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Strengthening industry-university collaborations: synchronising industrial opportunities with research capabilities using roadmapping

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Strengthening industry-university collaborations: synchronising industrial opportunities with research capabilities using innovation roadmapping

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ABSTRACT

The benefits of collaboration between universities and industry have been widely recognised, however, little practical guidance is provided as to how to establish successful strategic collaborations and support the different types of interactions between these two very different stakeholders. We have successfully adapted and used innovation roadmapping as a method to help these two heterogeneous partners to establish collaborations of common interest. The approach has been used twenty times to establish collaborations between firms and academia at various scales: a) the whole university, b) a large part of a university i.e. several departments, and c) specific academic groups. Feedback showed that roadmapping can be a powerful method for aligning the needs of the two communities, helping to identify common priorities and aiding communication and clarity in the collaboration activities. Overall, participants from both communities indicated that the method was simulating and provided new and useful insights.

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INTRODUCTION

Knowledge-based economies are realising the potential of proactive collaboration between universities, industry, government and the third sector. There is increasing evidence that collaboration between academia and industry is an important factor in the development of efficient national innovation systems. It helps upskill the national workforce with industrially relevant skills, generate and adopt innovations and promote an entrepreneurial culture (Guimon 2013).

Modern economies are increasingly dependent on technology, science and education for the preparation of researchers, technologists and the community at large. Integral to a knowledge-based economy is a transformation of the educators, curriculum and learning environments so that there is relevance for students, today and in the future, as they prepare for an ever-changing world. Thus, the importance of university community and industry engagement has become increasingly apparent (Langworthy, 2007).

With the increasing financial uncertainties associated with higher education funding, universities are planning to capture value from wider business networks to sustain their standing and, above all, deliver economic and societal benefits. Knowledge exchange and technology transfer trends for English universities in the period of 2005–14 (Ulrichsen 2018) show that, despite sub-optimal income growth from commercialising facilities and equipment, income growth in the form of contract and collaborative research has been much higher in the years since the financial crash of 2008. This is a result of the emergence of knowledge-based University–Industry partnerships. Furthermore, research and knowledge-based income is much more sustainable and less prone to economic shocks as shown by the public research funding in Germany in the period of 2000–7, depicting the high growth in funding from industry and public research grants (Hottenrott & Thorwarth 2011).

This paper gives an overview of literature and practice followed by a practical approach to setting up strategic University-Industry Collaborations (UICs). The results from 20 cases of UICs are reviewed and discussed with respect to practical outcomes, before overall conclusions are drawn. The cases fell into three categories, a) setting the University-Industry collaborations strategy for the whole university, b) a large part of a university i.e. several departments, and c) specific academic groups. To improve practical relevance and to communicate the approach succinctly, the method includes an example roadmap template with an explanation and an annotated process diagram. From a practitioner perspective these two elements are the centrepiece around which the paper revolves, aiming to give a clear account of the method deployed to support strategic UICs.

LITERATURE & PRACTICE REVIEW

Benefits of UIC research collaborations

The advantages of collaboration between industry and universities are widely recognised. Companies can improve business performance, academics can access new opportunities and the outcomes help drive growth and productivity at the national, organisational and personal levels (Dowling 2015; Lee 2000). University-Industry Collaboration research activities can range from open-ended knowledge generation, through ideas testing and technology development, to focused problem solving (Perkman and Walsh 2013). Work in open innovation (Chesborough 2003) has further demonstrated the benefits of collaboration within a wider innovation eco-system.

Collaboration with industry and commercialisation of research outputs is an avenue which many universities are actively pursuing (Hughes & Kitson 2012). Apart from gaining value for the institution, such commercialisation activities - often in the form of start-ups - are providing a high technological edge to the industrial sector they are servicing with their unique products and service offerings. Some

universities are establishing an ecosystem of institution supported start-ups and are working with regional and central government, as well as consortia of industry and organisations (Finardi, U., 2013). Equipping university start-ups with appropriate innovation frameworks and tools will make them globally competitive in their specialist field.

Strategic partnerships are an increasingly important and prevalent part of the university–industry landscape (Elmuti et al 2005). They add long-lasting value to both industry and academia that can extend beyond new knowledge generation from individual research projects and student recruitment. In addition, they can help companies leverage and exploit additional resources, knowledge and expertise and enhance their innovation capabilities and practices, thereby becoming global key players in their field of product or service specialisation. Finally, strategic partnerships help academia to generate societal and economic impact by creating greater opportunities for staff, students and researchers, and also help to develop a generation of industry leaders who can lead industrial innovation (Ulrichsen 2014). Furthermore, universities are becoming far better equipped to work collaboratively with industry to address innovation challenges (Minshall et al 2016).

Barriers and enablers to building university-industry research collaborations

A recent systematic literature review of motivations, barriers and outcomes to UI research collaborations (Vick & Robertston 2018) details well documented enablers, including:

- Prior experience of collaboration and inter-organisational trust (Bruneel 2010)
- Proximity and prior joint experience (D’Este 2012)
- The importance of boundary spanning roles (Gertner et al 2011; Lam 2011).

Documented difficulties include:

- Orientation and transactional barriers (Bruneel 2010; Tartari 2012) including misalignment and motivation
- Capability and governance-related and contextual barriers (Nsanzumuhire & Goot et al 2020).

Examples include the mismatch of academic and commercial timescales (Francis-Smythe 2008), lack of suitable partners (Tartari 2012) and lack of business resources to manage the collaboration (Hughes & Kitson 2012).

Processes and mechanisms for establishing university-industry research collaborations

A recent review (Nsanzumuhire & Goot et al 2020) identified three main forms of UIC implementation processes – educational, academic entrepreneurship and research related, which all need to be underpinned by continuous interaction to reach their full potential. Examples of such processes and mechanisms in action are:

- The role of doctoral students in UICs, as they can be a vehicle of connection between academia and companies, but also because they can positively influence knowledge transfer and knowledge sharing (Santos et al 2021).
- The impact of UIC on innovation through patent collaborations, as in nano-biopharmaceuticals (Guan & Zhao, 2013) and other technology areas (Fabrizio 2007).
- The importance of long-term research programme-based collaborations (Dowling 2015) and human resource transfers (Perkmann & Walsh 2007).

When bringing all these aspects together in a UIC research network setting, it was found that funding, IP management, knowledge-sharing routines and an effective project manager were necessary (O’Dwyer et al 2022) to build active collaboration. In this context, knowledge-sharing routines included regular technical meetings, presentations and training sessions organised by academics, and 3-month laboratory secondments organised by companies, in order to develop a mutual understanding of each other’s needs and capabilities and leading to spontaneous UIC projects.

However, two fundamental but under-explored mechanisms for building UICs are the search and match process between companies and universities and the organisation and management of the resulting collaborative relationships (Perkmann & Walsh 2007). In this work we discuss the use of roadmapping as a strategic framework to expediate matching between companies and universities and enable the initiation of strategic research initiatives.

Roadmapping as a collaborative mechanism for building university-industry research collaborations

Roadmapping is a well-established innovation management tool (Phaal et al 2004, 2007; Kerr & Phaal 2020, Kerr et al 2012a) to link market pull and technology push activities against a specified timeline. Technology landscape mapping (Spitsberg et al 2013) uses roadmapping as a systematic way of building technological awareness and identifying opportunities at the intersection of emerging technologies and customer needs. Roadmapping has been also used as a communication mechanism between suppliers and systems integrators (Kerr et al 2012b, Hirose et al 2021) and in linking technology push and partnership within open innovation environments (Caetano & Amaral, 2011). Dual roadmapping techniques (Geum et al 2013), explicitly involving both internal and external firms, take three possible forms. Firstly, in terms of including the partner's resources (two technology layers, one internal and one for the partner) upon the roadmap, secondly, in terms of having dual planning objectives (two technology layers and two product layers) and thirdly, in terms of sharing R&D (two R&D layers). These forms of dual roadmapping might be applicable to UICs, to the extent that the University is able to assume the role of one of the firms. This is not always straightforward or possible as Universities are set up differently, often with divergent motivations to firms.

Finally, in the specific area of UIC management, a new 'assessment and roadmapping' approach has been proposed by Gerdri & Manotungvorapun (2022) to overcome the difficulty in linking firms' interests and the value that can be provided by university research using a strategic roadmap. This guides the relationship development towards effective UIC collaboration, by helping to develop a shared knowledge base, strategic goals, and agreement on IP.

Building on this literature and practice review, it can be seen that there is a gap for further demonstration of the benefits, barriers and enablers to implementing roadmapping as a faster and more effective approach to developing strong UICs. In particular, using roadmapping as a means of aligning the academic research interests with the most pressing industrial challenges and identifying topics of common interest and value to take forward.

PRACTICAL APPROACH

In this paper, we detail how we used roadmapping as a collaborative mechanism to help explore and define three different types of UICs. These were:

- a. Setting the University-Industry Collaborations strategy for the whole university
- b. Organising the different University-Industry Collaborations possible for a particular cross-cutting theme between several university departments and industry
- c. Organising the University-Industry Collaborations possible for a specific university research group

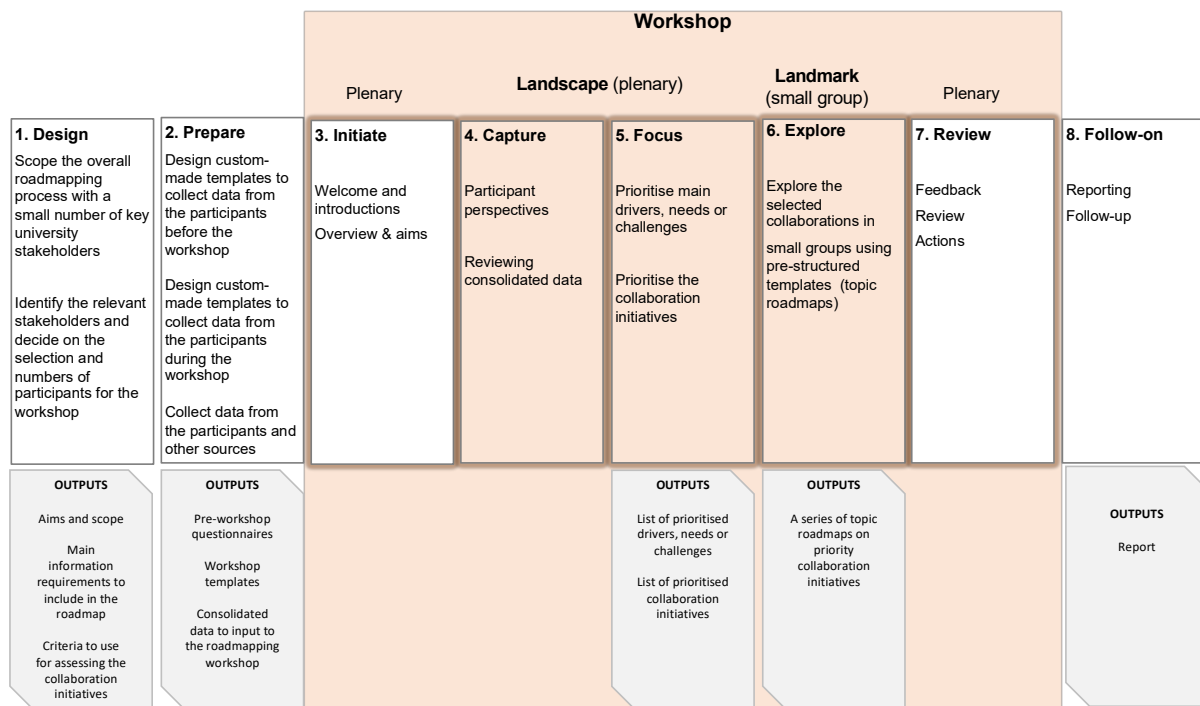
A common overall process was followed between all three different types of interactions. It contained the following key steps:

- Scoping and design of the overall roadmapping process with a small number of key university stakeholders. This included clarification and agreement of the specific aims and scope of the roadmapping process, clarifying and defining the main information requirements and areas of knowledge to be included in the roadmap.

- Identify the relevant stakeholders and decide on the selection and numbers of participants for the workshop.
- Design custom-made templates to collect data from the participants before the workshop and also aid the discussion between different participants during the workshop in a structured way.
- Collect data from the participants via questionnaires as well as using other existing information if available. Consolidate the data when appropriate to minimise multiple entries of the same information.
- Review and select the criteria to use for assessing the best collaboration initiatives.
- Organise and deliver a workshop with all participants to review the consolidated data, prioritise it and select and explore the most important topics.
- Summarise and report the outcomes in a form of a report or presentation

The general steps of the process are summarised in Figure 1 below:

Figure 1: Overall UIC roadmapping process summary



The workshops were delivered either face-to-face (typically over one day) or online (normally over three sessions of 2-3 hours per session). A typical agenda for the workshops was as follows:

- Welcome and introductions from [sponsor]
- Identifying and prioritising the main drivers, needs or challenges for the topic
- Identifying and prioritising the collaboration initiatives using the pre-defined criteria (Mitchell et al 2022)
- Exploring the selected collaborations in small groups, using pre-structured templates (Phaal et al 2017)
- Feedback and review
- Closing remarks and next steps by [sponsor]

There were slight differences in the process followed depending on case type (a), (b) or (c). For example, both cases (a) were preceded with a visioning workshop to set the overall vision and objectives of the institution for the UIC strategy. They were also typically longer workshop sessions (1.5-2 days). Depending on the specific topic discussed, additional steps and/or management tools may have been used in certain workshops, for example SWOT analysis. But these were small variations to support the overall workshop objectives.

Two examples of the topic roadmapping templates used during the 'Explore' step of the workshop for type (b) and (c) UICs are shown below in Figure 2.

Figure 2: Example roadmapping templates used for type (b) (top) and (c) (bottom) UICs

Example of a roadmapping template used for type (b) UICs

Topic		Participants' names																																																													
Step 1	a. Topic description/scope	a. Topic summary	b. Scope What's IN: What's OUT:		c. Desired future What success would look like																																																										
	b. Which sector is this topic most applicable to?																																																														
	c. Which needs does this topic address?																																																														
Step 2	WHEN	Short term (+1 year)	Medium term (+3 years)	Long term (+5 years)																																																											
	a. Required developments																																																														
	b. Required skills	From Government/ Industry From Academics																																																													
	c. Key barriers to market																																																														
	d. Role XXX can play in taking this forward																																																														
	e. Which will be the most appropriate mechanism to develop this topic <i>a.g. PhD, placement, contract research, network for funding applications</i>																																																														
Step 3	a. Enablers <i>What can help progress? Enablers? Strengths? Partnerships?</i>																																																														
	b. Risks <i>What can hinder progress? Barriers? Threats? Weaknesses?</i>	List and assess short term risks <table border="1"> <tr><td>High</td><td></td><td></td><td></td><td></td></tr> <tr><td>Med</td><td></td><td></td><td></td><td></td></tr> <tr><td>Low</td><td></td><td></td><td></td><td></td></tr> <tr><td>Time</td><td></td><td></td><td></td><td></td></tr> </table>	High					Med					Low					Time					List and assess medium term risks ^{High} <table border="1"> <tr><td>High</td><td></td><td></td><td></td><td></td></tr> <tr><td>Med</td><td></td><td></td><td></td><td></td></tr> <tr><td>Low</td><td></td><td></td><td></td><td></td></tr> <tr><td>Time</td><td></td><td></td><td></td><td></td></tr> </table>	High					Med					Low					Time					List and assess long term risks ^{High} <table border="1"> <tr><td>High</td><td></td><td></td><td></td><td></td></tr> <tr><td>Med</td><td></td><td></td><td></td><td></td></tr> <tr><td>Low</td><td></td><td></td><td></td><td></td></tr> <tr><td>Time</td><td></td><td></td><td></td><td></td></tr> </table>	High					Med					Low					Time			
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Example of a roadmapping template used for type (c) UICs

Application:		Participants' names:		
Step 1	Application description/scope	Application summary description	Scope What's IN: What's OUT:	Desired future What success would look like
Step 2	WHEN	Short term (+3 years)	Medium term (+5 years)	Long term (+10 years)
	Stepping Stones / Milestones / Demo Chain	» Demonstrators chain / stepping stones: What? To whom? When? How? Where? Why?		
	Required research/technology development			
Step 3	Link to Key Customer Needs			
	Enablers and Risks	What can help progress? Enablers? Strengths? 		What can hinder progress? Barriers? Weaknesses?

Although the example templates are quite similar, they have some distinct differences. For case type (b), there was a requirement for additional information layers especially in steps 1 and 2. For example, in step 2, an additional layer was added to collect information on the specific sectors where a particular research topic may be more important. In many type (c) cases this information was already known because of the nature of the research or the specific academic team and the industry invited to the workshops. In addition, , the way in which to structure the collaboration across different academic departments was not always straightforward for type (b) projects. In step 2, additional information was collected by the participants regarding who may be more suitable to lead a particular topic, the skills required and the most appropriate mechanism to proceed e.g. contract research, PhD sponsorship etc.

Participant feedback was collected at the end of each workshop. The feedback collected input on three main areas: the workshop preparation and design, the workshop delivery and the value to the participants. Each statement was rated on a five-point Likert scale where 1 was poor (or strongly disagree) and 5 was excellent (or strongly agree).

RESULTS

Twenty different University-Industry Collaborative projects were explored using roadmapping. These are summarised in Table 1 below.

Table 1: List of different industry-university collaboration projects conducted in this study

Roadmap focus	University location	Industry location	Type of engagement	Number of participants
Industry-University strategy	India	Local, national, international	a	18
Industry-University strategy	Pakistan	Local, national	a	32
Industry collaboration in clean energy	China	International	b	19
Industry collaboration with Social Sciences	UK	National, international	b	19
Industry collaboration in the areas of medical technologies, therapeutics and digital health	UK	Local, national	b	38
Industry collaboration in the area of medical devices for hard to treat cancers	UK	Local, national	b	13
Bulk superconductivity	UK	National, international	c	16
Laser-based manufacturing applications	UK	National	c	32
Innovative Manufacturing in Ultra Precision 1	UK	National	c	9
Innovative Manufacturing in Ultra Precision 2	UK	National	c	10
Large area electronics	UK	National	c	22
Engineering Design	UK	National, international	c	15
Predictive maintenance for manufacturing equipment	UK	Local, national	c	14
Nano-machine technology	UK	Local, national	c	15
Medical diagnostics	UK	International	c	23
Potato innovation ecosystem	UK	Local, national	c	15
Photoacoustic imaging	UK	National, international	c	35
Raman microscopy	UK	National	c	17
AI for infrastructure monitoring	UK	Local, national, international	c	40
Digital technologies for sustainable agri-food development	UK	Local, national, international	c	28

Key: a) the whole university, b) a large part of a university i.e. several departments, and c) specific academic groups.

Overall, the feedback results showed that over than 90% of the participants found the workshop design and preparation phase ‘Good’, ‘Very Good’ or ‘Excellent’. Equally high scores are demonstrated for the workshop delivery itself. Over 95% of the participants strongly agreed or agreed that the value to them in terms of time spent, contribution and insights derived during the workshop was very high. The consolidated feedback over the 20 workshops is shown in Figures 3, 4 and 5 below.

Specific participant’s comments collected from several workshops also indicate that: *‘The preparation is very important’*, that the workshop itself promoted collaboration and information sharing between the delegates: *‘I really liked the methodology. It was more participatory (and less confrontational) than I expected’* and that the whole experience was valuable for both partners: *‘This workshop was very fruitful for both industry and academia. Right step at the right time’*.

Figure 3: Consolidated participant feedback over the 20 workshops on roadmapping workshop design and preparation

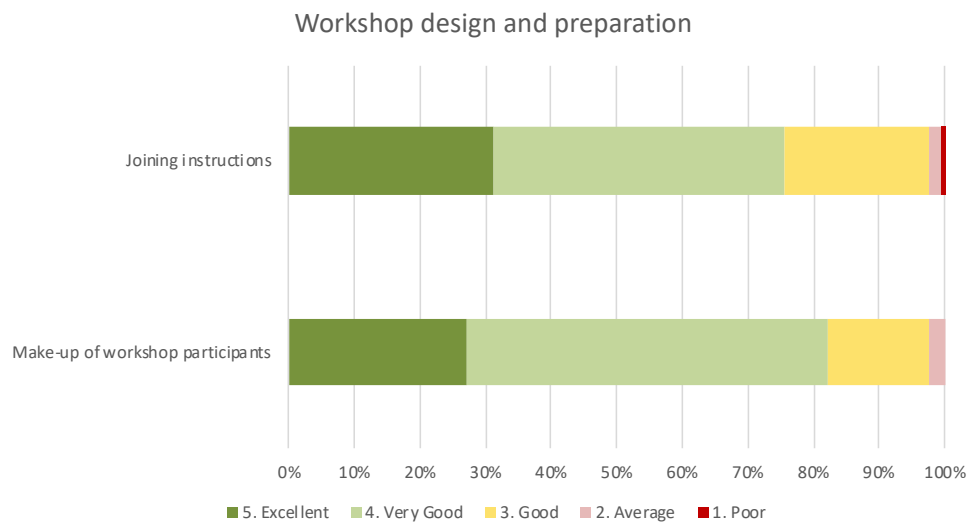


Figure 4: Consolidated participant feedback over the 20 workshops on roadmapping workshop delivery

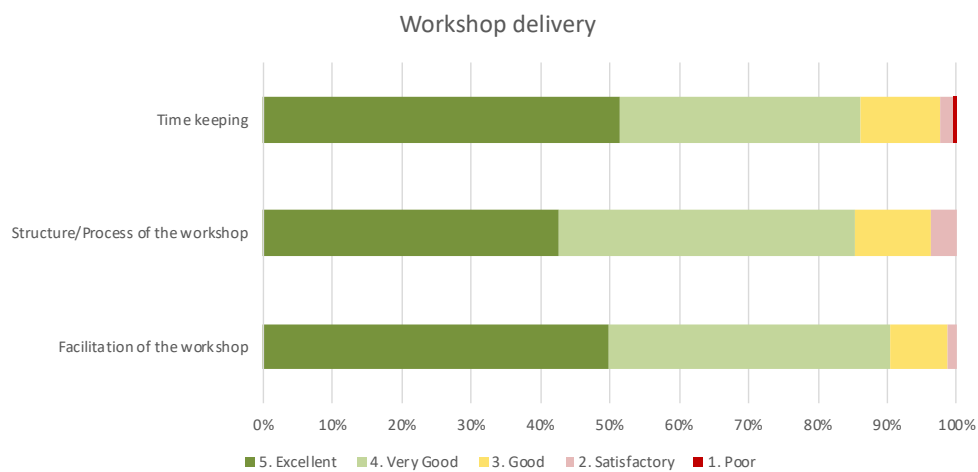
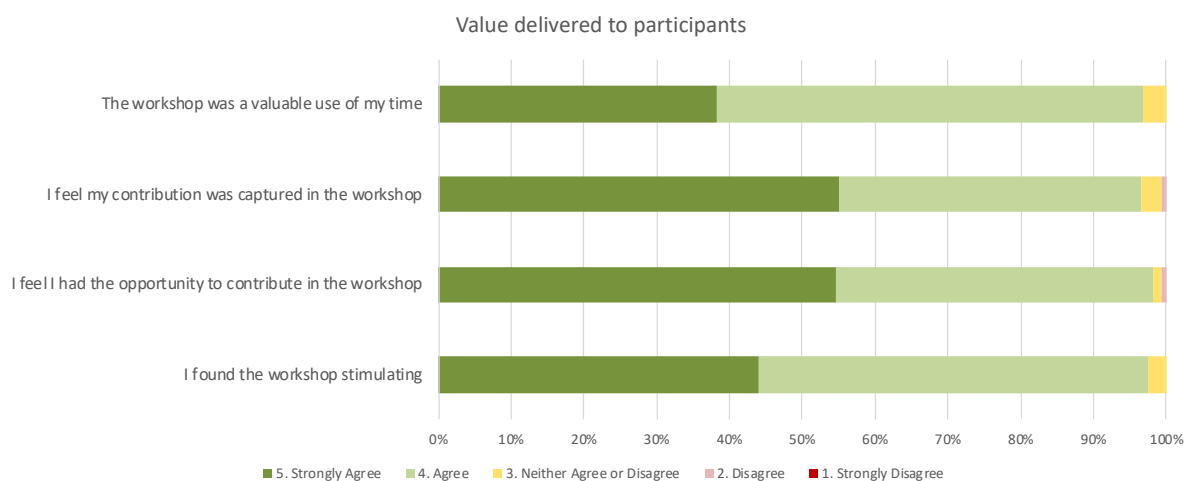


Figure 5: Consolidated participant feedback over the 20 workshops on the value derived from participating to the roadmapping workshop



Indirectly, we have also seen evidence that this method adds value to universities and academic teams as several academics have come back to us for further work or have recommended this approach to several of their colleagues and collaborators. This has indicated that they saw real value in using the roadmapping method to scope and structure their industrial collaborations and align their research with relevant industrial problems or the most pertinent challenges.

DISCUSSION

The 20 case studies illustrated that in a wide number of cases consistent outcomes were obtained in terms of facilitating useful interaction and constructive outcomes between academia and industry, resulting in innovation in tangible terms.

The roadmapping workshop approach is distinctly different to traditional approaches to UIC formation (e.g. meetings etc.). It allows a larger number of experts to review in parallel many potential collaboration opportunities, and agree on priorities and further actions. This is done in a structured way so commonalities and synergies can be easily identified between priority topics. One participant commented: *'It is very instructive to see how my very specialised know-how can be made to fit into the bigger picture.'* Roadmapping is also inherently a transparent and open method that allows people to have visibility on how priorities and decisions were reached and therefore have ownership of the outcomes. Several participant comments confirm this: *'Overall a wonderful experience. We started with 1000 words, agreed on 100 and settled on 10'.*

The advantages of using the roadmapping methodology for matching companies and universities and identifying strategic research initiatives of mutual importance are that that roadmapping is very time efficient. In a period of a day or two several potential collaborations can be identified and explored between the two communities. In particular, starting the process with a shared understanding on the challenges faced by the two communities can help focus the discussions to areas of most interest and potential impact for both. Delegate comments concur this: *'I agree that top challenges were identified and top solutions'.*

This can be very beneficial for identifying opportunities for research which can often be different or not a part of existing activities. The process helps academics collaborate better especially for case (b) activities where multiple academic groups or departments need to collaborate towards a common outcome. It helps bring all the necessary expertise together early on to enable a more structured and efficient technology scale-up from lab to manufacturing and to commercialisation. As one participant commented: *'A very useful tool to combine a consensus output for a range of different disciplines'.* The roadmapping process is also very flexible in its application as can be demonstrated by the variety of cases illustrated in this paper that span across different types of interactions, countries and topics.

Finally, a key advantage of roadmapping is that it provides a good networking opportunity between the workshop delegates. As one participant commented: *'[it was] Well facilitated. Great to meet other experts from a range of fields'.* Roadmapping also provides visibility of all areas selected and discussion improves delegate learning. In several cases for example, all explored collaboration topics were placed as a gallery exhibition so everyone could review them, comment and identify the topics with which they would like to further engage.

In order to maximise the value out of this type of workshop, the organisation of each session (physical or virtual) is very important. This is perhaps one of the potential drawbacks of this approach as it requires sufficient time to plan and design it. Many participants also confirmed this observation as

several commented on the importance of pre-workshop preparation i.e. *'This item [pre-workshop preparation] is very important', 'Participants should be involved in pre-work so that they can contribute better'*. In addition, identifying and inviting the right experts to contribute in a roadmapping workshop can be time consuming, especially when it involves collaborations in new research areas. Finally, universities need to consider who will be facilitating the workshop as it is often not advisable to be both a content expert (a delegate) and a facilitator, as it can affect the transparency and neutrality of the process. It is generally recommended that facilitators should be 'process-experts' and 'content-neutral' to ensure that everyone contributes, and that priorities and decisions are taken in an open and transparent way. This creates the necessary buy-in of the outputs and actions from the participants and contributes to their willingness to continue the collaboration. Participants can often notice the benefits of effective and professional facilitation, which creates a positive workshop environment: *'The handling of the working groups by the facilitators was very efficient and brought the best out of all the participants'*.

There is indirect evidence that this method is successful as a UIC mechanism and that it adds value to universities and industry. For example, several university research teams have come back to us for further work on similar or different topics. Several academics have recommended this approach to other colleagues and collaborators. A few academics have started utilising this method to help structure multi-disciplinary research proposals with industry before submitting them for funding as they believed it would make their proposals more successful. As one academic commented: *'This workshop was a very useful activity that provided us with an opportunity to capture an insight about UIC linkages and how to improve this'*.

This has indicated that academic teams saw real value on using the roadmapping method to scope and structure their industrial collaborations and align their research with relevant industrial problems or the most pertinent challenges.

CONCLUSIONS

The findings of the paper are best summarised in terms of practical outcomes for academia and industry. The method demonstrated that innovation roadmapping workshops were an effective approach in 20 very diverse cases when compared with more traditional methods of setting up UICs, as they helped to address key concerns found in literature and practice with respect to setting up sustainable UICs in the following ways:

- Roadmapping helps to address the search and match process between companies and universities (Perkmann & Walsh 2007) by allowing them to explore common ground in advance of a full collaboration contract.
- Roadmapping replaces the need for lengthy interactions including regular technical meetings, presentations and training sessions organised by academics and companies (O'Dwyer et al 2022), enabling partners to develop a mutual understanding of each other's needs and capabilities in a shorter timeframe.
- Roadmapping supports the organisation and management of the resulting collaborative relationships (Perkmann & Walsh 2007) by overcoming the difficulty in linking firms' interests and the value that university research can provide, as proposed by Gertsri (2022).

However, although the roadmapping process did indeed guide relationship development towards effective University-Industry Collaboration, - by helping to develop a shared knowledge base and strategic goals from the beginning of the interaction - (Gertsri 2022), in the process documented the roadmapping had a research content focus.

REFERENCES

- Bruneel, J., d'Este, P. and Salter, A., (2010). Investigating the factors that diminish the barriers to university–industry collaboration. *Research policy*, 39(7), pp.858-868.
- Caetano, M. and Amaral, D.C., (2011). Roadmapping for technology push and partnership: A contribution for open innovation environments. *Technovation*, 31(7), pp.320-335.
- D'Este, P., Iammarino, S., Savona, M. and von Tunzelmann, N., (2012). What hampers innovation? Revealed barriers versus deterring barriers. *Research policy*, 41(2), pp.482-488.
- Dowling Review of Business-University Research Collaborations (2015). Crown copyright July 2015, BIS/15/352.
- Elmuti, D., Abebe, M. and Nicolosi, M. (2005), "An overview of strategic alliances between universities and corporations", *Journal of Workplace Learning*, Vol. 17 No. 1/2, pp. 115-129. <https://doi.org/10.1108/13665620510574504>
- Fabrizio, K.R. (2007), University patenting and the paces of industrial innovation. *Industrial and Corporate Change*, 16(4), 505-534.
- Finardi, U., (2013). Clustering research, education, and entrepreneurship: nanotech innovation at minatec in Grenoble. *Research-Technology Management*, 56(1), pp.16-20.
- Francis-Smythe, J., (2008). Enhancing academic engagement in knowledge transfer activity in the UK. *Perspectives*, 12(3), pp.68-72.
- Gerdtsri, N. and N. Manotungvorapun, (2022). "Systemizing the Management of University-Industry Collaboration: Assessment and Roadmapping," in *IEEE Transactions on Engineering Management*, vol. 69, no. 1, pp. 245-261, Feb. 2022, doi: 10.1109/TEM.2021.3077447.
- Gertner, D., Roberts, J. and Charles, D., (2011). University-industry collaboration: a CoPs approach to KTPs. *Journal of knowledge management*, 15(4), pp.625-647.
- Geum, Y., Kim, J., Son, C. and Park, Y., (2013). Development of dual technology roadmap (TRM) for open innovation: Structure and typology. *Journal of Engineering and Technology Management*, 30(3), pp.309-325.
- Ghani A., Srai J.S., Kumar M. (2017). Supply network capabilities under industrial policy interventions and influences. 24th European Operations Management Conference (EUROMA). Herriot-Watt University, July 2017, United Kingdom.
- Guan, J. and Zhao, Q., (2013). The impact of university–industry collaboration networks on innovation in nanobiopharmaceuticals. *Technological Forecasting and Social Change*, 80(7), pp.1271-1286.
- Guimón, José (2013), *Promoting University–Industry Collaboration in Developing Countries*”, World Bank, 2013.

Hirose, R. Phaal, C. Farrukh, N. Gerdtsri, S. Lee and M. O'Dell (2021). "Practical Roadmapping Implementation: What We Learned From QinetiQ Group," in IEEE Engineering Management Review, vol. 49, no. 4, pp. 108-114, 1 Fourthquarter, Dec. 2021, doi: 10.1109/EMR.2021.3121872.

Hottenrott, H. and Thorwarth, S., (2011). Industry funding of university research and scientific productivity. *Kyklos*, 64(4), pp.534-555.

Hughes, A. and Kitson, M., (2012). Pathways to impact and the strategic role of universities: new evidence on the breadth and depth of university knowledge exchange in the UK and the factors constraining its development. *Cambridge journal of economics*, 36(3), pp.723-750.

Kerr, C. and Phaal, R., (2020). Technology roadmapping: Industrial roots, forgotten history and unknown origins. *Technological Forecasting and Social Change*, 155, p.119967.

Kerr, C., Phaal, R. and Probert, D. (2012b), 'Depicting options and investment appraisal information in roadmaps', *Journal of Innovation and Technology*

Kerr, C., Phaal, R. and Probert, D., (2012a). Cogitate, articulate, communicate: The psychosocial reality of technology roadmapping and roadmaps. *R&D Management*, 42(1), pp.1-13.

Lam, A., (2011). University-industry collaboration: careers and knowledge governance in hybrid organisational space. *International Journal of Strategic Business Alliances*, 2(1-2), pp.135-145.

Langworthy, A., (2007). Education for the public good: Is service learning possible in the Australian context. *The Scholarship of Community Engagement: Australia's way forward*, 70, pp.1-10.

Lee, YS (2000), The sustainability of University-industry research collaborations: an empirical assessment, *The Journal of Technology Transfer*, 25(2) pp. 111-133.

Minshall T., Mortara L., Ulrichsen T. (2016). "University-Industry Partnerships and Open Innovation. Key Development and Experience from the University of Cambridge", CTM Working Paper, February 2016, University of Cambridge.

Mitchell, R., R. Phaal, N. Athanassopoulou, C. Farrukh & C. Rassmussen (2022) "How to Build a Customized Scoring Tool to Evaluate and Select Early-stage Projects", *Research-Technology Management*, 65:3, 27-38, DOI: 10.1080/08956308.2022.2026185

Nsanzumuhire, S.U., Groot, W., (2020) Context perspective on University-Industry Collaboration processes: A systematic review of literature, *Journal of Cleaner Production* 258 (2020) 120861. <https://doi.org/10.1016/j.jclepro.2020.120861> 0959-6526.

O'Dwyer, M., Filieri, R. and O'Malley, L., (2022). Establishing successful university–industry collaborations: barriers and enablers deconstructed. *The Journal of Technology Transfer*, pp.1-32.

Park, H., Phaal, R., Ho, J.Y. and O'Sullivan, E., (2020). Twenty years of technology and strategic roadmapping research: A school of thought perspective. *Technological Forecasting and Social Change*, 154, p.119965.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A. and Krabel, S., (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research policy*, 42(2), pp.423-442.

Phaal, R., S-Plan Approach, http://www3.eng.cam.ac.uk/research_db/publications/rp108

Phaal, R., Farrukh, C.J.P., Probert, D.R. (2004). "Customizing Roadmapping", *Research Technology Management*, 47 (2), pp. 26–37.

Phaal, R., Kerr C., Ilevbare I., Farrukh C., Routley M., Athanassopoulou N. (2017). "Self-facilitating templates for technology and innovation strategy workshops", R&D Management Conference, DOI:10.17863/CAM.13936

Phaal, R., Farrukh, C.J.P., Probert, D.R. (2007). "Strategic Roadmapping: A workshop-based approach for identifying and exploring innovation issues and opportunities", *Engineering Management Journal*, 19 (1), pp. 16–24.

Santos, P., Veloso, L. and Urze, P., (2021). Students matter: The role of doctoral students in university–industry collaborations. *Higher Education Research & Development*, 40(7), pp.1530-1545.

Spitsberg, I., Brahmandam, S., Verti, M.J. and Coulston, G.W., (2013). Technology landscape mapping: At the heart of open innovation. *Research-Technology Management*, 56(4), pp.27-35.

Tartari, V. and Breschi, S., (2012). Set them free: scientists' evaluations of the benefits and costs of university–industry research collaboration. *Industrial and Corporate Change*, 21(5), pp.1117-1147.

Ulrichsen T. (2014). "Building long term strategic University-Industry Partnerships – Lessons and Effective Practices from UK and US Experiences". CSTI White Paper, June 2014, University of Cambridge.

Ulrichsen, T.C. (2018). Knowledge exchange framework metrics: A cluster analysis of higher education institutions. Bristol, UK.

Vick, T.E. and Robertson, M., (2018). A systematic literature review of UK university–industry collaboration for knowledge transfer: A future research agenda. *Science and Public Policy*, 45(4), pp.579-590.