 2006; Thorelli 1986). Existing literature emphasises the importance of trust in the creation and continuation of a collaboration (Aulakh et al. 1996; Iturrioz et al. 2015; Madhok 2006). Discussions on firm-level social capital emphasises the relational and structural dimension of social capital which identifies collaborative connections between firms and the development of trust between potential knowledge exchange partners (Galati and Bigliardi 2019). Adding on the cognitive dimension, Iturrioz et al. (2015) draw attention to the social nature of innovation and the position of the firm concerning a set of agents in the collaborative relationship with shared beliefs and goals. The inflow and outflow of knowledge across firm boundaries to accelerate internal innovation requires constructive interactions between partners to foster a beneficial relationship where there is mutual trust, leading to increased efficiency of action and knowledge diffusion. This relational dimension highlights the place of trust amongst others in the development of social structures and a collaborative innovation strategy (Galati and Bigliardi 2019; Tomlinson 2010). This implies that in collaborative innovation, a firm has to have some level of trust that forms the baseline for fostering an alliance relationship with a potential partner. Instances, where information on the trustworthiness of a potential partner is unavailable or inadequate at the onset of collaboration, may result in such alliances not taking place.

Based on the preceding, we investigate the barriers that prevent or restrict the formulation of collaborative innovation in SMEs, concentrating on two UK traditional sectors—foundries and metal forming. We focus on informational market failures in the adoption of collaborative innovation in these case-study sectors using a mixed-methods approach.

2.1 Research Methodology

A mixed-method approach was adopted in this study to understand the influence of informational market failures on collaborative innovation in the two SME case-study sectors. Our methodology was intended to qualitatively interview and quantitatively survey firms in the industry sectors on informational market failures. Fieldwork was conducted in partnership with two UK trade associations for the case-study sectors; the CBM (Confederation of British Metal-Forming) and the CMF (Cast Metals Federation).

Our methodology was a two-phase design that combined both qualitative and quantitative methods (Bryman 2016; Creswell and Creswell 2017). It begins with qualitatively collected data as the first stage of an exploratory sequential (QUAL/QUAN) mixed-methods analysis. The method is particularly beneficial for evaluating management concepts by allowing the clarification of results from the mono-methods. This forms a basis for more robust and generalisable outcomes with the potential of informing policy design (Tashakkori and Teddlie 1998). However, the method is time-consuming, and extra care is required to ascertain the validity and reliability of developed constructs. To overcome these shortcomings, the data collection for the mono-methods was separated into two phases over twelve months, and a case-study protocol was designed before data collection (Yin 2003).

In this mixed-method typology, the qualitative component is an initial exploration stage aimed at identifying variables, constructs, and taxonomies for quantitative study (Creswell and Plano Clark 2011; Tashakkori and Teddlie 1998). Thus, the interview questions were designed to provide a rich and holistic insight into collaborative innovation practices in the case-study sectors and the barriers to its adoption.

Employing a purposive sampling strategy, twenty-five semi-structured interviews were conducted across both case-study sectors, including suppliers (Creswell 1998) for three months (May to July 2018). Purposive sampling strategy though characterised by small sample size, engages respondents based on their in-depth knowledge of the topic, or being in a position of authority to provide answers and insight to the study (Guest et al. 2006). Firms registered as members of the CBM and CMF were sent participation requests via email and associations' monthly newsletter. Interested firms were contacted, and interviews scheduled. Interviewed firms varied in size, age, and revenue (see Table 1). Thus, our interview sample was skewed towards small and medium firms. The inclusion of large firms and suppliers was to provide a comprehensive overview of collaborative innovation practice and its perception across the case-study sectors. The interviewees were experienced business owners, senior executives/managers working across innovation, market expansion, and process and product development focused roles. The interviews were designed to understand common themes and trends regarding industry perception of collaborative innovation, the motivation and barriers to innovation and collaborative innovation and particularly; how a lack of knowledge on the benefits of a potential innovation partnership, capabilities of potential partners and trustworthiness influence a firm's decision to innovate collaboratively.

Table 1 List of interviewed companies

Interviewee	Position	Sector	Size of Firm	Revenue	Age of firm
1F	R&D Manager	Foundry	Large	> £nine million	> 40 years
2F	Chief Executive Officer	Foundry	Large	> £nine million	> 40 years
3MF	Managing Director	Metal-Forming	Large	> £nine million	> 40 years
4F	R&D Manager	Foundry	Medium-Sized	> £nine million	21–40 years
5MF	Managing Director	Metal-Forming	Small-Sized	£one–£nine million	> 40 years
6F	Technical Manager	Foundry	Medium-Sized	> £nine million	> 40 years
7MF	Managing Director	Metal-Forming	Small-Sized	£one–£nine million	> 40 years
8F	Operations Manager	Foundry	Small-Sized	£one–£nine million	21–40 years
9MF	Operations Manager	Metal-Forming	Large	>£nine million	< 20 years
10MF	Commercial Director	Metal-Forming	Medium-Sized	£one–£nine million	21–40 years
11S	Managing Director	Supplier	Small-Sized	>£nine million	21–40 years
12MF	Executive Director	Metal-Forming	Small-Sized	£one–£nine million	21–40 years
13F	Managing Director	Foundry	Medium-Sized	£one–£nine million	> 40 years
14MF	Executive Director	Metal-Forming	Medium-Sized	>£nine million	21–40 years
15F	Financial Controller	Foundry	Medium-Sized	>£nine million	21–40 years
16MF	Managing Director	Metal-Forming	Medium-Sized	>£nine million	> 40 years
17F	Managing Director	Foundry	Medium-Sized	£one–£nine million	21–40 years
18F	Business Development Manager	Foundry	Medium-Sized	>£nine million	>40 years
19S	Group Technical Director	Supplier	Small-Sized	>£nine million	<20 years
20S	Business Development Manager	Supplier	Small-Sized	£one–£nine million	21–40 years
21F	Managing Director	Foundry	Small-Sized	£one–£nine million	> 40 years
22F	Managing Director	Foundry	Medium-Sized	£one–£nine million	> 40 years

(continued)

Table 1 (continued)

Interviewee	Position	Sector	Size of Firm	Revenue	Age of firm
23F	Site Manager	Foundry	Medium-Sized	£one–£nine million	> 40 years
24S	Operations Manager	Supplier	Medium-Sized	£one–£nine million	> 40 years
25F	Operations Director	Foundry	Large	>£nine million	> 40 years

The interview analysis was guided by Nowell et al. (2017) and Thomas's (2006) framework for thematic analysis. Thematic analysis allows the development of themes from qualitative data through pattern identification (Braun and Clarke 2006). It is a flexible analytical method with the advantage of communicating data in an easy to understand manner. Despite the advantages of thematic analysis, the methodology may suffer from limitations related to sampling and projection (Boyatzis 1998). To overcome the sampling challenge, the unit of analysis in this study (case-study industry sectors) was clearly defined and demarcated from the unit of coding and other recommendations by Boyatzis (1998) were closely adhered to by; using definitive codes to represent respondent's statements and impressions and constantly reviewing the collected data all through the theme and code development process.

Data collection and analysis were done concurrently. All interviews were transcribed verbatim before analysis. Using an iterative process, a coding template was created from literature and the research objectives before the detailed evaluation of the transcript (King 2012). These 'priori' codes served as the first set of codes before coding from the data, and these evolved all through the transcript analysis, as codes were added on or disregarded if proven unuseful. Using the NVivo software, the interview transcripts were coded into nodes. More codes were added to the codebook as the text was examined in detail.

Based on emerging themes from the interviews, we surveyed firms across both industry sectors. In designing the questionnaire for the survey, the research objectives of the study were revisited, in association with a comprehensive literature search. This was necessary to ensure internal validity. Internal validity is the ability of a questionnaire instrument to measure what it is intended to measure (Saunders et al. 2012). Alongside questions adopted from collaboration literature, survey questions were developed explicitly from analysed interview themes on collaborative innovation in the industry sectors, motivations for adoption, barriers to adoption, and the influence of lack of information on potential partner's capabilities and trustworthiness on the decision to collaborate.

Data collection was undertaken between May and July 2019. This followed a short interview format that lasted for 10–15 min. The questionnaire design reflected the desire to maintain some comparability with data from earlier industry surveys and external benchmarks, particularly the Microbusiness Survey and the

Table 2 Population and survey response

	0 to 9	10 to 49	50 to 249	Total
Foundry population (local units)				
Total foundry sector (SIC07:2451, 2452, 2453, 2454)	225	120	60	405
Survey response for foundry sector	33	27	15	75
Metal-forming population (local units)				
Forging, pressing, stamping, and roll-forming (SIC07:2550)	330	180	55	565
Survey response for metal-forming sector	64	20	11	95

Longitudinal Small Business Survey. One hundred and seventy usable responses were obtained covering 95 Metal-Forming SME firms and 75 SME Foundries across the United Kingdom. Table 2 shows the allocation of surveyed firms into sectors based on their primary activity.

Data from the Office of National Statistics suggest that in 2018 there were 405 foundries and 565 metal-forming firms in the United Kingdom with employees in SIC 2007 categories 2451, 2452, 2453, 2454, and 2550 (Table 2). The size-bands were primarily restricted to SMEs, firms with no more than 249 employees.

2.2 *The Case-Study Sectors*

The UK metal-casting (foundry) and metal-forming sectors are two SME dominated sectors making major contributions to the UK economy. These industry sectors play a prominent role in UK manufacturing and global supply chains, providing high-quality metal products to the nuclear, automotive, aerospace, food, and various other manufacturing industry sectors (Khan et al. 2017). The metal-casting sector includes over 400 businesses (Khan et al. 2017; ONS 2019) with 80% employing less than 250 employees (Holtzer et al. 2012). The industry sector has an estimated annual revenue of $1.9BN and employs about 16,000 people (Statista 2020).

The manufacturing process in the foundry industry is characterised by six stages; melting, alloying, moulding, pouring, solidification, and finishing. Thus, in a typical foundry, molten metal solidifies in a shaped mould to yield the desired product (Khan et al. 2017; Salonitis et al. 2016).

Despite the foundry sector making significant progress in its use of production technologies such as; simulation software, binder formulations, alloy development, and high technology production machines (Thollander et al. 2013), it still contends with energy efficiency issues, quality monitoring and assurance as well as issues with knowledge creation and management (Roshan et al. 2014). Thus, the business of profitably managing a foundry, evidenced by long-term growth remains a tough and challenging endeavour in this period (Swartzlander 2012) and the fair share of closures the sector has experienced in the last few decades demonstrates this.

The UK metal-forming sector comprises of more than 500 firms producing about 1.3 million tonnes of metal fasteners, pressings, and forgings annually, to meet the UK market demand and exports (ONS 2019). Typically, metal-forming operations are governed by the use of tensile strength and involve the deformation of sheet or tube metals by external compressive forces or stresses (Ward 2015; Yang 2018).

In recent times, the metal forming industry has become competitive (Galdos et al. 2017) with an increasing need for specialised products using new metals and alloys. This has led to a growing need for the optimisation of already established metal forming processes for the making of high-value metal products that can compete with products made from less expensive metals and polymer materials (Misiolek 2017). Furthermore, due to process complexities, technical challenges ensue with increasing customer demand for high-precision products on the one hand and the rising need for firms to improve efficiency while reducing cost on the other (Galdos et al. 2017; Chen et al. 2018). Further iterating the need for innovation to promote industrial performance measures (Neugebauer et al. 2011).

The need for innovative practices in the foundry and metal casting sectors has been highlighted in various studies (Thollander et al. 2013; Trianni et al. 2013). The expectation would be that collaborations would be harnessed to compensate for capabilities, financial resources, and knowledge that may be lacking in achieving productivity and performance-enhancing innovative solutions (Chesbrough and Crowther 2006; Van de Vrande et al. 2009).

3 Findings

Focusing on informational market failures in SMEs, we anticipate that firms may not engage in collaborative innovation due to incomplete information or difficulty in assessing information on the benefits of collaborative innovation. We examined this market failure by exploring industry perception of innovation and collaborative innovation.

3.1 Ability of Firms to Identify the Benefits of Collaborative Innovation

Interview discussions and survey responses confirmed the importance of innovation and its benefit in the case-study sectors. Generally, firms were aware of the benefits of innovation. All respondents confirmed that they had, at some point engaged in innovative practices while a number indicated that they were continually innovating, as this was the backbone of their continued existence.

> 'Innovation! It is the only reason we are here. . .' (Participant 21F).

While there was a common consensus on the importance of innovation across the sectors, weighted survey responses indicated that less than half of SME firms in the case-study sectors engaged in innovation activities in the last 3 years (2016–2019). A large proportion of SMEs in the foundry sector—some 58.9 per cent—did not introduce new products or services in the last 3 years. Similarly, in the metal-forming sector, only 37.5 per cent of SMEs introduced new products or services in the previous 3 years.

Respondents identified several motivations for undertaking innovation. Remaining competitive and product quality improvements emerged as the most common motives for innovation across both industry sectors with—88.9 per cent and 86.3 per cent of foundry firms and 76 per cent and 69.2 per cent of metal-forming firms, respectively, specifying them as important motivations for innovation (Fig. 1).

> 'Without innovation, you can't compete on price, as it were, so you've got to compete in different ways, through technology and offering something different.' (Participant 18F).

Apart from these factors, meeting customer demand and Health and Safety (H&S) improvements also emerged as important motivations for innovation.

> '. . .we have a small team, and our R&D is just in-house. We have quite a number of clever people here, so we make up the R&D team.' (Participant 23F)

Interview responses suggest that firms in the case-study sectors engage in various innovation practices with in-house R&D being the most widely adopted practice. Across the case-study sectors, more than two-thirds of SME firms participated in in-house innovation activities in the last 3 years (2016 to 2019). In the foundry sector, 33 per cent of firms collaborated with external partners for innovation, while 67 per cent of firms conducted their innovation in-house (see Fig. 2). Similarly, in the metal-forming sector, only 28 per cent of firms engaged in innovation collaboration with 72 per cent remaining non-collaborators.

Probing further into collaborative innovation as a strategy for assessing external knowledge and expertise, survey and interview responses confirmed a range of collaboration types, with firm–supplier and firm–customer collaborations emerging as the most common collaboration type in the industry sectors (see Fig. 3). Twenty per cent of SME foundries in the sector collaborated with suppliers while 17 per cent engaged with customers. In the metal-forming sector, firm–customer collaboration emerged as the most common collaboration type with 25 per cent of firms actualising their innovation goals and efficiency improvements through such partnerships; closely followed by firm–supplier collaboration with a proportion of 19 per cent of firms adopting the practice.

There was no evidence of inter-firm collaboration within each industry sector. Respondents emphasised that such innovation practice was uncommon as market survival depended on originality and competitive advantage over other firms. Interview discussions indicate that the lack of inter-firm collaboration in the case-study sectors is not without historical undertones, as firms in the industry sector tend to be secretive, keeping their expertise within the boundaries of the firm. However, our

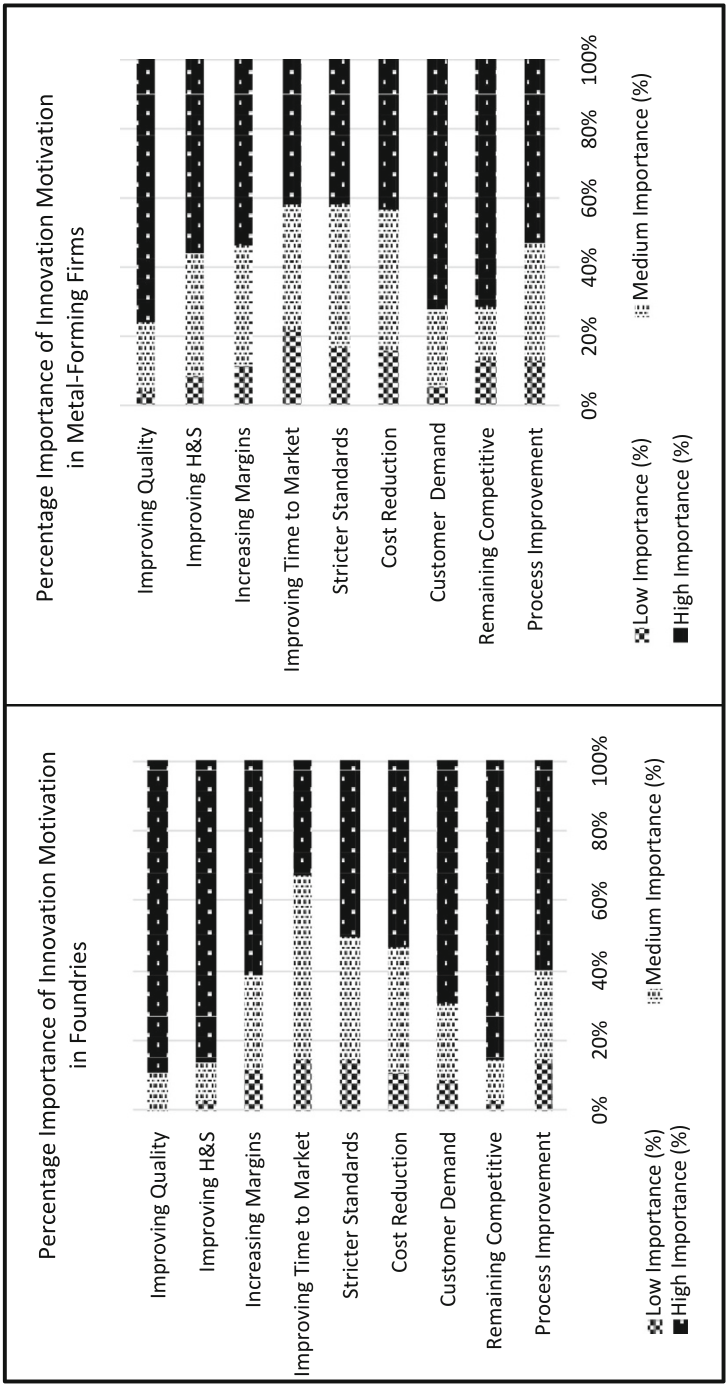

Fig. 1 Motivation for innovation in UK foundries and metal-forming SMEs

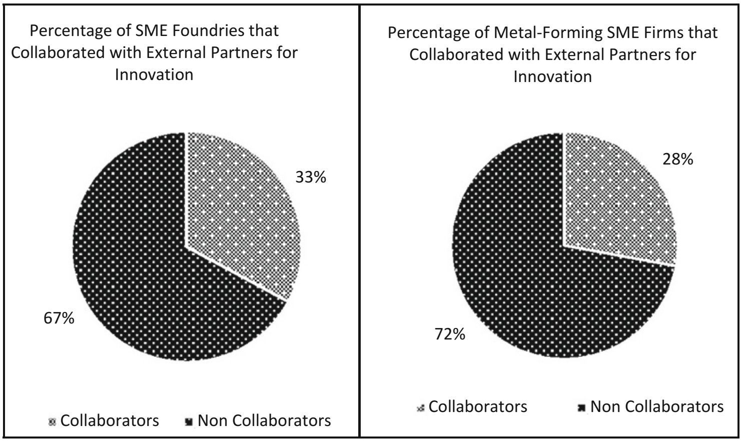

Fig. 2 Percentage of SME foundries and metal-forming firms that engaged in collaborative innovation

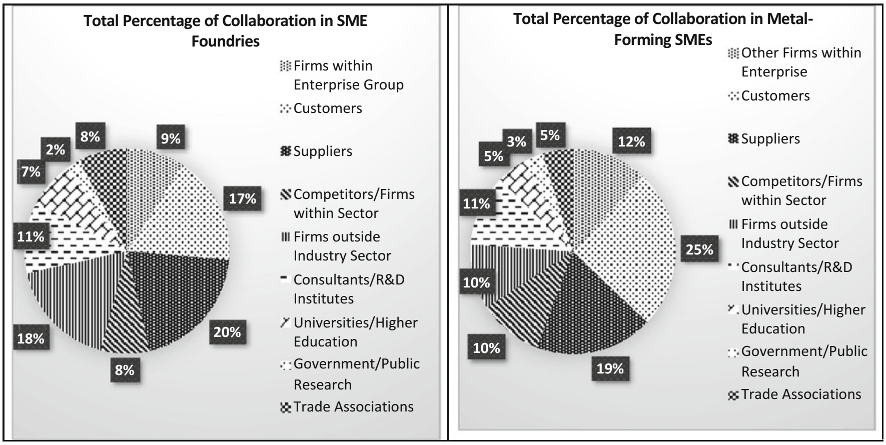

Fig. 3 Types of collaboration in SME foundries and metal-forming firms

findings indicate that apart from supply-chain collaborations, firms also engaged in a range of collaborative innovations with firms outside the industry sector, universities, trade associations, and consultants and research centres.

Across both industry sectors, collaborative innovation predominantly focused on quality improvement and the development of new or improved products. The development of new or improved products was the most popular reason for innovation collaboration across both industry sectors.

Many of the firms that engaged in collaborative innovation reported deriving a range of benefits from the alliance. Product and process development/improvement, improved productivity, increased capability, and customer satisfaction were the most cited benefits.

3.2 Understanding the Suitability and Capability of Potential Collaborative Partner

Lack of knowledge or insufficient knowledge of the capabilities of a potential collaboration partner is a barrier to collaboration.

> 'They don't like to tell you anything. Up until really recently, if I went to another foundry, I would not be allowed to walk around because I am a foundry-man. . .. . . So, would I work in collaboration with other companies? I would love to, but I can't find anybody that particularly wants to collaborate with us.' (Participant 6B)

Survey and interview responses identified barriers to collaborative innovation (Fig. 4). In both industry sectors, lack of funds, insufficient knowledge on the capability of a potential collaborator, and lack of trust and openness emerged as barriers with the highest influence preventing firms from collaborative innovation, thus confirming the importance of limited information flow on firms' collaborative strategy.

The majority of firms in both industry sectors regarded capability knowledge as very important in the decision to collaborate for innovation. Forty-eight per cent of metal-forming SMEs identified capability knowledge as a very important factor for innovation collaboration and 49 per cent of foundry SMEs had the same view (Fig. 5).

Where accessible, firms often sourced capability information of a potential innovation partner from exhibitions/conferences, supply chain partners, and trade associations. The latter two sources were identified as important information sources as they can act as knowledge brokers and pointers to industry expertise, especially as they tend to have a more comprehensive knowledge of the capabilities of individual firms.

Knowing more about a potential partner is an important preliminary condition for partnership consideration. Knowledge about capabilities encompasses a potential collaborator's skill sets, expertise, and all other competencies necessary for innovation and a successful alliance. Specifically, information about a potential collaborator's quality standards, product and process type, reputation, business strategy, and past projects, can act as a stimulus for collaboration when an opportunity or a need for such arises.

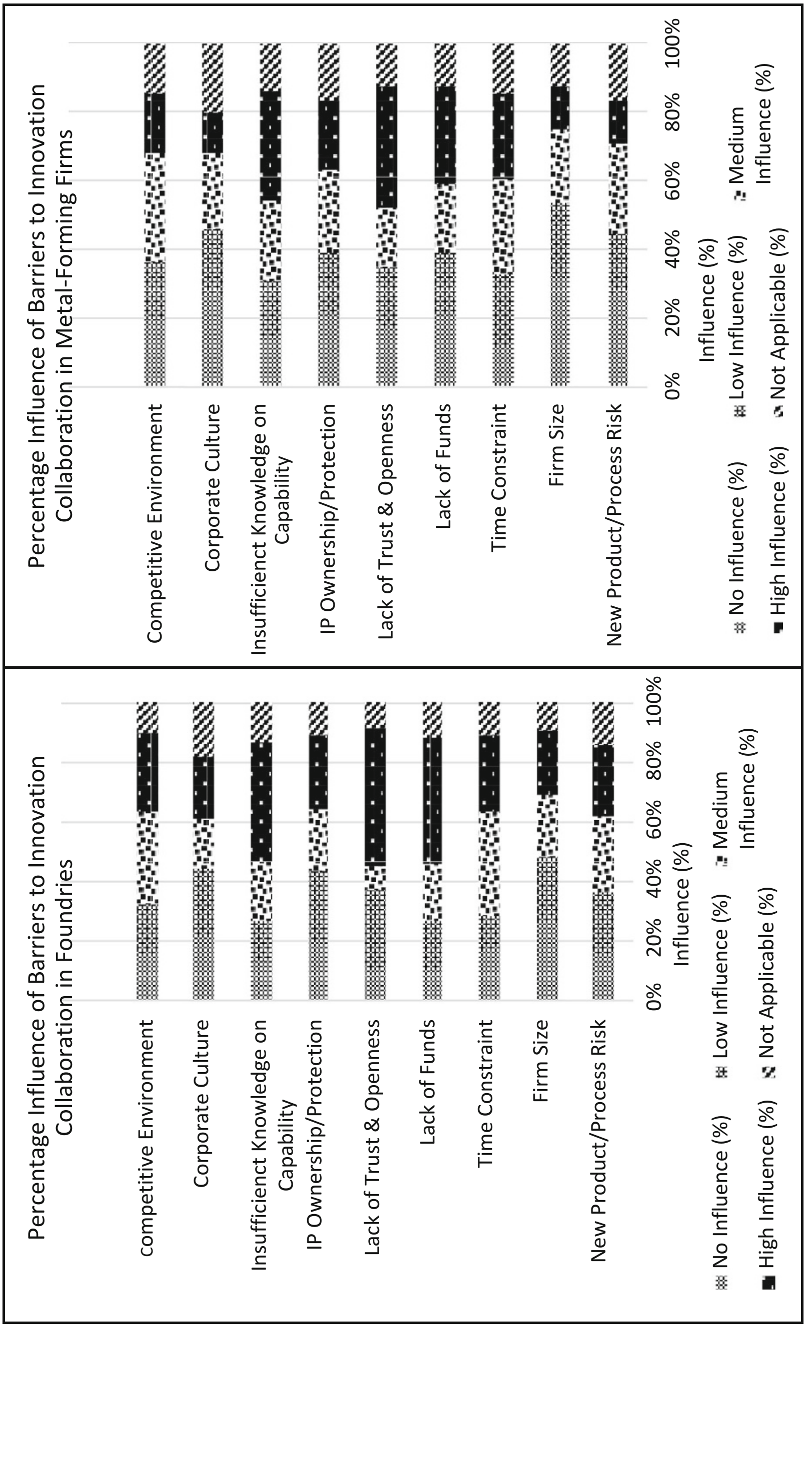

Fig. 4 Percentage influence of barriers to collaborative innovation in UK foundries and metal-forming firms

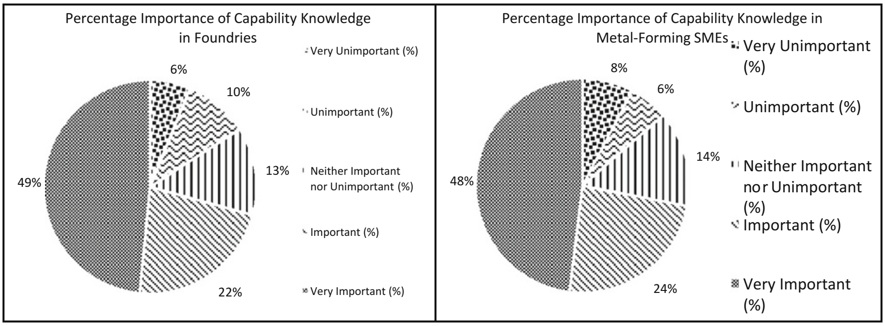

Fig. 5 Importance of capability knowledge for collaborative innovation in SME foundries and metal-forming firms

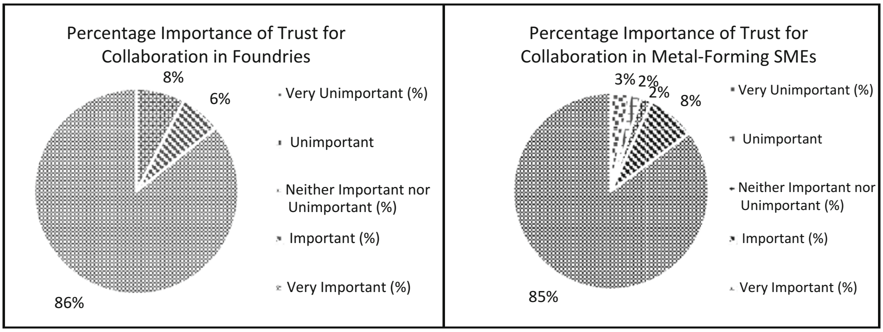

Fig. 6 Importance of trust for innovation collaboration in SME foundries and metal-forming firms

3.3 *Understanding the Trustworthiness of Potential Collaborative Partners*

Survey and interview responses report further evidence on the importance of trust for collaborative innovation. Across both industry sectors, Trust emerged as the barrier with the highest influence on collaborative innovation. Over four-fifths of SME foundries (86 per cent) and metal-forming firms (85 per cent) all viewed trust as a very important factor for collaboration (see Fig. 6).

Trust plays a prominent role in the decision to collaborate, and a lack of information on a potential collaborator's trustworthiness can be a deterrent to collaboration. Hence, for any form of collaboration, there has to be an element of trust.

> '. . .and there has to be that trust. With trust then comes the more, with the more comes more trust if you see what I mean. . . . It is a spiral that builds. . . So there has to be a lot of trust.' (Participant 5MF)

The use of NDAs (Non-Disclosure Agreements) across the sectors is a common practice that is often introduced in business transactions before any form of decisive engagement. NDAs represent baseline contractual agreements to ensure that confidential information is protected between potential collaborators, especially at the infancy stage of the collaboration. Analysed responses and surveys, however, indicate that NDAs are not fool-proof as there have been instances where firms failed to keep to agreed terms and conditions, leading to unfavourable outcomes. Thus, there is always some element of risk, especially at the infancy stage of collaboration and depending on one's 'gut feeling' is therefore necessary.

Probing further into how firms will assess a potential collaborator's trustworthiness, firms preferred meeting up and establishing a relationship that can be nurtured over time. Other ways of assessing trustworthiness include assessing a collaborator's openness to sharing information, protecting data, as well as references and recommendations from friends, family, and social network.

4 Conclusions

This study has examined the influence of informational market failures that may hinder collaborative innovation in UK SME foundries and metal-forming firms. Our findings emphasise the difficulty for smaller firms to engage in collaborations in competitive markets and the effect of informational gaps on the adoption of a collaborative strategy.

Our result suggests that firms in the case-study sectors are aware of the benefits of innovation and collaborative innovation. Many firms ascribed benefits to their past and current innovation efforts. Despite this sector-wide knowledge, a large proportion of SMEs in the case-study sectors did not engage in innovation activities. Innovation effort suggests a preference for process or service improvements to achieve business re-engineering, waste reduction, and product quality improvements. This aligns with findings on the motivation for innovation in the industry sectors, which shows that firms were taking significant steps to innovate to remain competitive and for quality improvement.

Our findings show that in-house R&D is the most popular form of innovation strategy in the industry sectors with less than one-third of the total percentage of innovating firms engaging in innovation-focused collaborations. Collaboration with supply chain partners is a popular innovation practice in the case-study sectors. Situations where knowledge for innovation is unavailable within the firm, firms tend to source for knowledge from their supply chain network as the first point of call. This supports the 'coupled process' suggested by Gassmann and Enkel (2004) and Enkel et al. (2009) which stipulates that for inbound focused collaboration, firms tend to increase their innovativeness by using, in addition to their internal knowledge base, external knowledge from customers and suppliers. There was no evidence of inter-firm collaboration in the industry sectors as firms perceived such a collaborative strategy in an already competitive market as risky and not beneficial. Further confirming the influence of competition and the sometimes opportunistic behaviour of collaboration partners as a barrier to collaborative innovation between firms (Enkel et al. 2009; Teirlinck and Spithoven 2013).

Our findings indicate that a lack of knowledge on the capabilities of a potential collaborator deters firms from engaging in collaborative innovation. This confirms findings by Hewitt-Dundas and Roper (2018) on market failures and OI. This also echoes findings by Dong and Pourmohamadi (2014) on knowledge structure and finding a potential partner with relevant knowledge for a collaboration to take place. Firms that have sufficient knowledge of the capabilities of a potential partner may be more inclined to collaborate for innovation if the capabilities are in-line with the firm's requirement and vision (Dong and Pourmohamadi 2014; Iturrioz et al. 2015). Thus, sufficient knowledge about a potential collaborator's capabilities can positively influence the decision to collaborate.

Finally, our result also indicates that a lack of knowledge on the trustworthiness of a potential partner can deter firms from collaborative innovation (Hewitt-Dundas and Roper 2018). In deciding to collaborate, there has to be some level of trust between potential partners. As a relational dimension factor, trust in collaborations can limit risk aversion tendencies and promote beneficial cooperation between potential collaborators (Iturrioz et al. 2015). Where NDAs serve as a basic contractual agreement, being able to trust a potential collaborator was deemed as more important than setting up NDAs (Connelly et al. 2018; Wang et al. 2008).

Our results suggest that firms can benefit from a mediating innovation broker with the responsibility of finding tailor-made innovation to meet a firm's innovation needs. Such interventions can be an effective way to override issues of lack of trust and lack of knowledge about capability since the innovation broker acts as an intermediary between the firm seeking knowledge and the inventor of knowledge or another seeker of knowledge willing to collaborate with the goal of actualising innovation (Dong and Pourmohamadi 2014). Both supply chain partners and trade associations can play a useful role in this regard, by supporting firms to overcome the informational market barriers to collaboration relating to potential collaborator's capabilities, trustworthiness, and an understanding of the benefits of the collaboration strategy. Trade associations by their role as an umbrella body and industry representative can take up a brokering role as an 'honest broker' or 'knowledge matcher' within their sector, and policy initiatives could be developed to enhance this 'intermediary role' (Dong and Pourmohamadi 2014). Providing support to trade associations in the form of tax rebates and other enhanced tax treatment options could help trade associations develop their brokering and networking activities with significant potential benefits for collaborative innovation. Also, supporting trade associations via the direct provision of resources and expertise to assist them in developing their brokering capacity to provide assistance and services as innovation broker to firms in their sector can help improve collaborative innovation across firms.

Also, policies aimed at empowering innovation hubs to act as brokers for SMEs by connecting firms and facilitating inter-firm collaborations for innovation purposes will help mitigate the informational barriers preventing firms from collaboratively innovating (Vrgovic et al. 2012). This would mean specifically adding a brokering role to the services rendered by innovation hubs, the provision of adequate resources, and constant monitoring to ascertain progress.

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Part III
University-Industry Collaborations

Managing a Major University–Industry Collaboration R&D Program

Gabriela Fernandes and David O'Sullivan

1 Introduction

University–industry collaborations (UICs) play a vital role in the research and development of new products, processes, and services (Rohrbeck and Arnold 2006). Industries within UICs seek to expand their knowledge base, share the risks associated with long-term projects, enhance their creative thinking and develop their ability to prototype and conduct experiments on long-term problems (D'Este and Perkmann 2011; Perkmann et al. 2011). Universities are attracted to UICs to secure more funding to support basic and applied research, to validate and field-test emerging ideas within the academic community, and to enhance their research-led teaching activities (Ankrah and Al-Tabbaa 2015). The number of collaborative programs between industry and university partners is increasing (Ankrah and Al-Tabbaa 2015; Nsanzumuhire and Groot 2020). For example, one source reveals an analysis of more than ten million papers tracked by the Web of Science and showing that the number of international collaborations has tripled in the past 15 years (Chawla 2018). UICs are now a key public policy promoting innovation by state funding agencies who view UICs as a means to enhance industrial growth and employment (Nishimura and Okamuro 2018). There are many challenges faced by UICs and primarily associated with the high degree of uncertainty and risk of individually oriented and self-motivated collaborators, often residing in different locations and working on projects with long-term outcomes (Brocke and Lippe 2015; König et al. 2013). Some of the critical management challenges are that

G. Fernandes (✉)
University of Coimbra, CEMMPRE, Coimbra, Portugal
e-mail: gabriela.fernandes@dem.uc.pt

D. O'Sullivan
National University of Ireland Galway, Galway, Ireland
e-mail: dos@nuigalway.ie

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organizations are guided by different incentive systems, motivations, and values (Bruneel et al. 2010). Differences between organizations also arise, including intentions, motivations, and responsibilities (Nomakuchi and Takahashi 2015). This assertion is summarized in the concept of the "cultural gap" coined by Barnes et al. (2006). Accordingly, the success of collaboration can be challenged due to the incompatibilities between the aims, limitations, and priorities of university–industry collaborators.

Literature research around UICs has focused on the effects of the so-called "cultural gap" (Barnes et al. 2006). This "culture gap" includes conflicts over ownership, academic freedoms, and differences in priorities, time horizons, and topics of research. Many of these issues can be attenuated by good project and program management (Barnes et al. 2006; Brocke and Lippe 2015; Du et al. 2014), which is the focus of this chapter. Project management (PM) can help to smooth over differences by engaging stakeholders in knowledge sharing activities, joint project deliverables, and achieving mutual benefits (Badewi 2016; Thomas and Mullaly 2008; Musawir et al. 2017). PM can have a significant impact on not only achieving better cost and schedule results (Thomas and Mullaly 2008), but also on less tangible aspects of the project related to meeting stakeholders benefit requirements (Musawir et al. 2017). The value of project management is a function of what is being implemented and how well it fits within the organizational context. Cooke-Davies et al. (2009) argue that PM value is created or destroyed depending on the extent of "fit" or "misfit" between the organization's strategic drivers and the characteristics of its PM system. At first, it may appear that managing a research collaboration is no different from traditional PM; however, there are additional challenges to be addressed. Brocke and Lippe (2015, p. 1022) argue that UICs *"present specific challenges, demanding of adaptations and adjustments to existing project management approaches."*

A UIC program is a more significant endeavor than an individual project. It can be defined as a group of interrelated projects whose own aims must meet the agreed long-term strategic objectives and benefits of the key stakeholders that typically include industry, university, and a funding body (Pellegrinelli 2011). Program strategic objectives and expected benefits inform and direct the specific goals of individual R&D projects. In return, the individual projects provide feedback that either strengthen strategic objectives or alter them within the overall program (PMI 2017). Programs assume a broad, more strategic, and open systems view of an R&D endeavor (Artto et al. 2009) and in this regard, complexity and uncertainty management become standard features (PMI 2017). Programs require specific management skills that are more tolerant to uncertainty, more open to change, and more mindful to the needs of all stakeholders (Lycett et al. 2004).

Some researchers have emphasized the influence of context (Shao and Müller 2011). Pellegrinelli (2002) suggests that directors and managers shape, embed, and align the program with the evolving needs of the organizations. The context of a program is the turbulent cultural, political, and business environment within which the program is deployed (Pellegrinelli et al. 2007). Previous research has also explored the dynamics between partners that may act as drivers for sharing resources

(Molina-Morales and Martínez-Fernández 2010), knowledge integration (Enberg 2012; Lundmark and Klofsten 2014), efficiency (Sánchez and Perez 2002), and the management style adopted (Chronéer and Bergquist 2012). Brocke and Lippe (2015, p. 1023) based on a systematic literature review aimed to answer the following question: *"What challenges in the management of collaborative research projects can be identified through reviewing scientific literature?"* Eight key challenges, divided into three categories, were identified:

Management of research work

- Uncertainty about working methods*
- Measurement of project performance*
- Balance between creative freedom and control*

Collaboration of heterogeneous project partners

- Diversity of individuals*
- Multiple, contradictory stakeholder expectations*
- Geographic distance of project staff

Role and skill set of project manager

- Limited authority of project manager and knowledge gap with individual researchers*
- Diversity of coordinator function*

Understanding these challenges can lead to the identification of new ideas and behaviors that can help to reduce the "cultural gap" between collaborating partners. This chapter presents Case Study research on some of these ideas and practices developed around one specific major UIC program with heterogeneous partners, collective responsibilities, and public funding support. Three main groups of ideas or topics that arose during the Case Study are presented in detail. The topics are listed below and mapped against seven of the listed challenges highlighted (*) by Brocke and Lippe (2015) above:

- Program and Project Lifecycles (1)
- Project Management (1, 3, 4, 7, 8)
- Benefits Management (2, 5)

Before presenting each of these topics in turn, we will briefly outline details of the Case Study with some background on the research methods used to develop the findings discussed in each of the sections that follow.

2 Case Study

The Case Study used in this research is characterized as a major UIC involving one sizeable multinational corporation—Bosch Car Multimedia Corporation (Bosch), one university—University of Minho (Minho) and a Portuguese government funding agency. All organizations or stakeholders are located in northern Portugal. Bosch and Minho agreed to propose the program to the Portuguese funding agency in 2012. The general motivations for the collaboration are as follows (Fernandes and O'Sullivan 2020):

Industry motivations:

- Increase market competitiveness
- Economic growth and wealth creation
- Cost-effective research
- Access to new knowledge
- Solving technical problems

University motivations:

- Funding for researchers and equipment
- Recognition of the university in the academic community
- Safe environment for ideas/results/theories
- Reinforcement of the university's know-how
- Ability to attract new researchers

Funding agency motivations:

- Regional/local economic development
- Recruitment of students (employment)
- Technological breakthroughs
- Professional development
- Knowledge transfer to industry

The UIC program studied as part of this research comprised two separate phases of work activity between 2013 and 2015 and between 2015 and 2018, respectively. The first phase involved an investment of around €20m on 14 R&D projects and included 300 researchers. The second phase involved an investment of €54m on 30 R&D projects and circa 500 researchers. Both phases together delivered over 570 deliverables that included 36 patents and 104 technical and scientific publications. The key application domains were electronics and instrumentation, information technology, mechanical technologies and materials, industrial engineering and management, and optical physics.

A small team of researchers studied the UIC program over 5 years between 2014 and 2019. The researchers studied both phases of the collaboration program, and the principal investigator spent an average of 2 days per week in the program's context. This enabled researchers to embed themselves at the center of all major activities in the program—interacting daily with key decision makers and observing at first hand both the challenges and successes of the consortium. Researchers remained as independent and objective "outsiders" to the program's activities. Data collection involved observation and participation and included the collection of various qualitative and quantitative types of data. Observations were made of daily work routines, workshops, celebrations, and meetings at every level, as well as informal

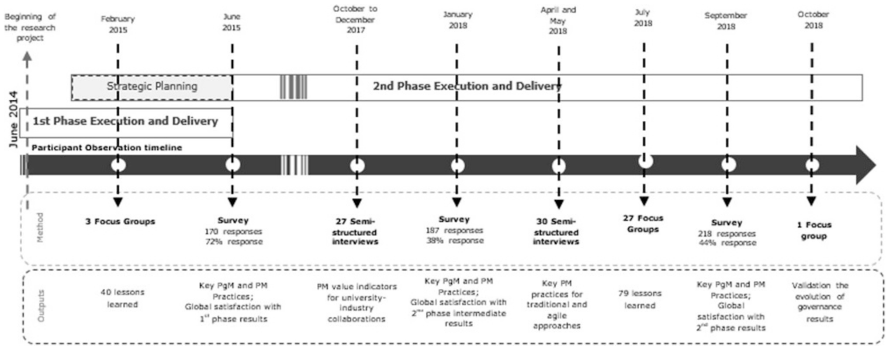

Fig. 1 Schematic illustration of the data collected over time

gatherings during the day-to-day activities of the members. Figure 1 summarizes the data collected over time.

The next three sections present three critical topics for discussion arising from the information generated from the research, to give a response to the leading management challenges faced at UMinho and Bosch collaboration, i.e., program and project lifecycles, project management, and benefits management. We begin with the discussion on program and project lifecycles.

3 Program and Project Lifecycles

In the Case Study, a Program and Project Management (PgPM) approach was adopted (Fernandes et al. 2015), which included a program management layer and PM layer (see Fig. 2), to some way address the challenge of "*Uncertainty of working methods*" and expected results (Brocke and Lippe 2015).

A standard set of lifecycle activities were established for the program and each R&D project. The life cycle at the program management layer as shown in Fig. 2 was divided into four phases as follows:

- Program Preparation
- Program Initiation

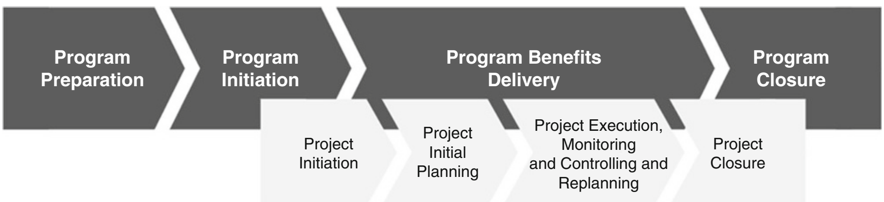

Fig. 2 PgPM approach adapted from Fernandes et al. (2015)

- Program Benefits Delivery
- Program Closure

The life cycle for each project in the Case Study could also be said to be divided into four phases mainly:

- Project Initiation
- Project Initial Planning
- Project Execution, Monitoring and Controlling, and Replanning
- Project Closure

Program Preparation initiatives were primarily aimed at defining a set of new R&D projects agreed by both organizations. Key management deliverables include: Innovation Idea Papers, Process Selection of Ideas and Project Leaders, Program Preparation Plan, Project Idea Papers, and the Funding Application. In summary, Program Preparation phase stands for the strategic planning of the program, before its execution and delivery.

Program Initiation mainly involved seven key management initiatives. The first was the creation of a Program and Project Management Office (PgPMO). The second was the definition and communication of the Governance Model. The third initiative was agreement on Collaborative Communication Platforms common to all parties, to facilitate transparent information sharing. Alignment Workshops were another critical initiative to guarantee the alignment of key stakeholders with the program objectives and to ensure the understanding of the interdependencies between the projects within the program. These Alignment Workshops triggered the creation of the individual R&D Project Charters. Project Charters also helped to identify the expected benefits and Key Performance Indicators for each project. Project Kick-off Meetings followed in the presence of all project members assigned to the Project Team and the Program Management, and its agenda included the presentation of the Project Charter and its official sign-off.

Program Benefits Delivery involved primarily six essential practices that included Project Progress Meetings with each Project Team. Each Project Progress Meeting was recorded in a Project Progress Report, which is communicated to the respective Project Leaders so that they can formally validate its content. Project's Risks and Issues were monitored and reviewed regularly during Project Progress Meetings. Given that the program was publicly funded, approval was required for any significant changes to the scope of projects. This Request for Change to the Project Charter was managed directly by the PgPMO team. Recognition and Motivation of resources were deemed a necessary initiative to stimulate the recruitment and retention of researchers during the whole program lifecycle. During the program, several Project Teams were losing experienced project members due to more attractive employment invitations by other organizations. One of the most motivational and alignment mechanisms was the Dissemination and Knowledge Sharing Events initiative. These events provide the environment to share project results between Project Teams and overall program stakeholders and to root the sense of belonging to something more significant than the projects by themselves.

Program Closure involved mainly two initiatives: the development and articulation of Lessons Learned and the development of a Transition Plan for translating research findings into an industrial product, process, and service improvements. Project closure meetings were agreed with all R&D Project Teams to accept on a dissemination plan of both achievements and lessons learned. Open discussions reviewed what worked well and should be used in future Programs, as well as what did not work and should possibly be improved or avoided in the future. Lessons Learned were converted into best practices and improvement actions to be reviewed and actioned in a future Governance board. The project closure meetings also discussed the Project Transition Plan. This plan was needed to transfer both knowledge and prototypes for future exploitation by industry, i.e., putting ideas into practice. For each phase, the PgPM approach identifies the main activities and the artifacts (templates) that result from each activity. For a more detailed discussion on the program and project activities, please see Fernandes et al. (2016, 2019a).

4 Project Management

The Case Study yielded several key insights into the activities of PM including governance structures, tools and techniques (practices), the role of the Program and Project Management Office (PgPMO), and the values anticipated by stakeholders from the PM activity to name a few. Three of these topics are now selected for discussion below: PM Practices; PgPMO; and PM Values.

4.1 Project Management Practices

Several PM practices were deployed in the Case Study. To help identify these, the researchers first created a table of potential practices from research literature and divided them into two types—*transversal* and *contingent*. *Transversal* practices are those must-have practices throughout all projects to assure the governance of the overall program (Fernandes et al. 2019a). *Contingent* practices are optional practices that can be deployed depending on the PM approach adopted by each project of the program. This hybrid PM approach of having *transversal*, i.e., must have PM practices, and *contingent*, i.e., nice to have PM practices, emphasizes the need to address the challenges of *"Balance between creative freedom and control,"* and *"Uncertainty about working methods."* Twenty-nine *transversal practices* were identified and divided into the key phases of the program lifecycle. Thirty *contingent* practices were identified and divided into three principal sub-types, traditional (or Waterfall), agile, and common practices, which can be used either in traditional or in agile PM approaches. Table 1 presents the results of this research exercise with practices ranked in order of usefulness by key thirty stakeholders who were interviewed.

Table 1 PM practices—transversal and contingent (with high % meaning highest ranking)

Transversal practices			Contingent practices		
Phase	Practice	Rank	Type	Practice	Rank
Program preparation	Project idea template	77%	Traditional (or Waterfall)	Work breakdown structure	67%
	Alignment workshops	3%		Gantt chart	63%
	Project charter	87%	Agile	Product backlog	47%
	Stakeholder register	83%		Planning for iteration-based agile	47%
	Kick-off meeting	87%		Sprint planning	7%
	Project competencies list	13%		Sprint backlog	50%
	Benefits log	70%		Sprint review	50%
Program initiation	Project plan	80%		Continuous integration	50%
	Milestone list	73%		Sprint retrospective	50%
	Project staff plan	83%		Release planning schedule	50%
	Responsibility matrix	77%		Kanban board	43%
	Risk register	87%		Daily stand-ups	47%
	Communication plan	87%		Self-directed work teams	47%
	Project procurement plan	83%		Burn charts	47%
Benefits delivery (Program execution)	Requirements analysis	40%	Traditional or Agile	Activity list	47%
	Ongoing delivery	17%		Decision log	50%
	Progress meetings	83%		Project communication room	53%
	Innovation meetings	10%		PM software	63%
	Progress reports	83%		Shared portal	17%
	Project issue log	77%		Requirements prioritization	53%
	Change log	73%		Meeting minutes	50%
	Quality inspection	83%		Effort estimation	50%
	External audits	83%		Modelling	50%
	Lessons learned register	80%		Demonstrations	50%
	New project ideas log	70%		Tests	47%
	Re-baselining	77%		Team-building event	47%
Program closure	Project closure meeting	77%		Information radiator	40%
	Project closure report	80%		Open Points List (OPL)	7%
	Transition plan	67%		Internal audits	7%
				Milestone party	3%

Useful *transversal* practices included project charter, stakeholder register, kick-off and progress meetings, risk register, procurement plans, communication plan, progress reports, quality inspection, and external audits. Common *contingent* practices included the use of Gantt charts, work breakdown structure and PM software, requirements prioritization, and the use of a dedicated communication room. Less common but indicated as useful by at least 50% of interviewees included sprint methods, decision logs, demonstrations, and modelling. For further discussion on *contingent* and *transversal* practices deployed in the Case Study, please see Fernandes et al. (2019a).

4.2 Program and Project Management Office

There is a clear distinction in the literature between the skillsets required for program and the project management. Programs that include a set of projects need PM coordination skills and also a rigorous approach to benefits management (Müller et al. 2013). As argued by Brocke and Lippe (2015), there is a *"Diversity of coordinator function,"* i.e., a diversity of management tasks that need to be performed, usually in UIC project managers played the role of management and research. Therefore, the creation of a Program and Project Management Office (PgPMO) not only to support program management but also to support the management of individual R&D projects is critical to program's success (Artto et al. 2011). Figure 3 positions the PgPMO in the governance organization structure adopted by Bosch and UMinho program.

The following list of PgPMO functions and responsibilities were identified from the literature review and validated using the Case Study (Fernandes et al. 2020a):

- Develop funding applications, and all technical and financial reports required by the funding entity, as well as provide support in the clarifications required during audits.
- Develop and embed the program governance model adapted to the program context.
- Provide tools to support the program governance.
- Develop PM competences through training, workshops, and seminars.
- Ensure mentoring and coaching on the use of the best PM practices, processes, and artifacts established in the program governance model.
- Develop and manage repositories that provide the relevant information of all past and ongoing R&D projects (knowledge management).
- Implement and manage a risk database associated with different types of R&D projects.
- Carry out several specific program and PM tasks to support the Project Leaders (e.g., project risk management, conduction of regular progress meetings with the R&D project team, and lessons learned archive) and the Program Management (e.g., maintain the Program Plan updated and report the Program Closure).

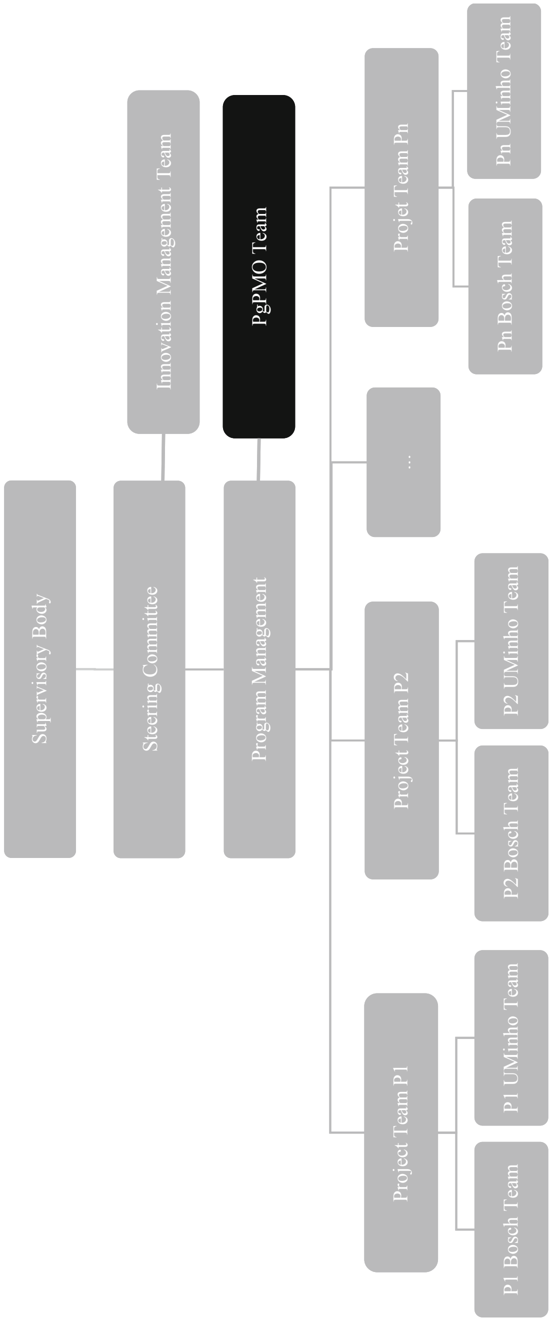

Fig. 3 Program organization structure adapted from Fernandes et al. (2020a)

- Facilitate cross-project coordination.
- Promote communication and social interaction, namely by stimulating research communities/groups to strengthen the bonds of trust between program members.
- Monitor and control R&D projects to report the status of the overall program to the Program Management and funding entity.
- Support the exploitation of the results of each R&D project (program benefits management), namely through effective communication.

The Case Study also provided insights into how these functions were allocated to four distinct roles in the PgPMO structure: (i) Management Officer; (ii) Finance Officer; (iii) Communication Officer; and (iv) Quality Assurance Officer.

The PgPMO Management Officers' key responsibilities included overseeing the program and project progress and reporting to the Program Management team. The Management Officer was required to have a background in Science, Technology, Engineering, and Mathematics (STEM), and a specialization in PM. The Management Officer was also required to have the following soft skills:

- Results orientation
- Orientation toward stakeholder satisfaction
- Ability to influence
- Management skills
- Personal effectiveness
- Analytical and conceptual thinking

The PgPMO Finance Officer supported the acquisitions and recruitment processes of all program projects and reported progress in financial terms to Program Management team. The Finance Officer needed to have a background in Economics or Finance, and also the same soft skills enumerated above for the Management Officer. The PgPMO Communication Officer had as main responsibilities to plan the communication needs of all the stakeholders involved directly or indirectly in the program, and to execute the Program Communication Plan. The Communication Officer had a background in Communication Sciences. Several soft skills are important for this role, particularly the orientation toward stakeholder satisfaction.

The PgPMO Quality Assurance (QA) Officer's main responsibilities were to propose the governance model to the Program Management team initially, and later to document, assure and assess the quality of the program and PM practices. The QA Officer also provided an umbrella for continuous process improvement and eliminating activities that do not add value. The QA Officer had a background in Organizational Project Management. For a more detailed discussion on the roles and responsibilities of the PgPMO, please see Fernandes et al. (2020a).

4.3 Project Management Values

PM brings value to achieving the success of UIC Programs (Du et al. 2014; Huang and Chen 2017). The value of PM is primarily measured in meeting program objectives on-time, within budget, and with a satisfactory level of quality. Other tangible and intangible values also measure the value of PM. These *additional* values include the achievement of long-term benefits (Eskerod and Riis 2009) such as greater communication, use of resources, customer satisfaction, knowledge sharing, and improved future possibilities (Thomas and Mullaly 2008). Even so, the role of the project manager, the program manager, and the PgPMO was sometimes not well accepted by key stakeholders, namely because of their limited authority. Therefore, it is imperative to raise awareness of key stakeholders of the different dimensions of PM value (Fernandes et al. 2014).

In the Case Study, the researcher asked key stakeholders to help identify the key values of PM. In answering this question, common PM values were initially identified from research literature and then presented to stakeholders for ranking in order of importance. New values, not found in the literature, could also be identified. Following the analysis of twenty-seven semi-structured interviews, a total of 41 PM values were identified. A sub-list of the most important values identified appears in Table 2.

Table 2 identifies the stakeholder who benefit from the PM value, its level of importance (ranking) as determined by all stakeholders and the *category* to which the value belongs. Twelve categories in total were used to group the values identified in the analysis. These categories offered additional insight into the PM values deemed of interest and were in alphabetical order:

- Academic Capabilities*
- Academic Value*
- Commercialization
- Competencies*
- Culture*
- Funding Agency Value*
- Future Funding
- Industry Capabilities*
- Industry Value*
- Long-term Partnership*
- Professional Development
- Project Performance*
- Relationships*

Examples of most categories (*) are presented in Table 2. Of the remainder, commercialization included values such as how individual R&D projects may lead to business start-ups, new license agreements, or patents. Future funding referred to a group of values such as the possibility that the experience gained in the UIC could help the collaborators secure future R&D funding. Professional development was a

Table 2 Values of project management (with "5" meaning highest ranking)

Stakeholder	Category	Value	Rank
University	Academic value	Achieve academic objectives	5
Consortium	Culture	Enhance collaboration culture	5
Industry	Industry Value	Achieve commercial goals	5
Consortium	Long-term Partnership	Increase future collaborations	5
Consortium	Project Performance	Assure cost, duration, and quality	5
Consortium	Relationships	Improve UI communication	5
Consortium	Relationships	Greater partnership satisfaction	5
University	Academic Capabilities	Improve PM knowledge	4
University	Academic Value	Enhance academic recognition	4
Consortium	Competencies	Organizational transformation	4
Consortium	Competencies	Improve collaboration skills	4
Industry	Industry Capabilities	Improve PM knowledge	4
Funding Agency	Funding Agency Value	Better collaboration experiences	4

group of values related to the development of skills, competencies, and experience of individuals involved in the UIC. Two of Brocke and Lippe's (2015) challenges "*Diversity of individuals*" and *"Limited authority of project manager"* is partially addressed under this topic heading, bringing evidence on the value of PM for the different UIC stakeholders. For a more detailed discussion on these issues, please see Fernandes et al. (2020b).

5 Benefits Management

Benefits Management (BM) was viewed as a critical activity in the Case Study. Before establishing a systematic BM framework, researchers first reviewed BM from the literature to develop a BM framework firstly and secondly identify potential benefits used elsewhere, and that can be considered for adoption. They found that existing literature on BM does not fully address the specific challenges of UIC Programs. UIC Programs are subject to two different organizational structures with entirely different cultures (Barnes et al. 2006). The large number of stakeholders commonly involved in this type of program also implies pursuing several distinct and sometimes contradictory benefits for each partner (Ankrah and Al-Tabbaa 2015; Brocke and Lippe 2015), which are joined together to pursue a set of contracted benefits with a public funding agency. Such public funding is usually conditioned by the agency based upon the well-defined benefits realization to society (Huang and Chen 2017).

5.1 Benefits Management Framework

Four frameworks were reviewed from the literature (e.g., Ward et al. 1996; Axelos 2011; PMI 2017; Jenner 2014) and were used as a starting point for the initial conceptualization of a customized framework. Ward et al. (1996) present the "Cranfield" model that encompasses five stages: (1) identify and structure benefits; (2) plan benefits realization; (3) execute benefits plan; (4) review and evaluate results; and (5) assess the potential for further benefits. This model is interactive and continues to be implemented beyond the end of the project. The "Standard for Managing Successful Programmes" from Axelos (2011) perceives BM as a continuous activity that starts before the program is accepted. It begins with the vision statement and unfolds into the following stages: (1) establish and maintain a BM strategy; (2) identify and map benefits; (3) plan benefits realization; (4) execute benefits realization; (5) review and evaluate realization; and (5) optimize and look for other benefits.

The "Standard of Program Management" from the Project Management Institute (PMI 2017) emphasizes that the potential benefits should be registered, analyzed, classified, and planned in detail, using a five-stage process: (1) benefits identification; (2) benefits analysis and planning; (3) benefits delivery; (4) benefits transition; and (5) benefits sustainment. One of the features of this five-stage process is it aligns with the three stages of the program management life cycle. Finally, the BM model from Jenner (2014) encompasses five cycle practices: (1) Identify and quantify, which includes identifying benefits approaches, such as benefits discovery workshops, benefits mapping and "costumer" insight; (2) Value and appraise, including value benefits in monetary terms and valuing nonfinancial benefits in monetary terms; (3) Plan the benefits realization; (4) Realize, including tracking, taking corrective action, and essential stakeholders engagement; and (5) Review, as a basis for learning and continuous improvement.

PMI (2017), Axelos (2011), and Jenner (2014) are professional frameworks, while Ward et al. (1996) is an academic framework, based on empirical data collected from 60 survey responses. These BM frameworks do not address the specific challenges of UIC programs; therefore, the frameworks were used as a starting point for the initial conceptualization of a new framework for UICs deployed in the Case Study. Figure 4 illustrates some of the key activities for BM used in the Case Study and the key controls, inputs, outputs, and resources identified following the SADT modelling methodology (Ross and Schoman 1977).

The first activity "Identify Expected Benefits" involved the following four activities: Define Program Vision, Establish Benefits Plan, Collect Expected Benefits, and Describe Benefits Metrics. The second activity "Plan Benefits Realization" involved four main sub-activities: Categorize Benefits, Prioritize Benefits, Link Benefits, and Develop Benefits Realization Plan. The third activity of the framework is "Pursue Benefits Realization," and this involved five main sub-activities: Implement Actions; Monitor Benefits, Evaluate Risks and KPIs, Report Measurements, and Provide Corrective Actions. The last activity is "Transfer and Sustain Benefits," and this involved four key activities: Transfer Results to Organizations, Monitor Benefits and

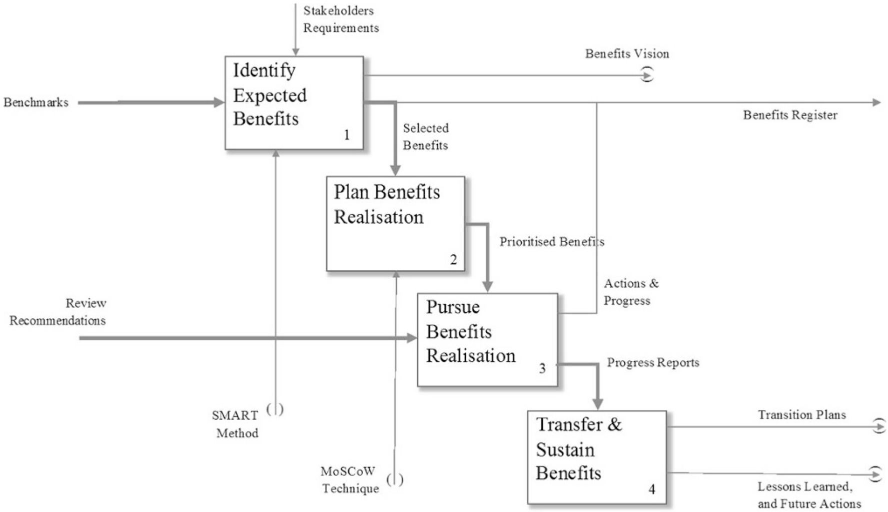

Fig. 4 Manage program benefits—activity adapted from Fernandes and O'Sullivan (2020)

Benefit CSFs, Identify Gaps, and Continue Benefits Monitoring. In addition to identifying key activities, their control, inputs, and outputs, the framework also defined essential resources including tools and techniques to be deployed across the program.

For a more detailed discussion on the benefits management framework, please see Fernandes and O'Sullivan (2020).

5.2 *Program Benefits*

Thirty-three individual program benefits were identified in the literature and used as a starting point for defining benefits that needed to be managed in the Case Study. These benefits were attributed to one of three stakeholders, i.e., industry, university, and funding agency. Focus group sessions then identified the relative importance of each benefit. Table 3 lists all of the benefits identified and sorted in order of importance.

It is not surprising what the benefits are since each can be justified on its own merits. What is surprising is the number of benefits that may need to be managed not only by the Program Management, supported by the PgPMO, but also by each PM team. Ranking benefits were seen as essential to allow stakeholders to focus on key benefits and retain their importance in terms of the program's overall mission. As Jenner (2014) argues, organizations should focus on the top three to five benefits, since people are not able to focus on too many variables. In this regard, the seven benefits ranked "5," for example, could be reported regularly whereas benefits ranked "1" less so. For more details on benefits identified from UMinho and Bosch Case Study, see Fernandes et al. (2017), and Fernandes et al. (2020c) on the critical factors for the benefits realisation.

Table 3 Program benefits grouped by category and ranked (with "5" meaning highest ranking)

Category	Benefits	Rank
Industry	Increase in market competitiveness	5
Industry	Access to new knowledge (state of the art)	5
University-Industry	Enhance the probability of future collaborations	5
Industry	Portfolio diversification (new products/services/processes)	5
University-Industry	Technological breakthrough	5
Industry	Independent high-quality product testing/validation	5
University	Increase the capacity to attract new students	5
Industry	Solving technical problems	4
Industry	Improvement of product quality	4
Industry	Increase of the industry's absorptive capacity for new knowledge	4
University	Reinforcement of the university know-how	4
University	Regional/local economic development	4
University	Recognition in the academic community	3
University–Industry	Reinforcement knowledge transfer to industry	3
University	Source of income for universities	2
University–Industry	Improvement of the innovation capability	2
Industry	Acquisition of complementary and/or substitute R&D	2
Industry	Access to specialized consultancy	2
Industry	Real-world experience for students	2
Industry	Economic growth and wealth creation	1
University–Industry	New business opportunities (e.g., creation of spin-offs)	1
Industry	Reputation growth among clients, partners, suppliers, and collaborators	1
Industry	Acceleration of commercialization of new technologies	1
University–Industry	Funding to hire human resources and equipment	1
University	Royalty and other benefits for researchers	1
Industry	Cost-effective research	1
Industry	Improved profit margins	1
Industry	Improvement of key performance indicators	1
University	Reorientation of the research/development plan	1
University–Industry	Recruitment of students (employment)	1
University	Increase the capacity of scientific production	1
University	Affiliation with a safe environment to receive feedback	1
Industry	Learning/continuous professional development	1

5.3 Key Performance Indicators

In addition to the most qualitative benefits identified above, thirty key performance indicators or measurable benefits were also identified in various documents used in the Case Study. As with the benefits above, these were ranked by stakeholders at workshops facilitated by the researchers. The highest-ranked performance indicators for the Case Study are alphabetically listed below for reference:

- Annual sales growth
- Deliverables executed on time
- Ideas/projects fully executed
- Ideas/projects generated
- Industrialists with a post-graduate qualification
- Industry satisfaction rate
- Investment (fellowships and laboratories)
- Patent applications (submitted/planned)
- Process improvement instances
- Product improvement instances
- Publications (jointly with industry)
- Publications (published/planned)
- Researcher satisfaction rate
- Technology readiness scores

Innovation is a complex concept that may require a wide variety of indicators (Smith 2005). Agreement on the criteria to be used to decide with performance indicators in the Case Study was a complex endeavor. Two of Brocke and Lippe's challenges *"Measurement of project performance"* and *"Multiple, contradictory stakeholder expectations"* were partially addressed under this topic. For more details on these topics, please see Fernandes et al. (2019b).

6 Conclusions

This chapter guided applying innovative management approaches to address the specific challenges facing a UIC. UMinho and Bosch also faced seven of the main challenges identified in Brocke and Lippe (2015), and their possible solutions were outlined. The first challenge was around *"Uncertainty about working methods,"* and therefore a Program and Project Management (PgPM) approach was adopted by the consortium, with well-established program and project lifecycles.

The second challenge was around developing a governance and management approach that *"Balance between creative freedom and control."* In this respect, a hybrid management approach was outlined, with PM practices divided into two groups—*transversal* and *contingent*. *Transversal* practices were distributed throughout the PM life cycle to assure the governance of the overall program.

Twenty-nine *transversal* PM practices were identified. Contingent stands for optional PM practices that can be used by project teams. These contingent PM practices, totalling thirty, were divided into Waterfall, agile, and common practices.

The third and fourth challenges related to *"Diversity of individuals"* and *"Diversity of the coordinator function,"* for which a PgPMO structure was implemented to support the Project Teams and Program Management team in management and control, namely the communication flow among the diversity of program's stakeholders. The PgPMO had clear functions and responsibilities adjusted to the specific needs of managing UIC programs. Four main roles were established, the Management Officer, Finance Officer, Communication Officer, and Quality Assurance Officer. The fifth challenge outlined concerned the role of the project manager, the program manager, and the PgPMO who because of their *"Limited authority of project manager"* were not well accepted by some key stakeholders. In this regard, the different dimensions of PM value were discussed, and the most important PM values were identified by stakeholders.

The final two challenges discussed were around *"Measurement of project performance"* and *"Multiple contradictory stakeholder expectations"* and that included benefits management to address the challenge of having heterogeneous partners. Therefore, a structured approach was presented from the Case Study for managing the anticipated program benefits.

Finally, it is worth mentioning that the challenge *"Geographic distance of project staff,"* identified by Brocke and Lippe (2015), was not regarded as significant by the collaborators since teams regularly met in person at both Bosch and UMinho sites. UMinho, for example, allocated a shared office space where collaborators could meet and work together on project tasks.

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Balancing Industry Value Proposition and Researcher Academic Interests

Peter E. D. Love and Derek H. T. Walker

1 Introduction

1.1 Background, Context and Scope

One way that universities generally measure research success is the extent of attracting university–industry collaboration research grants that provide recognised academic published outcomes in addition to research outcome 'impact'. The main aim being to achieve co-developed knowledge between the researchers and their industry partners that facilitate value-generating productivity gains as well as social benefits to enhance the overall living standards of society in general. The game is to frame a research proposal in such a way that it meets the university's strategic research goals and meets the value proposition of the industry partner(s). However, research is undertaken by individuals, and they also have a value proposition. The time, effort and energy required to frame and write a research proposal and shepherd it through the administrative maze of university and industry partner processes, is substantial. Low funding success rates make the process tedious and stressful. One difficulty in this system of granting research funds is that it is inherently competitive. It pits one researcher partner against another to maximise their share of the funding, and it requires finely honed and detailed research proposals that specify distinct outcomes, scope, resources needed and academic published outcomes. Plans are assumed to be notionally fixed, almost immutable. This leaves little room for an emergent strategy of research delivery and tends to inhibit researchers suggesting to industry partners that they know of others with better expertise in a particular area that might address the research question.

P. E. D. Love · D. H. T. Walker (✉)
RMIT University, Melbourne, Australia
e-mail: derek.walker@rmit.edu.au; p.love@curtin.edu.au

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The Commonwealth Government of Australian sets standards and metrics in Australia for research excellence through its Excellence in Research for Australia (ERA) policies and guidelines.[1] The Australian Research Council (ARC), Australia's government grant funding body, has a category of research grants called 'Linkage Grants'. According to the ARC website for linkage grants[2] 'The Linkage Programme promotes national and international research partnerships between researchers and business, industry, community organisations and other publicly funded research agencies. By supporting the development of partnerships, the ARC encourages the transfer of skills, knowledge and ideas as a basis for securing commercial and other benefits of research'. Winning ARC linkage research grants and gaining a high discipline ERA rating through grants and ERA outputs provides a potent university sector value proposition. The key to assembling a viable and attractive research proposal depends on the 'chemistry' of the research team and how cross-university or cross-discipline team members within a university frame and argue for the necessary resources (e.g. money, and timely access to equipment) supplied through these grants.

Research project leaders that frame the research proposal's aims and scope from collaborating university and/or discipline teams need to trust and have confidence in each other to ensure that anyone research group does not opportunistically shape the proposal to meet their own ambitions at the expense of others. Similarly, industry partners need to trust the researchers and have confidence in their expertise to win the grant application and to develop and maintain the value that they expect to gain from their participation in the research.

Undertaking collaborative research involving a team of researchers together with industry representatives is a far more difficult balancing-act task than it may appear. The starting point for successful *collaboration*, therefore, is on considering how researchers may develop and nurture *trust* and have *confidence* in each other and how they, in turn, develop and nurture mutual trust and confidence with their industry partners to deliver the value proposition.

1.2 Key Problems and Challenges to Be Addressed

Many academics, who have spent a decade or more intensely investigating a research field, frequently fail to attract enough industry interest to sponsor and, perhaps more importantly, collaboratively engage in research projects. At least two important prerequisites of successfully winning university-industry research projects are evident but often not adequately addressed. One is that mutual interest alignment is missing in failed grant applications. Another is that there may be a lack of trust and commitment between academic and/or industry collaboration partners.

[1] See https://www.arc.gov.au/excellence-research-australia

[2] https://www.arc.gov.au/grants/linkage-program/linkage-projects

The initial challenge, at the research proposal shaping and submission stage, is assembling a team that can successfully develop a convincing research proposal to win government and industry partner funding support. Industry supports these grant proposals with both cash and in-kind support. Government supplies cash through funding universities and cash grants. The challenge at the research outcome stage is to meet the value proposition of all parties, including any stated *public good* objectives and outcomes that provided the basis for government financial support. This prompts an interesting question. *How can academic initiators of collaborative research best shape their value propositions to meet both academic and industry value expectations?*

This question suggests a process is needed to combine marketing an initial concept (the proposed problem statement and research questions) with genuine dialogue (to collectively shape a research concept) that is trust and commitment based to develop a superior research idea where both academics and industry understand what each other values. Academics often find difficulty in providing quick and demonstrated industry outcomes and industry often fails to appreciate the extent of in-kind support needed—such as interviews, access to internal documentation and in some cases, time for key people to supply extensive survey data. Crafting a research proposal and managing the collaborative researcher-industry relationship is more of an art than a science.

This chapter provides a reflection on research collaboration from two perspectives. First, we explain how collaboration between two researchers from different universities resulted in them collaboratively writing a book chapter (Love and Walker 2020) based on insights gained from a shared industry partner. Second, we focus on how their independent interactions on different research projects with that common industry partner resulted in new knowledge and insights being published. The industry partner was engaged in an advanced and highly integrated project delivery (IPD) programme of projects. The academics' writing collaboration, and industry partners' collaborative IPD approach, link themes of collaboration between academia and industry.

A key element in this collaboration example is that the IPD approach. The adoption of IPD instils in participants an ability to appreciate the value of expertise and how to use collaboration as a guiding principle to ensure 'best for project' outcomes. Also, the principal means of trust and commitment being deployed within an IPD mindset facilitates confidence in the co-creation of value outcomes being delivered. This is because the industry partner might suggest in broad, perhaps fuzzy terms, what the desired outcome could be and the collaboration between the industry partner and the research team could concurrently refine the detailed approach and undertake the research on an action-learning basis. The starting point is the value proposition, 'what is the purpose that this project seeks to fulfil?' In Case Study 1, we illustrate how an IPD-style collaboration occurs in a book writing context. Then, in Case Study 2, we discuss how a research project proposal was able to be shaped through collaboration.

1.3 Key Highlights and Benefits

The anticipated benefit to be delivered by this chapter is to help university researchers better understand their own value and industry partner's value propositions to craft a winning research grant or industry-funded collaborative research idea that delivers expected 'returns' to all parties upon completion of the research project.

Crafting is an artistic form of shaping and moulding in a way that is responsive and reflexive. The concept has been used in terms of transcending knowledge as an ability to sense what is possible and to know how to shape situations to achieve what may be a fuzzy or even clear aim starting from an opaque starting point. Scharmer (2001, p. 138), for example, describes how Michael Angelo had 'seen' in his mind the statue of David. He was able to release the image of David as a statue from a block of stone. Others have used the concept for project managers who craft their careers through choices made about assignments they take and job skills they pursue (Crawford et al. 2013; Demerouti and Bakker 2013; Akkermans et al. 2020). In one sense, this chapter helps academics to think about crafting their careers.

A subsidiary benefit relates to helping industry partners understand the academic partner's value proposition. We highlight these two benefits but also recognise that research is predicated on valuable new knowledge creation and make this a taken-for-granted assumption in the goal of winning research funding and deliver anticipated outcomes.

1.4 Chapter Structure

Several concepts used in the chapter are explained, such as value and trust and commitment. Additionally, IPD and alliancing concepts are explained. The following section will outline and discuss these theoretical concepts and terms that informed our research interests. A section follows that briefly discusses the context and history of the two researchers and how they decided to collaborate on Case Study 1—the writing of a book chapter as a *collaborative project*. This is followed by a discussion on Case Study 2 collaboration of one of the researchers with an industry partner. The focus on book chapter Case Study 1 led to further research being undertaken with that industry partner. The final section concludes this chapter summarising and reflecting upon the answer to the chapter's research question: *How can academic initiators of collaborative research best shape their value propositions to attract industry and be aligned with its value proposition?*

2 Theoretical Concepts and Terms

Integrated Project Delivery is akin to alliancing, where collaboration, trust and commitment, and the underlying value proposition are shared. The theoretical concepts and terms of IPD are now briefly explained, but should readers require an in-depth exposition of the subject then it is recommended they refer to Walker and Rowlinson (2020b).

2.1 IPD/Alliancing Collaboration

Integrated Project Delivery has been defined as:

> '... a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimise project results, increase value to the owner, reduce waste, and maximise efficiency through all phases of design, fabrication, and construction.' (American Institute of Architects – AIA California Council 2007, cover page 2).

This term evolved from a Lean Construction perspective of minimising management energy waste through integrating the project owner participant, the design team, and delivery team being usually a contractor and several first-tier subcontractors and potentially, the facility manager for the built facility. The concept of IPD under the North American approach has three levels of collaboration. The most intense form, as defined above, is Level 3 IPD requiring an integrated form of agreement (IFOA) contract. Level 1 has no requirement for an IFOA, and Level 2 has some collaboration requirements specified, but levels one and two are more similar to general partnering arrangements based on traditional project delivery approaches. While the term IPD was more recently coined, the notion of having an integrated project procurement approach was first introduced in Australia in the mid-1990s in the T40 Report by Ireland (1994) and developed further by Mohamed and Yates (1995) and Love et al. (1998).

Alliancing, as it is practised in Australia (Department of Infrastructure and Transport 2015), New Zealand (Ibrahim et al. 2014), Finland (Lahdenperä 2014, 2019; Aaltonen and Turkulainen 2018) and the Netherlands (Laan et al. 2011) has more intense collaboration and team integration characteristics that North American IPD but with a lower level of integration of first-tier subcontractors. The literature on the North American IPD shows greater integration and collaboration with the major services organisations (mechanical and electrical, fire and digital controls) frequently fully participate in an alliance on infrastructure projects (American Institute of Architects, AIA Minnesota and School of Architecture University of Minnesota 2010; Pishdad-Bozorgi 2016; Fischer et al. 2017; Walker and Rowlinson 2020a).

A further feature of alliancing is that the project team is fully integrated and adopts a united front towards managing and delivering a project to ensure positive outcomes. Lehtinen (2013) identifies contractual, organisational and technological mechanisms used to achieve integration in the USA. In contractual and psychological-motivational terms, integration is enabled through a best-for-project mindset. This mindset is created when separate teams integrate into a collaborative entity. In this instance, a unified team is formed, which shares its plans and actions to ensure the best for the project outcomes (Department of Infrastructure and Transport 2011c).

Any performance pain or gain sharing is based on the final project delivery outcome and not on the performance of individual teams within the alliance. Positive or negative deviation from the project's initial agreed time/cost/key results area (KRA) outcomes is treated as pain or gain sharing for the alliance syndicate as a whole entity based on their agreed pain–gain sharing agreement (Department of Infrastructure and Transport 2011a).

Alliancing may occur as an arrangement to deliver single projects (project alliancing) or for a series of projects within a programme of work (programme alliance) (Victorian Auditor-General's Office 2017). Programme alliances present greater opportunities for leveraging knowledge, innovation and lessons learned from one alliance package to another.

In summary, alliancing and Level 3 IPD, can be characterised as a highly collaborative project delivery approach in which many of the separate teams (client representative, design, contractor, services sub-contractors and often a facility operator) are integrated by a common best-for-project outcome mindset; and with incentivisation arrangements based on a gain/pain sharing arrangement assessed on KRAs that measure at the overall project, rather than the individual team, performance level.

2.2 *Trust and Commitment*

Both integration and collaboration require high levels of participants' trust and commitment. Pishdad-Bozorgi and Beliveau (2016) argued from USA IPD research, that trust and commitment are prerequisites for successful project performance. This conclusion has been drawn by others studying relationship-based project delivery forms such as partnering in the Nordic countries (Kadefors 2004, 2005), within a Hong Kong context (Kumaraswamy et al. 2008; Lau and Rowlinson 2009) and in Finland, alliancing practice and the importance of trust and commitment that influence collaborative and nitration behaviours (Lahdenperä 2017). Trust has been studied from a number of perspectives. It has been studied from a justice perspective, for example, by Colquitt and Rodell (2011) where they investigate procedural, distributive, interpersonal and informational justice. Early scholars of trust recognised that it is determined by the interplay of people's values, attitudes, mood and emotions (Jones and George 1998). Gill et al. (2011) investigated trust from the relational contract perspective of the Heathrow Terminal Five (T5), and Kadefors (2004) in her oft-cited paper discusses trust from a calculus-based, relational and institutional-based perspective. Scholars of the trust concept point to it in collaboration as being about ability, benevolence and integrity.

The Mayer et al. (1995) model for explaining trust remains central to later elaborations on trust theory. It has three core elements: (1) ability, (2) benevolence and (3) integrity. Ability is important as competence, willingness and having sufficient resources are essential to fulfilling a performance promise. Benevolence relates to goodwill and lacking any ill-intentions. Integrity is about acting consistently with the manner espoused by a party. When trust is challenged by a trust risk-event, the level of trust achieved results from a feedback loop where the trusting party assesses the outcome based on their expectations of the other party's ability, benevolence and integrity. If the outcome supports the expected result, then trust is reinforced, and if the outcome is disappointing, then trust is diminished. The trustee's agency may be also be impacted by the trustee's organisational influence (Rousseau et al. 1998). This explains why one may trust an individual but also perceive that either their own or the other party's, organisational constraints or attitudes may adversely affect the expected outcome of a trust test. The level and type of commitment also play a role in how trust is perceived. Meyer and colleagues (Meyer and Allen 1991; Meyer and Herscovitch 2001; Meyer et al. 2004) explain commitment types as occurring at three levels of intensity.

A low-level motivation of commitment is represented by *continuance* commitment, where the cost of withdrawing support is greater than maintaining an adequately minimal level of support. *Normative* commitment is a second commitment level based on norms, tradition and feelings of loyalty with a perceived obligation to remain committed. This may imply greater enthusiasm to be trusted. *Affective* commitment is a 'want to' commitment with stronger emotional bonding feelings. It most strongly supports trust due to a perceived strong feeling to want and intent to perform what was promised. There are numerous calculations going on in the minds of parties deciding whether to trust or not when confronted with testing of that trust.

High trust and affective commitment levels, therefore, have a significant impact on collaborative team behaviour. If a trustful and trustworthy relationship is valued, and if it does lead to more successful project performance than relying on competitive tension, then we can see that it is essential for collaboration between individuals and teams. The importance of trust is that there can be no open and effective sharing of information and insights without trust and the commitment to engage in dialogue rather than each party to pursue their own agenda.

2.3 Value Proposition: Who's Interest and Why Bother?

The purpose of any project is to create value, a benefit (Zwikael and Smyrk 2011). Thus, it is vital to understand not only the nature of value generated but how it is *valued* by its recipient. The concept of project value, as noted from a recent literature study (Laursen and Svejvig 2016), is broad and encompasses value-for-money

(Department of Infrastructure and Transport 2011b) or perhaps better expressed as 'best value' (MacDonald 2011).

Value is a highly subjective concept. What one person may value and find highly desirable others may be completely indifferent to. This has implications on the way that value is modelled and assessed as well as how it is generated and exploited. Laursen and Svejvig (2016) identified from their review of project value literature four directions of future research that should be conducted and focus on moving from a (p. 743):

1. A traditional value management approach that focuses on cost management and reducing the capital cost towards the development of a holistic and integrated perspective that focuses on generating value and benefits at minimal costs.
1. Linear process of value creation akin to traditional value chains toward the development of value creation and capture as a broader concept in project management. As a result, this infers a short, long-term and emergent view of value.
2. Traditional project and portfolio management perspectives that take a tactical and operational view of disciplines towards their integration with strategic and programme management to imbue value.
3. Limited application of theoretical frameworks that are independent of the project value creation research field towards the development of new models and theories by applying frameworks of independent theory (e.g. resource-based view).

When we consider the topic of this chapter, it becomes clear that one of the challenges facing researchers in 'pitching' their research proposal to a potential research partner (or even another colleague to join them in a research project). There has to be value generated for all parties, but how can that value be identified and addressed? Seeing value as cost management is not as relevant to an academic as it may be to an industry client. As the first direction above suggests, it would be better to investigate value creation rather than cost reduction/optimisation. Similarly, in the case of direction two, value capture and its' phasing, is potentially more interesting than value chain mapping. Direction three may be interpreted as thinking about how value is realised within a portfolio of projects, and so its synergy may best be realised across projects. Taking this broader approach to value, the question of how best to initiate research and collaboration between academics and between academics and industry practitioners becomes quite complex.

Collaboration between academics may be of value in terms of reputation, research grant income, publication production, co-learning and mentoring or just plain fun! Collaboration value between academics and industry may be based on hard-money returns (at whatever phase may be desired), co-learning and challenging assumptions, being an innovation leader or support for research may be part of the industry partners' business KRA requirements. Figuring out what is *valued* is hard work!

This third concept that we explain is, therefore, concerned with what is *valued* as an outcome by a person or organisation. Anderson et al. (2006, p. 93) identify three components of a value proposition to explain how value may be perceived. Looking from a *total benefits* angle addresses the question 'why should I buy your offering?'

Table 1 Main stakeholders and their interests

Stakeholder	Interest
Academic researchers:	PL and DW had an interest in research outcomes, publications, potential grants, establishing industry support and disseminating research outcomes as well as mentoring PhD candidates.
The industry participant	They articulated in interviews a desire to engage with academia to have an independent assessment of their practices, and they looked forward to co-learning. In the DW-Barwon Water research interviews it was part of a wide study, and so Barwon Water was generous with their time, but they did end up getting the suggestion by DW that a significant concern of theirs could be addressed by PL.
The Universities	Universities like to have their senior researchers demonstrate impact from their scholarly work, including publication and reputation but also government research grants and PhD completions are highly valued.
Society at large	Government research funding, usually a match with industry partner in-cash and in-kind support, is meant to generate value to society in the form of productivity improvement, improved global competitiveness and a more educated and smarter workforce.

This relies on cataloguing benefits. Intimately knowing and understanding what the customer or stakeholder values is difficult without engaging in meaningful dialogue with them. The Anderson et al. (2006) second component, *favourable points of difference,* addresses the question ‘why should I buy from you rather than others?’ This requires intimately knowing and understanding the customer as well as competitors to be able to understand what priorities the customer has and the weighting of these features. This leads to the third element, *resonating focus,* that addresses the question ‘What is *most* worthwhile for us to keep in mind about your offering?’ It requires thinking about what benefit the other party can appreciate and how it links best to their needs and desires. These three elements of a value proposition help to explain what may motivate a researcher, or industry partner, for example, to be excited or deterred from entering a research collaboration.

The question of ‘why bother?’ is raised by the value proposition concept. In this chapter, we focus on four parties or stakeholders, and each has an interest. The two main parties are the research academics (PL and DW) and their industry collaborating participants. Two subsidiary stakeholders are the universities that the academics come from and society at large that provides the government research funding, and so social good is also a valid interest. Any research project proposal needs to address the interests of these four general stakeholder groups. This is summarised in Table 1.

As we can see from Table 1, the interests are diverse and initiating a research proposal needs to address the value proposition of each of the identified stakeholder’s interest. We discuss the analysis of the realisation of the collaboration between PL and DW and PL-Barwon Water collaboration in Table 2. The universities gained value from the research collaborations from publications, supportive mentoring of PhD candidates and substantial research funding for PL’s research. Society gained value from the more general up-skilling, and education and productivity improvements and substantial new knowledge about avoiding rework gained

Table 2 Researcher collaboration analysis

Concept	Evidence example	Comments and notes
Alliancing	Motivation and context.	The two researchers valued each other's opinions and insights when discussing drafts and ideas for papers. When DW was looking for a suitable book chapter co-author for the innovation diffusion chapter he naturally contacted PL as he was familiar with, and saw the value of, the Barwon Water Alliance research as a suitable focus for that chapter.
Value-proposition	Best-for-project mindset for the book.	Both DW and PL understood the context of the industry case study that was to chapter focus and were able to rapidly draw upon both their research data on that case study example. The book chapter value-proposition was also served by their writing collaboration. DW understood the book's overall aims (as co-editor) and how this topic fitted the books structure and aims. DW was confident that PL could deliver insights and analysis on that research that would fit the book's focus on alliancing and innovation diffusion.
Trust and commitment	Proven expertise (ability), close friendship (benevolence) and respect for professionalism (integrity) and personal commitment.	Their shared experience over the past 25 years and well-understood matches and gaps in each other's knowledge and research and their understanding of each other's strengths provided deep confidence that the book chapter could be delivered as expected and hoped for. Both researchers were enthusiastic about focusing on the Barwon Water Alliance case study and drawing new conclusions and insights from that work to fit the book's aims.

to the industry sector through PL's research work and its dissemination (now being applied more broadly with other industry participants).

2.4 Collaboration, Trust and Commitment in Practice

This chapter discusses how collaboration evolved between the two researchers and between one researcher and their industry partners. IPD/alliancing provides a context to explain the subject of the research field to be examined. Both researchers were interested in research into various aspects of collaborative team integration within a project and programme alliance. The two academics also formed a writing *alliance* to publish the book chapter on *alliancing* practices. The trust and commitment concepts help us explain how the researchers and the industry partner built and developed their relationship that supported collaboration. The third concept, value proposition, helps explain the rationale for collaboration. These concepts help us explain first, how collaboration may develop between researchers and between researchers and their industry partners and second, how that unfolds in practice.

We also note that this required a great deal of crafting to form a collaboration. We explained the concept of crafting in Sect. 1.3. This crafting was in part designed (through the development and maintenance of a collegial relationship and friendship over two decades), but much of it was serendipitous. Serendipity is an unexpected and unplanned for the occurrence of some benefit, but one which has been prepared for in general terms rather than being planned for. The PL and DW relationships were one of mutual trust, commitment and collaboration, and so both of them were well aware of each other's work. This led to DW being aware of how PL could address the excessive rework being experienced by Barwon Water as an issue for them, and so DW naturally suggested that they should talk to PL. DW was also aware that what Barwon Water needed was a lot of in-depth statistical analysis of their data on rework and he knew that PL was far more expert at that research approach that neither he nor his university colleagues were capable of. It was also serendipitous that years later, DW was looking for a good case study of innovation diffusion for a book chapter and he knew of the PL-Barwon Water study and was able to join with him in co-authoring the book chapter (Love and Walker 2020).

3 Case Study 1: Collaboration Between the Two Researchers

3.1 Context and History

Derek Walker (DW) completed his Doctor of Philosophy (PhD) during the mid-1990s in Construction Project Management, specifically looking at the determinants of project time performance. Later, but in a similar area, Peter Love (PL) completed his in 2002 in the field of Operations Management and focused on the determinants of rework in construction and the influence of project performance. Building on his doctoral studies, PL's research embraced collaborative project delivery forms such as alliancing, organisational learning, safety, innovation and continuous improvement. These and other research topics stem from his initial curiosity about the *how*, *why* and *what* causes rework manifest in construction projects. DW's PhD could be summarised as a study of why some buildings are built quicker than others. This somewhat banal topic led to an investigation into the impact of collaboration and IPD among project team members, organisational learning, innovation and its diffusion, leadership and governance and stakeholder engagement through co-generation of value.

Both became aware of each other's research 25 years ago and formed a friendship and sharing of insights and cross-over interests stemming from their original PhD thesis topics. Over the years they have collaborated on several research projects such as an earlier study on rework pathogens, which was a project funded by the ARC under its Discovery[3] programme (Love et al. 2009a, b) and more recently on IPD and innovation (Love and Walker 2020). More importantly, they have maintained close contact over this time by discussing their emerging interests and being sounding boards for research ideas and drafts of various papers. While they have not been 'living in each other's pockets' they have maintained respect and trust in each other's research work and have appreciated the overlaps and gaps in their research topics.

3.2 Co-authoring a Book Chapter

Our first case study example is a recent book chapter we co-authored (Love and Walker 2020) in *The Routledge Handbook of Integrated Project Delivery*. That book chapter draws on how innovation and learning from continuous improvement links to innovation diffusion within a water infrastructure programme alliance. Both researchers had undertaken independent research with the Barwon Water Alliance[4] Industry partner.

Relationships built between the two researchers and also individually with key Barwon Water Alliance subject matter experts enabled them to explain how their separate research projects could be best led. For example, the research interest and scope for a case study by DW revealed an interest by Barwon Water Alliance in rework, continuous improvement and innovation diffusion. DW was able to explain the work and expertise of PL to Barwon Water Alliance research participants when citing how alliancing may provide benefits that Barwon Water Alliance had found difficulty in quantifying and fully appreciating the scope of these benefits. DW acknowledged that he did not have the expertise to undertake the implications of alliancing on rework. This may have helped clarify the value proposition for Barwon Water to later discuss with PL how *his* expertise could best *fit* Barwon Water's needs and value proposition.

There is always a danger, especially with research that may drift into a partial consultancy role, that the researcher-consultant feels it necessary to 'hoard' a 'client'

[3] https://www.arc.gov.au/grants/discovery-program/discovery-projects

[4] A programme alliance with a contract value of $375 million- and 5-year schedule of works. The alliance was established in 2009 to deliver 129 water infrastructure projects comprising pipelines, water treatment plants, pumps stations, tanks and channel works throughout the Barwon region in Victoria in Australia.

and offer to undertake research-consulting in an area while knowing of others who are better equipped to provide better value to that client. Further, the university system, with its performance measurement being highly focussed on research income, there is a danger that delivering on the customer–client value proposition takes second or third priority. There is a paradox that needs to be managed, that is meeting the commercial interests of the university and/or researcher-consultant and those of the industry partner's value proposition.

This example of collaborative and supportive cross-researcher behaviour versus competition is important. Both researchers had been engaged with a range of research colleagues on research projects covering similar areas of study, for example, on the alliancing concept, innovation diffusion and organisational learning. The value of DW's and PL's researcher relationship was one of having contemporary insights across their independent studies that they could share and compare. For example, when they were writing drafts of papers from time to time, they were able to discuss, validate and expand theories and emerging ideas. This is not unique; many established professionals of many disciplines have lifelong friends and colleagues that they trust to expose and test ideas with or are engaged with their community of practice to achieve this end (Lave and Wenger 1991; Sense 2007; Arroyo 2009). This continued relationship over a quarter of a century led to their co-authoring the book chapter that embodied insights and findings from DW's IPD research studies and PL's inquiry into how the Barwon Water Alliance was able to address the problem of rework in its projects.

3.3 Case Study Analysis

We now summarise the nature of the collaborative relationship between the two researchers in the book chapter production (Love and Walker 2020). The case study example that is described illustrates how the book chapter came to be shaped and written by the two researchers. Readers may contemplate how books such as this one, and *The Routledge Handbook of Integrated Project Delivery* are developed, how co-authors are chosen to be invited to contribute and how path dependence (Sydow et al. 2009) impacts collaboration.

Books and their chapter structures do not just appear. A rigorous proposal and review process take place where a book's co-editors conceptualise a book' aims, objectives and theme: bringing new knowledge to the body of literature of the subject area. Authors are invited to submit chapter ideas based on the book's strategic aims that provide new insights (rather than the authors simply rehashing their existing research publications such as conference papers). The chapter authors form an alliance for this purpose and integrate their ideas and experience either on re-evaluating past research from new perspectives or by undertaking new research to focus on the chapter's intended output. They need to be effective in their collaboration and integration, they need to have a focus on the chapter being as good as possible, and they need to exhibit behaviours that support their collaboration and integration.

The authors also have a value proposition. It may be in part to maintain their publication record, to maintain an existing solid collegial relationship or to build a new one. The value proposition could be based on wanting to learn more about a topic by collaborating with others whose expertise is respected. The book chapter topic research may also emerge as a career steppingstone. There are many and varied reasons for collaborating on writing a book chapter. There also needs to be deep and solid trust between collaborating co-authors. The book editors expect a high standard of output and that the book *fits* the overall theme. There is a timeframe, and so writing is a project in its true sense. The outcome includes tangible and intangible results, often co-author learning from the research and writing process is highly important. Trust, as discussed earlier, is based on ability, benevolence, integrity and commitment.

Usually, affective commitment is the primary motivation, but there may be elements of continuous commitment because the author's universities expect regular publication output and there may also be an element of normative commitment as co-authors who regularly write together and collaborate may feel a duty to support each other. The university system (should) provide a culture of research and writing, but its priorities may lie outside the book's scope and direction, and so researchers may need to overcome a lack of institutional support or else subvert it somehow.

Trust and commitment may be a complex issue to navigate. Therefore, the choice of collaboration partners is an important consideration. Similarly, if the publication is based on industry collaboration, there is usually a need to comply with university and personal ethical standards on how the research is presented, what is disclosed or disguised or made anonymous, and how sources are acknowledged. Book chapters are often peer-reviewed, and so co-authors need to trust each other and be confident of their track record, expertise and reputation. This section explained how writing as a collaborative project takes place and how many IPD features and aspects apply.

4 Case Study 2: Collaboration Between a Researcher and Industry Partner

This section explains how PL framed a research project with the Barwon Water Alliance, its partners and contractors that developed into a collaboration that met the value propositions of both the industry partners as well as the academic (PL) participant. It also explains how the research that emerged from provided a segue for engaging with a new industry partner and line of inquiry. The relationship development process in alliance contracting can be drawn upon to describe the process of collaboration that can arise between a researcher and industry partner. The three phases of relationship development are (Davis and Love 2011):

1. *Assessment:* During this phase, an organisation identifies a particular need that they need fulfilling, and potential partners are identified. While the scope of the relationship at this stage lacks definition in terms of requirements and benefits, consideration may be given to potential resources and expertise. Judgments will be typically made on reputation (e.g. domain knowledge). During this phase, individual parties are not exclusively committed, and there is a limited degree of trust present.
2. *Commitment*: This phase is referred to as definition lock-in or exploratory. Negotiations take place and entail the bilateral communication of wants, issues, inputs and priorities. Common goals are essentially identified. While trust may not be principally at play here, there be mutual concerns about commitment. The relationship needs to reach a business friendship level, where norms that dictate standards of conduct are adopted.
3. *Enduring*: Trust is established. Parties become conscious of the project's definition, scope, their roles and responsibilities. Increasing levels of interaction occur, which enhance goal congruence and reciprocal adaptions (e.g. exchange of resources).

On completion of a project, the collaboration between researcher and industry partner often dissipates. But in the authors' experience, once a collaborative relationship is established with an industrial partner, its needs to be maintained, as there is a likelihood in the future that both parties could work with each again.

4.1 Preface to Collaboration

Having a sound understanding of theory and how it can be applied to a given context is a skill that is needed by researchers to be able to apply their knowledge effectively to practice. For over 20 years, PL has been conducting research in construction, particularly in the area of rework and its antecedents. It would be fair to say that PL has accumulated considerable knowledge about the nature of rework. The Barwon Water Alliance had been experiencing significant levels of rework in its projects, and DW had informed them of PL's domain knowledge in this area. An independent consultant that had been engaged by the alliance to facilitate an initiative entitled 'Rework Prevention Program' entered into a dialogue with PL explaining the change-management that had commenced to combat rework.

Funding had been provided to PL and colleagues by the ARC under its Discovery programme to investigate design and construction errors, and the subsequent rework that was is often required to rectify them. At this juncture, it should be noted that the acquisition of data is a challenge for researchers. In the context of rework research, often researchers do not consider the nature of data that is required from industry and its format. For many researchers' the default has been the use of a questionnaire survey to examine rework, then run some statistical analysis and provide a list of causal factors. Besides being unable to provide a context for rework causation, the same causal issues are repeatedly identified. What is more, the costs of rework reported from surveys are only 'guesstimates' as organisations seldom, if at all, quantify them. The absence of a context for rework studies has stymied an ability to understand how it manifests and the ability to create new knowledge. In sum, it is well known amongst practitioners that rework occurs in construction projects, but little is known about this phenomenon—it is a *zemblanity* (i.e. making unhappy, unlucky but expected discoveries by design) (Love et al. 2019).

After numerous conversations between PL and the independent consultant over several months where ideas and experiences were exchanged about how to address 'rework' in the project, a rapport was established. On making the consultant aware of PL's ARC Discovery research, an invitation was made to present preliminary findings and observations from the study to the Barwon Water Alliance and its contractors. Naturally, PL accepted the invitation as there was a desire to learn from what had been implemented in practice to address rework. The visit of PL to Barwon Water Alliance set the scene for a fruitful collaboration that enabled a new line of inquiry and the unearthing of new managerial issues that had been used in the *practice* of procuring construction projects.

4.2 A Willingness to Learn and Share Knowledge

The first step in solving a problem is to recognise that one exists. The alliance had arrived at the realisation that reworks had been adversely impacting the performance of their projects. If they continued on the same course, without making changes to practice, then significant delays and cost overruns would be incurred. The recognition that a problem existed reverberated throughout the alliance. There was desire and drive to address the issue at hand. The willingness of organisations that formed the alliance to jointly work together to engage in the process of change (i.e. Rework Prevention Program) was based by a virtue system of ethics, grounded in Aristotle's *Nicomachean Ethics* (Burger 2008), that had been underpinned and espoused by the leadership team. Here the virtues of ethical conduct, integrity, and moral character were brought to the fore within the alliance team and promoted to their contractors. The authenticity of the alliance leadership team engendered a best-for-project mindset to flourish and therefore for trust to be established and a commitment to change to be enacted.

The alliance leadership and management team commenced its change management initiative midway through the project's contract period. Simply put, procedures, processes, and KRAs as well as culture were re-engineered to ensure the alliance's projects achieved positive outcomes. The change initiative aimed to shift its mindset from a position of being *performance goal-oriented* (i.e. fixed mindset) to one of being of a *learning goal orientation* (i.e. growth mindset). The alliance's established growth-mindset enabled them to create an openness and willingness to learn from one's errors and those made by others. The result is that the alliance was able to move from a position from *errors can and need to be prevented* to one where *errors happen*. Of note, rework had been predominately materialising from errors and violations, though in some instances changes in scope result in it being performed. The aim of the change initiative was for the alliance to learn not from success, but the experiences of individuals and teams involved in the delivery of its projects. With a change process championed by authentic leaders engaging in a coaching process, individuals and teams were encouraged to continually ask questions and learn about how to reduce and contain rework. A detailed exposition as to how the Barwon Water Alliance was able to enact the shift from a fixed to a growth mindset can be found in Love et al. (2016a).

The Rework Prevention Program had already been enacted before the PL's involvement in the alliance. However, PL was aware through discussions with the consultant about what had transpired. Considering the invitation to visit the project and cognisant of the need to acquire data, PL offered to examine the alliance's experiences and provide a pathway for others to learn from what had taken place. During PL's initial visit to the Barwon Water Alliances office, separate meetings were held with the teams responsible for the design, construction team, safety quality and environment, supervision of construction and the alliance's leadership. Workshop examples of the knowledge sharing and experiences of rework in projects and how contractors proposed ways contain and reduce its occurrence can be seen in Fig. 1. Additionally, PL visited sites and worked with site management to capture rework related issues. The purpose of these meetings was for them to explain and describe the scope, process and outcomes of implementing their 'Rework Prevention Program'. It became evident, after the first meeting, that what had happened within the alliance was the pinnacle of 'best-practice' in construction. Having been working in the area of rework for 20 years or so, PL had never read, heard and seen such an innovative approach to addressing rework. Listening to the narrative presented by the alliance's teams provided PL with an opportunity to learn from actual practice.

Rather than drive an agenda and question, when engaging with a potential collaborator for the first time, researchers need to listen, understand and digest the problem that is confronting practice. Listening may be a challenge, as some researchers may let their ego get the better of themselves by espousing their domain knowledge and capability to the industry partner. Researchers may overlook the actual purpose of a meeting; that is, to address the partner's problem rather than their own. Iterating this view from another angle, an industrial manager involved in Sannö et al.'s (2019) research cogently stated '*From an academic perspective, it can be more interesting when things are not working than when they are. In industry, we don't find that interesting, only frustrating*' (p. 37).

Requests from the researchers for the industry partner to fund a project is ill-advised during the early stages of the relationship-building process (i.e. the assessment phase). Building trust between the researcher and industry partner is critical in the relationship-building process. It is, therefore, essential for the researcher to demonstrate to their industry partner that they can deliver positive outcomes and provide them with confidence in their abilities. The researcher needs to familiarise themselves with the requirements of the industry partner and the format of the data that may be necessary to undertake the research. Having access

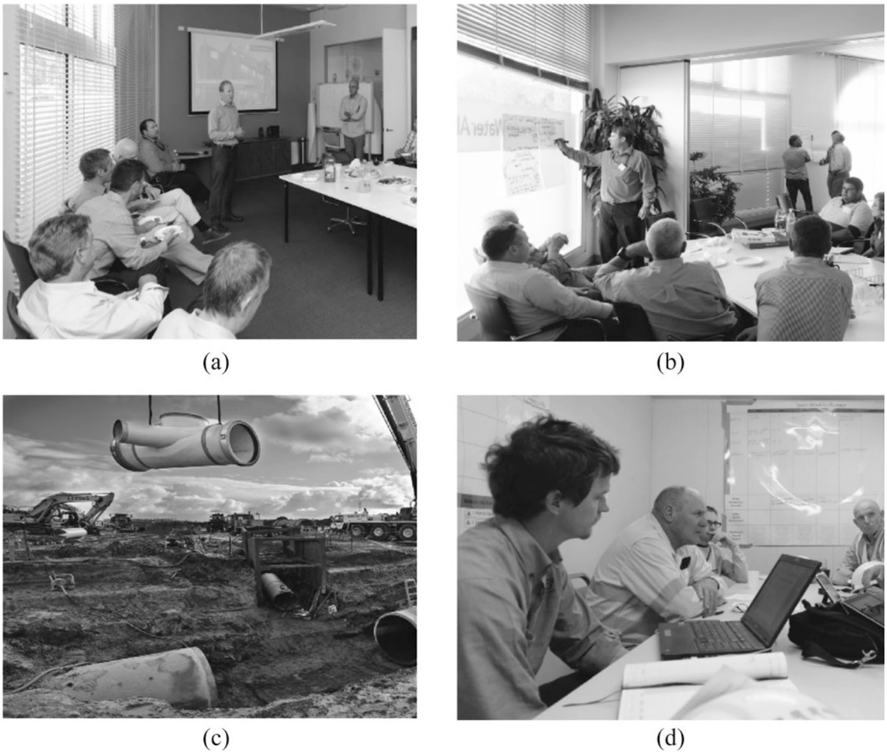

Fig. 1 Collaboration in practice. (**a**) Sharing of knowledge and experiences workshop. (**b**) Alliance and contractors developing solutions to address rework. (**c**) Pipeline project. (**d**) Knowledge sharing and capture on-site

to real data is akin to possessing a 'bag of gold' for academics, as it not only legitimises the study, but should a scholarly journal be produced, it may have a significant impact as the reported results lead to changes to practice.

The alliance's culture was committed to learning and sharing knowledge, and they were openly willing to communicate with PL their experiences with their Rework Prevention Program. The reciprocity of knowledge, as a result of several visits to disseminate observations and findings and to engage in open dialogue, between PL and the Barwon Water Alliance formed the basis of the collaboration that ensued (Fig. 1).

4.3 Relationship Maintenance

After several visits to the alliance and discussions with its contractors, and maintaining regular contact with its individuals, teams and organisations, PL sought permission to publish its experience with containing and reducing rework. The alliance agreed to provide PL access to data and its people. But, conducting research that is '*both practically relevant and scientifically rigorous, while also making a great societal impact, is a continuous challenge*' for researchers (Sannö et al. 2019, p. 37). Translating what had transpired within the alliance and creating new knowledge from which others could learn required meant they needed to be actively engaged in the research. It was, therefore, agreed a c*o-production process* would occur as trust, and a relationship had been formulated (Sannö et al. 2019). The role of the alliance was to provide PL with information to enable a narrative to be formed where consideration was given to (Coughlan and Coghlan 2002, 2008): (1) linking theory and practice, (2) capturing differences while sustaining collaboration and (3) managing the quality and ensuring the reliability of the data.

The goals of this phase of the collaboration were to generate new knowledge that would be of value to the construction industry, specifically highlighting the innovation, flexibility and value of using alliance forms of procurement. A shared understanding had been generated from the interactions and communication between PL and the alliance. Over 40 semi-structured interviews ranging from 45 min to 2 h were conducted to acquire insights into why and how rework occurred before the introduction of the Rework Prevention Program to capture its contextual backdrop. Then, interviewees were asked to describe the changes that take place and the effectiveness of this process. The interview data were supplemented with documentary sources (e.g. safety, quality, contract and financial) provided by the alliance and its contractors. While the data was collected and being analysed, communication remained between both parties continued to take place. Interviews were tape-recorded and transcribed. Then, the transcription was distributed to interviewees to check their accuracy, and also allow them to amend their statements. Draft working papers were prepared and distributed to the alliance for comment and review. These working papers were converted into jointly co-authored scholarly articles and with Barwon Water Alliance's permission were submitted to several journals for peer review and subsequently published including Love et al. (2016a, b, c).

4.4 Impact of Collaboration

The works that have emerged from the study of the Barwon Water Alliance have been able to provide a balance between rigour and relevance. The works have been able to breakdown the assumptions about the traditional unitary held view of rework and provide a more porous boundary between academia and industry. Thus, the research has made an impact as it has been (Antonacopoulou 2009):

I = *Influential* (technical, scientific and practical): Through the various papers that have been produced describing the managerial actions and processes that were implemented to contain and reduce rework new approaches are propagated. The alliance simultaneously embraced error management provided an environment for psychological safety to prosper, and implemented psychological contracts—these elements are typically missing from construction projects (Love et al. 2019). The alliance leadership has been regularly invited to speak at various industry conferences about their innovative work practices.[5]

M = *Memorable* (lasting experience, 'measurable' outcome): The alliance provided a lasting legacy to the community by constructing infrastructure to ensure there was a reliable supply of clean water. The alliance employed, trained and up-skilled local contractors. The behaviours and culture established by alliance were played-out by their contractors who openly reported errors and violations. The alliance identified that 40% of safety incidents have occurred during a rework event. This finding has stimulated research to examine the relationship between quality and safety. Furthermore, this discovery has contributed to the much-needed conversation about the status of quality in construction, which has been brought to the fore as a result the engineering failures associated with the Opal and Mascot Towers and Zetland apartments in Sydney.[6]

P = *Practical* (integrating knowledge about the practitioner): The research papers provide a narrative about what actually took place in the project. A theoretical framing was interpreted, and a collaborative process of co-production was enacted to ensure practitioners knowledge took centre stage in the interpretation of meaning derived from the analysis.

A = *Actionable* (connections based on authenticity): The frameworks of practice that emerged from initiating the 'Rework Prevention Program' were developed with an aim to tackle a problem that was adversely impacting not only the performance of projects but also safety. The alliance openly admitted it had a problem and took action to redress the issue—this was done cooperatively and collaboratively with its partnering organisations. The managerial actions taken within the alliance provide organisations with a legitimate avenue to confront the problem rework, which plagues construction projects.

C = Co-created (by learning to drive collaborations): Not only did the alliance create a collective learning environment within its project structure, but this also spread to its contractors (Love et al. 2015). As soon as an error incident occurred within a project, it was communicated to all contractors. Then, the alliance working with the contractor in the project where the error occurred, trued to quickly mitigate the consequences of any rework required. The alliance eschewed penalising contractors for committing errors, but instead encouraged their reporting in order to drive a process of 'learning through' (i.e. how to handle error) instead of 'learning from' a rework event by having in place error-correction mechanisms (Love et al. 2019).

[5]For example, at the LXRP Project (Melbourne) workshop held on fourth November 2018—Rework Hurts: https://vimeo.com/301757104/a32e3fdab0

[6]See https://www.abc.net.au/news/2019-07-10/sydney-apartment-block-evacuated-opal-card-facial-recognition/11293438

T = *Transformational* (create new questions and possibilities): The research with the Barwon Water Alliance has laid the foundation to challenge the conventional view of 'learning from' to 'learning through' errors. The approach was new for construction, and new lines of inquiry reside around its replication, particularly with other forms of project delivery method. Thus, a new question for researchers and industry to consider is whether an 'error management' culture can be created in a non-alliance environment?

The gap between rigour and relevance that often materialises from undertaking collaborative research stems from researchers distancing practitioners from the style and nuances of academic research (Kelemen and Bansal 2002). According to Chen et al. (2013), this resultant gap in the transfer and interpretation of knowledge lays in the inability or unwillingness of researchers to translate their insights into a vernacular that a practitioner can understand. Both PL and alliance were cognisant of this issue at the beginning of their relationship and thus strove to ensure a balance between rigour and relevance came to fruition.

4.5 From Little Things, Big Things Grow

If the research outcomes from a collaboration between academic researchers and industry result in having an impact, then the likelihood of further studies significantly increases. As a result of the research conducted at the Barwon Water Alliance, several leading Tier 1 contractors expressed an interest in an investigation into rework, particularly its impact on safety. Up until this point, there had been limited knowledge available about the interactions between quality and safety issues; contractors had paid limited attention to rework. A new collaboration between the researcher and an industry partner emerged. The work undertaken at Barwon Water Alliance was extended to examine the nature of errors and violations and their impact on quality and safety. Again, the collaboration resulted in the unearthing of new knowledge that was grounded in practice and meaningful outcomes for the construction industry in Australia. Several Tier 1 contractors have banded together to form their collaboration to examine how quality can be improved in construction.

5 Conclusions

This chapter answered the question 'How can academic initiators of collaborative research best shape their value propositions to meet both academic and industry value expectations?' for a specific collaboration involving two researchers who had collaborated in an alliance-style manner to write a book chapter based on research that both had individually undertaken with the same industry partner. They managed to achieve a value-adding outcome through their collaboration and understanding, the value proposition of the industry partner and not ‘hogging’ potential research work but carefully considering what might work best for their mutual industry partner. The outcome was a pleasant surprise for all parties. Both researchers met their own value propositions, initially, DW accessed valuable expert interview data for one ARC project that ended up developing the Collaboration Framework (Walker and Lloyd-Walker 2015, 2020) as one of several outcomes and through the interaction with Barwon Water and realising that minimising rework was a significant issue for that industry research partner, he was able to suggest that they consider PL’s work as a world expert in this area that was resident in Australia. Subsequently, PL met with Barwon Water, and this grew into not only a synergistic research project for PL and Barwon Water but also between DW and PL in writing a book chapter (Love and Walker 2020) based on PL’s research and DW’s detailed knowledge of the case study. Furthermore, PL has extended the research undertaken with Barwon Water to examining the nature of rework in a mega-transport project in Melbourne. Key elements that help explain the ‘how’ of this outcome derive from:

1. Making a concerted effort to understand the value proposition of parties involved in a collaboration (Table 1).
2. Taking the time, physical and mental effort to build trust and commitment between parties.
3. Adopting a ‘best-for-project’ alliance mindset when collaborating.

The chapter explains how a successful relationship between collaborating parties is fundamentally based upon these three elements. We acknowledge that other elements came into play, and the researchers had almost a quarter-century of history of interaction where tests of trust between them developed and were positive. Many readers of this chapter may not be fortunate enough to have built this level of social capital. However, we stress the importance of these three elements as providing a solid basis for shorter periods of interaction. Both DW and PL had only recently interacted with Barwon Water Alliance research partners over the past five years. Reputational (ability) trust was highly important but also by taking the effort to understand what they could offer and how they might meet Barwon Water Alliance’s value proposition as a key aim. This reinforced the benevolence and integrity aspects of trust and commitment followed in its wake. Case Study 2 illustrates the way that value for the industry partner emerged and how PL’s valuable publication opportunities were realised. This not only met the publication value proposition required of PL by his university and his own career needs, but it also provided new academic insights together with valuable guidance for practice.

One key aspect that we suggest is missing with many research collaborations is the alliancing ‘best-for-project’ mindset because often researchers may take a more transactional view of their relationship. The alliancing mindset allows for a deep exploration of value. Consequentially, unexpected positive co-creation outcomes are structured-in through the alliance mindset that emerges (Rowlinson and Walker 2020).

Finally, what can we generalise from this chapter? We believe that a key message is that every project and the working relationship starts with parties seeking to deliver some value or benefit. Shaping, or crafting, the way to do this requires us to first understand what value is expected to be co-generated and then, through collaborative dialogue, to shape and mould the plan with trust and confidence in each participant's commitment to delivering the expected project outcomes—rather than just achieving their part and gaining their best value from their interaction. Taking an IPD approach may provide a more effective approach for complex projects requiring shaping with manoeuvrability and allowing the emergence of serendipitous value that can more readily occur using a collaborative best-for-project mindset. Rather than endangering a situation where too many cooks spoil the broth' so to speak (Rese et al. 2013), an IPD mindset considers first 'what is best for this project?' and then works backwards from there using an emergent and dynamic strategy to provide the necessary resources and expertise. This was the approach to Case Study 2.

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Emergence of Governance Structure in Collaborative University–Industry R&D Programs

Roya Derakhshan, Gabriela Fernandes, and Mauro Mancini

1 Introduction

Interorganizational collaborative R&D programs between industries and universities are increasing (Ankrah and Al-Tabbaa 2015; Perkmann et al. 2011), and are being encouraged by governments as means of promoting innovation (Davey et al. 2018; Nishimura and Okamuro 2018). A study sponsored by the European Union to survey the state of university–industry cooperation in Europe shows that joint collaborative R&D is one of the main cooperation activities among universities and industries (Davey et al. 2018); other activities are student mobility, and commercialization of R&D results from the university. The study also shows that the main underlying motivations for academics to engage in joint R&D with industry are to gain new insights for research and to put in practice their research. In contrast, the motivations for collaborators from industry are to get access to new technologies and knowledge and to improve the industry innovation capacity (Davey et al. 2018).

University–industry collaborations (from now on UICs) are usually funded and named as "projects" by public funding entities, but often are organized by partners as "programs." A program is a set of projects whose objectives are strategically related and aimed at achieving a set of major benefits that are more than just the sum of the projects they consist of (Pellegrinelli 2011). Complexity and uncertainty are

R. Derakhshan (✉)
SDA Bocconi School of Management, Milan, Italy
e-mail: roya.derakhshanalavijeh@sdabocconi.it

G. Fernandes
University of Coimbra, CEMMPRE, Coimbra, Portugal
e-mail: gabriela.fernandes@dem.uc.pt

M. Mancini
Polytechnic University of Milan, Milan, Italy
e-mail: mauro.mancini@polimi.it

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attributes of collaborative programs (PMI 2017a). Programs require a specific way of thinking, more tolerant of uncertainty, closer to change, and more aware of business influence (Pellegrinelli 2002). The time of program completion is generally greater than of a project (Pellegrinelli 2011).

A UIC program can be defined as a temporary organization with a collaborative work environment, within a specific context, with heterogeneous partners, collective responsibilities and, in most cases, with public funding support (Brocke and Lippe 2015). Bruneel et al. (2010) argue that one of the main barriers to effective UIC governance lies in the fact that organizations are guided by different incentive systems, based on motivations and self-values that sometimes lead to a conflict of interest. However, UICs are increasingly based on the principle of symbiosis. Each collaborating partner has highly differentiated inputs since the individual capabilities of the industry as well as the expertise of university researchers cannot be simply transferred. UICs provide a set of advantages that contribute to the common and individual interests of the university and industry stakeholders involved, as well as to the interests of society in general (Ankrah and Al-Tabbaa 2015).

During the lifetime of UIC a program, dynamics are created among the organizations involved, namely related to knowledge transfer, which has impacts on organizations of the consortium that may go beyond the objectives of the ongoing program, resulting, for example, in further projects to explore other ideas (Manning 2017). However, as open innovation might compromise secrecy, which might be required by the industry partner, a careful balance between open and closed innovation practices might be needed during the project lifetime (Du et al. 2014). These, and other challenges that emerge in UICs, particularly due to the different nature of the organizations involved, lead to the need for adapting the governance mechanisms, such as the governance structure.

Governance is an area receiving greater attention in project management research (Sanderson 2012). Whenever two actors engage in an economic transaction under high uncertainty and with unequal access to information, they face the problem of how to monitor and control the collaboration, protect the interests of each party, and reach the most efficient outcomes (Williamson 1981).

Creating and maintaining sustainable value for the organization and its stakeholders requires a good governance structure (Ruuska et al. 2011). The lack of a rigorous governance structure is considered as one of the most likely causes of project failure (Marrewijk et al. 2008), in projects of all sizes, particularly in large-scale projects (Patanakul 2014). Governance structures are designed to ensure that projects run smoothly (Miller and Hobbs 2005). We can categorize governance structures into three different typologies: governance bodies as hierarchies (Müller 2009); governance bodies as nested systems (Too and Weaver 2014) and; governance clusters around a Project Management Office (PMO) member network (Aubry et al. 2012). Musawir et al. (2017) argue that effective project governance enhances project success and enables the realization of strategic objectives. However, governance in the particular context of inter-organizational collaborations appears scarcely discussed in the research literature.

Among all available definitions for governance, in this chapter, we adopt the definition of governance introduced by the OECD (2004). Governance is defined by the structures required to develop the objectives of the organization, the means of achieving those objectives, and the means of monitoring progress. According to OECD (2004), there are four principles involved in good corporate governance: *transparency* (e.g., accurate and timely disclosure of information); *accountability* (e.g., clear understanding of roles and rights); *responsibility* (e.g., task execution within the standards of the society); and *fairness* (e.g., moral and ethical principles). Biesenthal and Wilden (2014) suggest that several existing definitions of project governance share the view that governance is mainly concerned with the alignment of project objectives with organizational strategy. However, to achieve a creative and proactive synergy between UICs, the focus should also be given to managing relationships between roles and organizational units (Child 2005).

Governance is shaped at the different levels of the organization and within its context. Turner (2014) explains that governance is structured at the organizational level, project level, and project management level. He adds governance of capability and governance of program and portfolio as the contexts influencing the project governance structure. Derakhshan et al. (2019) illustrate how the strategies are transferred between different levels of governance. Decisions made at the organizational level based on the strategic aims are then transformed into tactical aims for the projects at the project management level. They are then in turn operationalized to achieve the tactical aims at the project level.

The importance of the permanent or parent organization, as a contextual factor influencing the temporary collaborative organization, has been studied by several researchers (Crawford et al. 2008; Engwall 2003). However, the emergence of a governance structure, stemming from a permanent structure to support temporary organizations (i.e., projects or programs), has been overlooked in project governance literature. Studying this evolution, as the project proceeds, can be linked to contextual factors (as parent organization or governance principles) to highlight what processes undergo to force a governance structure to emerge from the parent organization. Studying this subject would be even more rewarding when there are more than one parent organizations involved in the governance, such as the UIC programs.

This chapter explores the governance structure emerging over the two first phases of the program life cycle, i.e., strategic planning and execution and delivery (King and Cleland 1997; PMI 2017b). We explain how and why governance evolves and what changes the program participants' experience in their roles and relationships. To support the points raised in the chapter, the authors draw on experience from a case study of the collaboration between the University of Minho and Bosch Car Multimedia in Portugal. This case study involved 44 individual R&D projects targeting the topics of product development, quality control, and production management. It was conducted over 6 years, from 2013 to 2018, with a total investment of more than 70 million Euros, involving more than 500 people, partially financed by the Portuguese government (further explanations of the case in Derakhshan et al. (2020)).

2 Emergence of Governance Structure

University–industry collaborators do not maintain a similar role in the governance structure during the two studied phases of the collaboration life cycle. There is no distinct border reflecting the changing of the roles and interactions among the program participants. Instead, all parties gradually change their roles over a time, which starts before the official commencement of the execution and delivery phase, i.e., during yet the strategic planning phase and finishes after the "funding contract" sign-off. We call this phase the "transitional phase" (see Fig. 1), and in the remainder of this section, we explain the changes that occur during this phase.

While the "funding contract" is the official cutting point between the two phases, the border between the strategic planning and execution and delivery phases is blurred. Before the "funding contract" is even signed, and so when the collaboration is officially in the strategic planning phase, the collaborating partners start negotiating the nature of the governance model and the possible emergence of the UIC program is progressively clarified to both entities. They begin to redefine the roles and responsibilities of each party, and also start adding more practical details to the governance model.

In the transitional phase, the PgPMO (Fernandes et al. 2020a) is gradually formed, by members coming from industry and university, to translate program strategies and project ideas into agreed projects. The emergence of the PgPMO is one of the most tangible changes during the transitional phase to fulfil several aims:

- Provide tools to support program governance, i.e., supporting the transfer of program goals into project goals that, according to the OECD (2004) definition, can be placed under the accountability principles.

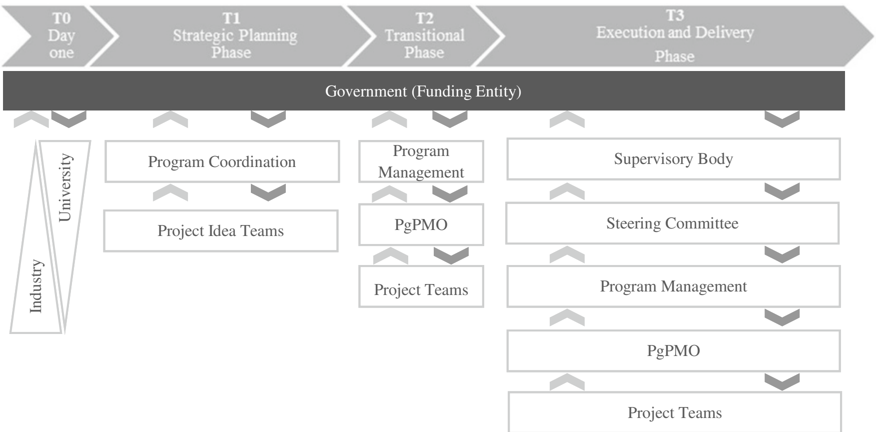

Fig. 1 Emergence of governance structure from the strategic planning to the execution and delivery phase

- Develop program and project management competencies through training, workshops and seminars. Referring to the work of Turner (2014) and Pemsel and Müller (2012), this can be linked to the governance of capability, where organizations adopt policies to collect, organize, and spread this valuable asset among different levels of the organization.
- Ensure mentoring and coaching on the use of the best program and project management practices, processes, procedures, and artifacts established in the program governance model. According to Gemünden et al. (1999), the acceptance of common norms, procedures, and interfaces shows high commitment, which is critical to partners be willing to continue investing their time and money to develop collaborative R&D.
- Develop and manage repositories that provide the relevant information of all past and ongoing R&D projects and provide knowledge management for the consortium. According to Eriksson and Leiringer (2015) developement and maintainance of a lessons-learnt database is one of the main seven functions of a PMO.
- Strengthen the bonds of trust between program members and facilitate the communication and social interactions among the participants. This aim is accomplished by stimulating research groups and communities within the projects. As argued by Zhong et al. (2017), interorganizational trust is developed not from calculation but from social interaction. Trust has been well-recognized in literature as a critical success factor of collaborative R&D projects, as shown by Gemünden et al. (1999), using a sample of European multi-partner research projects, the greater the trust of the consortium the more significant the project success will be.
- Create the "program charter" to support the project teams and the program management, by carrying out several specific tasks. The "program charter" works as an umbrella that defines and orients all of the projects, which work as wheels to achieve the program strategies (PMI 2017a). Following this step, the "project charters" are respectively defined following the "program charter."
- Facilitate the communication between different project teams and program managers, by promoting namely the use of social media tools. For more details on this topic, please see Fernandes et al. (2018).

Interorganizational collaborative programs involve many university researchers and industry collaborators with distinct expectations, experiences, and mindsets. These can hamper the program governance, as well as the stakeholder engagement and strategic alignment between both partners. Therefore, the PgPMO supports the program management to realize the value of the program, by improving project performance and achieving expected benefits and consequently developing long-term strategic university–industry partnerships (Fernandes et al. 2020b).

3 Findings

The governance structure of a UIC program is dynamic mainly in the last years where there is a growing emergence of all agile businesses. This is the most distinguishing characteristic for such context; change occurs over the program life cycle, and it provides us with new insights about this dynamic phenomenon. A new hybrid governance structure along the program life cycle emerges. The governance configurations appear at the conjunction of two collaborating parent organizations: university and industry, and taking into account a third one, the government (as a funding entity), which similarly, has the role of the sponsor in the governance literature.

At the program's strategic planning phase, the purpose is to do the right projects (Müller 2009), and the main mechanism of governance is based fundamentally on trust. During the execution and delivery phase, the purpose is to do the projects right (Müller 2009), and the main mechanism of governance is based on control. This change in the mechanism of governance induced changes in the governance structure of the program. In the following sections, we first discuss the drivers leading to this emergence in governance structure and then present an analysis of the subsequent changes imposed on the roles adopted by the participants.

3.1 Drivers of the Emergence of Governance Structure

Applying the four principles of governance (OECD 2004) for analytical purposes, we now explain why the collaborative governance structure emerges and changes during the two phases of the program life cycle: the strategic planning phase and the execution and delivery phase. More precisely, we discuss how the necessity or demand for the existence of new governance perspectives results in the emergence of new features. In the early stages of the strategic planning phase, the roles and responsibilities assigned to the stakeholders are not clearly defined. The tasks are therefore executed only in alignment with the demands of the context and the program. The emergence of projects calls for the emergence of governance at the project level followed by the definition of new roles, rights, and responsibilities (OECD 2004; ISO 2017).

This demand initiates the emergence of the transitional phase between the two official phases of the program. The main task of the introduced transitional phase is to address project demands by clarifying *accountability* and *responsibility* and achieving *transparency* and *fairness*. While these four governance principles exist from the initial phases of the collaboration, as the projects emerge and PgPMO comes into play, their nature must be adapted to fit the recently evolved governance structure.

Due to the evolution that takes place during the transitional phase, at the project level, the governance principles become settled, and its structure matures. That is, the flow of information among the stakeholders becomes smooth and transparent, the roles and rights of project participants (including the leaders) become clearer and the tasks of the project, embedded in the whole program, are defined according to the program goals.

During the transitional phase, the program management takes responsibility for task execution in line with the standards established at the end of the strategic planning phase. The aim is to attain the program's target values in different aspects such as improving program performance by being loyal to the iron triangle of time, cost, and scope, providing and promoting transparent and open communications among the program stakeholders, governing the participants' capabilities and finally strengthening the collaboration by fostering further joint initiatives in the future.

The program management team particularly plays an important role in the transitional phase. During the "funding application" submission and "contract funding" negotiation, the program management team is responsible for improving the communications by adopting the role of leading interlocutor. By achieving the project and program benefits during the execution and delivery phase, this team facilitates the collaboration. Government, as the second collaboration facilitator, frames the collaboration through legislation and policies (Seppo and Lilles 2012).

The project teams emerge to take the responsibility of project task execution per the approved "'funding application." The PgPMO is responsible for ensuring the *transparency* of activities in the projects by managing the flow of information between the projects and the program management and the top hierarchy at the corporate level.

During the execution and delivery phase, the steering committee is assigned to be *accountable* for the program execution and delivery, and the supervisory body is entrusted with the task of assuring *fairness* between the university–industry partners. In case of conflict between the university and industry, the supervisory body involves a third external and neutral body, which is the only actor with the responsibility of solving disputes between the representatives of the consortium.

The following dominant principles of governance drive the emergence of governance configurations (Fig. 2):

- *Fairness* is the driver for the establishment of a supervisory body, which is responsible, namely to ensure fair decisions made between the two partners.
- *Transparency* is the driver for the emergence of PgPMO, which is responsible for the accurate and timely disclosure of information at both the program and project level.
- *Accountability* is the driver for the creation of a steering committee, which is responsible for the clear establishment of roles and responsibilities among the program stakeholders.
- *Responsibility* is the driver for the creation of a formal program management team and project teams, which are, respectively, responsible for the execution of tasks to ensure program benefits realization and the execution of activities to ensure achievement of project outputs.

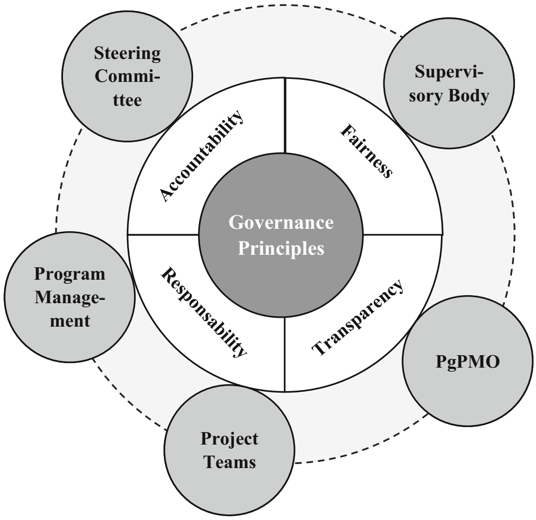

Fig. 2 The dominant governance principle driving the emergence of governance configurations in UIC programs

3.2 *Outcomes of the Emergence of Governance Structure*

The roles and relationships adopted by different program participants change with the emergence of the governance structure. We discuss these changes as the outcomes of the process of the emergence of the governance structure. As governance structure evolves due to newly emerging demands, changes also occur in the roles and relationships adopted by different participants of the collaboration. These discussions are summarized in Table 1.

At the earliest stages of the strategic planning phase, the university, industry, and government participate in a partnership collaboration to decide about the scope of the program and to develop its planning. Therefore, the three participants adopt a partnership type of relationship with the mutual aim of selecting the right project. Here, the definition of "partnership," follows the one suggested by Müller (2009) as the mutual endeavour to achieve goals.

However, this does not necessarily mean that the balance of authority is evenly distributed among the three partners. While the industry has more power to decide about the cancellation of some project ideas that were originally submitted in the funding application, the university simply collaborates in the development of those project ideas or in choosing the right projects (with more potential for scientific contribution). Nevertheless, government or funding agency is the final decision maker regarding the selection of the right project.

Table 1 Different types of interactions among collaboration participants along the program life cycle

Interactions	Strategic planning phase	Transitional phase	Execution and delivery phase
University–Industry	Partnership	Partnership/ Serving	Serving
University and Industry—Government	Partnership	Partnership/ Serving	Serving
Industry–University	Partnership	Partnership/ Directing leadership	Directing leadership
Government–University, Industry, and Program Management (Coordination)	Partnership	Partnership/ Directing leadership	Partnership/ Controlling
University and Industry–Program Management (Coordination)	Directing leadership	Directing leadership	Directing leadership/ Controlling
Program Management (Coordination)–University, Industry, and Government	Serving	Serving	Serving
Program Management (Coordination)–Project Teams	Serving	Directing leadership	Controlling
Program Management–PgPMO	Not existing	Controlling	Controlling
PgPMO–Program Management and Project Teams	Not existing	Serving	Serving
Steering Committee–Program Management and Project Teams	Not existing	Not existing	Directing leadership/ Controlling
Steering Committee–University, Industry, and Government	Not existing	Not existing	Serving
Supervisory Body–Steering Committee and Government	Not existing	Not existing	Serving

During the strategic planning phase, program coordination serves both the university and industry organizations and the project idea teams. The program coordination receives directions from a partner to support the project activities to reach the program's goals.

The stakeholders involved at the beginning of the strategic planning phase are limited to university, and industry participants plus program coordination and subsequently, the governance is limited to the corporate level (Müller 2017). In the strategic planning phase, the project idea teams emerge, and so the governance at the project level is also added to the governance structure.

As the collaboration proceeds, the majority of the partners enter into the transitional phase with their previously adopted roles during the strategic and planning phase. But these roles will gradually change, and before entering the next phase, they will have new settled relationships.

Moving along the transitional phase, the role of industry and government decline more toward a leadership type of relation, rather than a partnership, where leadership is defined by Robbins (1997), as directive leadership. Governance makes decisions about the projects and directs both the university and the industry. It leads program management, while simultaneously is a partner to them for negotiations about the contracts. On the other hand, the university role moves away from partnership toward serving the industry. Serving role here is defined as operating as a service organization for the collaborating partners (Müller et al. 2013). During this period, the project idea teams need to be changed into project teams, and accordingly, the main purpose moves from doing the right project to doing the projects right. In this way, decision-making shifts its focus to day-to-day project decisions rather than on choosing the projects to address the collaboration aims.

In the transitional phase, the government gradually gains more controlling power. Program management maintains its serving role toward government, university, and industry. But as the PgPMO emerges and the project ideas shape into projects, the program management controls the PgPMO.

During the transitional phase, the PgPMO takes responsibility for some of the project leaders' tasks to reduce their workload and additionally allow them to benefit from the accumulated expertise and economies of scale. It can be argued that the main reason behind the existence of PgPMO is the development of a mature governance structure. As Aubry et al. (2010) elucidate, the PMO's function to develop and implement standard methodologies, processes, and tools are the most relevant pattern identified for PMO transformation in organizations. However, during execution and delivery phase the PgPMO also has some functions and responsibilities of monitoring in some specific circumstances the achievements of the project teams, since the PgPMO has to support the program management, and periodically report the status of the overall program to the government (funding entity). The government has a controlling role of the overall funded program while the PgPMO maintains its serving role (Fernandes et al. 2020a). In summary, during the transitional phase, an evident change in the relations from partnership and serving toward leadership and controlling is observed.

At the beginning of the execution and delivery phase, the steering committee and a supervisory body emerge. The steering committee has the leadership, as well as the controlling for the entire consortium. Therefore, all of the collaborators inside the consortium receive directions from the steering committee, while the committee itself serves the three main partners. In case of disagreement between the university and the industry, the supervisory body serves alike the steering committee and the funding entity (government).

4 Conclusions

This chapter delved into the emergence of the governance structure during the strategic planning and execution and delivery phases of the program life cycle. We looked at the emergence of governance structure through the demands of governance principles and the influence these changes had on the roles and relationships between the program participants.

The study showed how governance structure is dynamic and changes over the program life cycle. This emergence, however, does not happen abruptly when the program life cycle phases occur. The transition is gradual over a certain period, and hence a transitional phase between the strategic and planning and execution and delivery phases was introduced. This transitional phase fades the official distinction between the two phases mentioned above. During this transitional phase, the PgPMO emerges, program coordination evolves to become a more established program management role, and the project leaders are assigned as long as the project ideas are replaced by projects. Extending the governance structure to the project level and defining the governance principles for the new stakeholders and recent collaboration structure.

The transitional phase prepares the required governance principles for the execution and delivery phase and project deployments, highlighting the salience of the four governance principles proposed by OECD (2004): *accountability*, *responsibility*, *transparency,* and *fairness*. These four governance principles are seen as the drivers for the emergence of the governance configurations in UIC programs (see Fig. 2), resorting in practical recommendations to successfully establish governance principles in UIC programs.

The temporary organization of the collaboration inherits its governance principles from two separate parent organizations, i.e., the university and the industry. This means that many of the roles, relations, contracts, task executions, and principles must be defined for the first time in such a context. Interorganizational collaboration programs demand more sophisticated and carefully defined governance structures than conventional programs. This calls for the emergence of the transitional phase between the two official phases and highlights the importance of the role of the PgPMO in collaboration's ultimate success. Finally, it is worth mentioning, that although formal governance mechanisms, as the here discussed PgPMO, has an important role in achieving program's benefits; informal governance mechanisms, such as trust is also critical to success (Gemünden et al. 1999). Governance mechanisms of the consortium gradually transformed themselves from control-oriented toward trust-oriented (Derakhshan et al. 2020).

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Open Innovation Alliances in Technology Colonies

Ronnie R. Rego

1 Introduction

As knowledge progressively assuming a broader distribution character, companies are forced not any longer to rely solely on their own research. The conception of *open innovation* describes that, instead of creating the best ideas, market leaders will be the ones who make the best use of internal and external ideas (Chesbrough 2003). The systematic circulation of ideas is the role assigned to universities, integrating key partners to enable innovation.

This concept finds a unique value in the early phases of a project scope proposition. During the ideation process, potential partners openly discuss and disseminate needs, ideas, and demands among themselves. As a spark, individuals in the same round are encouraged to add valued technical inputs, structuring a project with the enhancement of a combined intellectual contribution. The potential of joint funding enables ambitious project scopes, turning research into a business opportunity. The open discussions shorten the track for disruptive proposals by at least two efficient ways: (1) the ideation phase demands less time to achieve a matured scope and (2) unattainable deliverables become feasible by a collective budget.

The benefits of open innovation are highlighted when considering that the conventional process applied by companies to generate innovation is conducted primarily as an "on-demand approach." Task forces are organized to innovate usually when a technical challenge appears, as an abrupt change of the market share is imminent, or when a financial action is mandatory. Once the process is implemented, companies are hard pushed to allocate this dedicated staff back to activities directly related to productivity (Kelley 2009). As a result of the lack of

R. R. Rego (✉)
Aeronautics Institute of Technology (ITA), São José dos Campos, Brazil
e-mail: ronnie@ita.br

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human resources, knowledge management becomes a gap in the sustainability of innovation in the industry.

For both perspectives, the main advantage of open innovation is observed as the *improved efficiency of resources* to convert an idea into an ongoing innovative project. It is especially in this light that *low-wage countries* should treat open innovation as a mantra. Under the circumstances of limited resources, it means a feasible alternative on their intention to play a leadership role in the global scenario.

On the other hand, these countries are the shelter for the lowest levels of cooperation between university and industry. According to the current UNESCO database (United Nations Educational, Scientific and Cultural Organisation 2019), the private contribution over the Gross Domestic Expenditure in Research & Development (GERD) is lower than 46% in India, Mexico, South Africa, and Brazil. Meanwhile, in Israel, Japan, China, Switzerland, and the United States at least, 70% of GERD is funded by the business sector.

The gap between the Academy and the industry is the basis for defining a *technology colony*. Along with the product lifecycle management in highly developed countries, technology is smoothly progressed from basic research toward production and sales. On the same lifecycle progress curve for low-wage countries, though, there is a valley just after basic research: the region of the applied research. The insufficient transfer flow from university to industry interrupts the lifecycle, preventing a locally conceived technology to become an innovative product. The Colony expression derives from the natural consequence of this insufficiency, that is, the dependence of the technological sector of these countries on the innovations provided by the wealthier ones (De Wet 1999; Buys 2001, 2004; Kachieng'a 2009; Osunyomi et al. 2016).

Working under the model that defines the technology colony can be translated into innovation numbers. When analyzing the worldwide patent applications per GDP registered between 2007 and 2017, none of the four countries mentioned to have weaker financial links between industry and university appears in the top 20 list. On the other hand, high-income countries are predominant on the list of the top 20 origins (World Intellectual Property Organisation 2018).

This macroeconomic behavior is also reflected in industrial dynamics. Karabag (2019) analyses the failure cases of industrial firms in Turkey, another country in which currently less than 50% of GERD is funded by the business sector and is not ranking within the top 20 list of patent applications per GDP. The study approached political instability, national technology development policies, and the firms' technology management, among others. The firms' insufficient capability in learning and developing technology is the core conclusion to explain their failure. As the identity of a technology colony, the local industries are highly vulnerable to political and external effects.

Another register indicating that open innovation is not established in technology colonies can be observed in Brazil, where the case study of this chapter originated. In 2000, one of the largest research public funding agencies in Brazil launched a program to promote the creation of consortia among universities and industries. A modern frame for its time encompassed the basis of what was not yet widely known as open innovation. In almost 20 years, however, only four proposals were granted, being the last one in 2004 (*Fundação de Amparo à Pesquisa do Estado de São Paulo* 2020). Further analysis allows identifying that the created alliances were all structured to execute a specific research project. None of them was designed for project prospection, approached here as a featured recipient of the advantages offered by open innovation for low-income countries—the improved efficiency of resources.

The approach of Brazil as a technology colony is not a concept uniquely proposed by this article. In public speeches, two of the latest Brazilian Ministers of Science, Technology, and Innovation assigned Brazil this classification (Agência Brasil 2011; Pereira 2015).

The presented context reveals a gap in which the benefits of open innovation show not to overcome the uncertainties on its implementation. As a demonstration of its feasibility within the specific frame of technology colonies, the chapter approaches a strategy proposed for implementing an open innovation alliance in Brazil. The model was developed over the successful *Engrena ITA* case, with the segment of gear technologies in Brazil. It explores how several companies can be joined, moderated by the university, for prospecting new technologies in a society with a nonestablished mindset for applied research.

2 Modus Operandi and the Implementation Strategy

The Brazilian gear sector is responsible for the production of over 100 million gears per year, applied to industry segments such as automotive, aeronautics, wind energy, and sugar and alcohol (Schulhouser 2016). Despite the diversity of applications, these segments share similar challenges for innovation and demand for technological solutions. They claim for more productive teeth cutting processes, improved strength against fatigue failures, more cost-effective materials, lubricants for reduced power losses, among others (Schulhouser 2016; Goldstein 2018).

The conclusion from the observations about the similarity of demands in this sector, which is a requirement for open innovation implementation, engendered the conception of the initiative "*Engrena ITA*." Launched in July 2017, the effort is an *alliance between organizations to improve research prospections and disseminate knowledge* about gears and power transmission systems. The initiative is managed by the gear-dedicated research team of the *Aeronautics Institute of Technology* (ITA), a public higher education institution in Brazil. Sharing benefits and responsibilities among its members, *Engrena ITA* assumes the integrative role defined by the open innovation concept. Systematically circulating ideas, it integrates the key partners to facilitate innovation. It joins the Academy, the Brazilian gear industry, public funding agencies, other research institutions, and their partners.

2.1 Sharing Benefits and Responsibilities

The Engrena ITA key concept is to systematize actions for research prospection. The partners commit themselves, through an adhesion contract, to be regularly in contact with the organization staff and to be present in the promoted events. It replaces the conventional on-demand approach, in which communication between representatives of the Academy and industry is due to the advent of production problems and particular technical challenges.

The work meeting called "Reunião de Trabalho" (RT) is the most critical interaction moment among affiliates and is held semiannually at ITA facilities. The RT is a working meeting that provides members with a top attractive benefit: the possibility of defining research directions for the gear-dedicated research staff of ITA. Over an RT, the members are encouraged to expose their technical challenges and demands. The natural consequence of bringing the entire gear production chain together is the broad spectrum of topics considered to be investigated. The main goal of an RT is, therefore, to define a priority list of research topics. After stimulating directed discussions, a voting session occurs, and each company has the same voting rights, independent of its size, history, or origin.

At this point, the topic is still on a high level, needing to be further explored to become a project scope. Audio conferences, held within a month after the RT, join the potentially interested members. These conferences aim to collect detailed information and members' expectation to facilitate the convergence of the project scope generation. The topic discussion takes several perspectives, such as state-of-the-art, application, accepted simplifications, and risks to the execution.

The outcome of the audio conferences is a map of demands that supports the iterative action of defining an objective, the potential partners, and a business model for the project. These definitions are interrelated. The goals and business model are intrinsic to the expectations and limitations of the members that, at this stage, already declare interest to invest in the project execution. The map of demands systematizes how to identify the members with the higher chances to become a project partner. But as a usual project acquisition process, these main scope features derive from the project stakeholders.

The selection of partners within a consortium frame exposes two particular challenges. The first one is to deal with companies offering different possibilities of contributions for the same project proposal. Usually, financial funding and in-kind contribution are proposed by large and small-sized companies, respectively. The management of Engrena ITA determines no restrictions. However, the initiative encourages the funding members to accept, as project partners, the members offering their economic and intellectual capital, rather than possibly needing to approach them as suppliers. The difference in the mode of investment will be reflected in the discussion of the intellectual properties of the project. The second challenge involves the possibility of having competitors willing to be partners of the same project. Once again, Engrena ITA does not determine a rule for this scenario. In this specific point, the context of a technology colony has to be respected. If the mindset of cooperation

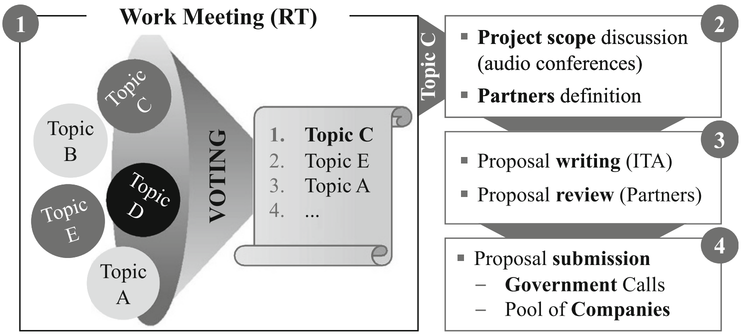

Fig. 1 Prospection procedure of the alliance *Engrena ITA*

between university and industry is already not widely practised in these countries, lesser will it be among competitors. In this light, the management of Engrena ITA understands that, for these first projects, the efforts should be concentrated on developing partnerships with companies throughout the production chain. In the future, after the experience of these first consortia reveals its value to the entire group, partnerships, including competitors in the same project, will also be stimulated.

Engrena ITA members have the benefit to draw the basic scope of the project. But from this point on, companies that are not engaged in the initiative can also be brought on board, proposing scope refinements. The external involvement is enabled by the *modus operandi* structured for research prospection. As soon as the proposal becomes a project, the results will be shared only with the partners of the specific project. Once they are confirmed, ITA researchers or a partner institution lead the project proposal preparation. Depending on the scope content, the proposal is submitted either to government calls or to a pool of companies.

The entire procedure illustrated in Fig. 1, is a direct projection of the co-creation concept (Osunyomi et al. 2016; Matsumae, Nagai 2018). Once a common goal is defined—the prioritized research topic—intersubjectivity is brought by the tacit and explicit knowledge of different individuals along sequential interactions to converge in the project proposal.

The association of several companies brings the first impression of an ordinary consortium model. However, the described concept has a differential that should be highlighted. Its main objective is to systematize a project *prospection* of projects. Instead of conducting the research itself, it brings the members together, as a voice of the entire segment, to define what should be researched from that point on. Therefore, a unique research objective with a fixed schedule and defined deliverables is not the objective of this initiative. It is a continuous mechanism of creating project proposals, enhancing the chances of the gear industry to be granted with resources that will be converted into innovation and thus global competitive leadership.

To stimulate the adhesion of many companies, further benefits are offered to members. Nonconfidential state-of-the-art material is shared, technical seminars are held, and technological workshops allow the demonstration of experimental and virtual solutions. At the same time, these activities characterize an environment of continuous networking among members and expose the students of the research staff for the potential recruitment of qualified human resources.

The engagement of new members is also on the agenda of the RT. Before each meeting, the ITA research staff collects the applications of the candidates. They basically need to state how aligned they are with the objectives of Engrena ITA. These statements are disclosed to the members attending to the RT, and a collective decision is taken. In case of divergences, the approval demands the consent of at least two-thirds of the members. The approved candidates are then able to sign the adhesion contract and take part in the following RT.

2.2 *The Phased Implementation*

Even proposing clear benefits from a more efficient model of leveraging resources, *Engrena ITA* had to be planned within the specific circumstances of a technology colony. The context presented in the introduction chapter indicates that the overall society of these countries hardly perceives the economic value of collaborative work between universities and industries. In this light, a smooth implementation composed of three phases was the strategy drawn (Fig. 2).

The "Phase 1," also called the *pilot plan*, was the experimental moment along the initiative's first year. The companies that show long-term communication with the ITA's research team were especially those that attempted to become members of the initiative. Based on a well-established level of trust, they were more willing to assume the role of developing the alliance together. This phase was designed and

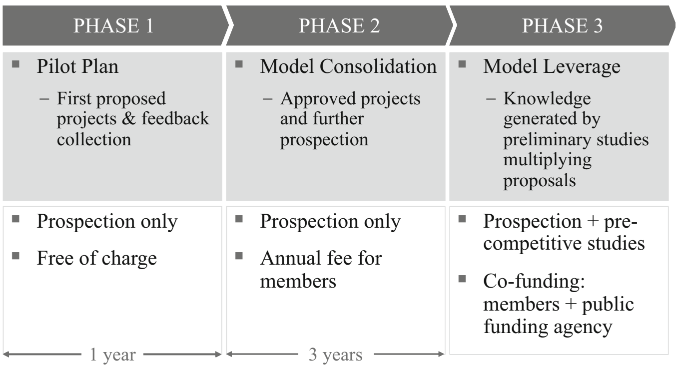

Fig. 2 The phased implementation used as a tool for consummating the alliance in a technology colony

submitted without the members making any financial contribution, hence, with mitigated risks of getting affiliated. Also, the legal amendments were created upon the directive of reduced bureaucracy. Also, the legal design was created on the goal of reduced bureaucracy. A short three-page letter of intent, exposing the aim at building *Engrena ITA*, was individually signed by each of the members.

Planned since the pilot plan, the "Phase 2" was structured to turn *Engrena ITA* into an *economically sustainable model*, based on membership contribution to financial support. The first phase's investments were the base to define the annual fee, which was, above all, shared and agreed with the associates of the pilot plan. Improved benefits were added as ideation dynamics now organized on hands-on activities, such as dynamic behavior tests and manufacturing demonstrations. The creation of a dedicated communication channel was possible, and more ITA research collaborators were involved to speed up the projects' proposition step. The legal communication vehicle, an adhesion contract, was based on the first one. Now, for a period of 3 years, it embraces, through a foundation to support research, the contractual clauses of the financial contribution.

The actions for a sustainable innovation system collect the central attention along with *Phase 2*. A straightforward analysis of the direct staff involved against the number of prospected projects leads to a potentially excessive workload in the short term. It derived the action on strengthening the involvement with the research partner institutions. Instead of only making part of the presented projects, they are also inserted in the position of main agents of the proposed ideas. A similar action is now being prepared to allow *Engrena ITA* members the lead position. The arrangement is to distribute the lead position from ITA, maximizing the initiative efforts to engender further new project proposals.

The continuous adhesion of new associates, and the reliability inspired by the first results, culminated in an incremental diversity of topics discussed throughout the RT's. The increased complexity of technologies under discussion became the next challenge: the demand for the technical background has risen together with the expectation of more ideas becoming projects. The approved projects in the previous two phases certainly increased group knowledge. However, in the short term, this continuous prospecting mechanism demands the incorporation of a new background. From the need of constantly creating this technical background to new proposals was derived the strategy of implementing the "Phase 3."

The organization gets closer to the possibility of start producing research results in addition to the project's prospection. The central differential of *Phase 3* is to *complement prospection activities with general and short-time projects execution*. Although being of execution character, they reinforce prospection. The concept is to perform feasibility studies enriched by tests and quick investigations, which will create a robust database to feed the forthcoming project proposals and to enhance the chances of granting.

The activities planned for this strategy certainly boost the expenses of the initiative. Again, under the perspective of a technology colony, a straightforward increase in the annual fee would have found resistance among part of the members. At the same time, this structure has recently gathered the attention of a public funding agency in Brazil, from which the systematic innovation model was of interest. To afford this next step for *Engrena ITA*, a co-funding proposal was then applied to the agency. The proposal, currently under assessment, basically consists of obtaining public funding equivalent to the budget leveraged by all members.

3 The Alliance Characterization Through the Experienced Results

Engrena ITA has concluded the first phase, and it is now operating the Phase 2 and the application above described denotes the preparation for the third one. This initiative managed to bring together 24 companies at the end of the first phase, and it was already composed of 21 members when the second phase completed a year. They represent the entire production chain, including tooling manufacturers, raw material and lubricant developers, gear and transmission factories, and OEM's. The profiles of the engaged companies are also heterogeneous. The members include small to large-sized enterprises, originated in Brazil and multinational ones. Regardless of the dimension of the company, *Engrena ITA* is structured to ensure the same rights are provided to each member.

Across the 2 years since the launch of Engrena ITA, five RTs were organized. As a result, and due to the parallel benefits offered, 22 project proposals prospected. They generated proposals submitted to the government, bilateral cooperation projects, and consortia. Altogether, the projects involved 44 organizations, 34 from Brazil, and ten from abroad (Fig. 3). Almost all of the members joined at least one proposal. Once part of the proposals assumes a consortium frame, the smaller sized companies usually get involved with an in-kind contribution, while the financial budget tends to be managed either by governmental funding or directly by the larger companies. As a comparative basis, the results cumulated in 2 years are twice higher than the ones summed along the 6 years before the creation of *Engrena ITA*.

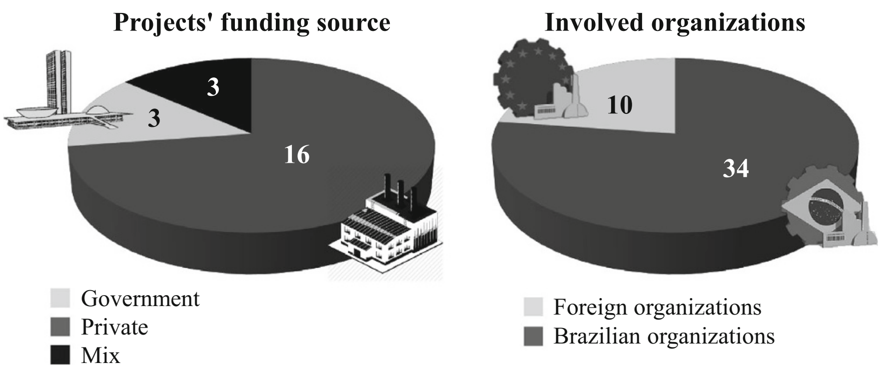

Fig. 3 Results collected after 2 years since the launch of *Engrena ITA*

The initiative's performance can also be highlighted in terms of approved projects. From the 22 proposals, five were accepted and already started. This number reveals that, in 2 years, the ITA research staff dedicated to gear technologies was engaged in the same quantity of industrial projects than in the period of 6 years before the launch of Engrena ITA. The metric can be even amplified since eight proposals are still in discussion. The missing nine ones were already declined.

These results must be interpreted simultaneously with one of the worst economic crises in Brazil (Oliveira and Coronato 2016). It struck the industry to one of its deepest recessions throughout history. A 4-year period of reduction in patents' application translates the immediate consequence to research investment in the country (World Intellectual Property Organisation 2018). The crisis, however, has indeed become the right opportunity. The conventional models of collaborative research, such as bilateral cooperation between university and industry (The United Kingdom 2003; Bagno et al. 2017), proved not to be sustainable in the new scenario. If innovation was still the chosen alternative to survive in the market, an open innovation alliance brought the chance of levering resources.

Under this point of view, the results show that the key-issue on the lack of innovation might not be over the availability of resources. A low-wage country will not be fated to be a technology colony if organizational efforts are *efficiently* addressed toward improving the transfer flow from basic research to the technological matters demanded by society. As stated by Kachieng'a (2009), technological entrepreneurship is in the roadmap to global leadership, demanding innovative technology, and skilled human capital. In this direction, the intellectual and financial contributions in a collective frame are the strengths provided by the open innovation alliance.

Systematically organized to generate regular discussions, the alliance allows an organic interaction resulting in continuous innovation. Replacing the inefficient on-demand collaboration between university and industry, it works as the basis for the incubation phase of the DNA innovation concept proposed by O'Connor et al. (2008). It is assumed that discoveries in companies need to be isolated from their daily demands, so innovation can gain enough potential.

Among the research topics prioritized by *Engrena ITA* are proposals approaching residual manufacturing stresses, powder metallurgy, tooth coating, predictive maintenance, new materials, and additive manufacturing. Although centered on the application for gears, they require different competencies and technical background. The discussion among members representing different industry sectors enriches the ideation. A tooth coating proposal, as an example, arose from a member with coating experience in automotive engine components, together with the demand for higher durability in gear forming tooling stated by a member of the metalwork sector and the opportunity that a gearbox producer foresaw to improve torque efficiency in their products applied to wind power turbines.

On the one hand, a management effort has to be taken in order to follow this wide knowledge required. A collaborative network, with partner institutes, was the well-succeeded alternative of *Engrena ITA,* especially before *Phase 3*. At least five partners, local and foreign ones, are involved with the prospected projects. On the

	HELPFUL	HARMFUL
INTERNAL	**S** ▪ Regular discussion on technological demands ▪ Shared intellectual contribution speeding up ideation (co-creation) ▪ Resources leverage for disruption	**W** ▪ Demand on wide technical background ▪ Collective involvement of legal departments
EXTERNAL	**O** ▪ Economic crisis ▪ Trend of integrated complex technologies	**T** ▪ Hesitation of potential members to a innovative model ▪ Development restrictions of multinational members

Fig. 4 Strengths, weaknesses, opportunities, and threats of implementing an open innovation alliance in a technology colony

other hand, as the demand for more integration by complex solutions becomes a trend, different technologies are progressively combined into a single research project. This trend gives the open innovation alliance an advantageous feature in comparison to the conventional bilateral models.

If sharing stands for strength on the technical and financial sides, attention must be given to the legal aspect. At every point in which formal documentation must be provided, the alliance has to deal with multiple partners' long-time demand. By linking large and small companies, the legal departments' disparity is noticeable. Moreover, for balance to exists, isonomy is demanded. This additional time has to be accounted for on the project proposal management since its beginning. Negatively, now in the external perspective, the implementation of the alliance can become so innovative to the mindset of technology colonies, that hesitation on potential members may be resultant. That is accentuated within multinational companies, whose branches frequently face a lack of autonomy during the development of new products or solutions.

Once the objective of this is chapter to approach the implementation of an open innovation alliance in a technology colony, the identified characteristics were summarized in a matrix of strengths, weaknesses, opportunities, and threats (SWOT), Fig. 4.

4 Conclusions

An industry sector historically characterized by similar technological challenges for widely different applications, suddenly involved with a deep economic crisis, engendered the launch of *Engrena ITA*. Conceived on the open innovation basis, the alliance deals with the non-established mindset for applied research of the Brazilian society. This particularity, featuring the technology colony concept, was the focus approached along with the chapter. Its *modus operandi* and the phased implementation provided the experiences for characterizing this specific cooperation model.

The alliance for innovation prospection on gear technologies brought together representatives of the entire production chain, encompassing companies with a supplier–client relationship, but also competitors. In 2 years, the 22 prospected projects, involving 44 organizations from Brazil and abroad, represent the success of a model to overcome funding limitations for research and innovation. The positive metrics are complemented by members' enthusiastic feedback statements, stimulating the model to be applied to further technologies rather than gears and even out of engineering.

The open innovation alliance demonstrates its strengths through collective intellectual and financial contributions, as well as a systematic connection between university and industry. In a technology colony, they prove to be essential on the goal of resource efficiency to convert an idea into an innovative project. The organization showed to overcome the importance of resources available for innovation, indicating a feasible roadmap to unlink low-wage countries to technology colonies.

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Part IV
Collaborative Project Management

Challenges in Managing Large-Scale Collaborative R&D Projects

Ana Correia Simões, José Coelho Rodrigues, and António Lucas Soares

1 Introduction

Companies are usually embedded in networks of actors, which some use to support the development and commercialisation of innovations. This phenomenon has different designations, such as open innovation (e.g. Chesbrough 2003) or innovation network (e.g. Lee et al. 2016). Large-scale integrating collaborative projects—LSICP—(in Portuguese called '*Innovation mobilising projects*') are research and technology development projects aiming to produce research results that address a wide range of challenges in a given economic sector. They are carried out by a large consortium including research organisations, sectorial clusters (an articulated network of companies), sectorial technology centres (non-profit organisations that support technically and technologically the cluster of companies of specific sectors), technology providers and end-user companies, resulting in a considerable amount of innovation produced for a specific sector. The sponsoring programmes provide mixed-funding schemes to these consortia to undertake strategic projects of R&D which aim to create or improve new products, processes or services with high technological and innovation content. They should improve the whole value chain and should be configured as focal points that foster scientific and technological competencies, inducing significant impacts at a multisectoral level, enabling the development and exploitation of new technologies.

Managing these projects involves clustering strategies or other collective dynamics through partnerships and cooperation actions. Due to the multidisciplinary and

A. C. Simões (✉)
INESC TEC, Porto, Portugal
e-mail: ana.c.simoes@inesctec.pt

J. C. Rodrigues · A. L. Soares
INESC TE and Faculty of Engineering of University of Porto, Porto, Portugal
e-mail: jpcr@fe.up.pt; als@fe.up.pt

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cross-cutting nature of competencies involved, a large-scale integrating collaborative projects should be disaggregated in sub-projects, which, as a whole, should contribute to a general common purpose. These sub-projects should bring together the several complementary capacities and be structured around specific, coherent and complementary objectives. Project management of an LSICP poses significant challenges due to size, multidisciplinary, and goals alignment. Coordination and collaboration are fundamental activities that ought to be properly managed to contribute to project success.

In this research, four different LSICPs (LSICP 1, 2, 3 and 4) are analysed. LSICP 1 and LSICP 2 were run in parallel, they had several partners in common, and had significant synergies. These two parallel projects took place between 2011 and 2014. In 2017 a new LSICP took place, LSICP 3 to provide continuity to the previous two. Since these 3 LSICP share several synergies and some common partners, they are analysed as a single case (Case 1). The other LSICP studied in this research is LSICP 4, which started in 2017 and will finish by the end of 2020. This fourth LSICP is analysed as the second case study (Case 2).

The traditional models in innovation management have focused on development projects of durable goods within large companies with R&D departments (Salerno et al. 2015). These models do not support innovation projects with a high degree of complexity and uncertainty as those that involve several and different types of partners in a collaborative approach that aims to impact the whole sector. Du et al. (2014) and Munkongsujarit and Srivannaboon (2017) argued that this environment calls for new models, tools and management techniques. Therefore, our contribution consists in identifying and characterising a set of relevant challenges and how they were overcome in projects involving partners with different cultures and expectations.

This chapter is structured as follows. The second section refers to the state-of-the-art section for collaborative projects. The third section presents the research methods and explains the methodological procedures. In the following section, the cases are introduced. In Sects. 5 and 6, the main results are presented. The final section refers to the main conclusions.

2 State of the Art

Collaborative projects fit within the open innovation paradigm (Chesbrough 2004), since collaboration, in this context, is a means to co-creation. Such projects face numerous challenges due to the complexity that emerges from having several and different types of organisations involved. The first challenge is the consortium formation. Individuals play a particularly important role in the formation process, as that is mostly a relational process where built-up trust is crucial (Holzmann et al. 2014). Therefore, learning dynamics and stabilising teams of collaboration among organisations from one project to subsequent projects is important to form trust and completely integrate new ideas into an established series of projects (Manning

2017). Moreover, during the project, a careful balance might be needed between the use of open and closed innovation by organisations (Du et al. 2014), as secrecy is compromised by open innovation, and might be necessary for some developments of each organisation of the consortium (Munkongsujarit and Srivannaboon 2017). These, and other challenges that emerge during collaborative projects, are usually managed using appropriate project management tools (Munkongsujarit and Srivannaboon 2017). However, some adaptations might have to be made in comparison to the standard formal project management approach, as loosely management practices tend to lead to better performance of science-based partnerships (Du et al. 2014).

Due to the specific needs of collaborative research projects, managers often use 'learning by doing' to develop a working set of project management practices and tools for each project (Barnes et al. 2006; Calamel et al. 2012; König et al. 2013). Practices to manage the high complexity of LSICP include: orchestrating dialogue between the right people, at the right time, about the right issues; guiding collaborative meaning-making to align key stakeholders; drawing on practical wisdom and judgement to progress complex project challenges; developing a range of power sources, and sensing a pathway through power dynamics; and negotiating project success for key stakeholders based on a broad concept of value (Floris and Cuganesan 2019).

Leadership capacities for project management are critical for successful projects. There is a high degree of complexity to be dealt with in a project of this nature. This complexity is due to high levels of uncertainty and risks, lack of partners cohesion, dependencies on many subjects and interconnected sub-projects, a broad range of interfaces and project needs, individually oriented project personnel, heterogeneous project partners located at different regions, and significant pressure in terms of creativity and innovativeness (Barnes et al. 2006; Calamel et al. 2012; König et al. 2013). This complexity makes leadership capacities even more crucial. Therefore, orchestrating dialogue between the right people, at the right time, about the right issues, guiding collaborative meaning-making to align key stakeholders, drawing on practical wisdom and judgement to progress complex project challenges, developing a range of power sources, sensing a pathway through power dynamics, and negotiating project success for key stakeholders based on a broad concept of value, are some capacities that project leaders have to develop to lead with this complexity (Floris and Cuganesan 2019). According to these authors, the results of this study contribute to project leadership by building an argument that these transitions can be seen as manifestations of an increase in capacity to deal with cognitive and emotional complexity, rather than as simply the development of competencies or skills. Due to the specific needs of collaborative research projects, managers often follow the 'learning by doing' principle and develop a working set of project management practices and tools for each project (Barnes et al. 2006; Calamel et al. 2012; König et al. 2013).

3 Case Studies

We followed an inductive research design, using a multiple case study (Eisenhardt 1989; Yin 2018). The primary unit of analysis was the large-scale integrating collaborative project. As case research allows detailed, in-depth empirical descriptions, it provides a suitable research design for examining and clarifying the type of complex processes that we face in this research (Yin 2018). Moreover, using diversified case studies and solid literature support, we were able to gather insightful scientific data to analyse and constructs to extract, as suggested by Eisenhardt (1989).

Two cases corresponding to four large-scale integrating collaborative projects were selected, using a criterion-based convenience sampling. These projects were/are running in Portugal and in the manufacturing context. Projects were selected based on the previous experience and knowledge of the research team, selecting projects led by colleagues (researchers) with extensive experience in participating in similar projects. The following two sections describe the case studies and the data collection and analysis.

3.1 Description

Case 1 involves two complementary projects (LSICP 1 and LSICP 2) plus a follow-up project (LSICP 3). LSICP 1 (2011–2014) aimed to research, design and develop new product-services systems that would be offered by companies belonging to the cluster for this sector of activity. This project was divided into six sub-projects and involved 40 partners. LSICP 2 (2011–2014) aimed to research, design and develop new technologies, advanced processes and innovative business models for the production technologies industry. This project was structured in four sub-projects and involved 19 partners. LSICP 3 (2017–2020) involved 49 partners and aimed to provide a comprehensive response to the development and implementation of new production systems. This project integrates eight sub-projects. A new project was prepared and submitted, scheduled to begin in 2020, in order to follow-up the LSICP 3. This new project will have 37 partners. In this case, one of the project promoters is the sectorial cluster and the other a sectorial technology centre.

Case 2 involves a single project, LSICP 4 (2017–2020), and addresses the areas of innovation, qualification and internationalisation. According to the strategic plan defined by the cluster for the activity sector, the project aims to drive innovation in the sector and in the internationalisation. In particular, this project aims to improve knowledge and develop the following areas: materials and parts and advanced technologies, new concepts and solutions to recover the production and post-consumption waste. This project is composed of a consortium of 32 companies across the product value chain, nine of which are R&D institutions, with multidisciplinary and complementary research competencies. This project is

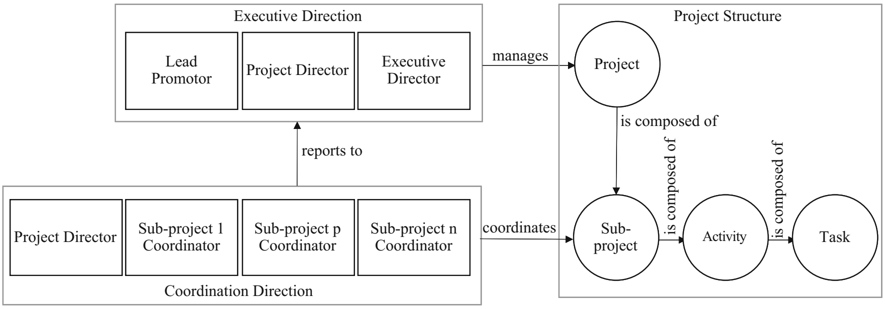

Fig. 1 Project governance, management and structure

breaking down into four sub-projects. In Case 2, the project promoter is the sectorial technology centre and there is no cluster partner involved. The role of the cluster in Case 1 is played by the technology centre (TC) in Case 2.

In both cases there are four types of partners involved in the consortium with different roles: clusters and TCs that are the project promoters, R&D institutions (Research Centres and Universities), with research competencies, technology developers (TD) and industrial companies (ICs) or technology end-users.

In Fig. 1, the project governance, management and structure are illustrated. On the left side of the figure, it is possible to see that an Executive Direction and a Coordination Direction together constitute the Project Direction. In this type of project, the Lead Promotor is always an IC. This governance structure is common to all four projects. The exception is LSICP 4, where the Executive Direction only presents a Lead Promotor and a Project Director, that is, in this case, the TC. The right side of the figure represents the project structure: the project is divided into sub-projects, each sub-project is composed of several activities, and each activity can have several tasks. The link between the right and the left side of the figure explains that the Executive Director is responsible for managing the project as a whole and that the Sub-project Managers with coordination functions (Coordinators) manage and coordinate the sub-projects activities and tasks. Moreover, for each sub-project, there are partners defined as Activity Managers and Task Managers.

3.2 *Data Collection and Analysis*

We conducted 11 retrospective semi-structured interviews in order to obtain different perspectives and cross-check responses to factual issues. Interviewees were selected based on their role in the project, experience with similar projects, and ability to provide information about the relevant challenges of collaboration and management from previous projects to consecutive ones concerning project and innovation management practices. They were also selected in order to ensure

Table 1 Interviewees characterisation

Interviewee ID	Case #	Partner role	Interviewee function
I1	1	Cluster (TC)	Executive management functions
I2	1	Technology centres (TC)	Project Director with coordination functions
I3	1	R&D	Sub-project Manager
I4	1	R&D	Activity Leader
I5	1	R&D	Activity Leader
I6	1	Industrial companies (IC) or technology end-users	Project Manager at the IC
I7	1	Technology developer (TD)	Project Manager at the TD
I8	2	Technology centres (TC)	Project Director with coordination functions
I9	2	Industrial companies (IC)	Lead Promoter and Sub-project Leader
I10	2	R&D	Activity Leader
I11	2	R&D	Activity Leader

including all the types of partners involved in this kind of project. Table 1 presents a brief characterisation of the interviewees.

The interviews were based on a protocol organised after familiarisation with each of the projects. Before each interview, the interviewee was asked to sign an informed consent. The interviews were recorded and transcribed using appropriate analysis software. Only one interviewee declined to have the interview recorded. In that case, the interview was conducted with the participation of two researchers, the collected data were cross-checked, and a report was written immediately after the interview, increasing the accuracy of the data collection process.

The analysis was divided into two stages: (1) within-case analysis, selecting and organising the relevant data and searching for within case patterns, and (2) cross-case analysis, searching for cross-case patterns (Eisenhardt 1989). We started the within-case analysis with a fine-grained reading of the data (Corbin and Strauss 2015). For each case study, as a result of within case pattern matching, a partially ordered meta-matrix was built (Miles et al. 2014), assembling descriptive data from each of the cases in standard formats to facilitate both the within and the cross-case analysis. These matrices associated summaries of the data from each interview to each topic under analysis (collaboration creation and management), organising the data to simplify pattern matching. Data were explored iteratively, going back and forth between the qualitative data and theoretical arguments (Corbin and Strauss 2015). Then, for each case, a report bringing together and organising the collected data was written and reviewed by peer researchers. The previously created matrices served as a database for the cross-case analysis and ensured the reliability of data collection by helping to minimise observers' biases (Yin 2018). Data were then analysed using interpretation together with narrative synthesis. The purpose of the synthesis was to identify higher-order concepts and to provide a larger narrative and generalisable theory on the creation and management of large-scale integrating collaborative projects. That purpose was achieved by compiling, conceptualising and reinterpreting the data while preserving its original integrity and wholeness.

4 Collaboration Creation

Data from the interviews provided the necessary information to identify and characterise the most relevant challenges for creating and managing the collaboration in LSICP projects involving partners with different cultures and expectations. In the current and the following sections, the challenges and how they were overcome are described in detail. Two important areas were highlighted during the data analysis: collaboration creation and management.

The process of creating collaboration is similar in the two cases (Case 1 and Case 2). This process took a long time (several months) and was divided into three stages.

For the first stage, the technological centre (TC) and the cluster invited the ICs to present project ideas for the sector that they would like to see addressed in the long-middle term, a kind of wishlist. The consortium to be formed should embrace companies in all the sectors' value chain. Regarding this process, some aspects were highlighted by interviewees:

- Some ideas from ICs are excluded from the project, as an interviewee Activity Manager explained: '*there were ideas that had to be left out because they no longer had a place in the project's rationale or because of the project's budget constraint*' (I10) (did not contribute for the development of all sector, which was one of the conditions to be accepted on the project). Furthermore, sometimes the ideas proposed by the ICs are too focused on the short-term challenges, which are not the scope of these projects (Case 1 and 2).
- ICs are selected based on previous experiences of work with R&D institutions (experiences that are not documented but rather lie on institutions as a tacit knowledge transmitted among its employees) (Case 1 and 2). Moreover, the ICs maturity, in terms of adoption of advanced technologies in the production process (digital maturity/technology leadership), as well in the well-succeeded participation in previous innovation projects, also influences the selection (Case 2).
- R&D institutions are selected to the consortium based on their research competencies and the contribution to the project objectives (Case 1 and 2). These competencies should be complementary.
- New partners for the follow-up projects (Case 1), mainly R&D partners, can be selected to the consortium whenever new competencies are needed to respond to the project objectives.

In the second stage, a rationale for the project is created by the TC promoting it and the R&D institutions based on the ideas collected in stage 1. For the Case 1, this rationale was created in order to be also aligned with the priorities defined by the European Commission for the area where the project fits (advanced manufacturing and processing) and with the technological roadmap previously developed for that same area by the cluster (which also evolved with the results of these projects).

Finally, at the third stage, the rationale developed in the previous stage is then presented to the whole consortium and discussed to reach an agreement on the project objectives and to define the topics to address, creating sub-projects inside the collaboration project to address each topic. For this stage, specific concerns were referred by the interviewees of Case 1:

- One concern is related to ensure that each sub-project included partners from the whole value chain. Including partners from the whole value chain from the beginning of the consortium also ensured a better match among partners involved in the project.
- This third stage started with the whole consortium/partners in a single meeting, which caused a lot of confusion among partners, as expectations were very different. This problem was overcome by conducting further meetings, specific with a few groups of partners at a time (each group related with a specific topic), to collect their needs and refine the purpose of the respective sub-project. As mentioned by a Sub-project Manager with coordination functions (I3): '*shortcuts provide bad advice!*'. These projects create an opportunity for other partnerships in emerging among the partners involved.

After this stage, the TCs and R&Ds partners were able to write the project proposal for funding. According to the project director from Case 2 (I8), '*the preparation (writing) of a good proposal is critical for the success of the project*'. This interviewee indicated some critical aspects of this stage: preparing a good state of the art in order to have resulted in the project that will improve the current knowledge, frame the project objectives and goals to be attained in order to include objectives for all the sector/industry, detailed the sub-projects objectives to engage the ICs, the objectives should be defined in order to be realistic (attainable), the project activities definition should be aligned with the goals aimed, and finally, clearly identify the resources needed to execute the project activities. The ICs' involvement in the early stages of the consortium creation and proposal writing will increase their commitment with the project objectives (Case 1 and 2).

ICs' partners are the most difficult type of partner to involve in the project. They accepted to be part of the consortium due to the expected value that the project would bring to them, typically because that value is aligned with their strategy and interests (Case 1 and 2). Some ICs that already have experience with working with other partners were easier to involve (Case 1 and 2). However, the short-term focus of ICs management makes their involvement difficult, as the results of these projects are expected to benefit ICs in a longer-term (Case 1 and 2). In the case of R&D institutions, some of them see their participation as a way to test and validate ongoing innovations in a real context, and at the same time, to create a network of relationships to define new challenges, and brought new ideas to create new technologies in the future (Case 1).

In the context of Case 1, the first project created was too ambitious (aimed results only with high TRLs—Technology Readiness Level) and involved too many partners (each investing a lot in the project and collecting very few results from it). These were lessons that were used for the following projects proposed: the balance between results with different TRLs improved and the planned results are increasingly closer to the final results of the project; the number of partners also decreased (also due to restrictions of the consecutive calls), mainly from LSICP 3 to the one that was recently submitted, trying to decrease the number of challenges faced during the project execution and increasing the benefits that each partner may take from the project, making the project and the investment involved more appealing.

Following on from Case 1, the articulation between sub-projects also increased in the consecutive projects, increasing the integration of results presented and the impact in the sector. Concerning the places to demonstrate the results while in the first projects the consortium (particularly the cluster, the technology centre and the R&D institutions) convinced some users of the technologies (ICs) to demonstrate their use in their premises, it became clear during the project that ICs were not interested in opening their premises to show the results of the project as that would also expose more information about the IC, particularly to competitors. Therefore, in the latest project proposed and submitted, a new form of an institution created in the country (Portugal), collaborative laboratories, CoLabs (which join ICs and R&D institutions in a formal laboratory), became the places to demonstrate such technologies.

These LSICP projects had to be formally led by an IC. From the experience of Case 1 partners, the choice of that IC also progressed from project to project, and in one project, the leader went bankrupt, creating serious problems for the project. In the following project, the leader was chosen to be a robust and solid IC that reduced the risk of having a similar problem considerably.

The process of creating collaboration is very similar in these two cases, possibly because some of the partners involved in the governance of the respective projects are the same. The creation, structure and management of these projects are very much influenced by the R&D institutes, which are pretty much the same in every LSICP. In both cases, during collaboration creation, an overall concern was focused on orchestrating a dialogue between the partners of the project, that would allow the project to function. Interestingly, both cases created the collaboration following a specific process composed of three stages, evidencing different challenges and interesting strategies used, once again very aligned among the two cases. It emerges that learning by doing is a common practice while creating these collaborations and that concerns of secrecy among partners (related with intellectual property protection) emerges not only during the project execution but also already in this stage of creation of the collaboration. Table 2 systematises the findings from the two cases, after cross-validation among cases.

Table 2 Collaboration creation challenges and strategies to overcome them

Challenge	Strategies
Collect new ideas from partners	Create a call for ideas
Select ideas to include in the project	Define criteria for selection Select ideas based on the criteria defined
Create a rationale for the project	Align expectations of partners Align rationale with the strategic direction of development defined (externally) for the sector Draw on practical wisdom and judgement of the project directors (promoters)
Reach agreement within consortium about project rationale	Align the interests of partners with project rationale, improving the engagement of ICs Negotiate success indicators for the project with partners Structure of the project to best contribute to the sector
Learning-by-doing with situations of conflict among partners while creating the collaboration	Adapt the arrangements of meetings for the third stage of the collaboration creation to be able to collect contributions and avoid chaos Involve partners in writing the proposal to build commitment/engagement Use different approaches to involve partners in the project according to the different type of partner Adapt the collaboration structure (number of partners) and ambition (results ambitioned) Adapt strategy of articulation between sub-projects and of defining demonstration sites for project results
Overcome concerns of secrecy (Using ICs as demonstrator sites for the results of the projects could compromise their intellectual property (IP) and create uncomfortable situations)	Define impartial entities, such as formal laboratories that bring together ICs and R&D, as demonstration sites (CoLabs).

5 Collaboration Management

The level of complexity of these LSICP projects is similar to a European project. One sub-project manager of Case 1 mentioned (I3): '*The absolute value in terms of budget is very different, but the practical management is very similar*', although LSICP projects do not have such complex cultural differences to manage. The number of partners is similar, the number and type of interactions as well, the expected outputs, however, are different, as '*we can have more real impact on a sub-project than on a European project*'. '*European projects can be seen as cruise ships and these collaborative projects as cargo ships*' mentioned by the same interviewee (I3) when comparing both types of projects.

Several sub-projects require careful articulation among them, revealing big complexity in the management of these projects. This articulation is an important focus for the cluster and the technology centre (Project Promoters) of the project during the project, and for the managers with coordination functions of each sub-project as well (Case 1 and 2). This is where the promoters of the project become more visible. The executive board of the project ensures communication among different sub-projects.

Motivations and expectations management is a very important part of the management in these consortiums. The project director (the technology centre) has an exceptional role in that management, namely by its effort of visiting every partner several times during the project to assess their involvement, motivation, expectations and benefits from the project (Case 1 and 2). Some ICs require closer monitoring and follow-up than others. There is an effort by every sub-project Manager to identify those cases from the creation of the consortium and during the project to follow-up those cases in partnership with the director of the project (Case 1). Sub-project Managers have the freedom to manage the sub-project according to their favourite practices and using their favourite tools (Case 1 and 2). However, each sub-project manager defines their own collaborative methods and rules.

The R&D institutions have a lot of experience in managing these LSICP projects: this experience has been consolidated through the participation in past collaborative projects (Case 1 and 2). However, regarding IC, they do not have the knowledge, competencies or the resources for project management activities. The TC partner gave support in the project management activities. '*The TC has increasingly good competencies in managing this kind of projects, which decreases the complexity of this dimension of management for ICs*', as mentioned by one Activity Manager of Case 2 (I11), '*as they [TC] ensure total management in all dimensions of the project, with increasing knowledge, makes everything much more agile because they can meet almost all the needs that the ICs in the consortium have*' (I11). Therefore, one lesson learned was to improve the autonomy of the ICs in the project management activities. Although this effort, ICs are not entirely independent during the project execution, since a great part of the project management activities is made by the TC. However, the increased involvement of the ICs in the proposal stage, in particular during the project objectives definition, has been positive for increasing their autonomy and involvement during the project running.

Generally, it is important to keep monitoring the state-of-the-art for the several domains included in the project, to ensure that the technologies developed are still at the forefront of knowledge (Case 1 and 2). Moreover, sub-project managers may have to adapt the execution of the sub-project according to the response provided by the partners involved, as some partners are not available to invest more in the project or their focus and interest of participation in the project may change as the strategy of the IC is updated (Case 1).

One final, but special concern, is the management of the intellectual property (IP) created in these LSICP projects. This concern emerged during LSICP 1. IP rights and their use are defined by a general contract signed by every partner at the beginning of the project. However, that is not enough to avoid conflicts, as many developments are made during project execution. In those cases, the idea that each partner decides how to use their IP while making sure that does not infringe partners' IP becomes difficult to accomplish as the separation of IP among members is blurred. Some IP management practices are useful in these cases, which require previous concerns from the sub-project managers. Particularly, promoting the separation of IP among partners since the definition of tasks, as well as promoting discussions and facilitate consensus about the division of IP of the final results of each task. Moreover, it is important to ensure careful and detailed reporting of activities developed by each partner, and a careful selection of which partners participate in each activity or task, to ensure that only partners that contribute to the development of the result participate and may claim ownership of part of it. Finally, it is also important to prepare the exploitation/commercialisation of the project results after the project ends, and prepare technology users for possible needs of start paying for the use of technologies (such as software) that were free during the project running time (as the provider of that technology—software—was a partner of the project).

Once again, the process of managing the collaboration is very similar among the two cases, for the same reason as previously. In both cases, the most relevant focuses of management during the execution of the project concerned: monitoring motivations and expectations; managing different competencies and degrees of availability of partners; careful articulate the several sub-projects of the LSICP; ensure freedom for sub-project manager to follow their own management style; and, careful management of intellectual property rights and their use during the project and after the project. The only concern that was not shared among both cases was the last (IP management), which was an important concern for Case 1 but did not seem so relevant for Case 2. This might be because in Case 1, there was an experience with previous LSICP projects, which results already reached the market, and some problems related to IP emerged. With this experience, Project Managers became more sensitive to such concerns and more conscious about the strategies to carefully manage IP. Table 3 systematises the main challenges of managing these collaborations and the strategies used to overcome them.

6 Conclusions

Large-scale integrating collaborative (LSIC) projects aim to produce scientific results that address a wide range of challenges in a given economic sector. They are carried out typically by a large consortium including research organisations, sectorial technological centres, technology providers, and end-user companies, and have a significant impact on the technological innovation produced for a specific sector. A large number of partners, with different cultures, backgrounds and expectations, deemed to collaborate and coordinate activities between themselves to achieve sometimes contradictory scientific and innovation goals, make this type of project a rich case to be studied.

Still, the literature on innovation management has not given, so far, enough attention to this type of project as sources of new knowledge on collaborative innovation, as well as on the impact of collaborative project management in the success of innovation projects. In this chapter, we identified and characterised

Table 3 Collaboration management challenges and strategies to overcome them

Challenge	Strategies
Monitoring motivation and expectations of partners	Conduct regular visits between the Project Director and different partners. Sub-project Managers were alert to identify cases that might require closer follow-up and ensured such follow-up.
Manage different project management competencies from different partners	Ensure high support by the Executive Direction in bureaucratic tasks (those were IC have more difficulties, based on past experiences) and freedom in operational tasks. Adapt partners involvement (by Sub-project Managers) in each task as the project is executed, according to partners response (i.e. they sense the path dynamics of the sub-project and adapt its execution accordingly).
Articulation between interdependent sub-projects	Efforts/attention to guarantee careful articulation between sub-projects ensured by the governance structure of the projects (very similar in both cases). Strongly supported, facilitated and monitored by the executive direction of the projects
Complexity created by the diversity of types of partners involved and several sub-projects with different focuses contributing to the same project	Loosely management practices ensured by the executive direction, providing freedom for sub-project managers to manage the sub-projects using the practices with which they feel more comfortable
Management of IP rights (Case 1)	Signature of a general contract defining IP rights and their use by partners at the beginning of the project (although by itself it is not sufficient to prevent infringement) Promote the separation of IP among partners in task definition (by the sub-Project manager) Promote frequent discussions about the division of IP of the final results of each task (by the sub-project manager) Ensure careful and detailed reporting of activities developed by each partner (by the sub-project manager) Monitor participation by sub-project manager in each task, allowing only the participation of partners that contribute to the development and will, therefore, own part of the IP produced

relevant challenges and how they were overcome in an ex-post study of two cases, involving four LSIC projects. The insights from this study fall into two topics: collaboration creation and collaboration management. The challenges and the strategies to overcome them are systematised in Tables 2 and 3 of the previous sections.

Right from their inception, LSIC projects reveal important challenges: the iterative establishment of the consortium and the scientific/technological goals reveal marked differences in the individual strategy and interests. If research organisations and sectorial technological centres exhibit enough flexibility to negotiate, industrial companies (end-users), most of the times, limit this negotiation due to short-term priorities. Previous knowledge of the partners, by participation in previous joint projects or due to personal acquaintances, induce trust relationships that obviously lessen this problem.

We identified that the process of partnership creation is similar in LSIC projects and unrolls in three stages: starting with a small core number of partners, the proposal initiator presents the challenges and project ideas for the sector that they would like to see solved in the long-middle term; based on the ideas collected, a rationale for the project is created by the core group, and the further potential partners are identified; the rationale is presented to the whole consortium and discussed to reach an agreement on the project objectives and to define the topics to address.

Regarding collaborative project management, we learned that the level of complexity of LSIC projects is similar to a European project, although these projects do not have such complex cultural differences to manage. The number of partners is similar, the number and type of interactions as well as the expected outputs, however, are different and are deemed to have a more 'real' impact on a given sector of activity than a European project.

Collaboratively managing the motivation and expectations is quite a challenge in LSIC projects. The project director has an exceptional role in that management, namely by its effort of visiting every partner several times during the project to assess their involvement, motivation, expectations and benefits from the project. Some partners require closer monitoring and follow-up than others (particularly the ICs). However, the degree of involvement in the proposal stage, in particular, during the project objectives definition, has been positive for increasing their autonomy and involvement of the end-user companies (ICs).

IP rights are another challenging area of LSIC project management. Even if addressed by a general contract signed by every partner at the beginning of the project, conflicts always show up, as so many developments are made in the partnership. In those cases, the idea that each partner decides how to use their IP while making sure that does not infringe partners' IP becomes difficult to accomplish as the separation of IP among members is blurred. This also impacts the plans for the exploitation of the results.

With the findings of this study, we have now a richer picture of the challenges that must be overcome in the collaborative creation and management of LSIC projects. Together with the strategies to how those challenges were overcome in the cases analysed, we are now able to develop new models, tools and management techniques that will improve the efficiency and effectiveness of LSIC projects.

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Critical Success Factors in Collaborative R&D Projects

Jeffrey K. Pinto and Mary Beth Pinto

1 Introduction

Research on project Critical Success Factors (CSFs) offers a fertile and still-growing field of scholarship, with some of the earliest work going back 40 years. Indeed, one of the earliest writers on CSFs, Rockart (1979; p. 83) offered what, in many ways, remains the key explanatory definition of the concept, as he suggested that CSFs were:

- *'. . .the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organisation . . .'*
- *'. . . the few key areas where things must go right for the business to flourish.'*
- *'. . . areas of activity that should receive constant and careful attention from management.'*
- *'. . . the areas in which good performance is necessary to ensure attainment of [organisational] goals.'*

These ideas were expanded upon by Pinto and Slevin (1987) and Pinto and Prescott (1988), who introduced the ideas of contingency into the study of CSFs. That is, they noted that one of the criticisms of the broader interest in CSFs was the implicit assumption that they remained static: that once a set of activities or areas of managerial concern were identified as critical to project success, they remained of relatively similar importance throughout the project's life cycle. Their work demonstrated that not only are CSFs different across industries and project types but that the relative importance of CSFs varied over the stages of the project life cycle itself.

This chapter will address the nature of CSFs for collaborative R&D projects. As part of this discussion, it is necessary to expand our remit to make some observations

J. K. Pinto (✉) · M. B. Pinto
Penn State Erie, The Behrend College, Erie, USA
e-mail: Jkp4@psu.edu; Mxp49@psu.edu

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of the nature of project success—how we understand it, the various component elements of success, and some key challenges in evaluating project outcomes. Project success, on the surface, would seem a relatively simple idea and one over which multiple stakeholders (with their unique perspectives) would be able to come to an agreement. In fact, nothing could be further from the truth. The determination of what constitutes a 'successful' project is a complicated undertaking, as it involves a number of separate contingencies and must address a multi-participant perspective. Indeed, in the collaborative R&D project setting, success can be an even more complicated and opaque idea, as R&D projects often posit only vague or broadly defined expectations for outcomes. Thus, the question: 'Was this project successful?' may not be an easy one to answer and must be addressed from a perspective that allows for alternative viewpoints and multiple success criteria. In short, the answer to the question: 'Was this project successful?' is often a subsequent question: "'*Successful*' based on what criteria?"

In the nearly 40 years since the original work on project CSFs was undertaken, a great deal of work has continued to be published in project management journals on the topic, suggesting that the original scholars (including significant contributions by Peter Morris and Geoffrey Hough (1987), Jeffrey Pinto and Dennis Slevin (1987), and Andrew Boynton and Robert Zmud (1984)) were tapping into an important perspective that continues to spark researchers and practitioners alike. Our goal is to offer a perspective that is both historical (framed within the critical research that has been done) and forward-looking (identifying gaps in our knowledge and proposing directions for future work on the topic). Project CSFs are particularly important for both theory and practice because they frequently highlight points of leverage; that is, actions or elements of the project management process that, if performed correctly, can have an immediate and materially positive impact on the project and its likely outcomes. As such, work on CSFs is grounded in theory and action research perspectives.

We noted above that the project management literature frequently refers to two components of project success (Müller and Jugdev 2012):

1. Project success factors (CSFs), which are the elements of a project which, when influenced, increase the likelihood of success; these are the independent variables that make success more likely.
2. Project success criteria, which are the measures used to judge the success or failure of a project; these are the dependent variables that measure success.

The challenge, however, is further complicated by the canny observation regarding the need to parse project 'success' into its deeper meaning; that is, the recognition that success really operates on two separate planes: (1) project success and (2) project management success (Cooke-Davies 2002). In essence, Cooke-Davies argues that the criteria employed to assess the performance of the project management process are distinct from metrics of project success and any attempt to understand success must be able to separate these two interlinked but independent concepts.

In the following sections, we will address each of these ideas in turn. First, we will more thoroughly examine that nature of project success, both in collaborative R&D and more general project settings, and then turn to the topic of project critical success factors and how these two critical ideas are equally important sides of the same coin.

2 Project Success

> 'Project success is a topic that is frequently discussed and yet rarely agreed upon. The concept of project success has remained ambiguously defined. It is a concept which can mean so much to so many different people because of varying perceptions and leads to disagreements about whether a project is successful or not' (Liu and Walker 1998, p. 211).

In order to understand the nature of CSFs, it is necessary to first explore more fully the idea of project success. 'Success' is a term that has received a great deal of interest and analysis over the years, as researchers and project scholars try and make a clear distinction as to what constitutes a successful project. In fact, Pinto and Slevin (1988) noted that the problem is that efforts to identify project success are not clear cut and often lead to a fundamental misunderstanding about what the project is trying to accomplish as well as our ability to accurately gauge its ongoing status (during development) or the degree to which it was able to accomplish its objectives (at completion). In this section, we will examine the challenges with fully understanding the complex nature of project success, particularly in the way that several key (and sometimes mutually exclusive) measures are nested within each other. That is, the first challenge consists of establishing a hierarchy or prioritisation scheme that allows us to isolate each element of success with its own concomitant definitions and challenges.

2.1 'Success' as Defined by What Criteria: What to Assess?

Defining what we mean by success can be surprisingly elusive. Some would suggest that determining whether or not a project is successful, can be reduced, much like US Supreme Court Justice Potter Stewart's definition of pornography, to a simple, '*I know it when I see it'*. However, this 'gestalt' idea of projects being assessed in their broadest possible dimensions, is not useful, nor particularly helpful to project-based organisations seeking to apply maximum leverage to their ventures. Simply aiming for successful projects without a means for distinguishing the features of a successful venture from an unsuccessful one is the equivalent of offering an engineer a half-blank tape measure. Let us consider some of the ways that scholars have addressed our search for the dependent variable (the success of the project).

Efficiency vs. Effectiveness Some authors and practitioners adopt a philosophy similar to Peter Drucker's ideas about efficiency and effectiveness, suggesting that successful projects can be understood to consist of two components: (1) efficiency, or '*doing things right'*. Under this conceptualisation, a project is successful if it has been managed with an eye towards staying within budget and schedule projections while getting project quality (functionality) correct. The focus here is almost exclusively internal, whereby the organisation seeks to develop projects that focus on the most efficient use of resources. Effectiveness, on the other hand, follows Drucker's simple definition of '*doing the right things'*. In this mindset, the firm focuses on ensuring that its projects respond to external (environmental) threats and opportunities. Projects are not judged by their efficient use of resources, but by the way in which they address the alternative question: '*Does it work?'*

The Iron Triangle In project management literature, one of the earliest and most long-lasting conceptualisations of project success follows Martin Barne's (1969) model of the '*Iron Triangle'*, suggesting that the three critical metrics of project success consist of budget, schedule, and functionality (project quality). Projects that achieve some minimal threshold in adhering to each of these criteria are considered successful. The degree to which one or more of the criteria are violated indicates the degree to which a project would be deemed a failure.

The Quadruple Constraint Pinto and Slevin (1988) offered a modified version of the iron triangle, arguing that project organisations err when they focus their attention exclusively on 'internal' measures of project success. They suggest that a necessary additional criterion for assessing project performance is the satisfaction of the client or customer for whom the project is intended. Thus, a project that ticks all the efficiency boxes but fails to attract sales in the marketplace or interest from potential customers would be considered a failure, no matter how 'well run' the project was. Alternatively, a project can fail to achieve any of its internal measures of success and still be viewed as successful if customers embrace it. As an example, consider projects like The Thames Barrier, the Fulmar North Sea Oil project, the Concorde, and the Sydney Opera House, all projects with (in some cases) massive cost and schedule overruns, but all viewed in retrospect as highly successful (Lim and Mohamed 1999; Ika 2009; Mir and Pinnington 2014).

The above draws attention to an important distinction when trying to understand the nature of project success: the distinction that can be made between 'project success' and 'project management success'. As the previous discussion points out, whether the focus is on a distinction between efficiency and effectiveness, or the quadruple constraint, what these ideas have in common is a recognition that the correlation between the success of the project and project management success is something less than 1.0. De Wit (1988) discusses the concept of project management success in terms of time, cost, and quality/performance (scope), suggesting that project success involves broader objectives from the viewpoints of stakeholders throughout the project life cycle. Although '*good project management can contribute towards project success, it is unlikely to be able to prevent failure*' (de Wit 1988, p. 164). Another way of understanding this distinction is with the oft heard saying that '*the operation was a success, but the patient died'*. Therefore, Cooke-Davies (2002) distinguishes between:

- Project management success, being measured against the traditional gauges of performance (i.e., time, cost, and quality).
- Project success, being measured against the overall objectives of the project.

This distinction is useful because it requires firms to broaden their focus on the causes of project success and failure to understand the importance of the customer. To illustrate, consider examples such as Google Glass, introduced as a technical marvel but quickly failing in the marketplace as consumers were increasingly confused by the product, when to use it, and how to use it. As one writer noted: '*The failure of Google Glass is due to the lack of clarity on why this product exists. The designers did not clearly define or validate: the users' problems, what solutions Google Glass would provide for its users, or how customers would use the glasses. This revolutionary product never succeeded because users could not figure out why they needed it in their lives*' (Yoon 2018). Although the project management success of Google Glass was undeniable, when evaluated against its overall objectives as an innovative product, it was a dismal failure.

Another problem with identifying project success has to do with who determines whether a project is successful. In other words, research suggests that different project stakeholders often have very different perspectives on what constitutes a successful project (Davis 2017; Todorovic et al. 2015). These often-divergent opinions make it that much more important to first understand the key parameters of the project—who it is intended for, how their goals are to be addressed, what potential trade-offs may result from trying to balance varying perspectives amongst these stakeholders, and so forth. For example, in developing a new pharmaceutical product, who are the critical stakeholders? What does top management suggest with regards to their alternative (and sometimes competing) views on the success of the project? How do we create a prioritisation scheme to best address these competing concerns? Unless these issues are settled early in the project's life cycle, before significant time and money have been invested, organisations can easily set themselves up for serious reckoning later.

A similar challenge exists with regard to collaborative R&D projects. Social network theory and the knowledge-based view of the firm suggest that collaboration enhances competitive advantage through enabling inter-organisational resource exchange and recombination (Nahapiet and Ghoshal 1998). Authors have further suggested that a relevant criterion for project success includes the creation of 'organisational knowledge', arguing that a goal of such cross-fertilisation should be the synergies that can be achieved (knowledge created) through combining the resources (financial and scientific) of multiple collaborating partners (Tripathy et al. 2013). The challenge, of course, lies in developing metrics—definitional and explicitly measurable—as to what organisational knowledge means, how (and, of course, when) it should be measured so as to offer a reasonable determination of collaborative R&D project success. Interestingly, 'knowledge', operates on two levels: the basic knowledge or organisational learning resulting from the R&D project itself, coupled with a more targeted knowledge of the business setting or commercial setting within which the collaborative work is being conducted or opportunities towards which it is aimed to exploit. To illustrate, Weck's (2006) study of collaborative R&D projects in Finnish commercial settings identified 'business viability' and 'knowledge creation' as the key criteria for identifying successful projects. She further noted, '*. . . it was very important that market knowledge and business insight are incorporated into collaborative R&D projects*' (Weck 2006, p. 260). The key point, of course, is that technical knowledge is a necessary but not sufficient condition for trying to understand the nature of knowledge. Knowledge of the broader business or commercial context must be addressed at the same time.

2.2 Success Over Time: When to Assess?

Another piece of the puzzle in determining success has to do with the observation that today's success may be tomorrow's failure and vice versa. That is, the decision to label a newly completed project a success or failure is often misguided, as it fails to consider that for many projects, particularly in the R&D realm, quick assessments are often wrong assessments. Shenhar et al. (2001) developed a model of project success over time, empirically demonstrating that it is possible to identify four dimensions of project success, depending on the time frame used in the assessment. In other words, depending on the time frame adopted to assess the project, the organisation's assessment criteria may be entirely different. The shorter the time frame for assessment, the more likely the organisation will adopt simple efficiency measures (budget and schedule performance), in the slightly longer term, their concern focuses on customer satisfaction. The business success of the project is the focus in the longer term, while the most long-term assessment of success involves 'questions of how organisations prepare for future opportunities. Did we explore new opportunities for further markets, ideas, innovations, and products? Did we build new skills that may be needed in the future?' (Shenhar et al. 2001, p. 716).

Moreover, with regard to their four-dimensional model of project success, Shenhar et al. (2001, p. 716) noted: '*The first dimension can be assessed only in the very short-term, during a project's execution and immediately after its completion. The second dimension can be assessed after a short time when the project has been delivered to the customer, and the customer is using it. Customer satisfaction can be assessed within a few months of the moment of purchase. The third dimension, direct success, can only be assessed after a significant level of sales has been achieved—usually one or two years. The fourth dimension can only be assessed after a longer time, of probably two, three, or five years*'.

Project success is often erroneously assessed only at the end of the project life cycle, as project management outcomes are available and convenient to measure (Munns and Bjeirmi 1996). For example, the construction and pharmaceutical project life cycles end at the final project phase and typically do not span the product operations or decommissioning phases. In contrast, the defence acquisition and software development project life cycles include the operations phase and, hence, portray a clearer connection to product use and business value. We can achieve a more holistic understanding of project success by measuring success during operations and decommissioning when effectiveness measures are taken into account and involve input from different stakeholders (e.g. end-users) (Atkinson 1999; Freeman and Beale 1992; Munns and Bjeirmi 1996).

3 Project Critical Success Factors

Given an enhanced understanding of the nature of project success, we can address CSFs as a key managerial concept. Critical Success Factors are, by their nature, predicated on the supposition that these factors are 'actionable'; that is they represent behaviours that organisational actors can undertake during project development to increase the likelihood of project success. We noted at the outset of the chapter that there is a rich history of scholarship in project CSFs, with early scholars positing (through theory or case studies) sets of CSFs. Later work expanded these ideas to include the impact of contingency variables on CSFs; for example, the relative importance of project CSFs by life cycle stage (Pinto and Prescott 1988), success factors by industry or project type: R&D (Pinto and Slevin 1989; Larson 1996; Tripathy et al. 2013; Mora-Valentin et al. 2004), construction (Sanvido et al. 1992), new product development (Lester 1998), pharmaceuticals (Hung et al. 2005), and so forth. Project critical success factor research has continued to branch out, addressing a variety of increasingly specific forms of projects or contexts within which projects are developed (c.f., Marzagao and Carvalho 2016; Ika et al. 2012; Osei-Kyei and Chan 2015; Yu and Kwon 2011). Research on CSFs in projects has been widely conducted and remains popular because it offers a set of guidelines for useful, proactive managerial behaviours supporting project development. This latter point is critical: organisations operate under conditions of resource scarcity and the better able we are to identify the 'correct' actions that must be undertaken to aid project development, the better we are able to make appropriate allocations of limited resources.

A literature review of project CSF studies was conducted by Fortune and White (2006), who examined sixty-three published works on the topic, seeking to identify and isolate the most common factors; i.e. those factors that were most commonly reported through empirical (survey or case studies) or theoretical models. Table 1 shows their derived set of most commonly reported CSFs from the literature. It is particularly noteworthy that these CSFs include combinations of communication and networking skills (stakeholder management, feedback, sponsorship), team development and leadership behaviours, project management skills (scheduling, planning, budgeting, developing a robust business case etc.), and so forth. While a compilation of multiple studies set across different industries and contexts, it is clear that many of the underlying managerial challenges relating to project management are subsumed in this CSF list. The goal for R&D professionals and scholars is to be able to apply

Table 1 List of the most common project critical success factors from the literature (in order of frequency)

Critical success factor	Explanation
Top management support	Perception within the project team and its stakeholders that the project is supported (publicly and financially) by senior management within the organisation
Clear realistic goals	Initial clarity and general agreement on the project's goals and intentions
Detailed plan kept up to date	A detailed and continually updated plan of the individual, detailed action steps required for project implementation
Good communication/feedback	The provision of an appropriate network and all necessary data to all key actors in the project
User/client involvement	Consultation and active listening to all impacted parties
Skilled/suitably qualified/sufficient staff/team	The project team contains a sufficient number of members who are technically qualified or skilled to perform their duties
Effective change management	Ability to handle unexpected changes or deviations for the original plan
Competent project manager	A technically and administratively capable project manager; strong team leader
Strong business case/sound basis for project	The project offers a compelling business case in terms of expected ROI or process improvements that will lead to greater efficiencies or firm performance
Sufficient/well-allocated resources	Project team staffing is composed of qualified people. Recruitment, selection, and training of team members
Good leadership	Manager exhibits strong teambuilding, motivational, and leadership skills
Proven/familiar technology	Employing appropriate technologies for the project or developing a project based on proven technologies
Realistic schedule	The project schedule is viewed as reasonable and derived through careful analysis and joint development with input from all key stakeholders
Risks address/assessed/managed	Comprehensive risk management was performed on the project prior to key decisions and on a continuous basis once the project goes underway
Project sponsor/champion	An identified member of senior management serving as the visible project sponsor; a champion committed to supporting the project through its development
Effective monitoring/control	Continuous project status monitoring and the timely provision of feedback and status reporting on the project during development
Adequate budget	The general perception of a budget sufficient to support project development
Organisational adaptation/culture/structure	A supportive organisational culture and a structure that allows the project to develop and progress

(continued)

Table 1 (continued)

Critical success factor	Explanation
Good performance by suppliers/contractors/consultants	Project support personnel and organisations, including its supply chain, are responsive and qualified
Planned close-down/review/acceptance of possible failure	Willingness to undertake lessons-learned and develop contingency plans for failure
Training provision	Members of the project team have received/are given sufficient technical or administrative training to perform their tasks
Political stability	Internal corporate political stability among top management or impact of external national political policies on the firm and its projects
Correct choice/past experience of project management methodology/tools	Employing the appropriate project methodologies in order to improve the likelihood of success
Environmental influences	Impact of events or individuals outside the organisation's control that can impact on the project
Learning from past experiences	Use of lessons learned mechanisms as a benchmark for assessing project development
Project size/level of complexity/number of people involved/duration	The sheer magnitude of the project, its complexity, and the number of people involved, and duration can all have a negative effect on the viability of the project
Appreciating different viewpoints	Stakeholders have a voice in the project development and perceive that their opinions, even if not followed, will be heard

Source: Fortune and White (2006)

some of the relevant contingencies to this list; for example, noting that some CSFs, like building a business case, are necessary preconditions for the project during its earliest life cycle stage.

4 Case Studies of Success Factors in R&D Projects

As was discussed above, all projects have a set of common factors that can lead to success or failure, depending on how they are managed. Moreover, when investigating the nature of collaborative R&D partnerships, it is useful to offer a distinction between two key types: intra-organisational collaborations, often framed as cross-functional ventures, in which a project requires the successful cooperation of multiple functional groups, and inter-organisational collaborations, based on the development of structures or platforms that enable independent organisations to work in joint space or for a mutual goal—a collaborative R&D project. This section discusses examples of both types of collaborative efforts; first, a breakthrough in wearable technology that had a very short product life cycle—Google Glass. Launched in 2013 to early adopters, Google pulled Glass from the consumer market in 2015 after investing hundreds of millions of dollars (Bajarin 2015). Second, we will examine some examples of inter-organisational collaborations to address the COVID-19 pandemic, particularly the manner in which public–private partnerships have been formed to focus resources and expertise on a variety of equally critical challenges.

4.1 Google Glass

From their initial planning with state-of-the-art engineering and a seemingly unlimited budget, Google appeared to be building a solution without first identifying a need or want in the marketplace. What were the core benefits of this product for typical consumers, like you and me? Consumer response was lukewarm at best. With an introductory price of USD 1500—and touted to be a gadget (albeit pricey) for everyday consumers, Glass faced serious resistance and criticism—which ultimately lead to its failure in the marketplace. Let us see how we can apply project critical success factors to see what can be learned from this project failure.

1. Consumer Needs and Wants (A strong business case). Did Google Glass satisfy any unmet consumer need or want? When a new product or service is created it must satisfy some level of needs and/or wants, and thus, provide clear value to the consumer; that is successful projects are propelled by a sound business case. By creating Glass, Google hoped to bridge the digital and physical worlds (Friedman 2016). It basically brought the internet up close and personal (so to speak)—right in front of the eyes. Users could speak voice commands to carry out specific functions, such as taking photos or videos. But many individuals asked: '*What are the practical uses of these features for my daily life?*' The answer was '*none*' (Doyle 2016, para 9).
2. Consumer Perceptions (User involvement). After the product launch and once the hype of celebrities had diminished, consumers' overall reaction to the glasses was 'underwhelmed.' The wearable device was seen as '*too expensive, bulky, and conspicuous*' and not at all aesthetically pleasing (Brunner 2018, para 8). Consumers did not like its design, calling the eyewear '*ugly and awkward*' (Brennar 2014, para 7). In addition, they had safety and ethical concerns. Many people believed that the glasses '*infringed upon the privacy of average citizens*' due to its built-in camera and the ability to record videos or take photos at any time (Spadafora 2016, para 6). From a safety perspective, not everyone was comfortable with having '*a gadget consistently emitting carcinogenic radiation so close to the head*' (Doyle 2016, para 3). Cellphones had been accused of emitting unwanted radiation too, but users do not 'wear' cellphones or constantly have them in direct contact with skin.
3. Target Market (Appreciating different viewpoints). From its product concept phase, Glass was targeted towards the consumer market. Remember, any product innovation is only as good as it is accepted and used by the customers for whom it is developed. Did Google target the wrong market? Critics argued that rather than

consumers, Glass should have been promoted and sold to professionals or industrial consumers, such as truck drivers, pilots, police, physicians, and so on—that could instantly access valuable information (e.g. reports, directions, and updates) that would help them do their jobs (Nieto-Rodriquez 2017). These alternative markets may have found more value in the product concept and the features Glass offered.

4. Product Quality (Proven technology). Glass was released too soon prior to the bugs and technical glitches being totally worked out. Analysts called the new product more of a '*prototype'*, than a consumer product, ready for commercialisation. Consumer electronic experts reported the product's quality was: '*terrible*', the '*UI connection unreliable*' and the information provided of '*little use*' (Bajarin 2015, para 7). The earpiece was reported to be irritating and uncomfortable for consumers. The components, such as the camera, did not work properly—i.e. with the wink of the eye. Further, the battery life was very short, lasting only 2–3 h. Overall, Glass seemed to have a poorly defined quality plan.

From this brief analysis, it is clear that from a critical success factor perspective, Google missed on several fundamental factors of product success: the management process occurs through to the customer. A project that has in-house achievement but derives no benefits from the marketplace is no help to any organisation. This difference between 'project management success' and 'project success' extends the notion of the traditional project life cycle (i.e. project management success) to include commercial performance or success in the marketplace. This outcome is often minimised or under-appreciated by project managers. There are several reasons why this perspective may be overlooked, including incentive systems that reward immediate outcomes but fail to recognise longer-term impacts and project managers being assigned to a project later in the life cycle after critical strategic and project scope decisions have already been set.

In the final analysis, Google Glass did create '*quite a stir and bring the world a step closer into the information age'*, even though their efforts ended in after less than 2 years of sales (Doyle 2016, para 1). As of 2020, Google Glass is not dead. Google announced that its latest augmented reality headset, Google Glass Enterprise Edition 2, would be available for direct purchase in 2020. '*This new headset is not designed for everyday consumer use, but primarily for jobs in construction and on factory floors as well as in the medical field and other disciplines that can make use of a simpler heads-up display*' (Statt 2020, para 3). Google appears to have learned from its mistakes. Who knows what the future holds for Google Glass?

4.2 COVID-19 Response Efforts

The Coronavirus, first detected late in 2019 in Wuhan, China, quickly became a pandemic, rapidly spreading across the globe and affecting the health and economies of nearly every nation on the planet (Bryner 2020). Coronaviruses are a family of viruses known to cause upper respiratory illnesses in animals and humans with symptoms ranging from mild to severe. In March of 2020, the World Health Organisation (WHO) declared the COVID-19 outbreak a pandemic. As of May 2020, the WHO Coronavirus Disease (COVID-19) Dashboard listed over five million confirmed cases worldwide with over 300,000 deaths (WHO 2020).

Since late 2019, COVID-19 has wreaked havoc across the globe—impacting not only the health and safety of individuals, families, communities, and countries—but, also the economic security and stability of both the private and public sectors worldwide—the fallout of which will be felt for many years to come. Domestic and international organisations are responding by joining forces to utilise their combined resources and expertise in an attempt to combat this deadly pandemic. Seetharaman and Gallucci (2020, para 3) reported some of the organisational responses seen around the globe:

- Donation of personal protective equipment (PPE) or other critical supplies, whether masks, aeroplanes, or the extended use of portable cell towers.
- Donation of infrastructure, expertise, logistics, transportation, manufacturing equipment, or space.
- Conversion of production lines and/or manufacturing additional critical supplies (e.g. hand sanitizer).
- Conduct of clinical research.
- Sharing data and technology.
- Taking measures to keep workers employed, paid, and insured.

These activities are part of the inter-organisational partnerships and collaborative R&D projects within the public and private sectors that have surfaced in response to the pandemic. Collaboration is critical because many different organisations and communities are facing similar issues. '*Collaboration creates an opportunity to align efforts, reduce duplications, optimise financial resources, and ultimately, improve the health and well-being of the community*' (Health Research & Educational Trust 2017, p. 7).

While the following list is not meant to be exhaustive, these collaborative efforts spotlight some of the key public–private partnerships and projects that are occurring to fight the pandemic, identify treatments and find a vaccine.

- By early March 2020, the media had reported on shortages of personal protective equipment (PPE) that was threatening the health and safety of workers worldwide. The World Health Organisation urgently requested that '*industry and governments increase manufacturing (of PPE) by 40 per cent to meet rising global demand*' (Chaib 2020, para 1). Recognising the critically low supplies of medical protective equipment (PPE) for the front-line workers across the United States, two Atlanta-based institutions, Emory Healthcare and the Georgia Institute of Technology, teamed up to produce face shields that would protect workers' eyes and extend the life of masks worn to filter out virus particles. Georgia Tech used 3D printers and laser cutting machines, to create innovative face shield kits that could be produced rapidly and easily assembled by health care workers and public safety individuals needing protection (Emory 2020).
- More efforts continued in March when The Bill & Melinda Gates Foundation, Mastercard, Wellcome, the Chan Zuckerberg Initiative, the Dell Foundation, and the UK Government have '*committed up to $125 million in seed money*' in the COVID-19 Therapeutics Accelerator to identify, assess, develop and gauge treatments to counter the virus (Clift and Court 2020; Bill and Melinda Gates Foundation 2020, para 1). One example of a potential treatment protocol being investigated was using blood plasma from recovered COVID-19 patients to fight the virus in others (Murphy 2020).
- In April 2020, AstraZeneca, a multinational pharmaceutical and biopharmaceutical company with headquarters in Cambridge, England, united with the University of Oxford, known as an ultimate expert in vaccinology. '*This new partnership will support research, manufacture and distribution of vaccine candidate*' (Oxford University 2020, para 1).
- Further news in April 2020, The National Institutes of Health (NIH) launched a major effort between the public and private sectors by partnering with 16 drug companies in hopes of accelerating COVID-19 treatments and vaccines. The partnership, to be known as Accelerating COVID-19 Therapeutic Interventions and Vaccines, or ACTIV, is meant to: '*standardise research between the federally funded researchers and a broad array of drug companies and prioritise research into drugs and vaccines that are having high near-term potential. The new collaboration will focus on standardising the methods and models that researchers are using to test promising Covid-19 compounds. It will also provide researchers access to high-level laboratory facilities and standardise endpoints to ensure different companies and researchers are judging potential medicines by the same criteria. Finally, it would establish one joint control arm to be shared among all clinical trials, the NIH said in a press release*' (Facher 2020, para 2–4).

'Success' of these ventures is measured in responsiveness, seamless integration of personnel and resources across multiple organisations, and time to market to these joint ventures. From a traditional project management perspective, the quadruple constraint of time, cost, quality, and customer acceptance is significantly truncated to focus almost exclusively on key metrics of time (getting these new treatments and prophylactic measures to the public quickly) and quality (ensuring that the products and services are of the highest—and safest—quality possible to curtail the spread of COVID-19 and begin containing infections and their social and economic impact. How successful have been these collaborative efforts? Only time will tell, however, as of the writing of this chapter, there is good news on the horizon for a coronavirus vaccine. The US government gave AstraZeneca $1.2 billion dollars to fund Oxford University, resulting in the expectation that 300 million doses of a potential vaccine are earmarked for America beginning October 2020 (Quin 2020).

Applying a framework for identifying critical success factors for dealing with a pandemic is, admittedly, more problematic. Nevertheless, when viewed through the lens of a project whose hallmarks are the necessary cooperation of multiple stakeholder partners, we can observe that several critical success factors, as identified in Table 1, are relevant to successfully battling this contagion. For example, good feedback and communication channels are critical to ensuring that all participating partners are sharing critical information. Top management support—in this case, 'top management' refers to governmental agencies and coordinating bodies, is a necessary CSF for COVID-19 response as the joint and individual efforts of dozens of laboratories, pharmaceutical companies, and research centres must be coordinated efficiently and effectively. Good leadership, competent project management, realistic schedules, and skilled team members are clearly all necessary for ultimate success against the COVID-19 pandemic. Indeed, when one considers the collective set of project CSFs and how we determine a 'successful' project, it is clear that many can be easily applied to the challenges facing the world during a troubling time.

5 Implications: Guidelines for Effective Use of Critical Success Factors in Collaborative R&D Projects

Given the previous discussion, it is useful to consider how previous research and practice can influence our understanding and effective use of CSFs in furthering project opportunities and increasing the likelihood of success. Although not an exhaustive list, among the best suggestions for practitioners, are the following:

- Lock in success metrics early. Determine what will constitute project success in your R&D venture. Is it customer acceptance? Speed to market? Return on Investment? Efficient use of corporate resources? Identify and make widely known the measures by which project success will be measured. These are the colours that have to be nailed to the mast. They form the basis for settling disagreements, balancing competing needs and demands, and keeping everyone on the project team focused on the same goal.
- Identify the CSFs for the particular project being undertaken. Once the measurement of success is agreed to, the next step is to match up the CSFs that will most enable the achievement of project goals. For example, if widest possible customer acceptance is a key performance indicator, it does not make sense to have, as one of the CSFs for the project, the efficient use of budget money. This is not

suggesting that budget efficiency does not matter at all; it simply recognises that some CSFs are more important than others in achieving project goals.

- Develop means to continually monitor and update the status of the project midstream. Among the legitimate criticisms of many project performance metrics is that these key performance indicators (KPIs) are not designed to offer insights into the means for improving current performance and therefore have limited use for internal management decision making (Bassioni et al. 2004; Pillai and Rao 1996). Moreover, it has been noted that KPI's are 'lagging' measures (Haponava and Al-Jibouri 2012); they are reactive and best used for review purposes after completion of the project and do not provide the opportunity for fixes during the project development and execution stages. That is, identifying the fact that the project is failing to achieve technical benchmarks or is running a significant budget deficit is important but, ultimately, not 'actionable' information in that it does not point to obvious corrective actions. Critical success factors differ from KPIs precisely because they do offer a basis for taking corrective action, but only if we have a clear understanding of the project's current status.
- Make an honest assessment of your organisation's strengths and weaknesses. For some R&D organisations, CSFs such as having a project sponsor or the provision for training are already firmly in place. For others, some of the CSFs on this list are actions that would be helpful, if possible, but may be difficult to attain. The list of CSFs in the table should be viewed as a clear guide to what it takes to achieve project success. Do we support strong internal communication and external interaction with clients? If this is an area that has been a historical liability for our organisation, it is particularly important to take corrective action, the sooner, the better. Significant research and clear examples exist of successful R&D projects that made maximum use of these critical success factors guidelines in furthering their own goals. By identifying the issues that our company strengths and recognising those that contribute to poor performance, it is possible to develop strategies for improvement.

6 Conclusions

Collaborative R&D projects present significant challenges in terms of identifying opportunities, planning, coordinating resources and other corporate assets, and once undertaken, accurately monitoring and successfully managing them to completion. One way that R&D managers can be more aware of their options is through a careful study of critical success factors, which, when addressed competently, can provide a basis for successful project outcomes. Moreover, as part of any discussion of CSFs, it is extremely important that key organisational stakeholders are in agreement as to how project success is to be measured. This chapter has offered a brief overview of these two critical components of the R&D project implementation process: a better understanding of what 'success' should be understood to represent while offering the latest research on those managerial (actionable) factors that are most critical in contributing to positive outcomes.

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Developing Trust Between Partners in Collaborative R&D Projects

Rafaela Escobar Bürger and Nadine Roijakkers

1 Introduction

This chapter develops a practical guide to stimulate trust development among partners within a collaborative research and development (R&D) project. Trust is based on the expectation that others behave in a predictable manner and thus enable collaboration (Kubbe 2013). R&D collaborations are one type of Open Innovation (OI) (i.e., coupled process), involving a new product or service development across organizational boundaries (Bogers 2011; Chesbrough 2003). The literature on trust exhibits diversity in the way trust is conceptualized and studied (Bachmann and Zaheer 2006; Lewicki et al. 2006; Nilsson and Mattes 2015). Some authors highlight the importance of trusting partners for effective collaboration (Chesbrough et al. 2018; Shamah and Elsawaby 2014; Salampasis et al. 2015). Others discuss the effects of trust on the organizational performance of the collaborations (Gomez et al. 2016; Pratono 2018). Many scholars relate trust to governance modes and the interdependence with contracts/control-based governance mechanisms (Puranam and Vanneste 2009; Bagherzadeh 2016; Biswas and Akroyd 2016; Guo et al. 2017).

In OI environments that are inherently unpredictable and where risk is a common variable, trust is a valuable mechanism as contracts cannot fully capture market dynamics (De Man and Roijakkers 2009). Research on trust is typically conducted at the firm level. We look at the individual level focusing on the managers who are responsible for building trust with partners and on what they can do to enhance the likelihood of trust actually developing. Some managers are more successful at

R. E. Bürger (✉)
Federal University of Santa Catarina, Florianópolis, Brazil
e-mail: rafaela.eb@posgrad.ufsc.br

N. Roijakkers
Open University of the Netherlands, Heerlen, Netherlands
e-mail: nadine.roijakkers@ou.nl

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creating an atmosphere of respect and trust than others. Although these differences can partly be linked to external trust antecedents such as culture, the wealth of economic, and social norms (Nilsson and Mattes 2015), we assume that there are general behavioral patterns that are likely to create a fertile ground for trust between partners to grow.

While R&D collaborations are rewarding, managers experience severe challenges in managing the underlying processes (Wikhamn and Styhre 2020). The complex relationship between two companies and their employees is an area of inquiry that requires insights from many fields such as business psychology, economy, and anthropology (Chesbrough et al. 2018). This study tries to incorporate such insights by introducing trust as a set of behaviors that if combined, can facilitate the bond between two firms in an OI project. The objective is to explore how individual managers that participate in a collaborative R&D project build trust with partners and to develop a practical guide with trust-enabling actions. Considering the phases of R&D collaboration proposed by Dyer et al. (2001) (Partner assessment and selection, collaboration negotiation and governance, collaboration management, and assessment and termination) and 5 case studies from different countries, we identify similar managerial actions for each phase that contributes to trust development. The interviewees are managers in charge of the R&D collaboration functions in companies from the energy, pharma chemicals, software development, and fast-moving consumer goods sectors located in different countries, (i.e., Germany, Brazil, and Belgium). Although the companies under study differ according to nationality, firm size, sector of activity, and number of employees, we identify a common pattern of trust-enabling managerial behavior where social exchange and partners' proximity arranged through face-to-face interactions and nurtured through, for example, regular relationship health checks are key.

In the next section, the case studies are specified together with the method of the study. Then, based on the managers' input, the role of proximity in trust development is discussed alongside trust-enabling actions for each phase of R&D collaboration. Finally, the conclusions, future research directions, and managerial implications are outlined.

2 Case Studies

To identify the activities that managers undertake to create an enabling environment for trust to grow, we make use of a multiple case study research design (Yin 2016) (See Table 1 for an overview of the cases). We interviewed five managers of R&D collaborations to pinpoint common behavior. The cases were selected from two perspectives: first, seeking to differentiate companies based on the criteria of nationality, size, and sector of operations; and second, based on a pre-existing relationship with the researchers. The first criterion is justified from the objective of understanding trust as a general factor, relevant to different types of companies, inserted in various contexts. The second search criterion is considered to be relevant due to the

Table 1 Description of cases

Characteristic	Hype Inno. (A)	Boone Intern. (B)	Natura (C)	Innogy[c] (D)	Bayer (E)
Manager's background[a]	(1) CEO and Founder (Habar Consulting Ltd) (2) BSc. Computer System Engineering (University of East Anglia)	(1) Managing Director (Bofin NV) (2) BSc. Management (Vlerick Business School)	(1) Committee Coordinator (Anpei) (2) BSc. Administration (São Paulo State University, UNESP)	(1) CEO/Managing Director (Innogy LLC/ Palo Alto, California) (2) Ms. of Political Economics (University of Passau)	(1) Non-executive Board Member (Futurium Berlin) (2) PhD in Biochemistry (Max Planck Institute Berlin)
Current position	Chief Consulting Officer	CEO	HR Manager for Development (Embraer)[b]	Chief Commercial Officer and General Manager Energy (Intertrust)	Vice President, Corporate Innovation, R&D and Societal Engagement and Executive Board Member Bayer Foundation
Nationality	Germany	Belgium	Brazil	Germany	Germany
Size	SME	SME	Large	Large	Large
Sector	Software development	Space-saving solutions	Self-care—Cosmetics	Energy	Pharma-chemicals
Customer	B2B	B2C	B2C	B2B/B2C	B2B/B2C
Foundation year	2001	1950	1969	2016	1863
Employees	51–200	20–30	5000–10,000	+10,000	+10,000
Market focus	International	International	International	International	International

[a](1) Previous experience (2) Academic education
[b]At the time of the interview, the manager was Innovation Manager at Natura
[c]Recently acquired by E.ON, which is also a large shareholder in Intertrust

theme addressed in the interview, requiring a certain degree of trust between interviewer and interviewee. A key approach to limit bias is interviewing knowledgeable informants who view the phenomena from a deep perspective (Eisenhardt and Graebner 2007). Notably, the cases differ in, for example, their industrial backgrounds, numbers of actors, actor sizes, actor types, technology applied, institutional environments, and locations—adding to the generalizability of the results in case of comparable results (Eisenhardt and Graebner 2007). The interviews were conducted via Skype, and the approximate duration was 45–60 min. In these interviews, not only trust-enabling actions were identified but also other aspects of collaboration were touched upon (e.g., partner selection, challenges and benefits of OI, governance, perception of risk, and internal arrangements to engage employees). The analysis of the cases was done by means of qualitative content analysis (Bardin 2014), by extracting quotes from the interviews that match our a priori categories (4 phases of R&D collaboration). After this step, we searched for other factors that were noted by all or most of the managers, and that were not framed in the analysis of the a priori categories. By comparing these elements to the literature, we could build a common pattern of trust-enabling managerial behavior. Based on the analysis of the cases, we infer some propositions about the development of trust in R&D collaborations. Figure 1 summarizes the methodological process.

3 Analysis and Discussion

In the strategic alliance and OI literature, there is a general consensus that trust is an important aspect in relationships (Gulati 1995; De Man and Roijakkers 2009; Six et al. 2010; Zhong et al. 2017; Pratono 2018). To realize the benefits of OI, trust is key in the interactions between parties (Shamah and Elsawaby 2014; Pratono 2018). Studies have identified aspects such as cultural distance, risk aversion, and knowledge tacitness as determinants of knowledge transfer while pointing to trust as an important moderating factor (Becerra et al. 2008; Easterby-Smith et al. 2008). Other studies have shown that the factors influencing the creation of trust include personality traits (McKnight et al. 1998), societal structures (Bachmann and Inkpen 2011), and beliefs and emotions (Droege et al. 2003). When it comes to the creation of resilient "deep" trust (necessary in complex situations such as R&D collaborations), it is agreed that direct social exchange is a prerequisite (Nilsson and Mattes 2015). "Direct" in this context implies not only face-to-face exchange but also careful and frequent maintenance of the relation by the parties involved in R&D collaborations. Here, trust is not just an inherent quality of an individual's mind or character, nor an external "object" that can be manipulated and controlled. Trust represents a psychological state that comprises the intention to accept vulnerability based on positive expectations of another person's intentions or behavior (Hoetker and Mellewigt 2009; Krishnan et al. 2015). One might assume that previous experience and academic education (Table 1) will influence the understanding of the importance of trust, but multiple backgrounds converge in a similar perspective of trust. The

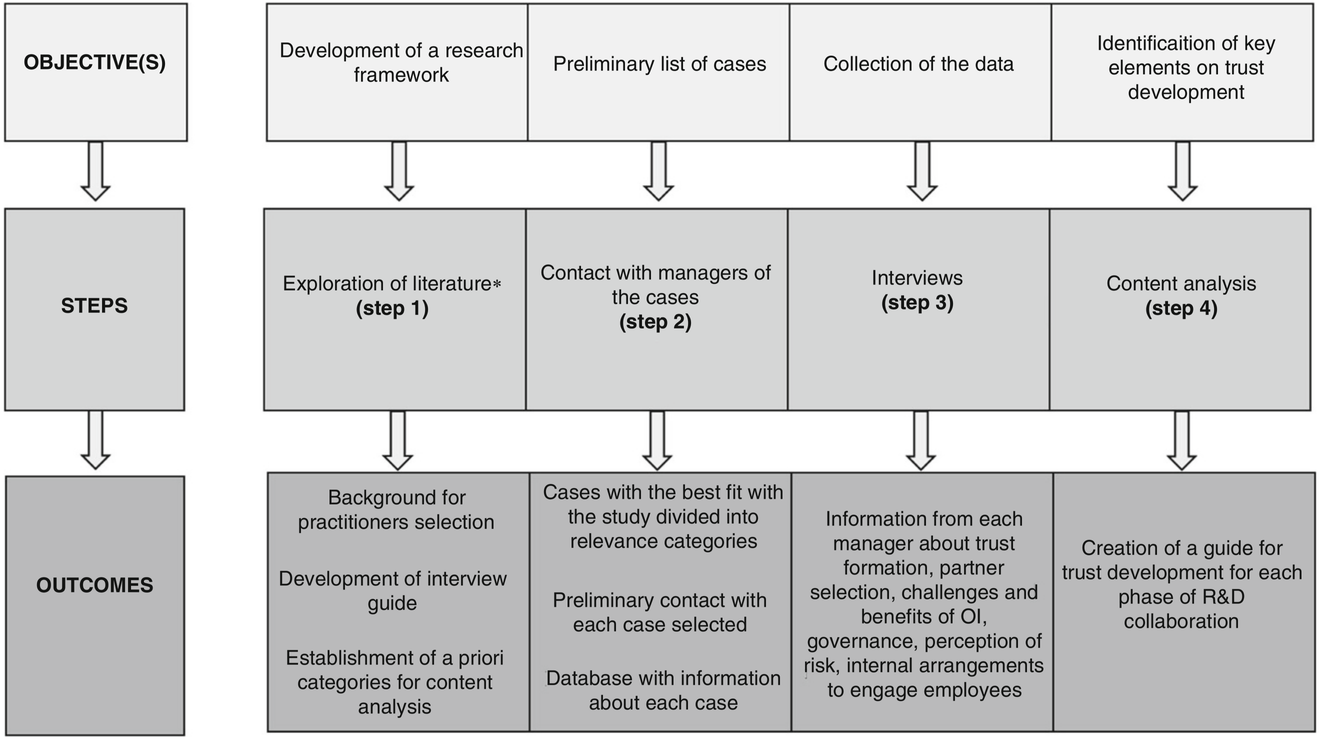

Fig. 1 Methodology process (We searched Wos and Scopus databases for titles using multiple combinations of keywords (Trust, Open Innovation, Alliance, Governance, and Collaboration) for articles, book chapters, and books)

interviewees confirm the crucial role of trust: "*Trust is a huge factor in OI*" (A). "*It is the basis. If there is a trust factor, we can tell a lot to each other. We can be very open to each other if we want*" (B). "*Trust is fundamental; it is key for us to engage people in the process*" (C). "*If you ask me on a scale of 0–10 how important is it, it is a 9.9, and there is nothing that comes close in terms of importance to trust*" (D). "*I think it is the factor that is most important, otherwise if you don't trust there is no option to get a partnership going*" (E).

Notwithstanding this significant research that was undertaken with respect to trust within collaboration over the last two decades (Gulati 1995; Bstieler 2006; Shamah and Elsawaby 2014), identifying a concrete pattern of behavior or a set of actions to create a fertile ground for trust development has been largely overlooked. Several authors have called for research on this particular topic in recent years; see, for example, Six et al. (2010), Zhong et al. (2017), and Pratono (2018). In what follows we describe the actions managers undertake in each phase of R&D collaboration to create a fertile ground for trust development (see Table 2 for a description of the managerial actions targeted at enabling trust, results in terms of paving the way for trust-building to occur, and quotes per phase).

In *phase 1*, the interviewees express that they either rejuvenate previous relationships (if they were successful) or use a wide variety of forms to prospect new ones and as such bring fresh new ideas into the firm. Many activities, such as the organization of challenges, are carried out to create a venue for this first contact. With these activities, the companies are looking for adversity, so their capabilities complement each other and challenge the average way of thinking. According to Teece (1993), the value of a network is derived from the commitment of partners to devote their complementary assets. Sarkar et al. (2001) show that the performance of synergistic collaboration can be enhanced by the complementarity in technology owned by each actor in the network. Miotti and Sachwald (2003) highlight that the success of cooperative R&D can be achieved when a central firm cooperates with partners who possess strong complementary resources.

At the *second stage* of collaboration, the interviewees highlight the special role played by a mediator or caretaker who is responsible for managing the collaboration and also holds the knowledge on managerial and legal aspects. This person or team acts as a coordinator and is a facilitator of the relationships between parties. This key-person acts as the glue for the R&D team by arranging frequent and personal contacts and also by matching expectations and goals. The interviewees emphasize structure and coherence in order to reduce relational risks and enhance the development of trust. According to Claro et al. (2006) and Nilsson and Mattes (2015), a structured and honest relationship provides the necessary basis for actors involved to feel that they are able to predict and trust others' behavior.

At *phase 3*, the interviewees expose the primary role of face-to-face interactions and proximity in order to bond and engage with the partner by showing transparency and empathy. McAllister (1995) and Lewicki and Bunker (1996) point at empathy as the ability of the individual needing to trust another to imagine himself in the position of the one to be trusted. For Bathelt and Turi (2011) and Nilsson and Mattes

Table 2 Quotes (adapted from Dyer et al. (2001))

Phase[a]	Actions	Results	Quotes	Supported by
1. Partner assessment and selection	– Landscaping and mapping – Events or conferences – Challenges	Adversity Complementarity Challenging Engaged/Committed	"We look for companies that are highly engaged, attend our events, loyal, constructive, and no too nice." (A) "It's a lot about the networking, the connections, meetings and also active contributions to science is important." (E)	Teece (1993), Sarkar et al. (2001) and Miotti and Sachwald (2003)
2. Collaboration negotiation and governance	– Caretaker managing the collaboration as a mediator of the parties involved	Match expectations and goals Coherence Structure	"Only a small group can decide who is part of it and we use always the same group, there are no exceptions. You cannot have exceptions because otherwise the group is controlling you. You have to be steady on your basic ideas." (B) "So what we do to facilitate trust is: a lot of coherence, clear policies, we don't avoid conversations, we always do the meeting and the integration. This is in the relationship with the other." (C)	Claro et al. (2006) and Nilsson and Mattes (2015)
3. Collaboration management	– Personal activities – Welcoming the partner into the firm – Investing in time spent together – Solidify the relationship	Frequent and personal contact Transparency Empathy	"I think in the beginning it is important to have a face to face meeting, also to see the environment because you can learn a lot not only about the meeting but also see how your partner is doing, how the	McAllister (1995), Lewicki and Bunker (1996), Bathelt and Turi (2011) and Nilsson and Mattes (2015)

(continued)

Table 2 (continued)

Phase[a]	Actions	Results	Quotes	Supported by
			mood is, how people behave." (E) "This is like when you date someone, you have to spend some time together and you have to talk. Then you find out if is there a signal for mutually beneficial engagement."(D)	
4. Assessment and termination	– Maintaining contact – Doing check-ups	Sustained and reliable trust	"It is a continuum. All the partners are still members and the group is still growing." (B) "One of the reasons why you don't change so much is because this is a trust business and it is a people business, this open innovation collaboration (...) it has a lot of exploration and it is also a risky business because you don't know where you are going to end up, this is how I define risk." (D)	León et al. (2019)

(2015), trust is more easily developed when there is face-to-face exchange considering the high risks associated with the collaboration.

In *phase 4*, it is expected that the partners' profit from their collaboration, share the results, and finalize the partnership. Instead, all interviewees revealed that the relationship (if successful) did not end at this point. All efforts involved in creating and maintaining a trustful relation are the reason why managers suggest that in future projects if the partner fits the selection criteria, this connection will be reclaimed. Maintaining the flow of communication and doing regular relationship health check-ups thus continue to be important. León et al. (2019) explain that repeated collaborations mitigate the risks and costs associated with identifying and selecting new external partners, which is why firms are urged to optimize relationship benefits by cooperating with the same external partner in the future (Pommerening and Wawi 2017).

The central trust-enabling managerial action in each phase is the arrangement of forms of social (face-to-face) exchange where these forms change as the relationship progresses through the collaborative phases. It is argued that repeated relationships (Gulati 1995; Gulati and Sytch 2008) and frequent communication (Becerra and Gupta 2003) over time gives partners first-hand experiences that lead to the gradual development of trust between actors. Not only frequency and length but also the nature of the interaction influences the trust creation process (Van-Wijk et al. 2008). Face-to-face interaction is seen as a particularly efficient mechanism for creating trust (Bathelt and Turi 2011). This is especially the case if the knowledge exchanged is highly complex or has a strong tacit dimension as in R&D collaborations. When it comes to communicating complex knowledge and creating and sustaining shared discourses, meanings, and norms, the face-to-face situation induces (though in no way guarantees) trust to develop more rapidly, primarily because the amount of social information exchanged is greater than in non-face-to-face situations (Nilsson and Mattes 2015). Considering that inter-organizational R&D collaboration often is a high stakes game for the partners involved and that the level of trust needed is considerable, a great amount of social information needs to be exchanged in order to enable a sufficient level of trust. That is why relying on non-face-to-face interaction would make knowledge transfer more time consuming and fragile activity in such situations.

The interviewees revealed a wide variety of communication channels but also emphasized the importance of frequent and continuous communication among employees within partners (in order to trust others, individuals within a company first need to trust each other and collaborate well within). In the words of the interviewees: "*Essentially there are different pieces that are the platform, there are the physical events, there are webinars, and there is one to one interaction as well. There is a lot of communication channels, but they are all well-structured*" (A). "*We have regular meetings with the partners but of course, if they have a question they just call or exchange email. Of course, we also have platforms where you store all the documents*" (E).

Within partners, there is a need for a cohesive and open in-group mind-set in order to effectively build trust and collaborate with the out-group (partners). The Not Invented Here (NIH) syndrome needs to be anticipated and managed. According to Hussinger and Wastyn (2015), successful adoption and implementation of acquired technologies rely on the openness of the individual employees toward externally developed technologies. Internal arrangements to support collaboration and daily communications among employees, according to Dahlander and Gann (2010) have been described as a requirement to attract and maintain competent collaboration partners. Thus, mutual trust helps to enhance—and is enhanced by—social interactions among employees of partnering firms (Dolfsma and Eijk 2017). Mutual trust and strong personal ties established through social exchange thus hold potential to positively affect employee's willingness not only to share their own knowledge but also to absorb knowledge inputs from partners (Muthusamy and White 2005;

Malmström and Johansson 2016; Dolfsma and Eijk 2017). Some quotes to support this: "*We have to educate customer-facing staff in terms of new capabilities which are away from their daily job and explain to them that these are things that the customers are asking for and they need to get comfortable talking about*" (A). "*We are concerned with having an internal policy that can be shared out, we are concerned with coherence and making internal alignments*" (C).

4 Conclusions

The objective of this study is to provide a guide with managerial actions to enable trust development for each of the phases of R&D collaboration. While the literature on trust is rich, it focuses mostly on the firm level rather than the individual level, and researchers have repeatedly pointed at a gap in our understanding when it comes to a concrete set of actions to undertake in the trust-building effort (Six et al. 2010; Zhong et al. 2017). In order to fill this gap, we have performed a multiple case study including five different companies (Hype Innovation, Natura, Boone International, Bayer, Innogy) where we identify a set of concrete activities managers can undertake in each phase of collaboration so as to create a fertile ground for trust to grow (stronger). Our results highlight the central role played by social exchange, albeit taking a different form in each phase, which constitutes a major contribution to trust development in R&D collaborations (Malmström and Johansson 2016). In a similar manner, the importance given to social exchange and close proximity among individuals from partner organizations should also be given to internal interactions among employees within partner firms so as to ensure alignment ("so within, so without").

In phase 1 (partner assessment and selection), managers use a wide variety of forms to prospect new partners and bring fresh new ideas into the firm. The focal companies are looking for adversity within their partners where capabilities complement each other, and interactions challenge the average way of thinking. Phase 2 focuses on negotiations and establishing the governance of the collaboration where a mediator plays a crucial role in arranging frequent face-to-face interactions among partners and in matching expectations and goals. At the collaboration management phase, we also identify a primary role for face-to-face interactions and close personal proximity in the bonding among partners. In the last phase of R&D collaboration (assessment and termination), efforts undertaken in creating and maintaining a trustful relation are the reason why managers suggest that future projects can be carried out with existing partners if they fit the selection criteria.

Our findings point at a *circular guide of trust development and maintenance* (Fig. 2) where each set of actions to increase the likelihood of growing trust among partners builds on the actions undertaken in the previous phase. As such, the initial phase of engagement is also the result of a dedicated search effort aimed at optimizing the likelihood of a trusting relationship between new partners to occur. In a similar manner, the activities for building and maintaining trust among partners

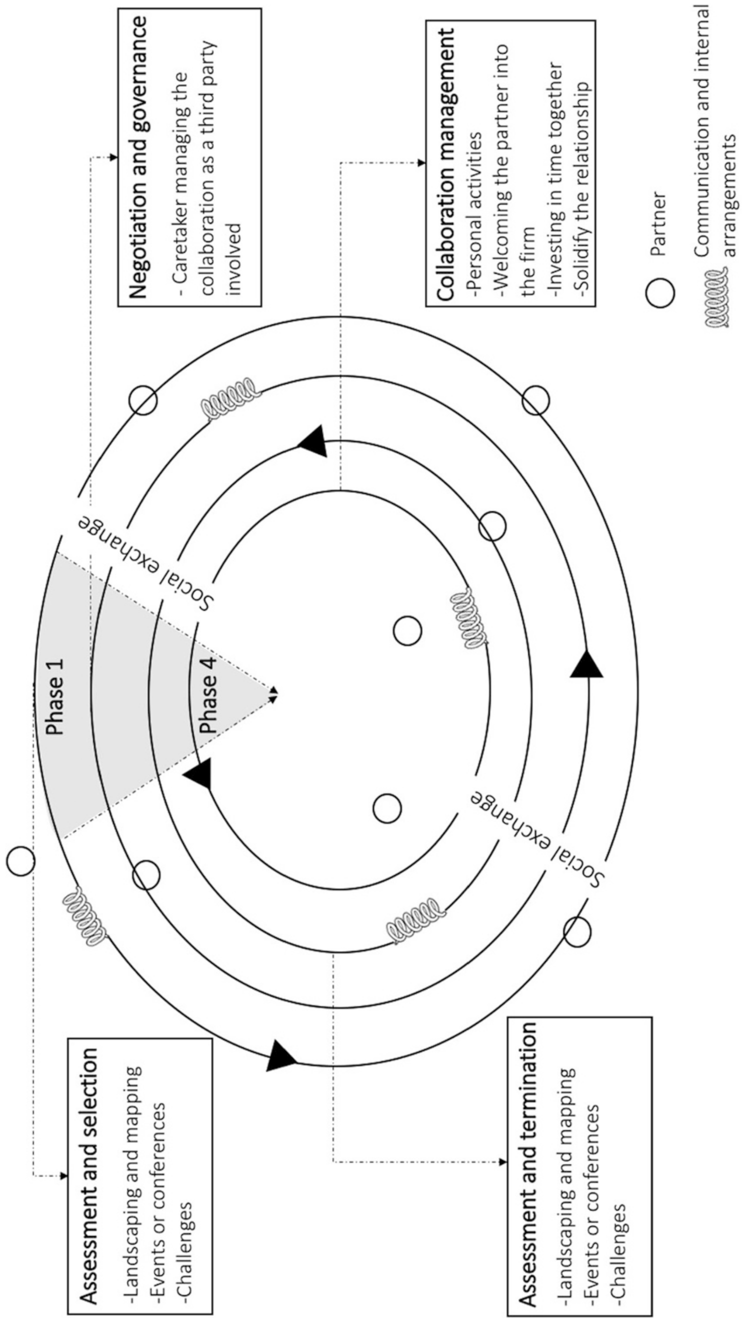

Fig. 2 The circle of trust

are not ceased when specific R&D collaboration projects end but are continued in order to keep relationships healthy for future collaborations.

These findings are relevant for *practitioners* searching for specific actions to undertake to stimulate trust among their R&D partners and thus to enrich their collaboration toolkit. The findings also aim to stimulate OI *researchers* on trust to focus on the individual level and to identify more concrete strategies for trust development. Today's challenges (e.g., energy transition) require partners to collaborate on innovations that may take longer to materialize; it is thus crucial for relationships to stay healthy in the long run and trust is a key element herein.

The empirical evidence presented should be considered carefully as the data collected is qualitative, subjective, cross-sectional, and based on assertions by individual managers about their company's trusting behavior. Also, the empirical evidence relies on five interviews of 60 min duration. Although we found strong support in the literature for all empirical evidence, some questions may be slightly subjective and draw from the perception of the respondent and his/her understanding of trust in collaboration activities. These limitations offer a wide and valuable spectrum of potential future research questions and increasingly relevant contributions in the realm of R&D collaborations.

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Part V
Collaboration Impact and Value

Do Perceptions of Academic Scientists Influence Non-Academic Collaboration?

Julia Olmos-Peñuela, Paul Benneworth, and Elena Castro-Martínez

1 Introduction

Recognizing academic research's potential as a source of economic growth and social welfare attracted both policymakers' and academics' attention in recent decades. Policymakers seek to identify and promote societally impactful research, with increasing policy support for scientific activities supportive of valorization, such as academic business plan competitions venture finance, public lecture series, school visits, and newspaper articles (exogenous valorization activities) (Benneworth and Jongbloed 2010). Academics seek to demonstrate their research's societal impact to ensure public support and funding for their activities (Stilgoe et al. 2014). These two issues may potentially conflict, particularly around research governance and decision-making, where heavy-handed top-down attempts to more directly align individual research agendas with thematic priorities have driven scientific resistance (Gläser 2019; Hessels and Van Lente 2008; Leisyte et al. 2008).

In this chapter, we ask whether researchers who use societal knowledge in their research activities (what Olmos-Peñuela et al. (2015) called "open" research micro-practices) engage in different kinds of engagement activities to those that do not. We address this question with an empirical study using a unique database created within the IMPACTO project, conducted in 2011 and commissioned by the Spanish Council for Scientific Research (CSIC). We develop a novel characterization of

J. Olmos-Peñuela (✉)
Universitat de València, Valencia, Spain
e-mail: julia.olmos@uv.es

P. Benneworth
Western Norway University of Applied Sciences, Bergen, Norway

E. Castro-Martínez
INGENIO (CSIC-Universitat Politècnica de València), Valencia, Spain
e-mail: ecastrom@ingenio.upv.es

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engagement activities based on the anticipated effect they have on future research directions, what we call “restrictive” and “non-restrictive” activities. We examine whether open researchers have a greater tendency toward restrictive activities than non-open researchers, and identify two potentially different modes of engagement, what we call “defensive engagement” and “assertive engagement.”

2 Literature Review

Policymakers have used many incentives to ensure scientific research is applied and exploited in society. There have been demand-side measures, encouraging users to seek out scientific knowledge such as innovation vouchers, and also mobility schemes that fund academics to work temporarily in user application contexts (Foray et al. 2015). Many incentives have targeted the supply side, the academics deciding whether or not to make their knowledge available. On the demand side, there has been support for exogenous valorization schemes, as well as for endogenous schemes; for instance, involving users in research projects in various ways, hoping that involvement will make the resultant knowledge more usable and accessible to users (Bammer 2019). Several frameworks, based on different criteria,[1] have been proposed to conceptualize engagement activities and valorization pathways (e.g., Molas-Gallart et al. 2002; Hughes and Kitson 2012; Abreu and Grinevich 2013; Muhonen et al. 2020). However, as far as we know, the restrictiveness criteria—the anticipated effect that engagement activities with users have on future research directions—has not been yet considered in this kind of frameworks about engagement activities.

User involvement in research practices influences the research direction as part of making it more usable (following Elam and Bertilsson 2003; Sarewitz and Pielke 2007; Neff 2014; Bammer 2019). That has raised concerns that could negatively influence on scientific progress, what Bozeman et al. (2013) have called the “dark side” of research collaboration; this endogenous engagement is potentially “restrictive” on research direction. Likewise, it tends to be burdensome for scientists, managing interactions with non-scientific users, and it may even be seen as representing “bad science” (Bozeman and Gaughan 2007). Conversely, exogenous engagement does not allow users’ influence over research direction; it is “non-restrictive” on research direction involving relatively low time inputs.

[1]Examples of typologies based on different criteria: Molas-Gallart et al. (2002) differentiate between third-stream capabilities and activities; Hughes and Kitson (2012) classify the spectrum of engagement activities on four main categories (commercialization, problem-solving, people-based and community-based), Abreu and Grinevich (2013) make the distinction based on the commercial nature of the activity (formal and informal), and more recently Muhonen et al. (2020) propose a typology of 12 impact pathways to societal impact on the bases of the dominant mechanism identified.

Researchers under pressure to demonstrate their engagement might, therefore, choose for non-restrictive activities. If non-restrictive engagement activities are as useful to users as restrictive engagement activities, then this is not a problem. But if restrictive engagement activities are better for knowledge exploitation, this creates a trade-off, changing research direction in return for greater engagement impact. There are conditions under which individual scientists would rationally choose to bear the restrictions of user engagement, and it is in those cases where users make a direct contribution to that scientific activity (what Olmos-Peñuela et al. (2015) call open scientific practices).

Because science is resource-dependent and resource-scarce, user-contributed resources may allow scientists to ask questions that they individually deem to be interesting (Gläser 2019) and for which resources cannot otherwise be found. Scientific activity is what Knorr-Cetina (1981) calls "*path-impregnated*": researchers' current decisions regarding their plans are shaped by their past experiences (Neff 2014). We would expect scientists who undertook past restrictive engagement activities would be willing to undertake future restrictive engagement if it helps to achieve individual research goals.

Drawing upon literature related to knowledge production and non-academic influences (Gibbons et al. 1994; Stokes 1997; Kitcher 2001; D'Este et al. 2013), Olmos Peñuela et al. (2015) define "open research" as the research characterized by incorporating external knowledge resources in their research practices at five research stages: inspiration, planning, execution, dissemination, and reframing. We expect scientists with open scientific practices would be more willing to consider "restrictive engagement" activities. Open scientific practices are associated with higher usability of the knowledge produced in research; higher burden activities are typically harder to organize, but deeper incorporation of user knowledge increases contribution to what Sarewitz and Pielke (2007) call the "*knowledge reservoir*." We specifically address the following research questions:

- RQ1: Do researchers who conduct open research micro-practices (open researchers) engage differently in (non-)restrictive engagement activities compared to non-open researchers?
- RQ2: What policy approaches could steer academic systems to stimulate more restrictive engagement practices?

3 Methodology

3.1 Population, Sample, and Data Gathering

To address these questions, we used data gathered from the IMPACTO project, conducted in 2011 on Spain's largest public research organization: the Spanish Research Council for Scientific Research (CSIC). The project analyzed empirically the characteristics of relationships established between CSIC researchers and non-academic agents. The study population was restricted to CSIC researchers holding a PhD and with the right to act as principal investigators in third party contracts and agreements: 4240 CSIC researchers held that status at the end of 2010.

Data were gathered between April and May 2011 through a questionnaire covering several aspects related to researchers' profiles, and researchers' research/engagement activities. The questionnaire was distributed online to the complete population, and a telephone follow-up was conducted to ensure a final representative sample according to researchers' scientific field and seniority. We obtained 1583 responses, accounting for 37% of response rate (*cf.* Olmos-Peñuela et al. 2014). Although we repurpose existing data for our novel empirical study, the questionnaire items correspond directly with our primary concepts ("openness" and "restrictiveness of engagement activities"), which justifies its use for exploring our new set of research questions.

3.2 Variables Operationalization

For our study, we constructed two variable sets: those related to researchers' openness micro-practices (inspiration, planning, execution, dissemination, and reframing) and those related to the different forms of researchers' engagement (restrictive/non-restrictive).

3.2.1 Open Research Micro-Practices

To measure researchers' openness micro-practices (our independent variables), we draw upon previous work conducted by the authors that built five variables measuring openness corresponding to the five research micro-practices (Olmos-Peñuela et al. 2015). We also utilize their previous operationalization of "open star researchers" and "non-open researchers," a binary variable that considers the number of open micro-practices implemented by academics during their research (Olmos-Peñuela et al. 2016). We draw on the work conducted in previous studies[2] and present below the operational definition of the six variables, five related to openness within different research micro-practices (Olmos-Peñuela et al. 2015) and one capturing open star researchers (Olmos-Peñuela et al. 2016):

- *Inspiration:* Binary variable coded "1" if the researcher scientific activity was inspired or substantially inspired by the practical use and/or application of knowledge outside the academic environment, and "0" otherwise.
- *Planning:* Initially measured as an index on a Likert scale of frequency ranging from 1 (never) to 4 (regularly) regarding the frequency with which the researcher

[2]Following Weingart (2009), we acknowledge we have already used these operational definitions when publishing with this database.

engages in each of the following activities when conducting a research project: (i) Identify the potential results of your research that can benefit users, (ii) Identify the potential users who can apply the results of your research, and (iii) Identify intermediaries to transfer the results of your results. We then transformed the resulting "openness" continue variable into a binary variable coded "1" if the researcher is ranked at the top 50% in terms of open research behavior at the planning stage, and "0" otherwise.

- *Execution:* Initially measured as an index on a Likert scale of frequency ranging from 1 (not important) to 4 (very important) regarding the degree of importance the researcher attaches to each of the following items, as a reason for interacting with non-academic agents: (i) To keep abreast of about the areas of interest of these non-academic entities, (ii) To test the feasibility and practical application of your research, (iii) To obtain information or materials necessary for the development of your current lines of research, and (iv) To explore new lines of research. We then transformed the resulting "openness" continue variable into a binary variable coded "1" if the researcher is ranked at the top 50% in terms of open research behavior at the execution stage, and "0" otherwise.
- *Dissemination:* Binary variable "1" if the researcher, as a result of collaborating with non-academic entities, reported as important or very important the following three results identified as co-creative dissemination activities they got: (i) Obtaining patents or other intellectual property rights; (ii) Developing exhibitions and/or exhibition catalogues, generating clinical guidelines, and standards; and (iii) Codes of practices, and "0" otherwise.
- *Reframing:* Binary variable "1" if the researcher has experienced changes or substantial changes in the past research agenda as a result of the relationships with non-academic entities, and "0" otherwise.
- *Open star researcher:* Binary variable "1" if the researcher is open in at least four out of the five research stages, and "0" otherwise.

3.2.2 Restrictive/Non-restrictive Engagement Indices

To measure restrictive/non-restrictive forms of researchers' engagement, we draw on a single IMPACTO question covering a reasonable range of engagement activities with non-academic partners (see the first column of Table 1 for more details). Specifically, respondents were asked to report whether they had participated, within the last 3 years, in engagement activities with different types of non-academic partners (firms, government agencies, international organizations, or non-profit organizations). We coded as "1" if they participated at least once in the activity (regardless of the type of non-academic partner) and "0" otherwise. The distribution of the 14 engagement activities is depicted in Fig. 1. For instance, 36% of our sample reported having participated in consultancy through committees and expert meetings, while 59% reported having participated in technical services, technical reports, or technological support.

Table 1 Correspondence between the IMPACTO project survey items and expert survey items

IMPACTO project survey items	Expert survey items
Use of CSIC infrastructures or equipment by this entity	Use of academic organization infrastructure or equipment by the non-academic partner
Consultancy through committees and expert meetings	Consultancy through committees and expert meetings
Technical services, technical reports, or technological support	Technical services, technical reports, or technological support
Participation in diffusion activities in a professional environment *(congress or professional conferences, trade fairs)*	Presentation of findings to a non-academic/generalist audience
Occasional contacts or consultations (not formalized through a contract or agreement)	Occasional informal contacts or consultations with non-academic partners
Collaborative research funded by a Spanish public program	Collaborative research funded by national public program
Collaborative research funded by international programs	Collaborative research funded by international programs
Contract research (original research project totally sponsored by the contracting entity)	Contract research completely funded by the non-academic partner
Creation of a new firm in partnership	Creation of a new firm in partnership with the non-academic partner
Participation in the creation of a new center or joint unit of R&D	Participating or creating a new R&D unit or center together with the non-academic partner
License of patents (or other types of intellectual property protection)	License of patents (or other types of I.P. protection)
Temporary stay of a person of your team outside the academy	Secondment of an academic researcher into a non-academic organization
Training of postgraduates outside the academy *(including PhD Thesis)*	Postgraduate students (PhD and Masters) undertake research placements in non-academic partners
Courses and specialized training activities taught by the CSIC	Courses and specialized training activities taught by the academic organization

Fig. 1 Distribution of CSIC researchers' participation in engagement activities (IMPACTO Project) by restrictiveness

To distinguish "restrictive" and "non-restrictive" engagement activities,[3] we conducted an expert survey in 2019 following a convenience sampling method via the EuSPRI scientific community.[4] We designed a questionnaire containing three questions: (1) respondent's job title, (2) their previous experience in knowledge transfer and exchange, and (3) the degree of restrictiveness of the engagement activities (measured in a 5-point Likert scale). We redrafted the IMPACTO items for clarity (see the second column of Table 1 to see the items correspondence). We asked experts to score the 14 engagement activities according to whether they believe they represent a High Potential Restriction (Very High = 5) or a Low Potential Restriction (Very Low = 1) according to the following definition: *high (low)* potential restriction engagement activities have a *higher* (*lower*) chance of later constraining how the academic can use the knowledge for later scientific exploitation.

To gather the data about activities' restrictiveness, we individually approached 58 experts[5] through a personal email explaining our expert survey and requesting their participation. Those that agreed were sent a link to the survey, which took on average 6 min to be completed. We received 50 completed surveys, a response rate of 86%. Analyzing these 50 responses, we segmented the 14 activities into seven "restrictive" engagement activities—those with an average rate higher of 2.5 out 5—and seven "non-restrictive" engagement activities—those with an average rate of 2.5 or lower. Figure 1 matches the information coming from our two sources of information (IMPACTO survey and expert survey) depicting the 14 engagement activities divided by its restrictive and non-restrictive nature, along with CSIC researchers reported participation in each activity. For example, we found that 56% of our sample reported having participated in contract research completely funded by the non-academic partner (restrictive activity). In comparison, 82% reported having involved in occasional informal contacts and consultations with non-academic partners (non-restrictive activity).

To build the restrictive/non-restrictive engagement indices, we draw upon Bozeman and Gaughan (2007)'s "involvement scale index" methodology used to capture researchers' engagement activities with non-academic partners. This methodology has been used and adapted in more recent engagement studies (Tartari et al. 2014; Tartari and Salter 2015; Llopis et al. 2018). Specifically, it allows creating a weighted scale that considers the item's occurrence, thus retaining "the theoretical

[3]In an earlier version presented at a conference, we segmented the items based on our judgement into "restrictive" and "non-restrictive" engagement activities. The expert method was introduced to improve study validity. Expert opinion only differed in two items from the initial classification attempt.

[4]The EuSPRI community is a scientific network comprising research centers where recognized experts investigate topics such as university innovation/valorization activities; an early version of this paper was presented at the EuSPRI conference in 2018.

[5]We targeted experts with more than 5 years of experience in the field to ensure minimum expertise that contributed to a more reliable segmentation.

value of providing greater weight to "more difficult" items while not enforcing requirements for ordered symmetry'(Bozeman and Gaughan 2007: 702).

The first step in applying this methodology consists of computing the level of occurrence b_j for each engagement activity (whether the researcher has engaged at least once in this activity within the preceding 3 years). Thus, as indicated by the formula below, we computed for each researcher (n) of the whole sample (N), the frequency b_i of the researcher's engagement in each type of activity j (since we consider 14 activities, $j = 1,\ldots,14$):

$$f_i = \frac{\sum_{n=1}^{N} b_{n,j}}{N}$$

The second step to build the engagement indices is to compute the frequency of the non-occurrence ($1 - fj$) as depicted below:

$$\text{Index} = \sum_{j=1}^{J} (1 - f_i)$$

For illustrative purpose, in the case of "*Consultancy through committees and expert meetings,*" the frequency is 0.36, and the frequency of non-occurrence is 0.64 (1–0.36). We conduct these calculations for the 14 engagement activities.

The final step involves applying both the theoretical distinction between "restrictive" and "non-restrictive" engagement and the results obtained through the panel experts' procedure to obtain the two engagement indices. Considering this distinction, we sum up, on the one hand, the frequency of the non-occurrence ($1 - fj$) of restrictive engagement activities and, on the other hand, the frequency of the non-occurrence ($1 - fj$) of non-restrictive engagement activities. As a result, we obtain the two variables, namely "restrictive engagement index" and "non-restrictive engagement index."

4 Results

Table 2 presents the descriptive analysis of our study variables. Given that our engagement activity variables are built as scales from Bozeman and Gaughan's (2007) methodology, we assessed the Cronbach Alpha to check the scale's reliability and whether its value improved by removing any items. For both scales ("restrictive" and "non-restrictive" engagement activities), results indicated that the scales do not improve by removing any of the items and have acceptable values (>0.50) for emergent constructs (Ahire and Devaray 2001). We also assessed the distribution of the engagement indices (continuous variables) and checked that logarithmic, or square root transformations do not reduce the degree of skewness, so we kept the original engagement indices, which fit better with a normal distribution.

Table 2 Variable descriptive statistics

Variables	Nature	Mean (SD)	Range	Cronbach (α)
Openness[a] (research micro-practices and open star researchers)				
Inspiration	Binary	0.71 (0.45)	0–1	N.A.
Planning	Binary	0.48 (0.50)	0–1	N.A.
Execution	Binary	0.50 (0.50)	0–1	N.A.
Dissemination	Binary	0.29 (0.45)	0–1	N.A.
Reframing	Binary	0.28 (0.44)	0–1	N.A.
Open star researchers	Binary	0.22 (0.42)	0–1	N.A.
Engagement activities				
Non-restrictive index	Continuous	1.49 (0.89)	0–3.01	0.65
Restrictive index	Continuous	1.28 (0.96)	0–4.62	0.60

SD Standard Deviation, *N.A.* Does Not Apply
[a]We built openness variables following Olmos-Peñuela et al. (2015, 2016)

Table 3 *t*-Test results about differences between engagement in restrictive and non-restrictive activities (columns) and about differences between *open star* and *non-open* researchers for restrictive and non-restrictive engagement activities (rows)

	Open star	Non-open	*t* value (*p*-value) Open star vs. non-open
Restrictive engagement index	1.85	1.27	−9.82[a] (0.000)
Non-restrictive engagement index	2.03	1.52	−9.71[a] (0.000)
t value (*p*-value) Restrictive vs. non-restrictive engagement	3.35[a] (0.001)	10.43[a] (0.000)	

[a]Indicates significant differences at 1%

This study seeks to explore empirically whether researchers' openness is associated with their participation in restrictive and non-restrictive engagement activities. Therefore, firstly we examine whether there are differences between researchers' participation in restrictive and non-restrictive engagement activities (Table 3, fourth row); and secondly, we explore whether there are differences between open star researchers and non-open researchers in their engagement patterns (Table 3, fourth column). We run t-tests to assess the following null hypotheses:

- H_0 = There are no differences between the participation in restrictive and non-restrictive engagement activities *(t-test Restrictive vs Non-restrictive engagement).*
- H_0 = There are no differences between open star researchers and non-open researchers for the restrictive and non-restrictive engagement activities considered *(t-test Open star vs Non-open).*

We reject these null hypotheses if the p-values found are lower than 5%. The means of the variables restrictive and non-restrictive activities, along with the *t*-test results, are presented in Table 3.

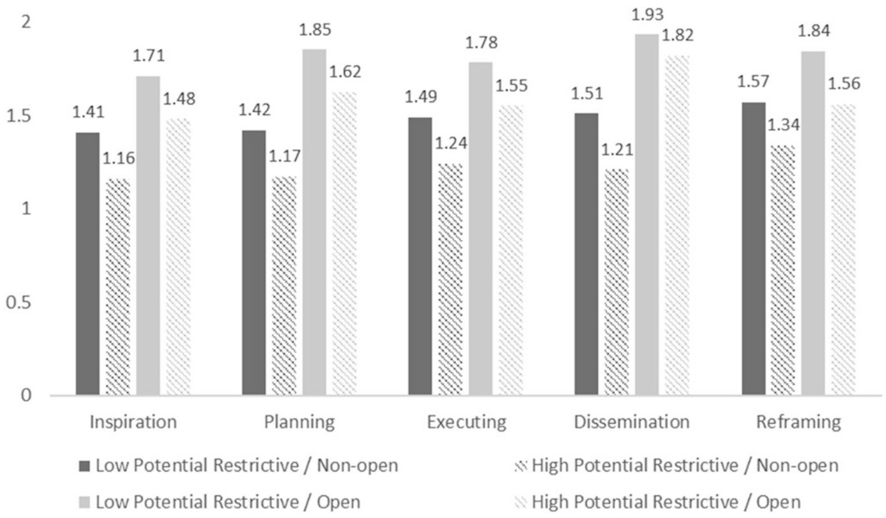

Fig. 2 The distribution of engagement index scores across the five academic research practices, open vs non-open researcher, restrictive vs non-restrictive activities. Source: Authors' design based on Table 3

We identify two significant results from Table 3. *Result 1* is that restrictive engagement activities are significantly less prevalent than non-restrictive engagement activities for both open star and non-open researchers (Table 3, fourth row). This, in turn, suggests that there is some material difference to researchers in the efforts that these practices impose, otherwise we would expect that there would be no statistically significant difference in the prevalence of each engagement activity. *Result 2* is that open star researchers undertake significantly more engagement activities than non-open researchers, both restrictive and non-restrictive (Table 3, fourth column). This suggests an association between openness and engagement intensity: more open researchers undertake more engagement activities.

From this inference, we seek to understand whether the research micro-process at which a researcher is open affects the engagement index. In Fig. 2 and Table 4, we, therefore, separate engagement indices between open and non-open researchers, across the five different research micro-practices. Figure 2 suggests that we can strengthen our second result: open researchers undertake substantively more engagement activities than non-open researchers if they are open in that particular research micro-practices: this allows us to treat the groups' behaviors as if they are separate groups in our population (*Result 3*).

We use this group distinctiveness property (*Result 3*) to compare the engagement index (restrictive and non-restrictive) in the five research practices. To test these differences, we run a one-way ANOVA using a posthoc analysis, Duncan's multiple range test, which compares the means for each compared group (open vs non-open). The null hypothesis tested is the equality of means for the engagement indices between the different research practices, while the alternative hypothesis is that

Table 4 Results of *t*-test about differences between *open and non-open* researchers for restrictive and non-restrictive engagement activities

	Non-restrictive engagement index			Restrictive engagement index		
Research micro-practices	Non-open	Open	*t* value (*p*-value)	Non-open	Open	*t* value (*p*-value)
Inspiration	1.41	1.71	−5.27[a] (0.000)	1.16	1.48	−5.76[a] (0.000)
Planning	1.42	1.85	−9.97[a] (0.000)	1.17	1.62	−8.97 (0.000)
Executing	1.49	1.78	−6.52[a] (0.000)	1.24	1.55	−5.95[a] (0.000)
Dissemination	1.51	1.93	−8.69[a] (0.000)	1.21	1.82	−10.83[a] (0.000)
Reframing	1.57	1.84	−5.39[a] (0.000)	1.34	1.56	−3.91[a] (0.000)

[a]Indicates significant differences at 1%

there is at least one difference between the mean of each research practice group. We conduct this analysis for both open and non-open researchers and restrictive and non-restrictive engagement activities. The result of the Duncan' test is reported in Table 5 an indicates significant differences between open/non-open researchers' engagement in restrictive/non-restrictive activities across research practices. Specifically, activities are grouped with those with which they do not have a significantly different mean (i.e., research activities whose means are not significantly different are grouped in the same column in Table 5).

Table 5 allows us to make two statements regarding the distributions shown in Fig. 2, refinements that we reflect upon in the discussion section. In Fig. 2, we see that the engagement index is lower in earlier practices and higher within later practices; this pattern holds for open and non-open researchers and for restrictive and non-restrictive engagement activities. Table 5 allows us to establish, via the Duncan test, that there are distinct and homogenous groups of practices in terms of engagement index (*Result 4*). The second result is that the patterns for open and non-open researchers are not equivalent, so non-open and open researchers can be considered as having different behavioral patterns for engagement (*Result 5*).

5 Conclusions

In this chapter, we have asked two research questions. The first was whether open researchers engage differently in restrictive vs non-restrictive societal engagement activities compared to non-open researchers. Our results indicate significant differences between these two groups in their behaviors, and this is observable across research micro-practices (see Table 6 for a summary). Our second research question related to policy frameworks for steering researchers toward restrictive engagement

Table 5 Comparison of means of the engagement indices (restrictive and non-restrictive) for open and non-open researchers (post hoc—multiple comparisons test)[a]

(a) Open researchers Non-restrictive engagement practices[a]					(b) Open researchers Restrictive engagement practices[a]				
		Subset for α = 0.05					Subset for α = 0.05		
Research stages	N	1	2	3	Research stages	N	1	2	3
Inspiration	992	1.71			Inspiration	992	1.48		
Execution	686	1.78	1.78		Execution	686	1.55	1.55	
Reframing	262		1.84	1.84	Reframing	262	1.56	1.56	
Planning	674		1.85	1.85	Planning	674		1.62	
Dissemination	406			1.93	Dissemination	406			1.82
Significance[b]		0.17	0.15	0.07	Significance[b]		0.17	0.23	1.00

(c) Non-open researchers Non-restrictive engagement practices[a]				(d) Non-open researchers Restrictive engagement practices[a]			
		Subset for α = 0.05				Subset for α = 0.05	
Research stages	N	1	2	Research stages	N	1	2
Inspiration	320	1.41		Inspiration	320	1.16	
Planning	638	1.42		Planning	638	1.17	
Execution	626	1.49	1.49	Execution	626	1.21	
Dissemination	906	1.51	1.51	Dissemination	906	1.24	1.24
Reframing	949		1.57	Reframing	949		1.34
Significance[b]		0.06	0.11	Significance[b]		0.12	0.06

[a]Duncan's test compares means for groups in homogeneous subsets when equal variances are assumed

[b]When the significance test is above the threshold of 0.05, the null hypothesis (no differences between means) cannot be rejected

practices. Addressing this second question requires a degree of creative inference from our five findings (with the resultant limitations this has for certainty).

The first inference we draw (from *Results 1–3*) is that restrictive engagement does impose a burden, given that restrictive engagement activities are less prevalent than non-restrictive activities. This burden is a "*dark side*" of engagement (Bozeman et al. 2013) that creates trade-offs for researchers. Open researchers do more restrictive activities than non-open researchers, suggesting that this burden is easier dealt with by those for whom engagement provides a payback. These clusters of means offer a means of comparing the burdensomeness of particular activities and comparing between how the two groups experience this reflective burden, mindful that the burden is always higher for non-open researchers with respect to open researchers (and following finding that three non-restrictive activities are less burdensome than restrictive activities).

Non-open researchers find dissemination and reframing less burdensome than inspiration, planning, and execution. Likewise, openness in dissemination and reframing would be associated with higher engagement. Dissemination is typically an activity that occurs once research findings have been produced, and so has limited scope to influence research; likewise, the involvement of users in reframing is

Table 6 Summary of results

Results	Inference
Analysis for the research process as a whole	
Result 1: Restrictive engagement activities are less prevalent than non-restrictive engagement activities regardless of the level of researchers' openness	Restrictive engagement may impose a higher burden on researchers than non-restrictive engagement
Result 2: Open researchers undertake more engagement activities than non-open researchers, regardless of the level of activity restrictiveness	There may be an association between researchers' openness and engagement activities intensity
Analysis differentiating by research micro-practices	
Result 3: Open researchers undertake substantively more engagement activities than non-open researchers if they are open in that particular research micro-practices	Different engagement profile may be identified: Assertive engagement for open researchers Defensive engagement for non-open researchers
Result 4: There are different groups of research micro-practices in terms of engagement practices	
Result 5: Pattern for open and non-open researchers are not equivalent and show a different behavioral pattern for engagement	

usually passive, in that societal users have given a signal that a novel research line would be interesting to pursue. We style this engagement profile as a *defensive engagement approach*.

Conversely, open researchers find planning and dissemination less burdensome, and execution more burdensome than these (with these distinctions being sharper for restrictive activities). We infer that open researchers could be considered as used to balancing the trade-offs in engagement, and therefore would use more active planning and post-research interaction (dissemination) to optimize these engagement burdens. We style this engagement profile, associated with open researchers, as an *assertive engagement approach*.

The *defensive* engagement approach is not an "ivory tower" approach—these researchers still engage, but to minimize their burden. In the *assertive* approach, researchers seek to optimize the trade-off between the burden and the benefits it brings in terms of external knowledge resources. The possibility of these two engagement approaches provides a means to address our second research question. Different treatments could be necessary for these two different groups, those with an assertive research profile could be better equipped to engage in full co-creation. At the same time, those with a more defensive approach could create impacts by being more open in dissemination and execution.

In terms of the wider significance of our findings, we would stress that we did not control for scientific excellence between these two different groups: we do not claim defensive engagement researchers should be stimulated to become more assertive. A more likely explanation for this, in our view, is that different scientists face different trade-off calculi influenced by different factors. Some disciplinary areas find it easier to maintain scientific excellence while being open to research practices than other fields. Certainly, this is an area that requires further research, to develop a better selection of policy levers and measures that reflect the fact that academics in different disciplinary fields, with different users and different susceptibility to content steering, may have to make different choices around engagement to sustain excellence while delivering engagement.

This broader point about the trade-off that scientists are forced to make in terms of collaborating in R&D programs is also germane to the overall theme of this chapter. This debate is often reduced to stylized facts relating to absolutes. Still, our chapter highlights the fact that scientists negotiating a single trade-off, the "dark side" of collaboration, may face different material calculi. That can lead to different kinds of behaviors shaped not by the relationships between the scientists and non-academic partners, but between the academics' own needs within their own wider disciplinary communities, and critically, their understanding of their efficacy to manage that trade-off (openness and restrictiveness).

This provides an additional way of understanding the mismatch between academic and industrial scientists in R&D collaborations. Mismatches between academics and their collaborators are not timescale or excellence vs relevance but arise out of a calculation of whether the benefits of the collaboration outweigh the burdens they face in sustaining their academic status and profile. What determines academic status and profile can be shaped by policymakers in terms of the ways that they define excellence, the ways that criteria for promotion and tenure are set, the requirements of fundamental research schemes, and evaluation approaches. And our recommendation is clear—policymakers should plan for different approaches to engagement, the defensive and the assertive—to make clear the conditions under which academics should consider R&D collaborations as being beneficial to their research.

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Demystifying Value Co-destruction in Collaborative R&D Projects

Linzhuo Wang, Mengtong Jiang, and Fangwei Zhu

1 Introduction

As a growing amount of research and development projects (R&D projects) failed to achieve their pre-defined goals, the collaborative failure in R&D projects has aroused wide concern among researchers and practitioners. Collaborative R&D may not always co-create value that is expected by participants. Some inter-organisational interactions during R&D processes might have adverse consequences and an underlying effect that may lead to value co-destruction instead of co-creation (Plé and Chumpitaz Cáceres 2010). The one-off nature and temporary organisations of R&D projects exacerbate the value co-destruction (Adler et al. 2016) and drive the projects towards Valley of Death (Midler 2019).

Collaborative R&D projects, as emerging organisational form towards innovation and creativity (Zhu et al. 2020), can bring the co-production of the main delivers (through co-design, joint production, collaborative inventiveness, etc.), which becomes a component of value co-creation (Lusch and Vargo 2006). Unsurprisingly, value can not only be co-created, but value can also be co-destroyed (Echeverri and Skalen 2011). In other words, that inter-organisational collaboration does not necessarily lead to positive outcomes (Prior and Marcos-Cuevas 2016) but may result in unexpected failure or even loss of benefits. Failures in collaborative R&D projects prevail, which have been often blamed for environmental uncertainties and technical complexities. However, malice intention and opportunistic behaviour also grows along with those uncertainties, risks and complexities. The identification of these dark sides of value co-creation is seemingly undiscovered due to the sensitive issue of business ethics.

L. Wang (✉) · M. Jiang · F. Zhu
Dalian University of Technology, Dalian, China
e-mail: dlutjmt@mail.dlut.edu.cn; zhufw@dlut.edu.cn

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Co-destruction of value is interactive in nature. Flint and Woodruff (2015) noticed that during the interactive process of value co-creation, a phenomenon of devaluation may occur and reduce the value of co-creation by the dispute and abuse of power (Pinnington et al. 2016). Value co-destruction refers to the situation that participants' welfare is reduced due to the misuse of their own or other resources during the interaction of value formation (Echeverri and Skalen 2011; Plé and Chumpitaz Cáceres 2010). Recent advancement calls for studies on exploring the process of value co-destruction through inter-organisational collaboration (Adamik and Nowicki 2019). Little is known on what value co-destruction means at the project level, or the impact of value co-destruction process on R&D collaboration.

Value co-destruction occurs when two partners have incompatible expectations of the way in which the resources should be created, used, and integrated. This unexpected or inappropriate misuse of the available resources may be accidental or deliberate (Harris and Ogbonna 2006; Ogbonna and Harris 2002). There is a need to unfold the complex processes of co-destruction undermining inter-organisational collaboration. However, current literature is inadequate to gain a thorough understanding of value-related processes in general (Payne et al. 2008), especially in interpreting potential negative behaviours and outcomes (Flint and Woodruff 2015).

The aim of this chapter is to investigate the failure in collaborative R&D projects through the lens of value co-destruction. The dual nature of value, both as an outcome and enabler of the process (Le Pennec and Raufflet 2018), is adopted as a theoretical lens to investigate the dark side of R&D failures. Therefore, we ask:

RQ1: How is value co-destructed during collaborative R&D projects?

The study will contribute to value co-destruction theory by unpacking how the failure of R&D project is caused by value co-destruction as an inter-organisational process, which could reduce the risks of value co-destruction fundamentally and motivate participants to ultimately achieve value co-creation. Practitioners also benefit from the results by aligning the mutual expectations and implementing the efficient management strategies to limit the misuse of resources and recovering from misuse.

To fulfil this aim, in this chapter we focus on two typical R&D projects that fail because of the value co-destruction processes. The exploratory nature of this study calls for a case study (Eisenhardt 1989). Data for this chapter were collected in way of case study approach. Semi-structure interviews for two R&D projects were conducted with major participants of involved parties. The first project is 'O-robot' project initiated by Company QQ and Company HT, which is a champion project in 2 consecutive years of entrepreneurship competition. The other project is Magnet project by Company ZB and Company VAC, which is a renowned project in rare earth industry. The companies involved in this chapter were anonymised for privacy protection.

The remainder of the chapter is as follows. First, the current literature on value co-destruction and R&D projects is reviewed. Second, a brief introduction of the two projects is presented discussing background and events that were conducive to failure of both projects. Third, the discussion and conclusion of the theoretical model is presented, unpacking and demystifying the value co-destruction mechanisms that leads to failure of R&D projects.

2 Value Co-destruction and Collaborative R&D Projects

Existing research shows that technology R&D brings benefits to participants through value co-creation, while it will also cause value co-destruction. Plé and Chumpitaz Cáceres (2010) define value co-destruction as a situation in which participants deliberately or accidentally abuse their own or other resources during the interactive process of value creation, resulting in a decrease in the welfare of at least one party. This chapter characterises value co-destruction into the following three aspects: cause, process and result and adopts this theoretical perspective to unpack the processes for value co-destruction processes. In terms of causes, the so-called abuse of resources means that a participant fails to integrate and/or apply resources in a suitable or appropriate manner that the opponent expects (Harris and Ogbonna 2006; Ogbonna and Harris 2002), or due to other reasons including insufficient resources (Järvi et al. 2018; Vafeas et al. 2016) and the resource differences between actual and committed (Echeverri and Skalen 2011). In terms of process, value co-destruction occurs during the interaction between actors, which may be conducted directly or indirectly. Value co-destruction is more like a state in the dynamic process, rather than a concrete observable behaviour. In terms of results, welfare refers to the self-regulating ability or environmental adaptability of a participant (Vargo et al. 2008), which is asymmetric and temporal. Asymmetry is that, for all participants, the degree of value destruction suffered by each party during the interactive process is imbalanced. In addition, the loss of value of one party, however, may lead to the value creation of the opposing party (Plé and Chumpitaz Cáceres 2010). Temporality is caused by perception and development, as Stieler et al. (2014) pointed out that the value co-destruction includes not only the actual decline in value creation but also the negative deviation from the expected increase of welfare.

Due to the uncertainty, risk and complexity of cooperative R&D, the project alliance requires all parties to cooperate in good faith, jointly share the high risk, and make consistent decisions to improve the project performance. The key feature of the successful implementation of cooperative R&D projects is the collective focus on the value creation and value for money (Pargar et al. 2019). Existing researches on value creation, especially in the field of marketing, concentrate on the general service exchange and hold a view that the value would be created by the customers in the process of use (Grönroos 2011; Salomonson et al. 2012; Patala et al. 2012). From this perspective, a cooperative project can be viewed as a service with unique goals and resource applications. In a cooperative exchange of R&D projects, different kinds of resources are delivered by a single or multiple stakeholders, and the value is co-created by all cooperative partners. A case study by Mills and Razmdoost (2016) shows that even based on mature cooperative networks, projects may evolve into uncoordinated relationships, if not well managed, resulting in the withdrawal of resources and the value co-destruction. In addition, factors such as unethical behaviour, misalignment of values, unequal power and lack of contextual awareness will also negatively affect project cooperation (Fuentes 2019), destructing value of one or both parties. Researchers have identified value co-destruction as dark side of R&D projects. However, in-depth investigations and systematic analyses of this field have not been conducted.

3 Cases

The exploratory nature of the study calls for a qualitative approach to unpack the underlying patterns for value co-destruction of R&D collaboration. To answer the research question, comparative case studies were conducted based on the interview data. This inductive approach facilitates exploratory process of theory development (Eisenhardt 1989). Since companies are driven by their own interests, the commercial R&D collaboration between companies probably are more prone to co-destruction opportunities than other types, for example, the university–industry R&D collaborations. From March to April 2020, two collaboration cases involving four companies were chosen on the basis of information-oriented sampling technique (Flyvbjerg 2006), for the following several reasons: (1) both projects are leading projects in their regional industry; (2) both projects experience serious collaborative difficulties; and (3) both projects can be accessed for all participating parties along with whole R&D collaboration processes. Project Magnet (top managers and project members) and Project O-robot (CEO, the project manager and engineers) were selected, and 15 person-time interviews were conducted for data collection in total, which later analysed through (1) within-case analysis; (2) cross-case comparison (Eisenhardt 1989).

3.1 Background Introduction

3.1.1 Project Magnet

ZB Magnetic Technology Co., Ltd (Company ZB) was founded in August 2000 and officially listed in the national small- and medium-sized enterprise stock transfer system on August 8, 2014. It is a national high-tech enterprise specialising in the production of high-performance neodymium rare earth permanent magnetic materials and application devices. It specialises in the design and processing of Vacuum furnace and magnetic medical components. At present, the company has the capacity of producing high-performance sintered magnet of 3500 tonnes. ZB has independent intellectual property rights of all processes and equipment technologies such as vacuum rapid solidification, hydrogen treatment, air flow grinding, magnetic field forming, vacuum sintering, etc. The Magnet R&D project was initiated by Company VAC. Company VAC is a renowned company in manufacturing magnet. Company VAC intended to explore the high-end drone and robot market, which requires high-performance magnets. Therefore, they came to Company ZB to form the joint R&D Magnet project. Company VAC asked for collaborative technical improvement in building Magnet with minimum reduction of remanence (the magnetic flux that remains in a magnetic circuit after an applied magnetomotive force has been removed), but with high-level coercive force.

The project was initiated in 2016. Both parties were heavily involved in maximising the performance of Magnet. Company VAC provides technical details and potential theory that proved efficient at the lab. Meanwhile, Company ZB was responsible for the operationalisation of techniques and building a Vacuum furnace that would produce the best Magnets. However, the project was terminated because of the withdrawn of Company ZB, which results in value loss of both parties.

3.1.2 Project O-Robot

Beijing HT Information Technology Co., Ltd (Project party A, hereinafter referred to as HT), founded in 2014, is a professional service and guidance company focusing on entrepreneurship incubation. It provides comprehensive services for early entrepreneurs, such as management assistance, technical guidance, investment and financing support, etc., to help start-ups quickly realise the full life-cycle process of establishment, growth and development. Up to now, HT has invested and managed about 300 projects and enterprises with a scale of more than 4.24 billion USD, mainly focusing on the fields of artificial intelligence, big data, advanced manufacturing (smart manufacturing), consumer education, and medical health. The other party B of project “O-robot”, Dalian QQ Technology co., LTD. (hereinafter referred to as QQ), is a start-up technology company specialising in the field of mobile robots. It is founded in 2017 by several college students from different schools, such as mechanical engineering, software engineering, artificial intelligence and enterprise management, etc. At present, QQ is estimated to be worth about eight million USD.

In the field of the new type terminals and intelligent manufacturing, the two parties have cooperated in the research and development of a small wheel-ball self-balancing robot project (named “O-robot”) and signed a cooperation agreement in 2019. The goal of the project is to jointly develop and mass-produce the “O-robot”, an automatic intelligent robot with walking and audio-visual abilities, and put it on the market. Among the two parties, HT provides related support for the mass production of project, including: process design, pre-testing, assembly production, financing sales, post-production related technologies, after-sales services, and business consulting required. While QQ Technology is responsible for the design of main technical development, programme algorithms, circuit components and mechanical structure design, so it enjoys the intellectual property and patents rights of the above research and development achievements.

3.2 *Case Description of Value Co-destruction*

3.2.1 Project Magnet

The collaborative project did not go as expected. In the two-step development strategy of the collaborative project, the close cooperation between Company ZB and Company VAC has become an important link in the production chain of permanent magnet products. Company V benefits from Company ZB's technical support in improving the furnace. Company V has realised module development, electroplate coating, efficient and high-quality processing methods of its product, which can give full play to the excellent mechanical properties and capacity density of permanent magnet devices. The improved technique is conducive to the lightness, thinness, miniaturisation or ultra-miniaturisation of magnetic components. The collaboration also boosts up the R&D technique of Company V. During their collaborative effort, company ZB has discovered a specific technique that would immensely increase the performance of magnet. This abrupt discovery of unexpected techniques changed the mind of CEO of Company ZB. Company ZB also produces high-performance magnet, then Company ZB decided to terminate the collaboration and focus on producing new magnet products.

Company ZB changed his mind in collaborate with Company V, and then Company started to absorb all important tacit and implicit knowledge of Company V. Without letting Company V know about his plan, Company ZB had made a breakthrough in the core technology of products. It has put forward the technology of permeating metals. Through the diffusion of heavy rare earth grain boundary and the reduction of grain size, the dependence on heavy rare earth has been reduced from 3% of the industry average level to an extreme value close to 0, becoming a "*dysprosium free product*" with important strategic significance. This new technology can make the heavy rare earth elements concentrate on the interface between grain boundary and grain, almost without reducing remanence, but the coercive force is greatly increased. The progress of this series of core technologies has greatly reduced the dependence of enterprises on heavy metals, reduced the cost by an order of magnitude, and finally realised the high-end product characteristics of high magnetic performance, high temperature resistance, high magnet and other industries. This technology will make Company ZB's products outstanding in the industry. However, Company ZB eventually terminate the collaboration with Company V in a fairly amicable manner.

3.2.2 Project O-Robot

With the progress of the project and the deepening of the cooperation, some discordant sounds emerged, and the rhythm of the project was disrupted. The main conflict at the moment is a seemingly insignificant trifle, but what lies behind it caught our attention, it caused the two parties to accumulate bitterness towards each other for a long time.

The QQ technology engineer sent the design drawings to HT, looking forward to their reply, but after a long wait of 2 months, they got only one sentence from the product designer of HT: add three threaded holes. Which irritated the engineer greatly, on the one hand, repeated delays had caused serious delays in the project. As a start-up company specialising in high-tech innovative, QQ would suffer a lot by missing the right opportunity to enter the market. On the other hand, QQ should be responsible for the mechnical structure design, not HT, as was discussed in prior negotiation.

Regarding this conflict, both parties held their own opinions. Through additional interviews and documents with the main leaders of both sides, we further understand each other's ideas. QQ Technology believed that, first, HT did not fulfil the agreed-upon tasks and responsibilities agreed in the original plan. Modifications to the structural design are technical research and development within the scope of QQ Technology. As long as the design drawings do meet the processing requirements, HT should provide the shape optimisation and the manufacturing material selection according to the design drawings submitted, rather than put forward such a modification reply. Secondly, the working efficiency of HT is far below the normal level, there are too many problems, like excessive hierarchical structure, misunderstanding of information transmission, barriers of management and technical staff, slow response and communication, and so on. All these evitable losses and unnecessary ineffective communication caused the delay of project progress.

4 Discussion

The in-depth analysis of two cases was conducted through three coding stages: The first stage aimed to select and code the original data, including the definition of the initial code and the refinement of the code structure. In the second stage, three researchers jointly compared and verified the codes they had formed independently. On the final stage, the researchers sorted out the theoretical framework, and the relationship between the new framework and existing theories was continuously iterated, verified, and compared. As a result, we have identified three stages of value co-destruction processes and their corresponding sub-dimensions. The two cases are inherently different from one another, which can be further categorised into two different types of value co-destruction paradigms, including direct intention (for Case project Magnet) and indirect intention (for Case project O-robot). The following sections describe the constituting sub-elements that differentiate two cases and the value co-destruction processes that unfold along with these two cases.

4.1 Collaboration Motivation and Backgrounds

The collaboration motivation are pre-project intentions for participating parties. Typically, the participants of the R&D project have their own strengths and advantages, and their capacities and techniques complement each other through cooperation in order to meet their own value proposition.

- Respective Capacity: As for the Magnet project, there are potential threats in the capacities of both parties. Company ZB is capable of making furnace products of high quality for Company VAC, but Company ZB is also capable of making magnets itself, especially top-tier products. As for "O-robot" project, HT has a great number of large-scale and investment projects, whose main targets cover major cities including Beijing, Shanghai, and Guangzhou, rather than second-tier cities like Dalian. As a start-up, QQ's core management and technical team consists of only 6 people, and 15 people for all employees including marketing and business departments.
- Complementary Technique: As for the Magnet project, Company ZB is capable of providing vacuum furnace technology, and Company VAC has the mastery of new high-performance Magnet solutions. To a certain extent, Company ZB is also willing to cooperate with enterprises like Company VAC, which can improve its technology sets to a great extent. This complementarity is also recognised in "O-robot". The mechanical engineer Peng from QQ said: "HT's high-profile in the industry helps us to win the competition, obtain certificates and bonuses, and also increase financing. We are facing a fact that there is no technical support inside our province, which requires us to seek processing production and supporting technology from HT." … "*However, the core technology ultimately depends on ourselves, and 'O-robot' is imitated by other teams, but the final performance is far less than ours*".
- Value Proposition: In the Magnet project, during the process of collaborative R&D, Company ZB realised the core technology issues, and planned to "capture" this technology for its own production of a high-performance Magnet. The value proposition for both parties are different, company ZB intends to improve its technology through collaboration, while the VAC aims for commercialising mass production equipment. As for O-robot, QQ provides both the mature structure and the good stability of a robot, hoping that HT will provide the shell image and mould design. A project coordinator from HT also agreed: "*They do the bottom-level control (internal structure), integrate with our upper-level applications, such as AI assistants, educational resources, intelligent voice and other platforms, so that O-robot can achieve physical, and practical like run, speak and interact*".

4.2 In-Process Behaviours

For the two parties involved in collaborative R&D projects, the splitting of mindset ultimately led to different and even conflicting behaviours. These behaviours can be either deliberate or unintentional/accidental:

- Cognitive Splitting: For the FdNeB project, Company ZB always holds the attitude of "learning" and wants to know how to produce a high-performance Magnet. However, VAC intends to ensure the research and development progress of mass production equipment, VAC relatively lose the protection of knowledge spill over. As for project O-robot, "*The agreements are fine, but the actual offer is not what we want*", the CEO of QQ said as above. HT is responsible for the optimisation of the external structure rather than the mechanical structure, and the two parties may have different understandings.
- Behavioural Performing: For the Magnet project, VAC did not apply for a patent pool (a series of patents for patent protection) for its core product but choose to apply for only one patent. The lack of comprehensive technical protection give room to mimicking. Through imitating, optimising, and improving, Company ZB successfully applied for similar but different patents avoided the legal block. As for the O-robot project, the Project manager said, "*The two parties, technology and management, have some misunderstanding for each other*". More precisely, there are four agents: technicians and managers from HT and from QQ, respectively. The QQ's CEO Zuo complained: "*The schedule is dominated by HT. Although the meeting is held regularly, the progress is not fast enough, and we have to wait passively. We were so eager that we found a third-party workshop to design and pre-produce the model in just two weeks and uploaded it to HT's system to wait for the subsequent expert review and other processes*".

4.3 Outcomes of Value Co-destruction

The outcomes of Value co-destruction are the results affecting the overall project and participating stakeholders. Besides causing project early termination and schedule delays in project progress, some explicit and implicit value losses have also emerged in both cases:

- Project Progress: In the Magnet project, the loss of Company ZB caused the non-completion and abandonment of the R&D project. The mass and batch production of their products were cancelled. Company ZB chose to actively quit the collaborative project and produce the high-quality magnet by itself. This also caused severe loss to VAC. In the other project O-robot, due to the slow progress of the HT's online system, both parties are not very active in the later period, and the current project is stuck in the craft model design process. The project manager of HT said: "*Yes, it took a long time and a lot of effort on* *both sides to get the demand right*". QQ engineers also added: "*I don't know much about art shaping, and I have communicated with him many times, which led to the delay of progress*".

- Value Loss: For the Magnet project, due to ZB's own capacity defects, Company ZB did not fully grasp the market that new technology has been introduced to but was bound by the certification system and quality system required of a high-performance Magnet. This resulted in a loss instead of profit. Although the project O-robot is still in on-going status, the delay may cause loss of key market, and this opportunity cost is a potential loss of future revenue: "*The original plan is to sell the product to the market in around one year, but I'm not sure if the market opportunity has been missed after this delay*".

4.4 Direct Intention and Indirect Intention

The direct intention describes the cognitive aspects of one party (or both parties) who join the collaborative project without good faith. The failure of R&D projects prevails to such an extent that commonly encountered or unavoidable risks and uncertainties were taken as *opportunities* for the participants to execute their *rights*. Some conducts are violating business ethics and may result in loss of value to both parties. The Magnet Project case typically depicts a scenario in which Company ZB take their chances for opportunistic behaviours and encroach on the value of both parties.

In contrast, the indirect intention describes the cognitive aspects of one party (or both parties) who join the collaborative project with non-malicious intention. That party broke the value proposition and destroyed the collaboration through reckless behaviour or by other side effects. Usually, the indirect intention was triggered by plans and actions that were beneficial only to one party. More often than not, collective value becomes indifferent to one party or even contradicts the value of that party. For example, in the case "O-robot" project, neither side was maliciously hurtful to the other, but they ignored the relatively large differences of developmental state and inherent awareness.

According to Fig. 1, the value co-destruction processes encompasses three major stages, (1) collaborative motivation and background; (2) in-process behaviours; and (3) outcome of value co-destruction. The differences between direct intention and indirect intention in value co-destruction processes reside in the intentions, of one party or both parties. Value co-destructions processes are commonly seen in R&D projects. Value co-destructing behaviours are disguised or camouflaged in the daily process of collaboration on the pretext of uncertainties, risks and complexities of the nature of R&D. However, value is often destructed because of human factors rather than force majeure.

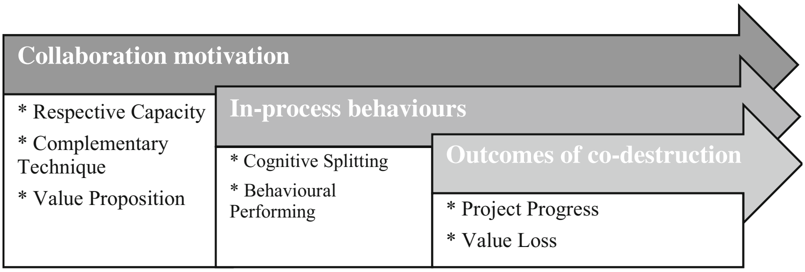

Fig. 1 Three primary dimensions of value co-destruction processes

5 Conclusions

R&D projects, in collaborative settings, are more fragile and brittle than ever. These uncertain, risky, and complicated projects often failed due to value-destructing direct and indirect intention of one or both parties. The value of at least one party is then destroyed, and these reckless and deliberate motivations cause negative cooperative behaviours and lead to loss of value. The value co-destruction processes consist of three main stages: collaborative motivation; in-process behaviours; and the outcome of value co-destruction. The collaborative motivation stage includes respective capability, complementary technique, and value proposition. The in-process behaviours include cognitive splitting and behaviour performing. The outcomes of value co-destruction processes are consisting of project progress and value loss. The sub-dimensions of these stages of value co-destruction processes characterise direct intention and indirect intention paradigms.

These typologies provide insights for stakeholders of collaborative R&D projects to identify the potential threats that might undermine the proposed value. Core participants of R&D projects should be aware of opportunistic behaviours that either deliberately conducted by one party or through reckless actions of the opposing party. The comprehensive governance strategies and thorough investigation of collaborating intentions are recommended before initiating the R&D projects. The dark side of R&D projects is unavoidable, newcomers and fresh players should be particularly aware of these value-destructing cognitive threats. Future research can investigate the value co-destruction process and validate it in a broader context. Moreover, we have studied two cooperation R&D projects held between companies, future research might be explored to validate patterns in other types of R&D cooperations, especially those held between universities and companies.

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Challenges in Measuring Performance of Collaborative R&D Projects

Olof Håkansson, Mattias Jacobsson, Henrik Linderoth, Annika Moscati, and Olle Samuelson

1 Introduction

Collaborative research and development (R&D) projects are increasingly common and play an essential role in value creation in society today. Universities, research institutes, and actors from both the public and private sectors are, in different ways, encouraged and incentivised to engage in such projects to enable synergies, bring about new knowledge, innovative ideas, and increase competitiveness (Martinsuo and Killen 2014). In large-scale initiatives such as collaborative innovation programmes, where multiple R&D projects reside, the overall goal is often also to produce societal impact leading to development and growth on a regional, industry, or national level (Grillitsch et al. 2019). However, the benefits and challenges of these initiatives both stem from the same inherent features, such as the cross-boundary nature and the bottom-up approach, where ideas are co-created by involved actors (OECD 2005). Among the clear benefits of such initiatives is that these features, and the configuration thereof, promote multivocality, practical anchorage, and increased relevance in both the process and outcome (Martinsuo 2019). Simultaneously, the same features make the governance and management of the initiatives challenging, where traditional plan-control measures might be

O. Håkansson · H. Linderoth · A. Moscati
Jönköping University, Jönköping, Sweden
e-mail: olof.hakansson@ju.se; henrik.linderoth@ju.se; annika.moscati@ju.se

M. Jacobsson (✉)
Jönköping University, Jönköping, Sweden

Umeå University, Umeå, Sweden
e-mail: mattias.jacobsson@umu.se

O. Samuelson
Luleå University, Luleå, Sweden
e-mail: olle.samuelson@ltu.se

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inadequate to assess and measure the performance (Adams et al. 2006). Based on first-hand experience of the performance measurement work done within a large, long-term, Swedish innovation programme, we provide a reflective account of how some emergent challenges are dealt with in practice. We aim to describe and analyse the lived experiences of a specific measurement initiative within a large Swedish innovation programme called *Smart Built Environment*.

This chapter is written as a collaborative autoethnography (CAE), in the sense that three out of the five authors have been deeply involved in, and thus have first-hand experience of, the work that has been carried out within the innovation programme. CAE is a common method for pooling researchers' lived experiences on a selected sociocultural phenomenon (Chang 2016). With the innovation programme still ongoing, and the analysis being based on lived experiences, alternative perspectives and interpretations are possible and even likely. Following the common recommendation for CAE studies, the interpretations of the events and actions taken have been continuously discussed, contrasted, and re-examined, to ensure 'relational ethics' in terms of a respectful connectedness between the researchers' lived experiences and studied practice (Chang 2016).

As the name *Smart Built Environment* indicates, the innovation programme is targeted at the (Swedish) built environment sector and is, to date, the single largest investment in innovation, research, and development in digitalisation made in this sector (Smart Built Environment 2019). The specific measurement practice that we analysed and reflected on has been organised as a strategic project to assess the performance of individual project outcomes and ensure the fulfilment of the programme objectives over time. To meet the aim and to provide some clarity to a sometimes iterative and complex process, this chapter is structured chronologically and divided into three parts. In addition to this introduction, the first part provides the general context and a brief background to the innovation programme, *Smart Built Environment*, at large. As part of this account, we will focus on how four strategically set objectives related to sustainability, time, cost, and business logics were introduced and translated into action. In the second part, the evolution of the specific performance measurement initiative called *Program-generic Measurement Methods* is outlined. This longitudinal initiative was launched as a strategic project to evaluate all the individual R&D project outcomes within the programme to ensure the fulfilment of the overall programme objectives. Finally, we provide some reflections and practical insights into the experienced challenges and outline some key takeaways.

2 Swedish Research and Innovation Agendas and the Built Environment Sector

The built environment sector plays an essential role in the economic development of Sweden. In 2018, the total construction investments (that is, investments in building and redeveloping real estate and facilities) amounted to 50.5 billion euros (527 billion SEK), which corresponds to 11.4% of the total Swedish GDP (Sveriges byggindustrier 2019). As in most other countries, however, the sector faces several complex challenges related to social and environmental sustainability, increasing costs, relatively low productivity, and long production times (Jacobsson and Linderoth 2018). With digitalisation being one of the significant forces for change in society today and with the built environment sector arguably also lagging in this area, innovation, research and development could in different ways provide the push needed to bring the sector forward. It is within this context that the innovation programme Smart Built Environment was established and operates. The overall aim of Smart Built Environment is to deal with the challenges mentioned above and promote sector-wide digitalisation and industrialisation to facilitate construction that is cheaper, faster, and more sustainable. The specific aim of the programme is to contribute to Sweden's journey towards becoming a global pioneer that realises the new opportunities that digitalisation brings (Smart Built Environment 2020). Before we go further into the details of this specific programme, it is relevant to provide a brief contextualisation.

2.1 One Out of 17 Strategic Innovation Programmes

Smart Built Environment is one of 17 ongoing strategic innovation programmes in Sweden, corresponding to a governmental investment of a total of 770 million euros (8 billion SEK) over 12 years. A basis for these 17 programmes is *The strategic research and innovation agenda* initiative that ran from 2012 to 2016, intending to meet important societal challenges, creating growth, and strengthening Sweden's international competitiveness. As part of this *Strategic research and innovation agenda*, stakeholders from different parts of society jointly formulated visions and defined needs to help develop several innovation areas (Vinnova 2020). In total, over 100 agendas were formulated, some of which merged to apply for strategic innovation programmes. The 17 strategic innovation programmes that came out of this process are joint initiatives, hosted and funded by three Swedish research agencies as actor-driven collaborative programmes in areas that are strategically important for Sweden. The overarching goal for the programmes is to '. . . *create the preconditions for finding sustainable solutions to global social challenges and increase Sweden's competitiveness in the international arena*' (Vinnova 2019).

2.2 Financing Agencies

The three research agencies backing these programmes are Vinnova, the Swedish Energy Agency, and Formas. Vinnova is a Swedish government agency under the Ministry of Enterprise and Innovation with the vision for Sweden to be a robust, innovative force in a sustainable world (Vinnova 2020). The Swedish Energy Agency is subordinate to the Ministry of Infrastructure, intending to lead the energy transition into a modern and sustainable, fossil-free welfare society (Swedish Energy Agency 2020). Formas is the Swedish government research council for sustainable development with two appropriation directions, one from the Ministry of the Environment and Energy, and one from the Ministry of Enterprise and Innovation (Formas 2020). Within all of the 17 jointly financed programmes, actors such as companies, public operations, non-profit organisations, universities and colleges, and research institutes, are encouraged to collaborate through bottom-up generated, co-creation process focused on several strategically important areas to develop sustainable products and services of the future (Vinnova 2019). This means that within each programme, actors from different sectors point out and define areas where they see development needs. Thus, the actors are jointly responsible for formulating challenges, setting common long-term goals, and prioritising investments.

3 Establishing Smart Built Environment and Setting the Objectives

In the process of establishing Smart Built Environment, 'IQ Samhällsbyggnad' (IQS) was one of the important actors supporting the government's idea of investing in strategic innovation programmes. IQS is a member organisation in the Swedish built environment sector that brings together companies, academia and public sector organisations with a focus on innovation, and R&D. For example, in the process leading to the establishment of Smart Built Environment, IQS gathered the stakeholders in the sector around the goal, developed a strategic agenda in the area of Building Information Modelling (BIM) and allied with several other strategic agendas to jointly form and apply for an innovation programme. The application process was extensive and continued for almost 2 years before Smart Built Environment was approved and could be established in 2015. IQS is today the host, or platform organisation, for Smart Built Environment.

Smart Built Environment is not the first initiative of its kind. In 1998, a programme called '*IT bygg och fastighet*' (IT BoF, eng: IT in construction and facility management) was initiated as a research and development programme in the Swedish built environment sector to facilitate IT use in construction. The programme, which ran until 2002, was partly financed by the business community and partly by government funds. Its primary purpose was to create a common IT platform and a national IT strategy for the industry (Samuelson 2003).

3.1 Smart Built Environment

Smart Built Environment is targeted at the contemporary challenges of the Swedish built environment sector. The programme (officially launched in 2016 but established in 2015) is a long-term initiative of up to 12 years. In addition to the three financing bodies, the programme consists of more than 80 partners, comprising companies and organisations in the built environment sector that have the potential to influence both the direction of the programme and the more specific project calls. The strategic plan of Smart Built Environment is updated in every 3rd year, enabling incremental adjustments based on input from the partner organisations. Smart Built Environment is open to both public and private actors when it comes to the initiation and execution of projects through open calls. All open calls are subjected to standard review procedures. As in most government funding programmes in Sweden, however, a demand is that the applicant actors can co-finance 50% of the project. In addition to these co-funded projects, Smart Built Environment also funds 'individual' or 'strategic' projects that have been initiated by the programme board. The strategic projects are used for areas in which many stakeholders must participate and/or gain from the results. The outcomes are often long-term and strategically important for the sector, like standardisation, digital platforms, or broad implementations. However, all initiated projects should contribute to solving the contemporary challenges of the Swedish built environment sector.

3.2 Developing an Assessment Framework

Similar to the other Swedish innovation programmes, Smart Built Environment was commissioned by the three funding agencies to produce an 'impact logic' at the start of the programme. An expectation was that the impact logic should contain a logical chain in four steps. In short, this logic implies that a link should be established among (1) the programme's activities in individual projects; (2) the results (short-term, concrete, and measurable); (3) the effects (visible effects on the stakeholders); and (4) the overall goals (long-term and visionary) (see Fig. 1 for an example of the impact logic for the period 2019–2021, developed during 2018). The purpose of the impact logic is partly to help the programmes in the strategic guiding towards their long-term goals, and partly that the research agencies funding the programmes should be able to follow up and evaluate the programmes. Therefore, within the Smart Built Environment, a strategic decision was made early on to conduct continuous measurements regarding the programme's results and effects concerning this impact logic. Furthermore, it was decided to establish and do this as a

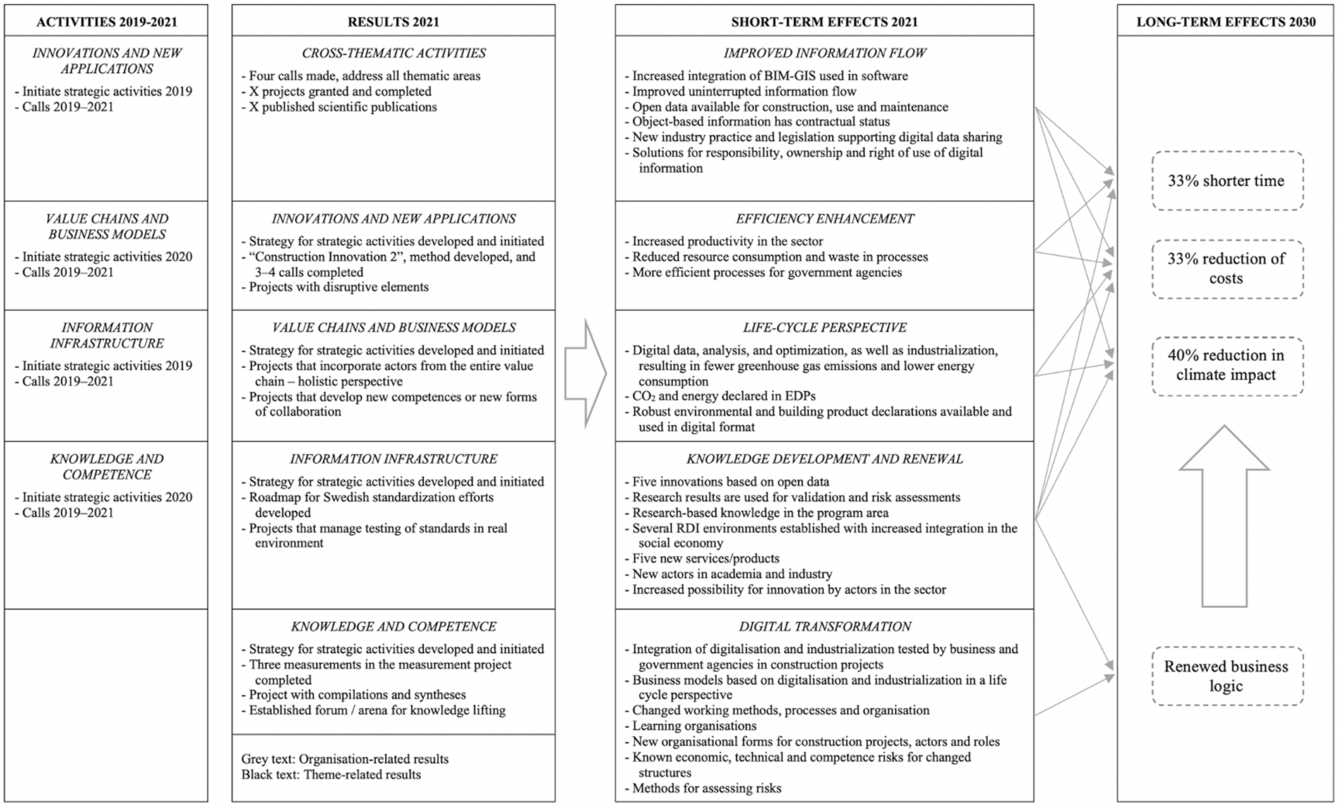

Fig. 1 Impact logic

longitudinal follow-up research project called *Program-generic Measurements Methods* performed by both senior researchers and doctoral students. We will discuss this project more later in the chapter.

In the application process for Smart Built Environment, four overall and visionary objectives were formulated concerning sustainability, time, cost, and business logics. More specifically, it was stated that, by the year 2030, the programme should have:

- Enabled the reduction of environmental impact in new construction and renovation by 40%.
- Reduced the construction time from planning to the completed project by 33%.
- Reduced construction costs by 33%.
- Created renewed business logics—new value chains and business models.

The final objective of renewed business logic can be seen as a facilitator for the first three targets, which are more quantitative. The assumption was that without renewed business logics within the sector, it would be challenging, if not impossible, to meet the first three objectives, because 'business as usual' is seldom a great source of innovation. Instead, the underlying idea is that initiated projects, in a bottom-up way, should contribute to specific short-term effects, contributing to the overall long-term visionary objectives. Thus, the programme was designed based on an idea of co-creation of value where no single actor/project can deliver on all the objectives. Instead, all actors must produce relevant fragments that, together, shall enable the programme to deliver on all the targets and, ultimately, its overall objective.

The visionary objectives were developed by the working group that formulated the programme application in dialogue with a large number of representatives from the sector. The objectives would address the overall benefits for both the sector and the society and, at the same time, be challenging and contribute to system changes. To move towards the visionary objectives, an impact logic was developed in the early stages of the programme. It contained activities, results, and 26 short-term effects that would be strived for during the first 3-year period and in the following 3-year period (see Fig. 1). The effects ranged from rather abstract targets (or targets that were difficult to measure), such as '*improved productivity in the industry*' and '*learning organisation*', to more concrete and measurable effects like '*five new services or products*'. Other examples of short-term effects were '*improved seamless information flow*', '*reduced resource consumption and waste in processes*', and '*new organisational forms in construction projects*'. Consequently, the short-term effects are diverse in terms of how they were formulated and more or less complex to measure and assess. The next step was to develop a way of evaluating or measuring these long- and short-term effects.

A group of five researchers who were active in the construction management domain and had varying backgrounds were given the task of conducting a pre-study in which metrics should be developed. These metrics should be used to assess and measure the short-term effects and the long-term objectives. The researchers in this group were aware of the complexity of trying to assess and measure the wide variety of effects that were aimed at, as well as the visionary objectives. In this process, which took approximately 9 months, the researchers agreed that traditional numerical measures would make little sense for all of the 26 short-term effects. Instead, the group tried to identify a variety of indicators that could be connected to both the short-term effects and long-term objectives.

The result of this work is exemplified by the visionary objective '*Enable the reduction of environmental impact in new construction and renovation by 40%*' and the short-term effect '*CO_2 and energy are declared in EPDs*'. This short-term effect was, together with two other short-term effects, assumed to have an impact on the long-term visionary objective (see Fig. 1 under life-cycle perspectives). To operationalise the short-term effect '*CO2 and energy are declared in EPDs*,' three indicators were connected to the effect:

- Energy use in the completed building
- CO_2 emissions
- Energy use in the production

Also, two indicators were directly connected to the visionary objective: (1) Are decisions made based on technical life cycle analysis? (2) Are decisions made based on economic life cycle analysis? Thus, the indicators, or metrics, that were developed and connected to the short-term effects and the visionary objectives would be seen as a way of moving towards the visionary objectives and short-term effects.

When continuing the development of the indicators for the short-term effects, the group of researchers also suggested that some of the short-term effects could be clustered. While this idea was not further developed in the pre-study, the framework was revised (see Sect. 3.3) and the definition of '*effect areas*' was a further development of clustering the short-term effects.

Finally, the results from the pre-study were handed over to two other researchers, who had the challenging task of running the strategic project *Program-generic Measurement Methods*, where the methods and indicators for measuring or assessing the results from the R&D projects were further revised and developed.

3.3 Revising the Framework

Before we delve further into the above-mentioned strategic project and the operationalisation thereof, a short reflection on this overall framework is in order. It is clear that an impact logic for a programme that potentially lasts for 12 years needs to be updated and revised at some point. Short-term results and effects that will be achieved in 2–3 years need to be renewed for the upcoming periods. At the same time, digitalisation (the focus area of the innovation programme at large) in general is developing rapidly, which means that the content, organisation, and focus of the programme must be continuously adjusted and the '*impact logic*' must be aligned with and adapted to that development. Otherwise, the programme runs the risk of being obsolete. Thus, it becomes challenging to design a measurement method and to make longitudinal measurements when the basis for the measurement changes. At the same time, it is inherent that long-term measurements are to be made against a moving target. To date, the described impact logic has undergone a few minor changes and one larger revision. The larger revision was made after 3 years in connection with the start of the second programme period. To deal with the problem of long-term measurements, where the measurement method needs to change, a new level in the impact logic was introduced, which was called '*effect areas*'. A total of five '*effect areas*' were formulated that were considered to be unchanged for a longer time and that affect the four long-term goals, which also remain unchanged. Within these effect areas, the individual indicators that are assessed can then vary over time. The measured effects become indicators of changes in the effect areas, which affect the long-term goals.

4 Assessing Project Outcomes

Having described the background and evolution of Smart Built Environment, as well as the development of the assessment framework, we now move on to how the assessment of project outcomes was operationalised and carried out.

4.1 Program-Generic Measurement Methods

The strategic project *Program-generic Measurement Methods* was launched in 2016 and intended to run for 2 years. During that period, and based on the successful outcome of the project, the board at Smart Built Environment decided to continue the project for at least 3 years to continue with the assessment programme. The main aim of the project is to develop metrics to control and follow up the programme goals of Smart Built Environment, validate the metrics, and indeed measure. In particular, the project's specific goals were to:

- Develop scientifically based methods and metrics to measure and analyse the outcome of projects and activities regarding digitalisation and industrialisation carried out within the Smart Built Environment towards the four programme's long-term goals and the 26 short-term effects.
- Develop a plan for measurements by setting up procedures for data collection and evaluating how these can be used for measures across stakeholders that support Smart Built Environment's focus and have expressed a precise aim to work and contribute towards the programme success and across the research project activities funded or co-funded by Smart Built Environment itself.
- Analyse and explore actions taken by companies and organisations as consequences of the measurements' results and how conditions, mechanisms, and regulatory requirements change at the policy level.

The measurements were planned and conducted in two different cycles with different sets of measurements. The first set of measurement was designed to measure the level of digitalisation and industrialisation in the sector and to detect any barriers hinder to pursue the scope of the programme (Moscati and Engström 2019). It was conducted through 12 in-depth interviews and a questionnaire addressing a sample of partners in the programme, which included materials and components suppliers, consultants, architects and engineering companies, contractors, clients, facility managers, property owners, and public authorities. The questionnaire was developed through dialogues with a reference group of construction management researchers and with representatives from the sector. It included 66 questions structured in the following thematic areas:

- Digitalisation and industrialisation
- Development and change work practice during the period 2016–2017
- Information flow, including:
  - BIM and GIS integration
  - Open data
  - Object-based information
  - Digitalisation and data sharing
- Environmental and energy declarations

The second set of measurements was intended to measure the contribution brought into the programme by the funded R&D projects and the collaboration between academia and industrial partners. Projects considered were ongoing for at least 1 year or recently finished and those that applied to the calls for research projects 1, 2, 3, and 4. Strategic projects were not considered at this stage. For this measurement, semi-structured interviews were conducted with the project managers of the individual R&D projects after they had filled in a short survey, the main goal of which was to investigate what long-term goals and/or short-term effect/s the projects addressed. During the interviews, the project managers were asked:

- To evaluate the projects' results towards the addressed long-term goals and short-term effects.
- To describe the metrics used to self-evaluate the project results (if any had been created).
- How the project contributed to changes in the partner industries
- To describe if and how the project led towards changes/improvements in digitalisation/industrialisation of the built environment.

The two circles of measurements that were conducted (towards programme's partners, and towards the funded research projects) were intended to alternate throughout the existence of the programme. In even-numbered years, the partners of Smart Built Environment are measured based on their level of digitalisation and industrialisation. In odd-numbered years, the funded R&D projects will be measured based on their contribution to the impact logic. However, the metrics developed in both cases will undergo revision before each new measurement.

4.2 Dilemma and Challenges

As the above accounts illustrate, developing a measurement framework and trying to assess R&D performance brings a variety of challenges and considerations. The *Program-generic Measurement Methods* project is an ambitious initiative in terms of its aim to measure the performance of the whole innovation programme. Even if different types of assessment frameworks and measurement methods are used in everything from single projects, to organisations, and programme management, no similar initiative of this scale was found in the pre-study leading up to the initiative. Thus, there was no relevant benchmark to use to avoid mistakes that had already been made, even if inspiration was drawn from previous initiatives (e.g. Samuelson 2003). Moreover, as explained above, all metrics were initially based on the visionary objectives of Smart Built Environment. However, as outlined in the 'revisiting the framework' section, during the 3-year lifetime, the original metrics had to be adjusted and further developed. Therefore, the temporal scope of the programme was (and remains) an inherent challenge for the reoccurring measurement effort. However, with the industry and its conditions changing over time, the assessment mandates flexibility. Thus, the lack of similar initiatives and the temporal scope of the programme constitute inherent challenges in assessing the R&D projects.

From a more operational point of view, it was also clear early on that it would be challenging to use the same metrics to measure case partners active in different stages of the building process (from public authorities to consultant to facility managers), as well as R&D projects of different natures in the other cycle. Additionally, the project portfolio of Smart Built Environment includes a wide variety of R&D projects in which the constellation of actors, project aim, and the expected contributions differ significantly. For example, while one projects set out to deliver decreased environmental impact when casting concrete, another set out developed a new digital tool for environmental simulations and analysis in the early stage of the design process. As an outcome, the first project reports data on the reduction of CO_2 emission in one out of many sub-processes of the construction, and the other project describes how to facilitate the decision-making, regarding sustainability in the early stage of design. Despite the different nature of the projects due to the co-creation processes through which they were developed, both have the intention to contribute to the reduction of the environmental impact (long-term goal A), but in different ways. Consequently, the outcomes also need to be measured in very different ways. In a nutshell, one could say that one size does not fit all, either vertically (between cycles) or horizontally (between projects).

Apart from a lack of documented frameworks to draw inspiration from, and the temporal scope and challenges related to vertical and horizontal variation, challenges are also related to measuring and comparing what is being done on the project level, when the impact logic focuses on the industry level. During the second cycle, the impact and contribution to the short-term effects were much higher than the long-term goals. The short-term effects are designed as steps that must be taken to achieve the long-term goals. However, there is a risk that both 'fuzzy' and ambitious goal setting can affect the fulfilment of the goals and create a gaming performance behaviour where the measurement and the goals are more important than the actual outcome. This risk is likely if the R&D projects and the measurement initiative are unable to lift the project contribution from the short-term (project level) to the long-term (industry level). Today, Smart Built Environment has been up and running for 4 years and it therefore too early to say anything about the final fulfilment of the visionary objectives.

A final challenge encountered in the work of measuring the performance relates to conceptual volatility regarding concepts such as digitalisation and industrialisation. The fact that these concepts lack a generally accepted definition (leading to a lack of common understanding among industry actors) was challenging when designing the metrics. However, it was also detected as a dilemma during the actual measurements. The terms digitalisation and industrialisation have been described differently among the programme partners and the project managers. Even if many partners claim to have invested both time and money towards more digital workflows and processes (that is, digitalisation and industrialisation), it was apparent when compiling the results that the efforts pointed in different directions. When some organisations, mainly public authorities, spent their resources on scanning analogue documents to digital PDF files, other organisations, such as consultancy agencies, described their digitalisation efforts as increased work and development of 3D models, BIM, and object-based information solutions. Different understandings of critical concepts for an R&D programme of this size provide a challenge that will affect the outcome and also present challenges in comparing different outcomes. However, predefining what the concepts would imply in a normative way might limit or hinder innovation.

5 Conclusions

The quote '*not everything that counts can be counted, and not everything that can be counted counts*' is often attributed to Albert Einstein. While we are not sure whether Einstein ever spoke these words, we do know that the essence of this quote holds and is important when it comes to measuring performance in a case like this. To be able to cover the great variety of relevant and essential contributions developed within the programme, not everything could be counted in a traditional sense, and not everything that could be counted (or measured) was relevant to count (or measure). Alternatively, non-quantifiable assessment methods had to be developed and, due to the emergent nature of the contributions, the extensive horizontal and vertical variation, as well as the moving target and temporal scope, one might argue that the process was closer to '*you measure what you get*' than '*you get what you measure*'. Thus, three key takeaways can be summarised based on the case characteristics of the studied innovation programme. First, when the effects in an impact logic (see benefit map in Fig. 1) are formulated shortly and concisely, there is a risk of alternative interpretations by the wide variety of actors involved in the programme and individual R&D projects. Therefore, and based on the conceptual volatility described, it is essential to clarify the intent of each effect unambiguous when both designing and performing the measurements. Second, measuring the contribution of multiple R&D projects in a large-scale and long-term innovation programme is not a linear process. It requires flexibility, adaptation, and innovativeness when both designing, conducting, and further developing the measurement initiative based on the contingencies of moving targets, temporal scope, and industry development. Third, to capture the wide variety of R&D project contributions and industry impact, more than one set of metrics and/or assessment methods need to be developed. This includes alternative ways, such as non-quantifiable assessment methods, that have been described here. However, all of this is easier said than done.

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