Innovation Brokerage

Enabling collaborations through emerging digital tech

February 2020

nesta

Acknowledgements

This project and the resulting report were prepared by Nesta in collaboration with 100%Open and Science Practice. At Nesta, the team included **Laurie Smith**, **Christopher Haley**, **Kirsten Bound**, **Juan Mateos-Garcia**, **George Richardson**, and **Chantale Tippett**. At 100%Open, the team included **David Simoes-Brown**, **Peter Hutchison**, **Roland Harwood**, **Francesca Cowley**, and **Katie Walsh**. At **Science Practice**, the team included **Richard Batty**, **Andrea Wong**, and **Ana Florescu**.

We would like to thank the following for their time, contributions and focus at the Digital Innovation Brokerage workshop in February 2019: **Brendan Spillane** (University of Warwick), **Ed Hobson** (KTN), **Jake Larsson** (KTN), **Graham Doe** (konfer), **Lampros Litos** (Royal Society of Chemistry), **Lou Woodley** (AAAS), **Richard Young** (Univate), **Rob Wilmot** (Crowdicity), **Roland Harwood** (We Are Liminal), **Zoe Piper** (CSIRO Data61), **Rebecca Hinton** (CSIRO Data61), and **Jonathan Knight** (BSI). Whilst their contributions of these experts were essential, the report and its conclusions remain the responsibility of the editorial team.

Additionally, we would like to thank the people and organisations who agreed to be profiled in case studies: **Joe Marshall** (NCUB) for konfer, **Zoe Piper** and **Rebecca Hinton** (CSIRO Data61) for D61+, **Torsten Kolind** for YouNoodle, **Brendan Spillane** (University of Warwick) for Piirus, **Brandon Klein** for Collaboration.Ai, **Lou Woodley** (AAAS) for Trellis, and **Auryn Macmillan** and **Jack du Rose** for Colony.

About Nesta

Nesta is an innovation foundation. For us, innovation means turning bold ideas into reality and changing lives for the better.

We use our expertise, skills and funding in areas where there are big challenges facing society.

Nesta is based in the UK and supported by a financial endowment. We work with partners around the globe to bring bold ideas to life to change the world for good.

www.nesta.org.uk

If you'd like this publication in an alternative format such as Braille or large print, please contact us at: **information@nesta.org.uk**

Design: **Green Doe Graphic Design Ltd**

nesta

Innovation Brokerage

Enabling collaborations through emerging digital tech

Executive summary

Innovation rarely happens through the actions of a single person or organisation. More often, it is the result of collaboration and the exchange of ideas. Yet the role of intermediaries that bring innovators together is frequently overlooked, despite digital technologies offering new ways of connecting.

This report examines the phenomenon of 'digital innovation brokerage' that aims to connect ideas, people, organisations, and communities through digital technologies. We've investigated this under-explored field and found that digital tools can make important contributions throughout the brokerage process. To ensure novel ideas benefit people more quickly, we recommend that policy-makers do more to recognise the importance of digital innovation brokerage and support the field.

At the heart of digital innovation brokerage is a challenge: how best to combine human and machine capabilities. Innovation brokerage involves very human skills – building relationships, evaluating fit between potential collaborators, and making judgements about strategy – but it can also involve tasks where machines excel, such as analysing large amounts of data to find a match. This is a collective intelligence problem that, if solved, could significantly reshape how we innovate.

Our research has identified four phases for innovation brokerage:

In the **Prepare** phase, the broker helps innovators understand what they are looking for.

In the **Search** phase, the broker helps innovators find what they are looking for.

In the **Align** phase, the broker helps innovators establish trust and align their motives, culture, and working practices so they can collaborate effectively.

In the **Support** phase, the broker supports the innovators to make the relationship a success in the long run.

Whilst much innovation brokerage is performed by human consultants, scouts, or other specialist brokers, we specifically examine how innovation brokerage is increasingly being supported by digital tools such as machine learning and blockchain technology.

The greatest impact of these tools is currently seen in the **Search** phase, where relatively mature technologies such as relational databases and search engines are well established. Emerging applications of technologies for this phase are proposing new ways of formulating queries and finding relevant data; one example is Innography, a search engine for patents, where instead of relying on short phrases to query a search, users can submit whole research documents.

In contrast, technology has made fewest inroads into the **Align** phase. Aligning innovators is currently tricky for machines since it requires human skills such as building relationships and judging social situations. Yet these challenges mean this phase may also present the biggest opportunities for technology to make an impact where the field is still relatively open. Novel ideas are emerging in other sectors that can be applied to help broker innovation through alignment. For example, Collaboration.Ai supports alignment by analysing data on potential team members to recommend who should work together. Undoubtedly, many unrealised opportunities remain.

The picture for digital innovation brokerage in the other phases is more mixed. In helping innovators **Prepare** for brokerage, technologies are being used to analyse opportunities. For example, Quid can extract meaning from all sorts of written content, such as product reviews or web forums, to help identify opportunities for innovation. Yet it is currently of limited use for helping to define problems.

The **Support** phase often involves managing relationships and translating between cultures. These are fundamentally human tasks, yet some aspects are amenable to digital technologies. One approach is offered by Colony, which provides a platform for decentralised organisations. It uses blockchain technology to provide a transparent structure for coordinating and incentivising work so that contributors can work together and be rewarded fairly. This opens the possibility for innovation brokerage to occur without the intervention of brokers, as blockchain technologies might allow connections to be made in a decentralised manner without a conventional broker in the middle.

Looking to the future, we speculate that digital technologies have the potential to change the nature of innovation brokerage in four main ways:

- Lowering the relative costs of different parts of innovation brokerage, particularly in the Search phase.
- Reducing vertical integration within digital innovation brokerage so that different phases are offered by different providers.
- Breaking down existing barriers to collaboration allowing smaller or resource-poor organisations to participate.
- Increasing the role and power of brokers as their networks and capabilities grow, enhanced by digital technologies.

Without good brokerage, novel ideas can be wasted or their implementation delayed; universities might find it harder to identify suitable business partners to help commercialise academic research or companies might be unable to pinpoint academics with the right expertise to help develop their products. To ensure digital technologies are harnessed for innovation brokerage we recommend that policy-makers:

- **Recognise the importance of digital brokerage** by publicly adopting the idea of digital innovation brokerage to consolidate the field, integrating digital brokerage into the policy mix, sign-posting these tools to innovators, coordinating activity, and supporting professional networks.
- **Support and understand digital innovation brokerage** by directing public funding to create tools that fill gaps in digital innovation brokerage and understand how best to use digital tools for brokerage. This should prioritise understanding the most suitable roles and relationships for humans and machines in innovation brokerage – especially in the Align phase, which is relatively under-explored despite the opportunities it presents.
- **Improve data for innovation brokerage** by responsibly making relevant public data more open, implementing appropriate data standards, and providing suitable metadata. Data on intellectual property (IP) offers a particular opportunity in this regard.
- **Experiment with digital innovation brokerage in the public sector** by making greater use of existing and emerging digital brokerage tools to improve public services, enhance innovation, and support the emerging field of innovation brokerage. One immediate opportunity is in the public procurement of innovation.

1. Introduction

Innovation is much more than invention. For an idea to become a successful innovation it needs to be designed, prototyped, engineered, commercialised, distributed, and more. This process invariably requires multiple people and organisations, especially for complex innovations.[1, 2] However, finding potential collaborators and developing relationships with them can be hard and often requires capabilities that innovators do not have. This is where innovation brokers help.[3]

Put another way, innovation thrives on connectedness. It requires networks and the ability to draw together distributed resources; typically, the more radical an innovation, the more it disrupts existing networks and creates new ones. These networks are increasingly brokered both by specialists and well-informed generalists sharing information, knowledge, experiences, ideas, and solutions to needs and problems. As well as connecting different parts of networks, there is also a role for brokers in understanding the network as a whole, which requires systems thinking.

Why is digital innovation brokerage relevant now?

Innovation brokerage has a long history (see Box 1). However, several trends make it particularly timely to think about emerging digital innovation brokerage:

- **The increasing complexity of innovation**: As innovation becomes more complex, the potential for recombination and collaboration expands, which makes opportunities harder to navigate.
- **Emerging technologies**: New technologies such as blockchain, machine learning, virtual reality (VR), and augmented reality (AR) are currently starting to aid brokers in search, analysis, coordination, and communication.
- **The growth of brokerage in other sectors**: Brokerage more generally has become a powerful force within industries like online dating, e-commerce, and the sharing economy (e.g. community car-sharing schemes), much of it using digital platforms. Many of today's most successful companies (including Amazon, eBay, Uber, and Airbnb) are brokers of some kind, partly since such 'marketplace' approaches are more readily scalable than other business models.[4] If we compare how brokerage has reshaped various industries, we can gain insights into how it might reshape innovation itself.
- **Increased attention on digital filtering**: 'Information overload' problems have become commonplace in numerous areas, creating the need to filter and prioritise relevant and meaningful digital content and connections. However, we are becoming increasingly aware that filtering information is not the same as filtering data against a noisy background, and brings new risks such as 'filter bubbles', monopolistic content, and bias.

What is the value of innovation brokerage?

Innovation brokers can be crucial in enabling innovation as, like any market, the innovation system only runs when all the intermediaries who make interacting and partnering possible are in place.[5] More specifically, brokers can add value to innovation in a variety of ways. Because they are specialised in their brokerage role, they have particular skills and networks that innovating organisations may lack. Additionally, their understanding of the different sides they are brokering allows them to know which actors to introduce and helps with issues such as translating from one framework, vocabulary, and perspective to another. Brokers can also promote trust among the people and communities they are brokering.[6]

Box 1: A recent history of innovation brokerage

Innovation brokerage has a long history, with many of the themes in this report emerging and evolving over time to provide the conditions, context, and environment where digital innovation brokerage is now looking to grow. Below is an overview of some of the recent developments important to digital innovation brokerage.

1980s onwards – universities and tech transfer

Universities emerged as significant organisations in innovation brokerage. Since the 1980s, technology transfer offices have become a common feature where a university acts as a broker connecting researchers who have developed innovations or IP with companies that might want to licence it. University-industry brokering grew quickly, with the number of US university technology licencing and transfer offices growing from 25 in 1980 to 200 in 1990.[7]

1990s onwards – World Wide Web and evolution of the business ecosystem

The World Wide Web with its characteristic URL and hypertext features greatly expanded the ability of innovators to find each other. Since Tim Berners-Lee and CERN released the first browser to the general public in August 1991, the World Wide Web has been used to advertise through web pages, connect via e-mail and search through web crawlers that index content continuously. The development of social media such as LinkedIn and collaboration software such as Google's G Suite has increased the ability of businesses to connect and co-innovate.

2000s onwards – Open innovation

Greater openness in innovation dates back to the 1960s, but rose to prominence with Henry Chesbrough's book *Open Innovation: The New Imperative for Creating and Profiting from Technology* in 2003. In the last couple of decades, the role of innovation brokerage has been accelerated by the rise of technology platforms, open innovation, and new physical and virtual spaces in which innovation is encouraged to flourish such as startup accelerators and corporate incubators. Whilst such spaces are often focused on developing early-stage technologies, they can present important targets for established companies or their technology scouts looking to find new solutions and innovation partners.

2010s onwards – Artificial Intelligence (AI) and machine learning

Advanced computing technologies such as search algorithms and AI have started to have a significant impact in innovation brokerage processes and outputs, most significantly by making search easier and more efficient. Machine learning, a branch of AI, is concerned with developing systems that have the ability to automatically learn and improve from experience without being programmed.

Who is this report for?

This report is intended for innovation brokers, people thinking of setting up new innovation brokerage projects, anyone interested in finding new ways of connecting with others, and policy-makers interested in innovation and collaboration who want to choose between different approaches or evaluate the success of different interventions.

We aim to provide readers with:

- A clear explanation of what is meant by 'innovation brokerage' and 'digital innovation brokerage'
- An overview of the state of the art of digital innovation brokerage and how emerging technologies might provide opportunities and risks for innovation brokerage
- Considerations to bear in mind when setting up or running a digital innovation brokerage project, whether at a platform or policy level.

Policy-makers in governments, international institutions, and foundations need to know how to design and implement new digital innovation tools. They will benefit from a greater familiarity with digital innovation brokerage to enable new innovation collaborations. The codification in this report will outline the circumstances in which policy-makers might choose digital innovation brokerage technologies as a policy intervention and which type of brokerage tool is appropriate for the goals they seek.

Report structure

Following the introduction, this report features three major sections. **Defining digital innovation brokerage** defines key terms relevant to this report. **A framework for innovation brokerage** explains how innovation brokerage works and presents a framework that classifies innovation brokerage activity into four phases. This section also examines how emerging digital technologies can be used in innovation brokerage, including the benefits and risks of doing so. **The future of digital innovation brokerage** explores the ways in which digital innovation brokerage could evolve in terms of costs, changes in the balance between participating organisations, breaking down barriers, and increasing the power of brokers. Following the **Conclusion, Appendix 1** provides practical guidance, including key considerations for setting up or running a digital innovation brokerage project. **Appendix 2** provides detailed case studies for several digital innovation brokerage technologies featured elsewhere in the report. Finally, the last section provides **References and endnotes** for the entire report.

Methodology and process

This report is based on a review of the literature on innovation brokerage, together with interviews and a workshop with experts and practitioners in innovation brokerage. As part of this process, we compiled a database of over 150 digital innovation brokerage projects to help illustrate the landscape of digital innovation brokerage, and selected seven of these for more detailed case studies; these are introduced at relevant points in the report, and described in more detail in Appendix 2. We have made the larger database available online at innovationbrokerage.nesta.org.uk

2. Defining digital innovation brokerage

One of the challenges of understanding innovation brokerage is that the term potentially spans many different activities. There is no unified field of innovation brokerage and very few dedicated studies of the topic. Defining the topic is, therefore, important. Accordingly, the definition of innovation brokerage that we have adopted for this report is:

Innovation brokerage is the activity of connecting ideas, people, organisations, and communities to enable and support the innovation process.

By **ideas**, we mean thoughts that are useful for innovation whether IP, such as designs or algorithms, or tacit know-how, such as exactly how to get a particular piece of equipment to work the way you want. This report only considers the brokerage of ideas where adopting them involves connecting with other people or organisations; accordingly, a platform focused on enabling access to academic papers but not on connecting people with their authors would not count as innovation brokerage. This strikes a balance between an overly-broad definition that could include any type of brokerage and an overly narrow definition that might exclude brokerage of things that are crucial to innovation.

By **innovation**, we mean 'a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)' as described in the Oslo Manual of the Organisation of Economic Cooperation and Development (OECD).[8] This means we are not only considering brokerage for breakthrough high-tech product development, but also other types such as service innovation and incremental innovation.

This report is particularly focused on ideas, people, organisations, and communities. The definition above, therefore, suggests that there may be multiple different outcomes from innovation brokerage – based on different combinations of ideas, people, organisations, and communities – and hence potentially different applications. For example, innovation brokerage could lead to:

- Many individuals working with one organisation, e.g. in crowdsourcing
- Many individuals working towards one end, e.g. in wikis and prediction markets
- Matching individuals with each other, e.g. in networking software
- Bringing together organisations with ideas, e.g. in idea management software
- Bringing together multiple communities, e.g. in interdisciplinary conferences.

Because there is no unified field of innovation brokerage, there are a variety of terms and concepts similar to it, including 'knowledge transfer', 'innovation intermediation', and 'technology transfer'. Some of the organisations that undertake innovation brokerage without necessarily referring to it as such include:

- **University technology transfer offices**: These act as brokers connecting researchers who have developed IP with companies that might want to license it.
- **Challenge platforms**: These enable organisations that have a challenge to post it on an online platform, and have people work to solve it.
- **Technology scouts**: Typically working within or on behalf of a large corporate, these are charged with finding emerging technologies and/or startups developing new products and services.
- **Startup accelerators**: These connect early-stage startups with advice and funding.
- **Innovation networks**: These provide networking opportunities for innovators.
- **Trade associations and academic societies**: Organisations such as the Royal Society connect people of a particular field or industry.

In this report, we are particularly interested in how innovation brokerage is being changed by emerging digital technologies, meaning digital technologies that have become practically useful in the last few years, such as machine learning and blockchain.

This definition is designed to emphasise novelty but exclude technology that isn't (yet) practically useful, such as that which has only been implemented in a research context. Two important emerging digital technologies are discussed in Box 2.

Box 2: Machine learning and blockchain

As this report frequently mentions machine learning and blockchain technologies, they are explained briefly here.

Machine learning

Machine learning is a set of techniques that enable a computer system to learn from data, instead of following a set of explicit steps that are programmed in. When provided with sufficient data, a machine learning algorithm can learn to make predictions or solve problems, such as identifying objects in pictures or winning at particular games.

Blockchain

Blockchain technology provides a way for people to store data in a database without there being a central authority who manages changes to the database. It can provide a verifiable and permanent record by linking together 'blocks' of data using cryptography, in a way that makes the data effectively immutable. The most prominent blockchain technology is the bitcoin cryptocurrency.

Digital technologies enable three main capabilities that are particularly relevant to innovation brokerage: communications, coordination, and data analysis. Table 1 shows how established and emerging digital technologies help innovation brokerage by supporting these capabilities.

Table 1: How established and emerging digital technologies support capabilities relevant to innovation brokerage

Capability	Established supporting technologies	Emerging supporting technologies	Relevance to innovation brokerage
Communicating	• Websites • Video calling • Email	• VR • Games • Simulations	Help people communicate with each other more quickly, cheaply, and at a greater distance. Useful both for finding collaborators and building a collaboration.
Coordinating with others	• Task management systems • Online marketplaces • Wikis	• Blockchain • Various forms of digital tokens	Help people organise their work if they are collaborating for innovation. Can create additional incentives for successful collaboration.
Analysing information	Search engines	Digital technologies that have a machine learning component, including: • Semantic search engines • Recommendation algorithms • Matching algorithms • Natural language processing	Help people analyse information to identify potential collaborators.

3. A framework for innovation brokerage

Through a literature review, interviews, and a workshop with innovation brokerage experts and practitioners we compiled a database of over 150 digital innovation brokerage projects. This database provided a basis for our understanding of the innovation brokerage landscape.

Through initial analysis, we found that certain digital innovation brokerage tools were more common than others; we saw numerous challenge platforms, networking platforms, and many different kinds of vertical search engines. Similarly, we also saw a range of different technologies in use by these tools, from machine learning to data analysis, blockchain, and more.

We also found that each of the examples enabled innovation brokerage at different points in the innovation brokerage process. This process can be understood as unfolding over four phases:

In the **Prepare** phase, the broker helps innovators understand what they are looking for.

In the **Search** phase, the broker helps innovators find what they are looking for.

In the **Align** phase, the broker helps innovators establish trust and align their motives, culture, and working practices so they can collaborate effectively.

In the **Support** phase, the broker supports the innovators to make the relationship a success in the long run.

Most of the examples we found were tools that enable the Search phase. Of these, more enabled searching for potential collaborators than for solutions directly. There were fewer tools for the Prepare and Support phases, and even fewer for the Align phase. Tools enabling the Prepare and Search phases could largely be said to digitise existing ways of working. Those enabling the Support phase either digitised existing ways of working, or proposed new ways of working altogether.

Brokers serve innovators by helping them to perform certain tasks associated with each phase. For example, to enable the Prepare phase, brokers may help their clients define problems or identify opportunities. Table 2 lists these and other actions brokers take across the four phases of innovation brokerage.

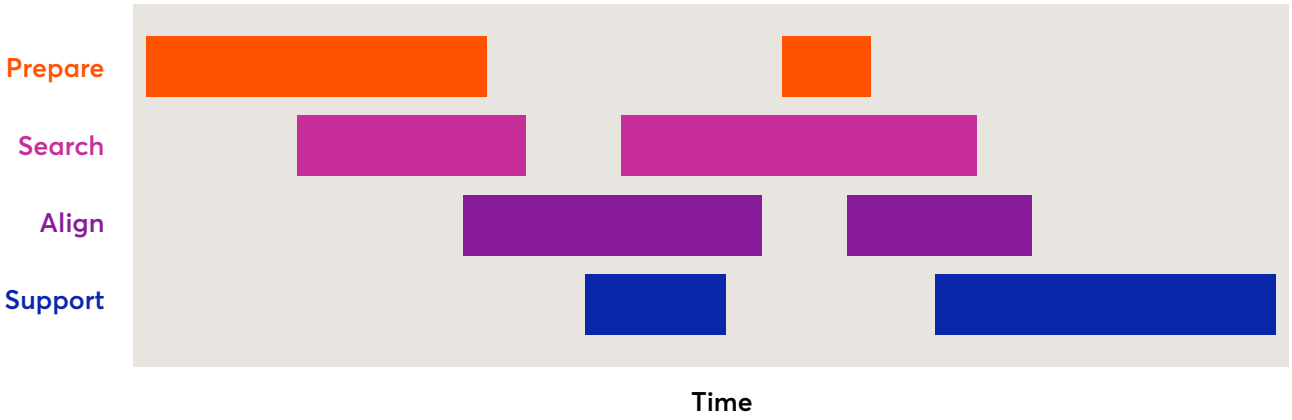
Table 2: Broker actions within digital innovation brokerage phases

Prepare	Search	Align	Support
Define problems	Find ideas	Adopt ideas	Structure and incentivise
Identify opportunities	Find collaborators	Initiate collaborations	Support implementation

These phases should be thought of as modes of action, rather than strict sequential steps. An innovator can jump between phases and can do more than one phase at once. Similarly, a broker may work in more than one of these phases. Furthermore, there is not necessarily a sharp division between the phases; for example, as collaborators become more aligned they can gradually work together on the innovation, thus entering the Support phase. The overall process may also be iterative in that, during or after developing an innovation, the innovator may start looking for more collaborators.

This sense of overlapping phases is represented in Figure 1. An innovator may go through all four phases with some overlapping, then start a collaboration but realise it's not working and have to go back to the Prepare phase and begin again.

Figure 1: Timing of innovation brokerage phases may overlap



The following subsections explore which emerging digital technologies are likely to be most relevant for the four phases of innovation brokerage. To help illustrate these, examples are used throughout. For each phase, specific references are made to relevant case studies. A more in-depth version for each of these case studies can be found in Appendix 2.

Prepare

Before an innovator can begin to look for ideas or collaborators, they need to understand the types of ideas or collaborators they are looking for and how that fits into their wider strategy. This is often particularly difficult in the case of early-stage innovations, where the route to market (or other implementation) is unclear and the product or service itself is poorly defined. In this phase, brokers can help innovators to:

- **Define problems**: This involves understanding what the innovator's strategy is and what problems they are trying to solve by being brokered. Often, the broker needs to dig deeply into the innovator's stated problems and try to find what their underlying problem is.
- **Identify opportunities**: The innovator also needs to understand the landscape of opportunities available. The broker can help them learn about the types of technology available or trends in their industry, so they will be able to more clearly target their search.

At the end of the Prepare phase, the innovator will ideally have a clearly-articulated strategy for what they are looking for and why.

Challenges of this phase

Getting at the underlying problems

It's often difficult for people to articulate what they want and to define what success would look like. Innovators may come to a broker with a specific problem based on an imperfect understanding of the market, but further digging may uncover a different underlying problem. The Knowledge Transfer Network (KTN), a UK-based knowledge transfer organisation that brokers relationships between businesses, academics, government agencies, and research organisations, has found this is a crucial part of what they can do to help companies. For example, a manufacturer came to them looking for a supplier of components for robotics systems. When a KTN manager explored their request, they found that the underlying problem this company was trying to solve was improving the productivity of their manufacturing. This deeper exploration revealed that instead of jumping to robotics, a more appropriate approach would be to find a way of analysing the manufacturer's data to find ways of boosting productivity. This insight led the KTN to connect the organisation with people who could help with that data analysis.

Linking problems to strategy

Sometimes, innovators may lack a clear innovation strategy. They may need help addressing this before they are ready to specify what they want to achieve by being brokered.

Roles for emerging digital technologies

The two main ways that emerging technologies can help with the Prepare phase is to analyse data to identify opportunities, and to enable people to coordinate to identify problems and opportunities.

A digital tool that helps with the first of these is Quid, which analyses large amounts of text to answer questions like 'What is the future of food?' or 'What does the current landscape look like for digital health?' It outputs diagrams showing clusters of discussion around certain topics. Two other examples, described in Box 3, are konfer and D61+.

Box 3: Analysis tools enabling the Prepare phase

konfer

konfer is an online platform created by the UK's National Centre for Universities and Business (NCUB) and UK Research and Industry (UKRI) to help businesses connect and collaborate with universities in the UK. It searches a wide variety of existing, publicly available data sources to help businesses find and connect with universities who have relevant experts, discoveries and developments, and specialised equipment. Although it primarily functions as a search tool, konfer also helps to prepare organisations for brokerage. Businesses unsure of the kinds of expertise, research outputs, or equipment that exist in the UK can use konfer to identify opportunities for innovation given the existing work in a space. They can also use the platform to identify regional research and development (R&D) hubs according to a given interest, or, vice versa, to surface the types of expertise present at nearby institutions.

D61+

D61+ is a suite of three related products developed with over 50 industry, research, and government partners – including The Conversation Media Group, IP Australia, the Australian Department of Industry, Innovation and Science, Clarivate Analytics, and the Australian Research Council – to serve different innovation brokerage needs for academics and businesses in Australia. One of these products, Expert Connect, helps industry representatives looking for a particular kind of expertise to search existing data sources, find relevant experts, and contact them directly or through their institutions. When using Expert Connect to prepare for innovation brokerage, a business can take advantage of the natural language processing to search for signs of relevant activity around a topic however they are able to articulate it, and then find expert-relevant terminology they can use in later, more specific searches for collaborators or solutions.

As well as software to help with analysis, technologies can help coordinate people to identify problems and opportunities together. One way to do this is to have an online discussion platform focussed on problems. For instance, XPrize Community brings together communities of experts to identify challenges around topics for which XPrize is considering setting up a prize.

Emerging technologies could supplement this approach by analysing discussions to help manage these conversations better. For example, Epistema analyses discussions to find areas of controversy and consensus to help as a way of improving decision-making processes.

As well as the qualitative approach of having discussions, there are platforms that bring people together to make quantitative predictions. One example of this is forecasting competitions, where participants compete to make the most accurate predictions. In the IARPA Hybrid Forecasting Competition, human forecasters work with machine forecasting systems so that the strengths of both humans and machines can be combined.

Another approach to bringing people together for quantitative analysis is prediction markets, where people can buy and sell shares in a potential outcome. The market price of an outcome, therefore, aggregates the views of the people in the market, and market participants are incentivised to have accurate predictions. An example of this approach being used to identify opportunities is Consensus Point's Huunu platform, which enables companies to run prediction markets on business problems such as understanding market trends. There is also a protocol for creating prediction markets based on the Ethereum blockchain called Augur. Augur enables anyone to create their own prediction markets.

Considerations for emerging digital technologies

Developing the right combination of human and machine

The Prepare phase relies heavily on unstructured, qualitative reasoning and social skills – things machines aren't good at (yet). For example, it's difficult for machines to have conversations to uncover underlying problems. Conversely, it's difficult for humans to analyse large amounts of data like Quid's system does. Approaches like the hybrid forecasting competition which combines the strengths of humans and machines are a promising way forward. IARPA's Hybrid Forecasting Competition summarises these contrasting strengths and weaknesses in the context of geopolitical forecasting:

> Human-generated forecasts may be subject to cognitive biases and/or scalability limits. Machine-generated (i.e. statistical, computational) forecasting approaches may be more scalable and data-driven, but are often ill-suited to render forecasts for idiosyncratic or newly emerging geopolitical issues. Hybrid approaches hold promise for combining the strengths of these two approaches while mitigating their individual weaknesses.[9]

Search

Once an innovator understands what idea or collaboration they are looking for, the broker can help them find it. The two main things they are looking for are:

- **Collaborators**: people, organisations, or communities that they could work with.
- **Ideas**: ideas, often in the form of patents or other IP, research, or proposed solutions.

At the end of this phase, the innovator will have made the first moves toward building on an idea or developing a collaboration.

Challenges of this phase

Lack of clarity

People are often unsure of what they are searching for, which makes it difficult to express what they want to a broker or a search engine. They may also not know precisely what they have to offer to potential collaborators. This problem may be partly mitigated by going through the Prepare phase, but often problems and opportunities are further refined through exploring a range of available options.

Searching can take a long time

Searching and filtering can be challenging. Users of innovation brokerage services need help with finding suitable rather than sufficient partners with whom they can innovate, and to do this as quickly as possible so they can begin working together.[10] This need may be challenging for digital innovation brokerage tools to address, as evidence suggests that internet exchanges struggle with the 'unsystematic' nature of the partner identification process; search processes are resource-intensive because they have limited rates of success.[11]

Brokers who don't have a big enough network

To be useful, platforms that help with Search need to generate results from a data set that is large enough and relevant enough for users' needs. Network effects are critical for brokers; the success of an innovation network depends not only on the success of its individual projects, but also on the 'critical mass' of projects happening concurrently.[12] However, having multiple brokers dilutes this effect. To develop a large network, the broker needs to be well-known and members of the network require motivation to participate.

Difficulty matching

Matchmaking can be a complex market transaction, often involving both parties considering difficult strategic questions.[13] There may be differences between the innovator and their potential collaborators in how they describe their needs and offers, making searching difficult. They also need to be able to find complementary organisations or ideas, which is a harder problem than finding similar organisations or ideas. Poorly-designed algorithms may also cause problems; for example, if popularity is weighted highly, it may be difficult for innovators to uncover unexpected options.

Roles for emerging digital technologies

Search is the area where most of the focus of digital innovation brokerage technology has been, with many examples of challenge platforms, professional networking tools, and industry-specific search engines.

The Search phase is probably the most amenable to digital technologies as a core part of search fits in well with the digital capability of analysing information. Mature technologies such as relational databases, search engines, and web applications can help with this. Emerging digital technologies such as machine learning can also play a role.

With emerging digital technologies, several improvements could be made. The first is to make it easier to perform searches. For the purpose of innovation brokerage, one challenge is that people may not know exactly how to formulate the right query to return relevant results. For example, should an innovator search for 'cleantech', 'renewable energy', or 'green technology'? In the early days of search engines, searchers had to work out what string of text was likely to appear in the type of page that they were looking for. As search engines improved, they made this process easier by searching for synonymous terms, auto-completing queries, and answering simple natural language questions such as 'What time is it?' One way of handling this is to enable people to search by entering whole documents rather than short queries. For example, Innography is a search engine for patents where people can put in a research document and see what patents might be related to it.

Another way of enabling people to search even if they don't know what they are looking for is to build a recommendation engine rather than a search engine. This could work somewhat like Amazon and Netflix who recommend media to consume based on users' past habits and search behaviour rather than them having to specify what they are interested in.

As well as making it easier to search when people don't know what they are looking for, emerging technologies could help improve the results they receive. Applying new machine learning techniques to search is one way of doing this. For example, Airbnb used deep learning to improve their search results.

Innovation brokerage is often a matching market, where innovators can't just choose who they want to collaborate with, they also have to be chosen.[14] One example of such a tool was Piirus (see Box 4), which built a matching market between academic researchers. If digital technologies are to help with matching, they need to take account of both party's preferences and try to give everyone in the population the best match possible. The field of 'market design' studies matching markets, and has been applied to problems such as matching doctors to medical residencies and matching food donations to food banks.[15] These issues also occur in the world of dating, where apps have a variety of algorithms to try to match people together effectively.[16]

Box 4: Piirus

Piirus sought to improve the Search phase by building a matching market to broker relationships between would-be academic collaborators. Though currently inactive, Piirus was a tool that early-career academic researchers could use to build their professional networks by finding other early-career researchers to collaborate with. Researchers often rely on their networks to carry out other tasks core to their academic position. However, early-career researchers often have incomplete or undeveloped networks and find it difficult to accomplish these tasks to do their work. In response, Piirus featured academic profiles populated with key words indicating interest areas. The system then algorithmically matched profile creators to other early-career researchers with profiles on the platform. Crucially, matching was not direct and based on similarities, but based on complementary relationships – the aim was to pair people doing related, but slightly different things to maximise the potential for innovative, cross-disciplinary collaboration.

Another way of improving search is to use better data. For example, YouNoodle generates data through direct engagement with users rather than collecting from existing sources (see Box 5), while konfer (see Box 3) relies on the existence of suitable, quality data sets such as ORCID and information that they can scrape from university websites.[17] New data that captures a richer picture could also be generated. For example, Key Values is a job board for software developers that features companies according to their values, which means it has to provide a means for gathering that data.

Box 5: YouNoodle

YouNoodle seeks to improve the Search phase by using better data – and rather than collecting it from existing sources, the platform generates this data through direct engagement with users. In this case, better data means qualitative information about what potential collaborators either need or can offer so that they can be better matched. YouNoodle enables corporations, governments, and foundations to source and select early-stage startup companies with services and products that are relevant to their needs. It does this in two ways. Primarily, the platform can be used to run innovation challenges and similar selection processes. It enables organisations to manage applications, screen applicants, and to then send applications to experts for evaluation before selecting a winner. As a result, YouNoodle gains access to application data profiling each startup, and evaluation data assessing the potential success of each. By combining this data from across all innovation challenges, YouNoodle achieves a broad view of which early-stage startups using the platform have the greatest potential for success. Through a semi-automated process, YouNoodle can then broker further connections between startups and potential clients, beyond the bounds of any one innovation challenge.

As well as improving search engines, the Search phase can be improved through human curation. An example is Sparrho, which is a search engine for scientific papers that also has human-curated collections of papers on particular topics. As part of this, it's worth considering the balance of search and curation. According to Benedict Evans of venture capital firm Andreessen Horowitz, there are three main ways of providing search. There is giving you what you already know you want (e.g. Amazon, Google), working out what you want (e.g. Amazon and Google's aspiration), or suggesting what you might want (e.g. bookshop Heywood Hill's recommendations). Evans argues that 'All curation grows until it requires search. All search grows until it requires curation.'[18] Curated lists of recommendations are valuable in that they are often more relevant. But they take a lot of labour to produce, and as they grow in size they become hard to navigate – and they need to be discovered in the first place. Search engines provide an answer to these concerns, but they lose the value of human curation.[19]

Considerations for emerging digital technologies

Filter bubbles

If a system is trained to optimise for a certain metric, it may give a narrower and narrower range of results. This problem is seen in social media applications that show people content similar to content that they have engaged in, thus narrowing the range of what they see.

Unclear impact on serendipity

A risk of using digital tools extensively is that it could reduce the serendipity that often results from in-person interactions. On the other hand, having access to a greater variety of options could increase serendipity.

Limitations of available data

Data on which to base search technologies may be incomplete, inaccurate, or out of date.

Align

Once an innovator has found a potential collaborator or idea to build on, they will need to establish that they are a good match and develop trust and alignment of motives, culture, and working practices with the other party. This process will lead to the development of an agreement and plan to work with each other. Brokers can help innovators:

- **Adopt ideas**: If the innovator is looking for ideas rather than collaborations, then the broker can help them adopt these ideas. This will likely involve at least some negotiation and collaboration with the originator of the idea in order to adopt it effectively.
- **Initiate collaborations**: If the innovator is looking for a collaboration, the broker can help start this in a good way. For example, they can help mediate negotiations and resolve issues caused by differences between the parties.

Challenges of this phase

Dealing with mismatches in culture, timelines, and priorities

There are often gaps between different people or organisations, especially if they come from different types of organisations or industries. They may have different knowledge, terminology, norms, values, or incentives that make it difficult to communicate.[20] For example, the Dowling Review of Business-University Research Collaborations identified incentive problems affecting business-university research collaborations, such as the short-term focus of many businesses, and lack of incentive among academics for collaborating with business.[21]

Challenges around IP

Innovators that hold IP may be concerned about sharing it with other organisations, and it may be difficult to establish the value of this IP and the rules around it when a collaboration is at an early stage. Small and medium-sized enterprises (SMEs), in particular, need to trust that the benefits of collaborating outweigh the costs, and that they won't lose the competitive advantage they have in technical competence through working with larger firms.[22,23] It will also be important for any collaboration to understand the risk that might come from claims that they are infringing on existing patents. This can be difficult given the volume of patents and the difficulty of searching for them.

Building trusting relationships

According to one practitioner interviewed for this report, 'For open innovation to work, it needs to be transparent and people need to be rewarded fairly; otherwise, trust evaporates'.[24] The Dowling Review found that 'strong and trusting personal relationships' was the most frequently cited success factor in business-university research collaborations.[25] In its recommendations for an online brokerage platform, it also emphasised that businesses needed not just an online matching platform but personnel to guide them through the process. Building good relationships often involves many face-to-face conversations, and may involve approaches such as human-centred design that aim to deeply understand the needs of different parties. Digital innovation brokerage often concentrates on helping people and organisations search for collaborators, but often the relationship-building is the most challenging part.

Roles for emerging digital technologies

The Align phase is very dependant on skills that humans are much better at than machines, such as building relationships, judging social situations, and making complex decisions. It is therefore currently difficult to think of ways emerging technologies could help, except in a few particular sub-tasks. However, there may be more opportunities in the longer-term.

Facilitate negotiation and the development of a shared plan

One example that does not use digital technologies is the Lambert Toolkit. This contains a guide and model research collaboration agreements to help academics develop collaborations with industry. This kind of tool could be implemented digitally, and could perhaps identify potential problems with the plan such as differing expectations or timing conflicts.

Facilitate difficult conversations

Conversations during this phase are likely to be difficult as they involve building trust and establishing the nature of the collaboration. Digital technologies may be able to facilitate this by highlighting areas of potential conflict or misunderstanding. An example of this outside innovation brokerage is Actual, an app to help improve communication in personal relationships between people. It employs an 'AI-mediator' that helps prevent conflict due to misunderstandings.

Initiating productive relationships

As well as identifying potential collaborators, digital technologies can help by finding those relationships that could be most productive. One example from beyond innovation brokerage is Collaboration.Ai (see Box 6).

Box 6: Collaboration.Ai

Collaboration.Ai seeks to improve the Align phase by helping to initiate relationships between would-be collaborators. It does this by judging whether people are likely to make good (e.g. well-aligned, productive) matches given information like their interests, capabilities, perspectives, goals, and their past performance resulting from previous matches. The tool uses network theory, blockchain, and machine learning to process complex, often qualitative data to analyse communities and how their members relate to one another. It can be used in companies to build teams or in university courses to assign working groups. In these situations, it can help connect and group people based on shared motivations, connections, commonalities, or complementary characteristics as a way of encouraging better interactions, productivity, or other outcomes.

Considerations for emerging digital technologies

Messy human relationships

The Align phase is all about negotiating and developing relationships, which makes it a challenging phase for emerging digital technologies to help with.

Support

Once a collaboration is up and running, the broker can help make this relationship a success in the long run. Often innovators are looking for a structured process within which to build collaborations.[26] For this phase, brokers can provide:

- **Structure and incentives**: The broker can provide a way for collaborators to share both the work and the rewards between them, and to help with the project management of a collaborative project.
- **Support for implementation**: The broker can provide access to the resources needed to support an innovation. Support for implementation could include a wide range of operational functions that are only indirectly related to innovation, such as HR or IT support. It could also include support that is more directly related to innovation such as help with IP strategy.

Challenges of this phase

Dealing with mismatches in culture, timelines, and priorities

Although some of the problems around this will be resolved in the Align phase, some may persevere. For example, it might be necessary to manage the different languages and cultures of the different brokered parties.

Managing work

It can be challenging to manage work in one organisation, but the challenges increase as you involve more organisations or even large numbers of individuals as in the case of crowdsourcing. Managing work also has particular complexities when thinking about innovation, because it is not always possible to cleanly break down innovation projects into tasks. Although there are many project management tools available, they may not be suited to stages of innovation where it is hard to define goals and tasks.

Maintaining momentum

Although a collaboration may start well, it needs to be kept on track to avoid issues such as loss of focus or conflicts and misunderstandings between the participants.

Roles for emerging digital technologies

As with the Align phase, Support relies a lot on human skills such as relationship building. There are, however, some ways that digital technologies could help.

Coordinating and incentivising work

As well as helping with search, challenge platforms such as OpenIDEO can help with collaboration by providing a structure with which people can collaborate. Similarly, Github provides both a place to manage changes to code and incentives to participate as people can display their contributions. Blockchain could help with managing and incentivising work in a decentralised way. For example, Colony helps with running decentralised organisations by providing ways to incentivise participants and make decisions (see Box 7). There is an emerging field of Organisational Technology (OrgTech) that is exploring how the emerging blockchain sector can radically digitise and reinvent how organisations operate.

Box 7: Colony

Before founding Colony, Jack du Rose was a jeweller making extremely high-end items like artist Damien Hirst's diamond-encrusted skull. He credits his company's ability to compete with large brands to having built a team of the world's best craftspeople distributed around the world. But he found it difficult to manually coordinate, correctly incentivise, and build trust with team members. This experience led him to set up Colony. Colony seeks to improve the Support phase by providing a transparent structure for coordinating and incentivising work so that contributors to decentralised organisations can work together and be rewarded fairly. It provides an infrastructure for organisations to manage their resources and decision making in an automated and programmable way. It aims to allow organisations to operate without hierarchy, enable more equitable influence and profit-sharing than sharing economy platforms, and increase coordination efficiency when compared to standard worker-owned cooperative models.

Facilitating conversations

Another way that emerging technologies can assist is by helping overcome challenges in conversations, especially when large numbers of people are involved. This could be similar to technologies used in the Prepare phase for bringing people together to identify problems and opportunities. For example, Ment by Epistema helps teams manage their conversations and decisions by providing a space for discussion and analysing the ideas generated through AI. Consider.it facilitates community decision-making by visually summarising what participants think and why. Another example is Trellis from the US Association for the Advancement of Science (AAAS), which sought to facilitate conversations and coordinate work (see Box 8).

Box 8: Trellis

Trellis sought to improve the Support phase by providing means for participants to coordinate work and facilitate conversations among large groups of people in different time zones and working in diverse scientific disciplines. The platform was created by the AAAS to provide a single space to bring scientists together to share resources related to specific projects where they would be working in groups. In building Trellis, the AAAS aimed to support multidisciplinary communication and collaboration in science by providing 'a single place for anyone in science to engage with all of the communities to which they belong'. Trellis provided a space in which core tools for academic collaboration could be integrated together on one platform, and aimed to provide an environment that facilitated discussion and discovery across scientific disciplines. The platform made use of human facilitation for relationship building, but enhanced these activities by providing tools for hosting online panel discussions, sharing documents open to shared annotations, and connecting with other existing collaborative tools like Google Drive.

Enriched communication

New media technologies such as VR or AR could provide new and richer ways for people to share ideas and communicate. For example, VR has been used to help involve citizens in urban planning.[27] Another example of enriched communications is Anima, which provides a way to create interactive prototypes of software, so that teams can see what the product might look like and test it with users and stakeholders.

Considerations for emerging digital technologies

Messy human problems

A large part of the challenge of the Support phase is dealing with the messy human problems of misunderstandings, culture clashes, and divergent priorities. Although tools that can facilitate conversations may help with this, most of the work here will involve humans developing relationships.

Untested organisational structures

Blockchain-based solutions that allow for new institutional structures such as decentralised organisations are too early-stage to have proven whether and how they will work. There is a risk that they will miss something important about how organisations run or will be hard to use for people who aren't familiar with blockchain technology.

Summary of the role of digital technologies in each phase

The previous subsections discuss what we know about the challenges associated with each innovation brokerage phase, the technologies already enabling each phase, and the considerations for emerging technologies working in these areas. Table 3 draws on this discussion to summarise the outlook for each phase, including potential applications of emerging digital technologies, tasks that are challenging for digital technologies, and a prediction of the potential for digitisation of each phase over the next few years without intervention (i.e. the extent to which digital technologies will be able to address the key challenges of a phase).

Table 3: Usefulness of digital technologies within the phases of digital innovation brokerage

Phase	Potential applications of emerging digital technologies	Challenging tasks for digital technologies	Current near-term (approximately five years) potential for digitisation
Prepare	• Data analysis to identify opportunities and make forecasts • Tools to analyse and manage discussion of problems and opportunities • Tools for creating forecasting competitions and prediction markets	• Understanding underlying problems • Developing a strategy • Synthesising evidence and ideas about opportunities	**Medium potential** There are plausible technical options to help with analysing opportunities and trends. Internal crowdsourcing platforms can be used to co-create strategy. However, much of this phase will still rely on conversation and human analysis.
Search	• Ways of searching without having to give an explicit query • Improved search and matching algorithms	• Adjusting the search strategy in response to results • Making the final choice of who to collaborate with	**High potential** Search is already the phase with the most digital tools available, and this makes sense given how much the search phase is about processing information. This trend is likely to hold as search technologies continue to improve.
Align	• Tools to facilitate difficult conversations • Tools to facilitate the development of a plan	• Developing and facilitating relationships • Managing relationship difficulties • Translating between different cultures	**Low potential** The Align phase is largely about developing good relationships, and is thus very dependent on human skills. These challenges mean this phase may also present the biggest opportunities for technology to make an impact in the longer term since the field is still relatively open.
Support	• Tools for coordinating and incentivising work • Tools to facilitate conversations between collaborators • Communication tools that provide a richer way of communicating than was previously possible	• Managing relationships • Translating between different cultures	**Medium potential** While a lot of the Support phase is likely to continue to rely on human skills, providing structures for coordination and some support with implementation seems amenable to digitisation given trends in emerging technologies.

4. The future of digital innovation brokerage

Digital technologies from machine learning to network science have already transformed dating and shopping through brokerage. A similar opportunity exists for the process of innovation. New technologies tend to not only plug into existing systems but also reshape the world around them. Accordingly, this section suggests five ways in which digital technologies could reshape the essentially human activity of collaborative innovation.

Changing the relative costs of different parts of innovation brokerage

Technological change may affect different parts of innovation brokerage differently. For example, Search is currently more amenable to digital technologies than the other phases. This could lead to brokers focussing their human labour on the other phases and outsourcing most of their search efforts to digital tools. For example, Collaboration.Ai is being used to analyse communities and even assign working groups, but coalescing these into effective teams is human work.

Shifting the balance from end-to-end services to specialised tools

Changes in technology can lead to reduced vertical integration. For example, instead of travel agents offering a full holiday-organising service, many people now use a variety of search engines to find flights, hotels, and activities separately. Similarly, while some organisations can support the full innovation process, others choose to specialise in particular areas. Now and in the future, an innovator may seek an end-to-end service provider, a specialist service provider or a combination of the two. YouNoodle's semi-automated process indicates a possible direction for flexible service delivery.

Breaking down existing barriers to collaboration

Looking for collaborators can be costly, making it difficult for smaller players (such as SMEs) to do this.[28] For example, an innovator with a new technology for the digital mobility sector will need to research the requirements of companies and supply chains in that market globally, find the right contacts, set up and attend meetings, and project manage the process. Easier and cheaper access to brokerage could allow smaller organisations to do all this faster and more frequently. One consequence of this might be that smaller organisations will be able to engage in more R&D collaborations than previously; for example, 200,000 startups on the YouNoodle platform have responded to over 1,000 challenges posed by larger organisations.

Giving brokers a more important role in innovation

Businesses that gain a strong position by building a network can become dominant in the market. Those brokers that invest in the right balance of technology and human skills will have an opportunity to scale to global size at a relatively low cost.

Improving the productivity of innovation processes and management

As technology allows wider matching of talents and system components, the result could be more diverse and creative combinations. In turn, these could increase the relevance and speed to market of innovation in many spheres of activity, from the production of new products and services, to solutions to pressing problems such as climate change and disease eradication.

5. Conclusions

Digital innovation brokerage offers much to be excited about. This report defines the field and provides a framework for understanding its different phases. Throughout are case studies of digital brokerage tools. Practical guidance for those who wish to develop digital innovation brokerage tools can be found in Appendix 1. Yet to fully realise the opportunities presented by these technologies, digital brokerage tools need to be better integrated into innovation systems. This can be achieved in four main ways:

Recognising the importance of digital brokerage

The term 'digital innovation brokerage' is not widely recognised, yet our research shows that considerable work fitting this description is already underway. Public adoption of the idea of digital innovation brokerage by policy-makers will help consolidate the field and give it form. This could be achieved by including digital innovation brokerage in the government's next innovation strategy as part of the policy mix, alongside sign-posting for innovators, support for professional networks, and provision of training and development opportunities for potential digital brokers and users of these tools. There is also a role for government to help coordinate the development of the digital innovation brokerage system to ensure the different parts work together smoothly, resources are efficiently deployed, and to avoid inadvertent consequences of unmanaged arrangements.

Policy-makers should recognise the importance of digital brokerage by publicly committing to consolidating the field, integrating digital brokerage into the policy mix, sign-posting these tools to innovators, coordinating activity, and supporting professional networks.

Supporting digital innovation brokerage

While there are many circumstances where the private sector can be relied upon to harness digital technologies for brokerage, there are others when the state has to compensate for market failure. For example, there would be value in better understanding of how the strengths of humans and machines can be combined as part of brokerage, but companies might not be able to capture the benefits of such knowledge so may have limited incentive to invest. In such situations, there is a case for government support.

Public funding should be used to create tools to fill gaps in digital innovation brokerage and understand how best to use digital tools for brokerage where the market is not providing solutions. This should prioritise understanding the most suitable roles and relationships for humans and machines in brokerage – especially in the Align phase, which is currently relatively under-explored despite the opportunities it presents.

Improving data for innovation brokerage

Public data lies at the heart of many digital innovation brokerage tools. For example, konfer uses data from open sources such as ORCID and Equipment.data. The more data relevant to innovation brokerage that can be made open (ideally in a standardised form with accompanying descriptive metadata), the greater the opportunities for enterprising people and organisations to build novel digital innovation brokerage tools. Data on IP offers a particular opportunity in this regard.[29]

Data for innovation brokerage should be improved through responsibly making relevant public data more open, implementing appropriate data standards, and providing suitable metadata. Doing so will help unlock brokerage opportunities in areas like the IP market.

Experimenting with digital innovation brokerage in the public sector

Government has the opportunity to catalyse digital innovation brokerage by developing, experimenting with, and using these tools. This would also enhance innovation by connecting people and organisations, and could improve public services. One immediate opportunity is in the public procurement of innovation. This has been criticised for favouring a handful of large, known providers rather than others that are often smaller and less well-known but perhaps more innovative.[30] Tools such as BidSpark from CityMart can use digital innovation brokerage to help enable this by allowing cities to market procurement opportunities to vendors who themselves can be notified about suitable contracts.[31]

The public sector should experiment with digital innovation brokerage by making greater use of existing and emerging digital brokerage tools to improve public services, enhance innovation, and support the emerging field of innovation brokerage. One immediate opportunity is in the public procurement of innovation.

Digital technologies have already revolutionised many areas of life from shopping to dating. For example, digital brokers such as Tinder and Bumble allow people to identify potential partners nearby with shared interests or other desirable characteristics. A similar opportunity exists with innovation brokerage that could boost economic growth and help tackle challenges like ageing or climate change. By codifying and mapping the field, we hope that this report marks the beginning of a step-change in innovation brokerage, allowing us to build on past successes and see this field flourish.

Appendix 1: Practical guidance and advice

Providing practical guidance in a fast-changing field is one of the objectives of this report. The following guidance is based on the research cited but should be seen as advisory rather than definitive or comprehensive.

Who is this guidance for?

- Those who are setting up or improving a digital innovation brokerage project or service.
- The brokered – employees in large and small organisations as well as entrepreneurs, inventors, and researchers.
- Those who are setting government policies that are designed to take innovation brokerage into account.

Where and how can emerging digital tools support more effective innovation brokerage?

Digital innovation brokerage has the potential to both reduce the costs of innovation and to increase its returns or social benefits. In both cases, the return on investment from innovation more broadly will be increased. Some signs that indicate investing in digital innovation brokerage might be useful are presented in Table 4.

Table 4: Indicators of the need for digital innovation brokerage

An observed lack of collaboration	• A large supply of ideas for innovations, without enough corresponding implementation. For example, if ideas have trouble crossing over from academia to industry. • A strong need for innovations, without corresponding supply. • Lots of underutilised resources in organisations. • A high failure rate of collaborations. • High costs of finding existing collaborators. • A slow innovation rate or inefficient current innovation process. • Difficulty establishing trust between potential collaborators.
The presence of significant barriers to collaboration that could be overcome with digital brokerage	• Barriers in approach and terminology between fields that would otherwise collaborate. • Barriers due to the need for different types of organisations to work together, such as SMEs and large corporations. • Barriers in language, culture, and physical distance.
Weaknesses of existing digital brokers	• A perceived lack of credibility or neutrality. • Only serving one part of the market, such as portals that have fees that are too high for SMEs. • A lack of innovative solutions within the sector in question. Innovation brokerage can promote interdisciplinarity and the discovery of solutions from related disciplines or sectors.

Success criteria for innovation brokerage projects and services

Central design requirements

The literature and our research identified a number of central design requirements that need to be considered when setting up a digital innovation brokerage project. Below we highlight four of these, which are relevant to innovation brokerage more generally. Box 9 highlights specific design requirements for innovation brokers working with SMEs.

Maturity of digital offering

Digital brokerage technologies are emergent and currently will not cover each of the four innovation brokerage phases identified to a consistently useful degree. Technologies such as natural language processing, neural networks, advanced semantic search, AI and machine learning, or blockchain all show promise for specific brokerage tasks or sub-tasks. However, their role needs to be assessed in terms of their maturity and efficacy, but also matched to the gaps and inefficiencies in the current innovation system.

Strategic intent

The design of digital innovation brokerage systems depends on the required outcomes. The following should be considered:

1. What ideas are you looking for? Do you want market-ready solutions or early-stage ideas?
2. Would ideas from other sectors or lateral solutions be useful?
3. Are you looking to develop long-term innovative partnerships or technology transfer relationships?
4. What is the intended process and business model for commercialisation?
5. What is the role of digital technology in the innovation brokerage offer and how can this evolve over time?
6. What is the approach to adapting and redesigning systems to accommodate change and growth in the innovation portfolio?

Impartiality

A key premise of the facilitator role of innovation brokers is a neutral and independent position. Brokers should not adhere to a narrow selection of preferred suppliers, network partners, or certain preferred development strategies.

Availability of resources

A calculation to be made on the part of the innovator is the availability of resources they have to deploy. Both the amount and type of resources available should be considered. While a digital route has greater reach, the skills requirements and cost of the resource should be explored in appropriate detail.

Box 9: Design requirements for innovation brokers serving SMEs

Kolodny et al (2001) proposed six design requirements for 'technology extension organisations'. These organisations take a proactive approach to helping transfer technology from those who develop it to those in industry who can use it. They can be understood as specialised innovation brokers that help connect technology creators with SMEs. The proposed design requirements stipulate that an innovation broker of this kind must:

- Be visible and easily accessible to the SMEs
- Make itself trustworthy to the SMEs it serves
- Provide SMEs with access to appropriate sources of technology
- Make itself credible with the sources of technology
- Respond quickly to the requests of SMEs.

Additionally, these specialised brokers 'should complement the weaknesses of the SMEs [they] serve'.[32]

Advice for the four brokerage phases

This section includes advice and considerations for those setting up or supporting innovation brokerage services. The advice is grouped according to the four brokerage phases – provided again in Table 5 for ease of reference – and their associated actions.

Table 5: Brokerage phases and their associated actions

Prepare	Search	Align	Support
Define problems	Find ideas	Adopt ideas	Structure and incentivise
Identify opportunities	Find collaborators	Initiate collaborations	Support implementation

Prepare

Potential roles for emerging digital technology

- Taking the heavy lifting out of data analysis in activities such as identifying opportunities (e.g. Quid uses machine learning to analyse large amounts of text to help organisations understand the market landscape).
- Coordinating people to help with the Prepare phase of a digital innovation brokerage project (e.g. using a crowdsourcing platform within an organisation to co-create the search or innovation strategy).
- Connecting with a network of experts to help articulate the unmet need or research the market.

Considerations when defining problems

- Articulating clear and actionable requirements takes time for research and iteration. Build this into your schedule.
- Defining a value proposition that benefits both sides of a collaboration is complex. Do this in advance rather than leaving it to later phases.
- Independently developed technologies are rarely compatible. Identify how much flexibility or resource might be needed to adapt them.

Considerations when identifying opportunities

- Search targeting is important to consider in advance. Decide if there is a clear requirement and a degree of confidence that the solution is easy to find or whether you need to search more laterally for solutions from unexpected places or sectors.
- The search will produce different ideas at different stages of maturity. Research the idea/technology/IP landscape in advance so you know roughly what to expect and are able to notice what is missing.

Search

Potential roles for emerging digital technology

- Broadening horizons and offering more varied options in affordable ways, freeing up time and money to concentrate on later phases (e.g. CSIRO D61's D61+ platform aggregates research experts working within Australian research institutions).
- Curating lists of recommendations and high-quality data sets that are more relevant and, therefore, valuable. Search engine technology provides one answer, particularly if deployed in a way that complements human abilities.

Considerations when finding ideas

- Search, without a deep understanding of the eventual user of an innovation, can be inefficient. Some solution providers will not have had the resources to conduct user research. Therefore, care should be taken to conduct sufficient research to provide insights that are actionable and worth solving to guide search parameters.
- Searches need to address a core problem, not a symptom. Make sure you have interrogated the search terms to discover the highest-order requirement.
- Search can be too targeted or specific. Make room for serendipity by paying attention to related sectors and allowing flexible filter criteria.
- Technologies not intended for innovation brokerage can be useful (e.g. networking tools, industry-specific search engines, and patent searching tools).

Considerations when finding collaborators

- Searches are often performed focusing solely on the targeted technology but ignoring incentives for innovators. Make sure that there is sufficient potential incentive for all organisations involved in the brokerage (e.g. for organisation A, organisation B, and the broker) before embarking on a search. Clear commercial criteria will help attract appropriate ideas or partners.
- Reviewing search results can be a matter of opinion and lead to disagreements on which ideas or partners to follow up with. Agree upon search standards and numerical filter criteria before deploying.
- Matchmaking is complex, as both parties are considering difficult strategic questions, often speak different technical languages, and may take different approaches to IP. Consider each of these factors when conducting a search and filtering the results.

Align

Potential roles for emerging digital technology

- Improving patent search so that innovators can check that they are not infringing on others' patents and can quickly assess and research an emerging field (e.g. Innography patent search engine allow searches by whole documents).
- Helping with negotiation, for example by supporting the development of a shared plan and identifying potential problems such as differing expectations or conflicts in timing.
- Facilitating difficult conversations by highlighting areas of potential conflict or misunderstanding (e.g. Actual, an app that uses an 'AI-mediator' to support interpersonal communication) and improving personal relationships by using online workshop tools to enhance and collectivise decision-making. Technologies are increasingly available as purpose-built and 'hack-able' tools, with several options within Google's G Suite.

Considerations when adopting ideas

- Adopting ideas requires a flexible approach as many innovations-from-elsewhere will be initially incompatible with the systems and processes in their new home. Create a process and allocate resources for alignment so as not to limit adaptability.
- Collaborations can encounter difficulties due to different timescales and paces of operations in different-sized organisations (e.g. SMEs and corporates) or different types of organisation (e.g. academia and the private sector). Create a strategy to account for this.
- New relationships are often started with IP negotiations. It may be hard to establish the value of IP initially and such negotiations are often inappropriate for early relationship-building. Focus instead on the future value that will be generated and how this will be delivered.

Considerations when initiating collaborations

- Achieving a cultural fit between two organisations can be key to successful alignment. Many barriers can emerge such as differing appetites for risk, decision-making styles, and different positions on the control-collaboration continuum. Appoint someone to specifically manage the relationship and be responsible for learning and managing cultural change as required.
- Partners in collaborative innovation are often mismatched in terms of power and resources. Create a balanced process for a fair and transparent ongoing relationship and review it regularly.
- Trust is a fundamental component of new relationships based on innovation. This trust has to be earned over time and requires excellent and frequent communication. Focus on relationship-building in parallel to co-innovating.

Support

Potential roles for emerging digital technology

- Coordinating and incentivising work. As well as helping with search, challenge platforms can help by providing a collaboration process and structure. For example, CityMart helps local governments both design better bids and connect with and procure vendors. Alternatively, Organisational Technology (OrgTech) such as Colony helps with running decentralised organisations by providing ways to incentivise participants and make decisions.
- Enhancing experiences and enabling better remote collaboration. New media technologies such as VR and AR can enable a better collaboration around the design and development of new products and services for remote teams.
- Providing new and intuitive ways for people to share ideas, facilitate community decision-making, and accelerate idea development (e.g. Loomio enables groups of people to make decisions together, inclusively, and without having to meet in person).
- Sharing and adding to the knowledge of a group easily and in real time. For example, CSIRO D61's D61+ Expert Connect service helps industry representatives look for a particular kind of expertise with the support of natural language processing. In a different context, the humanitarian agency Solidarités International recently launched OCTOPUS, a platform on which engineers working to address faecal sludge disposal and treatment in emergencies can share knowledge, document their solutions and progress, make decisions on an ongoing basis, and collaborate to formulate solutions quickly in changing contexts and large sites.

Considerations when structuring and incentivising

- Set up a process and criteria for measuring and balancing costs and benefits as relationships develop.
- The longer a relationship continues, the more there can be habitual or vested interests in keeping it going. Introduce a process for reviewing and ending underperforming collaborations.
- Capabilities and organisational structures of innovation partners change over time, as do staff. Review teams, talents, and structures regularly and take appropriate action.

Considerations when supporting implementation

- Brokering networks and ideas alone will not ensure implementation. Prototype different routes to commercialisation/deployment and choose an optimal path as a priority.
- The needs of organisations change quickly. Build flexibility into your business model and review strategies for each partner regularly to increase focus and commitment to an idea. Innovation brokerage is a process, not a transaction. Build a clear but flexible pathway and review the partnership model, the roles of each partner, and assess the development of the idea regularly.

Appendix 2: Detailed case studies

The following case studies have been selected from our database of over 150 examples of digital innovation brokerage. Each demonstrates a different approach to using digital technologies to support innovation brokerage. Together, they illustrate a range of approaches to enabling innovation brokerage across the four phases: Prepare, Search, Align, and Support.

Case study 1: konfer

Purpose

konfer is an online platform that helps businesses to connect with universities so they can collaborate. Primarily, it aims to help SMEs connect with relevant researchers at universities.

For SMEs who are not involved in existing collaborations with universities and who lack dedicated teams for scouting university IP, it can be challenging to find universities that are doing work relevant to their business, and to also connect with the right person within those institutions.

More generally, konfer aims to uncover research, expertise, funding sources, and other under-utilised resources within universities and make this information available to businesses, governments, and the charitable sector to enable sharing, cooperation, collaboration, and innovation.

Design of the tool

konfer was created by the NCUB, the Higher Education Funding Council for England (HEFCE), Research Councils UK (RCUK) and Innovate UK in 2015.

The platform was intended to fill a gap in the innovation brokerage space by encouraging business-university interactions through a digital tool. Recognising that data on what universities were working on was already widely available, the partners decided against creating another database that universities would have to constantly update. Instead, they designed konfer to make use of these existing, publically available data sources. These include ORCID, the REF Impact Case Studies database, UKRI's Gateway to Research Portal, Jisc's Equipment.data, Youtube, university websites and funding opportunities from the UK's KTN.

The platform is primarily oriented around the needs of businesses and has two main use cases. The first is where a user can search for a type of expertise they are looking for, such as 'engineering production processes'. This search returns geographically mapped search results in the form of profiles and articles in categories including **experts, collaborations, funding calls, facilities (equipment), research, web and social, universities**, and **businesses**.

konfer then provides a way to connect directly to researchers or to each university's business engagement team via an in-platform messaging

service. Following a second use case, a business may instead choose to attract interest from universities by posting a collaboration request or open innovation challenge outlining a problem. konfer pushes these opportunities to universities that may be interested in helping to solve these problems.

konfer's search functionality uses Elasticsearch search engine technology. This allows it to search, sort, and return results based on whether a document contains the search terms. When prioritising search results to display, konfer also considers how many times these terms appear in the document compared to how many times they appear in all documents konfer can access through a search, and where these terms appear within a document (e.g. an appearance in a title and again in the body text of a document may indicate higher relevance than an appearance in body text only). Using this technology, konfer is able to add additional data sources, if relevant, and to tweak and improve search and ranking functionalities, as needed.

Implementation

Discussions between NCUB and the research councils started in 2012 to explore the possibility of using digital tools for innovation brokerage. A business plan was developed in 2013 and a prototype was developed in 2015. The first public beta release of konfer was in 2016.

Impact

The NCUB continues to update and develop konfer, including assessing usability and the extent to which the platform is able to broker university-business relationships and innovations. By tracking interactions through the contact tool, konfer can track whether businesses are successful in finding the right university fit, and help businesses who have been unsuccessful find another, more suitable institution. The tool helps to compare expertise and facility offerings between universities, which konfer's creators hope will result in better-matched research services for businesses, and also more successful industry relationships for universities. In the longer run, it could help enable more firms to be able to do R&D. According to Innovate UK, 75 per cent of R&D in the UK is carried out by 400 businesses. konfer hope that brokerage will help inspire other businesses to do R&D.[33] At the time of writing, konfer is backed by 132 UK universities and includes profiles of 130,000 academics who can collaborate on research projects. However, the success of the platform and its impact will need to be assessed over time.

Comparison with other sectors and tools

Strengths

Unlike many innovation brokerage tools, konfer does not generate its own data. Instead, it relies on data that is already in the public domain. This means that universities and researchers listed on the platform do not have yet another online presence to keep updated.

Weaknesses

konfer's use of external data also means that they are dependent on the characteristics and quality of existing data sets. Also, like most other digital innovation brokerage tools, konfer does little to handle the relationship-building side of innovation brokerage. konfer is intended to play a role in opening up more opportunities than any single knowledge exchange team would be able to have. However, for konfer-brokered relationships to realise innovation, human facilitation is still needed to select and build good collaborations.

Key takeaways

konfer takes a government-led approach to university-industry collaboration, and will have to attract both university and industry users to be successful. One challenge konfer have encountered is resistance from existing actors. For example, universities sometimes want to avoid it being possible to search for and compare across multiple universities. Instead, they might want to maintain relationships with the businesses in their area without competition from other universities. However, if konfer is able to overall increase the pool of businesses looking for collaboration, it should make universities less concerned about this issue.

Resources

konfer.online/about

konfer.online/howitworks

www.ukri.org/innovation/working-with-business/konfer

www.ncub.co.uk/blog/konfer-collaboration-platform-alpha-phase.htm

Case study 2: CSIRO Data61's D61+

Purpose

D61 are research and development consultants specialising in data science and technology. They provide data measurement, analysis and interpretation services to support other business units within their parent organisation, CSIRO. They also build custom platforms and data technologies for clients or commercialisation with partners and investors.

One of their products is D61+, a platform which draws on existing data sources to provide a database of researchers that helps industry find relevant experts. Developed with funding from the Australian Government's Department of Industry, Innovation and Science; IP Australia; and the Australian Research Council, D61+ aims to help industry identify and match with potential research collaborators and solutions, and helps researchers stay alert to opportunities to work on industry challenges. In doing so, it addresses some key problems in industry-academic brokerage: knowing where to look for or publicise expertise, and ensuring a call for collaboration captures the attention of the right people.

Design of the tool

The design process for D61+ started in 2015 with a project that engaged numerous stakeholders interested in industry-academic brokerage to propose a platform that would better enable industry and research to connect with one another.

Although they were not required to build on any previous work, through this project, participants discovered numerous existing resources that could help would-be collaborators find one another. They proposed consolidating access to these various data signals through a single platform. To realise this vision, Data61 has developed a suite of three related products that serve different innovation brokerage needs.

Launched in 2017, Expert Connect helps industry representatives looking for a particular kind of expertise and finds researchers with this expertise. At the time of writing, the platform features 70,000 searchable expert profiles from 220 research organisations. These profiles are created based on existing data from sources including patent data from IP Australia, grant data from the Australian Research Council and

National Health and Medical Research Council, journal articles from Clarivate Analytics' Web of Science, author profiles and media articles from *The Conversation*, and profile data from ORCID and research institution directories. When an industry user enters a search, they can do so using everyday, non-scientific language. Expert Connect analyses researcher profiles for indicators of relevant expertise as well as signals of industry engagement and interest, such as records of commercialisation training or industry internships, and then displays search results ranked according to both sets of factors. When users find a relevant researcher, they can initiate contact either through the researcher's organisation's nominated technology transfer or business development office, or directly – as long as the researcher has claimed their profile and indicated this preference. This service supports people with categorical requests for expertise that can be translated into search queries.

For situations where industry users are less certain about the kind of expertise they need, the Innovation Challenge Marketplace provides an opportunity to pose requests for collaboration by describing a problem in need of a solution. The platform aggregates existing innovation challenges from known sources including state government, federal government, and private sector origins. It also offers to list individual requests. Once a challenge appears in the Marketplace, the platform uses machine learning to identify experts who could contribute toward solving the problem, and then notifies them that a relevant opportunity has been posted. As with Expert Connect's contact function, these notifications are sent either through a nominated point of contact at a research institution or directly.

The Innovation Map visualises innovation data such as designated 'innovation precincts' and national research infrastructure from across government data sets to help researchers and policy-makers observe differences between regions and changes over time within the Australian innovation ecosystem.

Implementation

Although it was supported by substantial expertise from industry, research, and government stakeholders and preceded by previous strategy and design explorations, the current beta release version of the D61+ platform was developed over just 17 weeks. Data61 continue to improve the platform by adding functionalities, enhancing the platform's performance in terms of its matching capabilities, and exploring potential to scale beyond the Australian research system. Specific improvements being investigated for Expert Connect include the provision of different user-oriented search weightings to better facilitate government, media, and researcher use cases.

Impact

Overall, use cases for D61+ have been more diverse than its creators anticipated. Journalists have used it to source expert commentary, PhD applicants have used it to identify potential supervisors, and lawyers have used it to solicit expert opinions for legal matters. Industry has also used the platform to find researchers who can help them innovate. For example, one of CSIRO's clients needed to improve worker safety in a warehouse. CSIRO used Expert Connect to identify researchers across a range of fields including preventative medicine, predictive analytics, sensors and wearables, and behaviour. They notified these experts of the opportunity, encouraging them to submit solution ideas. As a result, the client received numerous relevant responses to their challenge, and was able to select an applicant to work with further in developing a solution.

Comparison with other sectors and tools

Strengths

Using external data sources means that researchers do not have to be asked to create a profile on yet another platform, and helps ensure the platform dynamically updates in sync with changes within the data sources. Using data processing techniques that allow users to use natural language to search without sacrificing the relevance of the results helps non-experts search with the terms they know rather than asking them to become experts themselves. Finally, using machine learning to identify relevant experts for challenges and then notifying these experts without requiring their prior subscription increases the chances that challenge calls will receive qualified applicants rather than come and go unnoticed.

Weaknesses

Getting to this point required substantial stakeholder coordination from over 50 collaborators and counting. If challenges are not posted on known platform sources, industry representatives have to make a specific request to post theirs to the Innovation Challenge Marketplace, and this process appears to be manual in the current release. Although facilitating other use cases is in planning, the platform is currently focused on providing for industry's needs to connect with expertise, and not for the needs of other potential users (e.g. postgraduate students, press researchers, government researchers), so the search results are currently oriented toward providing for this use case and not others.

Key takeaways

The D61+ platform is at this time designed to help search for research experts working within Australian research institutions. It does not facilitate access to experts beyond Australia or those who work outside of academic and other public research institutions. Further data sources will need to be secured in order to scale this platform's relevance globally. The platform has an open request for details about experts and data providers to add access to information, although it is unclear what defines 'expert'.

Resources

www.data61.csiro.au/en/Who-we-are/Our-Science-Vision

www.data61.csiro.au/~/media/D61/Files/Science-Vision.pdf?la=en&hash=E577A4AEA7F2B05CAA8E2F7D1BFE17B159F5D867

www.data61.csiro.au/en/Who-we-are

www.data61.csiro.au/en/Our-Work/Year-In-Review

www.data61.csiro.au/~/media/D61/Files/Year-in-Review-FY17.pdf?la=en&hash=C0E1299A27312B698609DA80AA532FC2F90B0919

blog.uiin.org/2019/01/embedding-entrepreneurship-auas-new-10k-pre-incubation-program

expertconnect.global/about

Case study 3: YouNoodle

Purpose

YouNoodle is a sourcing and selection platform that corporations, governments, and foundations can use to source and select early-stage startup companies that meet their solution needs. Users can pay to use the platform to facilitate grant programmes, innovation challenges, and similar selection processes. The platform provides tools to manage applications to grant programmes, run an initial screening process, and to then send applications to user-designated experts to evaluate and select relevant candidates. Applicants use the platform to apply for competitive opportunities to work with established organisations, and can access these opportunities at no fee.

As a result of facilitating these programmes, YouNoodle has gained access to data about startups and what they can offer according to startups' own description, and the judgement of expert evaluators. This data gives YouNoodle insights into the potential success of startups even if they are not chosen as a 'winner' during a selection process. These insights allow them to broker further relationships between large organisations and early-stage startups.

Design of the tool

YouNoodle started with the intent of becoming a social network for startups where entrepreneurs could look for co-founders, investment, team members, and advisors. The network model has evolved. In its current model, startups cannot join YouNoodle without submitting an application to a posted call. The platform operates a 'closed network' that does not feature publically-viewable profiles. Organisations who want to run a grant programme, innovation challenge, or other selection process use YouNoodle to set up an application form for startups to pitch their interest. Once submissions have been collected, organisations screen them to remove spam and extraneous entries. They then send the valid applications out to an external committee of experts which they have designated, and ask these experts to evaluate the submissions according to specific metrics. Experts are typically unpaid, and voluntarily contribute evaluations from within the service of the organisation which recruited them, whether a government, university, foundation, or other organisation. The platform aggregates evaluation scores and then submits these to the organisation running the programme, who selects a winner.

In addition to the specific process, the distributed evaluation process also gives YouNoodle an idea of the value of a startup in relation to other applicant startups as based on submitted applications and the perceptions of experts. By combining this data from across all programmes, YouNoodle achieves a broad view of which early-stage startups using the platform are most interesting. Using machine learning and custom algorithms to analyse programme-specific application forms, they can classify and analyse similar data fields to identify which startups have the greatest potential for success, and use these insights to increase the value of their system. Through a semi-automated process, YouNoodle can make contact with these startups, match them with additional organisations who have issued calls on the platform, and then broker a connection between the two parties to ensure relevant startups with high potential are directed toward the right opportunities. In doing so, YouNoodle hopes to enable startups, and the organisations in search of their help, to better take advantage of opportunities which already exist but which might not otherwise be discovered.

Implementation

Although YouNoodle the company was founded in 2010, work on it started as early as 2007 with a project funded by Peter Thiel (Founders Fund), Max Levchin (PayPal), and Charles Lho (Amicus Group). In its early days, YouNoodle proposed an alternative valuation method that algorithmically predicted the success of startups who initiated the process by filling in a detailed questionnaire. Another platform, Quid, also grew out of this project, and now helps to search, model, and analyse strategic opportunities. YouNoodle received $1.1m in investment in 2014.

Recent activity includes work on machine learning platform, Longplay. Longplay draws on submission and evaluation data to curate searches to help organisations find relevant startup collaborators and their solutions. This platform is in an earlier stage of development than YouNoodle's service, but provides another means for large organisations and small companies to match with one another.

Impact

YouNoodle has attracted participants from over 180 countries. The platform has engaged with over 200,000 startups, received detailed evaluations from over 20,000 experts, and enabled over 1000 selection processes that have connected relevant startups with organisations in need of their solutions. Its work has also been studied in research literature to assess the impact of entrepreneurship competitions. Around 10,000 new startups submit applications through the platform every three months.

Comparison with other sectors and tools

Strengths

Over nearly a decade of iteration, YouNoodle has established a system for enabling funding organisations to connect with relevant startups. Smart use of data from applications and expert evaluations enables sophisticated ranking and matching.

Weaknesses

Startups enter the YouNoodle ecosystem by submitting an application to a particular programme on the platform. Matching these startups to programmes/organisations other than the ones to which they applied is done through a semi-automated process. This may ensure a higher quality of interaction and more sophisticated matching – but also potentially limits the extent to which this functionality can scale.

Key takeaways

YouNoodle has built up a large, rich data set over time, and appears to have proven its effectiveness as a platform for running grant programmes, challenges, and similar contests to pair organisations with relevant early-stage startups. However, its ability to match organisations and startups globally on the platform – beyond the structure of an individual contest – appears to be less mature. This activity is currently semi-automated and seems secondary to YouNoodle's core business as providing a platform to source and select startups via dedicated contests, but has the potential to provide further brokerage services between the actors it serves.

Resources

younoodle.com

www.crunchbase.com/organization/younoodle#section-overview

www.inc.com/magazine/20081201/whats-your-company-worth.html

longplay.com/how-it-works

static.younoodle.com/static/wordpress/one/GeoffreyBarrowsWhitepaper.pdf

Case study 4: Piirus

Purpose

Piirus got its start as Research Match, a tool created by library employees at Warwick University in response to the observation that early-career researchers lack networks that could help them perform key functions of their academic roles. Researchers rely on their networks for industry and research insights to inform policy and to carry out other tasks core to their academic position. However, early-career researchers often have incomplete or undeveloped networks, and find it difficult to accomplish these tasks to do their work. Piirus was created to overcome this barrier by matching early-career researchers with each other.

Design of the tool

In its most basic form, Piirus featured academic profiles populated with key words indicating interest areas. The system then algorithmically matched profile creators to other early-career researchers with profiles on the platform. Crucially, matching was not direct and based on similarities, but based on complementary relationships – the aim was to pair people doing related, but slightly different research to maximise the potential for innovative, cross-disciplinary collaboration. Longer-term plans for the platform included using more sophisticated techniques to mine data, and to enable matching between complementary but not identical research interests using neural networks. The platform sought to introduce researchers with contrasting but mutually beneficial expertise and interests who would not otherwise meet.

Implementation

When it was first created, Research Match started to be used internally at Warwick University, and spread quickly by word of mouth. Based on this initial success, a small team within the university decided to take the tool beyond the University, raising funds to hire a company to build the software.

Impact

The initial early internal successes of Piirus failed to make a wider impact. The project encountered organisational and technical challenges around academic logins, and wider uptake faltered. A plan to embed the tool within Jobs.ac.uk, another University of Warwick spinoff project, was attempted but later abandoned, and the project is currently dormant.

Comparison with other sectors and tools

Strengths

Piirus addressed a problem that users recognised. Numerous universities around the UK currently try to address this problem by running early-career researcher networks, but these seem to be traditional, based on in-person networking events, and confined to single universities – unlike Piirus, which sought to expand beyond its point of origin.

Weaknesses

Piirus's matching technology was unsophisticated, though the development of this aspect was planned. By relying on academic

logins to gain access to the platform, Piirus also embroiled itself in technical and administrative difficulties that may have been avoided had the platform found an alternative way of granting access to its target community while keeping others out.

Key takeaways

Solving a real problem allowed Piirus, in its earliest incarnations, to spread quickly without marketing. In the absence of other interdisciplinary collaboration-matching tools for early-career academics, the platform's idea may have mileage in it yet.

Resources

www.jobs.ac.uk/careers-advice/careers-advice/2599/piirus-absorbed-by-jobsacuk

www.rluk.ac.uk/warwick-library-piirus

blogs.bournemouth.ac.uk/research/2017/09/25/update-from-piirus-service-transferring-to-jobs-ac-uk

warwick.ac.uk/insite/news/intnews2/piirus_launch

Case study 5: Collaboration.Ai

Purpose

Collaboration.Ai is a platform that aims to help communities of users to understand what members contribute to the community. Using a combination of network theory, AI, proprietary algorithms, blockchain and machine learning, Collaboration.Ai gains a system-level view of networks gleaned from custom data inputs. The platform can be used to help build optimal combinations of people for a specific purpose. For example, it could be used to determine who to work with to achieve a particular goal, how to seat people at an event according to shared motivations and social connections, or how to build teams.

Design of the tool

Collaboration.Ai has two products: HumanOS and a free Team Builder tool.

Collaboration.Ai HumanOS processes data from sources that might include open-ended survey questions, social media profile data, or custom data sources such as registration forms, employee performance data, or organisational and personal email records if the user grants privacy rights.

In addition to customising how data is sourced and elicited, users can also customise how the engine weights the data it considers. This allows them to override AI in the platform's algorithms, effectively enabling them to prioritise selection criteria according to their own expert preferences. Users can elect to ignore frequently occurring data to exclude them from analysis, or to emphasize less frequently occurring data by assigning them a higher priority. For instance, an instructor on a biology course using Collaboration.Ai to build teams of students could choose to ignore the commonly stated interest area of 'biology', and choose instead to prioritise more specific indicators of sub-interests, like 'synthetic biology', 'immunology', or 'plants and people'.

Accordingly, teams can be created based on characteristics or interests that emerge from the data set rather than being imposed beforehand, or filtering can be applied to identify subsets of participants with certain characteristics or interests. Users can also use previous team configurations as exclusion criteria for future

configurations to prevent participants from working with the same group of people again. Groupings can also be formed based on one-to-one relationships matching those who express opportunities or problems with those who articulate relevant skills, experiences, or solutions. Users and participants can both contribute to improving the performance of the system. Users can rate the quality of the generated groups, their individual skills, and work output – either immediately or after reviewing how they worked together; they can also feed in performance data. Participants can rate the quality of the teams that result from Collaboration.Ai's groupings or confirm the new connections they acquired within the network.

Collaboration.Ai's free version offers fewer options for input customisation, and is designed specifically for creating teams or groups of people.

Implementation

To help users make the most of the platform, Collaboration.Ai facilitates online user groups with representatives from different clients. From Collaboration.Ai, clients learn how to use the tool better. From each other, they learn potential techniques, applications, and ways of integrating the tool into their organisations.

Initially, Collaboration.Ai was focused on statistical outputs, but after discovering that users desired more transparency and control over how the platform prioritised what it considered, they introduced the custom weighting, as well as dashboarding and individual data authorization rights functionalities. Following this development, the platform provides automation but still allows for the re-introduction of human judgment.

Impact

A science organisation tackling climate change has used Collaboration.Ai to figure out which scientists should speak with each other in order to come to an agreement to move work forward more quickly. The US Air Force used the tool to find a new combination of actors within their existing supplier network who could contribute their services to quickly create a cheaper alternative to an existing helmet design.

Collaboration.Ai has also been used at events, such as TED Conferences and the World Economic Forum's Forum of Young Global Leaders. Here, the platform was fed data about participants' connections, career interests, and hobbies, as well as 'softer' information about friendships, families, faith, and personal initiatives. Data was gathered from registration profiles and an event-specific participant questionnaire. It was analysed to create groups of people who seemed to have the highest likelihood of creating meaningful work to achieve the World Economic Forum's mission of 'improving the state of the world'. These groups convened for structured icebreaker activities to facilitate networking at various points throughout the event. Based on feedback from participants after each group session, the platform could again be used to generate subsequent, new groups.

Comparison with other sectors and tools

Strengths

Collaboration.Ai is highly customisable in terms of data inputs and analysis. It also provides opportunities for users and participants to feed back into the platform to improve its performance over time.

Weaknesses

In the same way Collaboration.Ai augments human ability, humans have to augment the platform's outputs in order to ensure its benefits are realised. Collaboration.Ai may help people form teams and connect with others in a network, but it does not guarantee that once relationships are initiated, they will last, or result in innovation or other desired outcomes. Although it can be customised to

consider a variety of factors, matching people to build productive teams and establish valuable relationships is complex and there is always the chance that in real life, matches suggested by the platform do not work as hoped. This may be particularly relevant in terms of soft skills, working styles, or tacit knowledge that people bring to relationships but are difficult to ask about or express. Collaboration.Ai also relies on users (or organisations that users belong to) granting the platform access to data, making its handling of consent and privacy another potential concern.

Key takeaways

How well the system functions overall for team creation and networking can vary widely, depending on data source and quality, willingness of participants to provide responses or access to social network data, and the application. The platform is likely to be better suited to certain applications and contexts, but for any given user, this may take some trial and error to get right. Because Collaboration.Ai involves collecting data from different individual users and grouping or encouraging connections between them based on this data, how this data is elicited, used, and shared will need to be considered by any organisation thinking about using the tool.

Resources

www.collaboration.ai

www.fastcompany.com/3067103/the-collaboration-software-thats-rejuvenating-the-young-global-leaders-of

thedifferenceconsulting.com/solutions/people-science

Case study 6: Trellis

Purpose

Trellis was created by the AAAS to provide a single platform to bring scientists together to share resources related to specific projects where they would be working in groups. At the time of writing, the platform is still in use but will not be supported past its current beta release.

The AAAS is the largest multidisciplinary scientific society in the world. Membership is broad, including anyone active or interested in science, technology, engineering, and mathematics. The society's activities are focused on innovatively addressing topics that cut across disciplinary divides. These include, but are not limited to, public engagement, science diplomacy, science education, and the shaping of science policy. In building Trellis, the AAAS aimed to support multidisciplinary communication and collaboration among its membership by providing 'a single place for anyone in science to engage with all of the communities to which they belong'. All 120,000 AAAS members were invited to Trellis, as well as non-member scientists who belonged to other professional associations, working groups, and scientific teams.

Design of the tool

In operation, Trellis's core features include document sharing (uploading and annotating), the integration of existing services like Google Drive, threaded forum discussions, a profile-based connection and collaboration system, advanced search, tagged browsing, and shared group calendars. AAAS focused on how

these different functionalities could interact to support platform users through a system of interconnected documents that could be linked or displayed when and where they were referenced or relevant.

Beyond these core features, Trellis's dominant characteristics are its group orientation and its focus on content. AAAS members belong to one large MemberCentral Community group, as well as discipline-specific sub-groups that they self-selected through their membership in the association. These subgroups range in size from a few hundred to a few thousand members. In addition to the AAAS, numerous external organisations have used the platform as well.

Groups on Trellis are either completely private, or public and discoverable within Trellis. Some public groups were open for anyone to join, whereas others operated on an approval basis. AAAS noticed that these groups had different content needs and means of encouraging interaction between members. In the main AAAS MemberCentral Community group, discussion is facilitated by AAAS community managers and kept very general, mostly to higher-level topics that members would want to convene around in smaller groups. In subject-specific groups, the AAAS has provided resources to group leaders in determining a content and engagement strategy, having recognised early on that groups with active community managers were much more successful at engaging their members than those with inactive leadership.

Trellis groups have used the platform for a variety of activities including planning teaching activities through sharing resources, discussing within communities of practice, hosting journal clubs where readers log in to discuss at a designated time, and live text-based chats with experts.

Implementation

The development of Trellis was part of a larger transformation initiative at AAAS that sought to experiment with alternative business models and engage its membership by facilitating connections between them. As AAAS was scoping its own work in this area, they noticed that other scientific organisations and communities were also struggling to connect their members and facilitate collaborations between them. They realised that if they were to build a platform that addressed their own needs, they could help address common challenges. However, sustaining the implementation of this project became challenging for AAAS, a not-for-profit, and they are no longer pursuing additional product development for this project.

Impact

The AAAS regularly asked for user feedback and took a transparent, community-guided approach to building the platform. Trellis's model sought to provide an environment that facilitated discussion and discovery across scientific disciplines. The platform tended to be used more for in-depth discussion on particular topics rather than high-volume link sharing. For example, Science Group, an organisation external to the AAAS, used Trellis to bring together scientists, scholars, and professional practitioners to figure out how scientists can better engage with the public. The group hosted weekly live chats. They advertised topics in advance, produced a one- or two-page summary that participants could read beforehand, and uploaded related content. Group members could then participate in live chats with experts close to the topic, which in some cases included people with experience implementing a certain project. Participants could ask about implementation and potential for translation and scale.

Comparison with other sectors and tools

Strengths

By allowing people to convene around and connect through topics that interested them in a fairly open platform, it seems like Trellis was able to successfully encourage members to work across disciplines. The platform's unique consideration of content as an opportunity for collaboration was appropriate for the community members, who were mostly scientists regularly engaged in reading, writing, and commenting on research.

Weaknesses

The AAAS will not continue to develop the platform beyond its current beta release. This decision has been attributed to an incompatibility between product development timelines and the need to sustain a not-for-profit organisation.

Key takeaways

AAAS relied on a high level of human involvement to run Trellis – not just the technical infrastructure, but also for providing community infrastructure. However, while this meant that the platform became unsustainable for the not-for-profit, the high level of engagement, particularly with group leaders, was a key attraction and resulted in higher levels of group participant engagement.

Resources

www.trelliscience.com

www.aaas.org/mission

www.aaas.org/focus-areas

Case study 7: Colony

Purpose

Before founding Colony, Jack du Rose was a jeweller making high-end items such as artist Damien Hirst's diamond-encrusted skull. He credits his company's ability to compete with large brands to having built a team of the world's best craftspeople distributed around the world.[34] But he found it difficult to manually coordinate, correctly incentivise and build trust with team members. This experience led him to set up Colony.[35]

Colony provides an infrastructure for organisations to set up 'colonies' so that they can manage their resources and decision-making in an automated and programmable way. This allows for new forms of organisation that would have previously been difficult, such as decentralised organisations.[36] In a decentralised organisation, ownership is distributed according to the value that each person contributes. And rather than having hierarchical management, influence emerges through people reviewing each others' work.[37]

This approach aims to allow organisations to operate without hierarchy, enable more equitable influence and profit sharing than sharing economy platforms, and increase coordination efficiency when compared to standard worker-owned cooperative models.

Design of the tool

There are many ways to customise Colony depending on the desired organisational design. But one example is to organise a colony around tasks. In this case, collaborators earn reputation by being active and successfully completing tasks. Those with sufficient reputation can, in turn, create a task. When someone creates a task, this task is assigned to three roles at a time: a manager, a worker, and an evaluator. The manager is responsible for setting a due date, 'bounties' of tokens for each of the three roles to reward task completion, and a specification or brief that can also be used for evaluation. The manager also chooses collaborators to fill the worker and evaluator roles. To help organise tasks, Colony also allows for the creation of domains. These are modular groupings of tasks that can be organised and nested in whatever way makes sense to a colony. Collaborators earn reputation within domains, and cannot contribute toward decisions that are unrelated to the domains to which they have contributed. This ensures that people only contribute to work-streams in which they have demonstrated competency. Colonies can earn revenue in a normal currency like any other business. They would then need to convert it into the cryptocurrency they are using in their colony. This can then contribute toward their working capital, or be distributed among their collaborators.

Colony's use is not limited to task-oriented organisations; it could be used by organisations compensating members for types of work as well. However, the general principles of earning reputation by completing work actively, and being able to define work and payments according to sufficient reputation would still hold.

Implementation

Colony was founded in September 2014 and they released a technical white paper outlining the system in September 2017. At the time of writing, they have done a couple of rounds of beta testing with users and are preparing to release a version with real value being transacted. They have organisations, mostly in the blockchain space, ready to use it. They almost launched an initial coin offering (ICO, the cryptocurrency equivalent to offering shares in an initial public offering, or IPO) in September 2017 until they realised that it might be considered a security by the US Securities and Exchange Commission.[38]

Impact

Given that Colony is yet to be released, it seems too early to assess its impact. However, they do have a set of use cases that they think would be particularly suited to using Colony.

- Worker-owned cooperatives: Colony would make them easier to manage, for example by reducing the need for a quorum of workers to vote on lots of decisions. This could enable collective organisations to make decisions more efficiently, effectively, and transparently by ensuring the right people input into decisions they have demonstrated expertise in relation to, and that everyone can have oversight over decisions without always having to convene en masse.
- Grant funding: Colony could be used to set milestones that grantees need to meet. As grantees meet milestones, they could earn reputation which would enable them to participate in future grantmaking decisions. A grant fund could eventually become self-managed by grantees. This could potentially lead to a wider range of people helping to decide which innovation initiatives get funded.

- Community engagement: An organisation that wants to engage with external contributors could set up a colony for the purpose.
- Wikis: payments could be made for making edits.

They think it would work less well for:

- Organisations that need to be secretive: Putting transactions on the blockchain makes them public. There are ways to obfuscate this, but some information will always be public.
- Centralised organisations: Although it would be possible to implement many of the functions of a conventional centralised organisation in Colony, it might not make sense to.
- (At the moment) Organisations not already interacting with the blockchain: There are currently user experience difficulties that result from interacting with the blockchain.

They also have a key metric that they focus on: the total value of transactions across the colony network.

Comparison with other sectors and tools

Strengths

Colony has some similarities to other blockchain-based tools, in particular, an emerging sector that has been described as Organisational Technology (OrgTech). OrgTech tools aim to explore how the emerging blockchain sector can radically digitise and reinvent how organisations operate.[39]

Weaknesses

Colony will have to overcome widespread scepticism and lack of awareness about blockchain to succeed, and it will have to have a transparent, easy-to-use interface to match. This seems an especially tall order as the platform's suggested use cases go beyond the early adopter, tech-savvy community.

Key takeaways

Colony's genesis in and focus on solving an organisation's problem bodes well for its potential to do the same for other organisations. It could be relevant to innovation brokerage by helping to overcome existing organisational barriers to collaboration and the exchange of work and ideas. It could also help provide a more 'frictionless' environment to better reward contributors to the innovation brokerage process. Explaining blockchain to people – and getting them to use it – will be a barrier Colony will have to overcome.

Resources

colony.io/whitepaper.pdf

blog.colony.io/why-colony-2a1e479dc40d

tokeneconomy.co/the-colony-whitepaper-review-64c12459eb29

news.ycombinator.com/item?id=15406724

blog.colony.io/the-colony-reputation-system-5616293c3949

blog.colony.io/colony-beta-product-summary-2121a357d61d

blog.colony.io/what-does-colony-look-like-edd7e709fc86

References and endnotes

1. Dodgson M (2017) Innovation in firms. Oxford Review of Economic Policy 33(1): 85–100. https://doi.org/10.1093/oxrep/grw034
2. Dalziel M (2010) Why do innovation intermediaries exist? Proceedings of DRUID Summer Conference, London. http://www.theevidencenetwork.com/wp-content/uploads/2017/12/Why-Do-Innovation-Intermediaries-Exist_.pdf
3. Katzy B et al (2013) Innovation intermediaries: a process view on open innovation coordination. Technology Analysis & Strategic Management 25(3): 295–309. https://doi.org/10.1080/09537325.2013.764982
4. See, for example, Thompson B (2017) Defining aggregators. Stratechery. https://stratechery.com/2017/defining-aggregators Accessed: 12 November 2019.
5. Katzy B et al (2013) Innovation intermediaries: a process view on open innovation coordination. Technology Analysis & Strategic Management 25(3): 295–309. https://doi.org/10.1080/09537325.2013.764982
6. Dalziel M (2010) Why do innovation intermediaries exist? Proceedings of DRUID Summer Conference, London: 8. http://www.theevidencenetwork.com/wp-content/uploads/2017/12/Why-Do-Innovation-Intermediaries-Exist_.pdf
7. Mowery DC et al (2001) The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh–Dole act of 1980. Research policy 30(1): 99-119. https://doi.org/10.1016/S0048-7333(99)00100-6
8. OECD (2018) Oslo Manual: Guidelines for Collecting, Reporting and Using Data on Innovation. https://www.oecd.org/sti/inno/oslo-manual-2018-info.pdf Accessed: 24 July 2019.
9. Hybrid Forecasting Competition (2019) Hybrid Forecasting Competition. https://www.hybridforecasting.com/ Accessed: 12 November 2019.
10. Katzy B et al (2013) Innovation intermediaries: a process view on open innovation coordination. Technology Analysis & Strategic Management 25(3): 295–309. https://doi.org/10.1080/09537325.2013.764982
11. Lichtenthaler U and Ernst H (2008) Innovation intermediaries: why internet marketplaces for technology have not yet met the expectations. Creativity and Innovation Management 17(1): 14–25. https://doi.org/10.1111/j.1467-8691.2007.00461.x
12. Katzy B et al (2013) Innovation intermediaries: a process view on open innovation coordination. Technology Analysis & Strategic Management 25(3): 295–309. https://doi.org/10.1080/09537325.2013.764982
13. Katzy B et al (2013) Innovation intermediaries: a process view on open innovation coordination. Technology Analysis & Strategic Management 25(3): 295–309. https://doi.org/10.1080/09537325.2013.764982
14. This is based on Nobel Prize-winning economist Alvin Roth's description of matching markets as ones where 'you can't just choose what you want... you also have to be chosen.' From Social Science Bites (2017) Al Roth on matching markets. Social Science Space. https://www.socialsciencespace.com/2017/08/al-roth-matching-markets/ Accessed: 12 November 2019.
15. Kominers SD, Teytelboym A and Crawford VP (2017) An invitation to market design. Harvard Business School Working Paper 18-019. https://www.hbs.edu/faculty/Publication%20Files/18-019_b138aaa9-55f6-484e-a7c5-84b31ed71759.pdf Accessed 12 November 2019.
16. Tiffany K (2019) The Tinder algorithm, explained. The Goods by Vox. https://www.vox.com/2019/2/7/18210998/tinder-algorithm-swiping-tips-dating-app-science Accessed: 12 November 2019.

17. Interview with Joe Marshall, 1 March 2019.
18. Evans B (2016) Lists are the new search. Benedict Evans. https://www.ben-evans.com/benedictevans/2016/1/31/lists-are-the-new-search Accessed: 12 November 2019.
19. Evans B (2016) Search, discovery and marketing. Benedict Evans. https://www.ben-evans.com/benedictevans/2015/6/24/search-discovery-and-marketing Accessed: 12 November 2019.
20. Klerkx L and Leeuwis C (2009) Establishment and embedding of innovation brokers at different innovation system levels: Insights from the Dutch agricultural sector. Technological Forecasting and Social Change 76(6): 849–860.
21. Dowling A (2015) The Dowling Review of Business-University Research Collaborations. https://www.raeng.org.uk/publications/reports/the-dowling-review-of-business-university-research Accessed: 12 November 2019.
22. Haley C (2019) Improving the Market for IP (part 2). https://www.nesta.org.uk/blog/improving-market-ip-part-two/ Accessed 20 August 2019.
23. Katzy B et al (2013) Innovation intermediaries: a process view on open innovation coordination. Technology Analysis & Strategic Management 25(3): 295–309. https://doi.org/10.1080/09537325.2013.764982
24. Interview with Roland Harwood, 6 March 2019.
25. Dowling A (2015) The Dowling Review of Business-University Research Collaborations. https://www.raeng.org.uk/publications/reports/the-dowling-review-of-business-university-research Accessed: 12 November 2019.
26. Katzy B et al (2013) Innovation intermediaries: a process view on open innovation coordination. Technology Analysis & Strategic Management 25(3): 295–309. https://doi.org/10.1080/09537325.2013.764982
27. van Leeuwen J et al (2018) Effectiveness of virtual reality in participatory urban planning. Proceedings of Media Architecture Biennale, Beijing. https://urbanux.nl/wp-content/uploads/2018/10/2018_MAB.pdf
28. Interview with Joe Marshall, 1 March 2019.
29. Haley C (2019) Improving the Market for IP (part 2). https://www.nesta.org.uk/blog/improving-market-ip-part-two/ Accessed 20 August 2019.
30. Symons T (2015) How not to spend it: 6 ways procurement blocks innovation. https://www.nesta.org.uk/blog/how-not-to-spend-it-6-ways-procurement-blocks-innovation/ Accessed: 24 July 2019.
31. Further details about CityMart and Bidspark are available at: https://www.citymart.com/
32. Kolodny H et al (2001). Design and policy choices for technology extension organizations. Research Policy 30(2): 201–225. https://doi.org/10.1016/S0048-7333(99)00119-5
33. Baughan K and Bassett N (2018) Accelerating patient capital. Innovate UK Blog. https://innovateuk.blog.gov.uk/2018/01/25/accelerating-patient-capital/ Accessed 12 November 2019.
34. Breteau J (2018) Blockchain technology and the future of work. Blockchain Review. https://medium.com/blockchain-review/founders-in-focus-episode-1-646d17192cec Accessed 12 November 2019.
35. Colony (2016) #TrueDAO. Colony Blog. https://blog.colony.io/truedao-d270a94877b1/ Accessed 12 November 2019.
36. Colony (2016) #TrueDAO. Colony Blog. https://blog.colony.io/truedao-d270a94877b1/ Accessed 12 November 2019.
37. Rea A, Fischer A and du Rose J (2019). COLONY. Technical white paper 2019-10-31, commit ca8b49c. https://colony.io/whitepaper.pdf Accessed 12 November 2019.
38. Colony (2016) The Colony token sale. Colony Blog. https://blog.colony.io/the-colony-token-sale-7ac14c845bc0/ Accessed 12 November 2019.
39. Laing J (2019) OrgTech and the networked firm. OrgTech Review. https://orgtech.substack.com/p/orgtech-and-the-networked-firm Accessed 12 November 2019.

58 Victoria Embankment
London EC4Y 0DS

+44 (0)20 7438 2500
information@nesta.org.uk
@nesta_uk
www.facebook.com/nesta.uk
www.nesta.org.uk