Pashley, D., Tryfonas, T., Crossley, A., Setchell, C., & Karatzas, S. (2020). Innovation Portfolio Management for Small-medium Enterprises. *Journal of Systems Science and Systems Engineering*, 29, 507-524. <https://doi.org/10.1007/s11518-020-5467-z>

Peer reviewed version

Link to published version (if available):
[10.1007/s11518-020-5467-z](https://doi.org/10.1007/s11518-020-5467-z)

[Link to publication record in Explore Bristol Research](#)
PDF-document

This is the author accepted manuscript (AAM). The final published version (version of record) is available online via Springer Verlag at <https://doi.org/10.1007/s11518-020-5467-z> . Please refer to any applicable terms of use of the publisher.

University of Bristol - Explore Bristol Research

General rights

This document is made available in accordance with publisher policies. Please cite only the published version using the reference above. Full terms of use are available:
<http://www.bristol.ac.uk/red/research-policy/pure/user-guides/ebr-terms/>

Innovation Portfolio Management for Small-medium Enterprises

Daniel Pashley¹, Theo Tryfonas², Andy Crossley³, Chris Setchell⁴, Stylianos Karatzas⁵

¹iMETRUM Ltd., Bristol, UK; daniel.pashley@imetrum.com

²Civil Engineering Department, University of Bristol, UK; theo.tryfonas@bristol.ac.uk

³Civil Engineering Department, University of Bristol, UK; andrew.crossley@bristol.ac.uk

⁴iMETRUM Ltd., Bristol, UK; chris.setchell@imetrum.com

⁵Civil Engineering Department, University of Patras, Greece; stylianos.karatzas@outlook.com

Abstract

For small and medium sized enterprises, portfolio management can be a difficult exercise; especially when the available paths forwards are shrouded in mystery. To overcome this, they are required to research and decide upon the path to follow, but this can be difficult when the information to gather is unclear, leading to ad-hoc processes and inconsistency. The motivation for this project originated from a small and medium sized enterprise experiencing this problem of unknown critical information and a technological portfolio with significant potential. With no procedure or method in place, they conducted the research in an ad-hoc way resulting in uncertainty and low repeatability of decisions. To tackle this problem, innovation structuring frameworks were synthesised with appropriate risks and context to pose a new structure for information capture. The resulting structure was tested within the small and medium sized enterprise to investigate the repeatability of the information capture and the subsequent ranking. The proposed structure was also analysed by - process experts for its wider applicability. For the small and medium sized enterprise, this led to a consistent and repeatable method that delivered increased confidence about selecting a path forwards for its portfolio. In addition, it was found to be applicable to external organisations increasing the model's worth and applicability. The implications of this work have led to a change in the operational procedure of the small and medium sized enterprise to utilise the defined process for researching new ideas for their portfolio which can lead to repeatable and trustworthy decisions. This also has applicability to other similar companies and could lead them through a repeatable process as presented here.

Keywords: Portfolio management, Directed research, Decision support, Small-medium enterprise.

1 Introduction

In order to ensure continual development, companies need to generate new ideas for products to extend their portfolio (Kaiser et al. , 2015). These new ideas need to present a - meaningful next step to ensure the product becomes

a worthy next iteration or radical development (Sperry and Jetter , 2009). Therefore, the generation of sufficient ideas in relation to the company's portfolio and strategy is required (Meifort , 2015). As a product that is separate from the company's offerings or selected strategy can pre-

vent desired growth and inhibit chances of survival (Sperry and Jetter , 2009).

Companies also generally operate and exist within a particular sector or market based around their product portfolio (Martinsuo , 2013), thus being focused on their offerings. For Small and Medium sized Enterprises (SMEs), this focus is even tighter with a more limited number of products (Mishly and Tereso , 2016). Often at the core of this product portfolio is a core piece of intellectual property which leverages their market position by offering a certain capability over their competitors (Daniel et al. , 2014). This core piece of intellectual property and product range make up their portfolio (Costantino et al. , 2015), which has to be continually investigated and invested in to allow for expansion and therefore a continuation of their position and revenue stream (Kester et al. , 2014).

In order to investigate this successfully, there has to be an identified path that the product portfolio should take which is defined as part of company strategy (Mitchell et al. , 2014). This path is a core component of the Portfolio Management process in the identification of ways in which the company can continue to grow. When a company is based around a single piece of intellectual property, only generating a single idea will struggle to deliver the required stimulus to the business (Kock et al. , 2015). Therefore utilising the ideation process to deliver a significant number of ideas is required, such that there is multiple to choose from (Meifort , 2015). With the required number of ideas generated, the difficulty arises with understanding each of them in sufficient detail in order to decide which to se-

lect (McNally et al. , 2013). Usually there are a number of metrics adopted by business to understand the ideas they have. These are often based around financial measures such as Net Present Value (NPV) or Internal Rate of Return (IRR) (Abbassi et al. , 2014). However, such financial measures are only a part of the picture. Furthermore, when trying to make a decision using other data points need to be the same across all potential ideas in order to achieve a true comparison for the basis of the decision (Patanakul , 2013).

This research was initiated due to the needs of a highly innovative SME (herein referred to as the SME) who is conducting the ideation process into potential developments that can utilise its highly adaptable intellectual property. Due to their current ad-hoc nature, as is common place for SMEs (Laforet , 2013), this investigation process is inconsistent and means decisions as to which idea to take further is made based on different data and “gut feeling”. This leads to a decision process that changes each time, leaving a sense of uncertainty about the decisions made and their validity (Costantino et al. , 2015). Therefore, by delivering a standardised and repeatable process of investigation, the comparison and selection will become more repeatable, reliable and trustworthy.

From this point, this paper will have the following structure. First, the background literature in relation to SMEs R&D processes and Portfolio Management will be discussed and critically analysed. Then, a novel, repeatable process for investigation will be introduced and demonstrated. Finally, a discussion on how this approach can be used for investigation and de-

cision making within other SMEs follows, before concluding the paper.

2 Literature Review

SMEs represent the majority of companies worldwide (Mishly and Tereso , 2016); contributing 67% of the workforce and 58% of value added in the EU (Brink , 2016). A small percentage of these organisations are known for their disproportionate impact on the economy (Lee et al. , 2015); this is driven by innovation creating new value and competitive advantage (Staniewski et al. , 2016). These organisations are characterised by being more agile and able to adapt to any changes (Liao and Barnes , 2015); originating internally or externally. In addition, these small firms have the ability to create new products that spawn their own markets (Lee et al. , 2015) in a product push approach. However, in order to do this, they require access to resources that are conventionally hard to attain for an SME; knowledge (Reidof , 2016) and finance (Lee et al. , 2015). This becomes their main barrier and disadvantage with comparison to larger, more established competition (Leithold et al. , 2016). Conventionally, this process is conducted in an ad-hoc way (Laforet , 2013), with no formal process followed. Despite this, conducting R&D can be critical and required in the formation of their future (Abbassi et al. , 2014). To complete the innovation required, access to resources is required such as funds and knowledge (Poorkavoos et al. , 2016). However, with their limitations with possessing and obtaining the required resource (McAdam et al. , 2014) they need to be selective as to which projects to initiate (Mishly

and Tereso , 2016). Furthermore, this ad-hoc nature of the process can be highly variable and lead to different results due to the lack of structure. This lack of structure can be found in the information capture and decision making phases.

In order to help with this process, Portfolio Management is used to maintain the ratio between existing and new projects (Kaiser et al. , 2015), as many can be identified and enacted at the same time (Patanakul , 2013). Portfolio Management is also used with coordinating these projects when pursuing the same strategic goals while competing for the same pools of resource (Martinsuo , 2013). This coordination enables companies to maintain a consistent product pipeline (McNally et al. , 2013), to continually hunt for new ideas and develop the promising ones. This process can be conceptualised as a funnel which narrows down the ideas to the worthy ones (Sperry and Jetter , 2009), which demonstrate significant promise. Therefore Portfolio Management can be thought of as a process of investigation, evaluation and prioritisation (Kaiser et al. , 2015) in relation to new ideas such that new ones are generated, investigated so they are understood, evaluated for their promise and then prioritised for how the company should proceed. The required investigation is conducted into the identified ideas such that a picture can be built on their outcomes and resource requirements. There are several methods that can be used to evaluate the identified ideas; such as those presented by (Tian et al. , 2005), (Coldrick et al. , 2005) and (Eilat et al. , 2006). A popular method of doing this is *scoring* which aims to convert the captured information into a series of numerical values (Henriksen and Tay-

lor , 1999), (Mitchell et al. , 2014). Once the ideas have been evaluated they can be prioritised which presents the order in which resource is to be committed to them. However, it is important to stress how to facilitate effective Portfolio Management that the required information is captured to enable the decision process.

One way to ensure the product portfolio of a company remains in motion is to constantly develop new ideas (Kock et al. , 2015). In this way, new ideas are devised, evaluated and prioritised alongside ongoing projects which can be deprioritised or terminated (Behrens , 2016); this ensures a constant pipeline of high-quality ideas exists to progress into the development process (Meifort , 2015). Early stages of ideation are critical for the success of the company’s portfolio (Kokshagina et al. , 2016), as without new ideas, the whole process stops. Therefore by generating a large number of new ideas over time a well-balanced and long lasting portfolio can be created (Kock et al. , 2015). In this way, there are strong links between ideation and the front-end of innovation (Behrens , 2016); this is because key aspects of the front-end of the innovation process includes idea generation and project selection (Trotter , 2011). In addition, the front-end of innovation forms the foundation for new product development (Koen et al. , 2014) with new ideas being generated, evaluated and concepts being formulated (Kock et al. , 2015). A key part of the front-end of innovation is the transfer of worthy ideas (Gupta and Maltz , 2015), which will present those identified requiring additional work as well as those that contain sufficient detail to be considered for further development.

To maximise the use of these ideation and Portfolio Management processes, companies need to align them to their objectives (Costantino et al. , 2015) (Kester et al. , 2014); this is because the majority of companies have too many developments occurring (Cooper , 2013). Therefore, with the correct investigation and evaluation, the chance of the correct project being selected will increase and also match to the planned direction of the company. One part of this alignment that is critical is the balance within the portfolio; this is from the diversification of what it contains (Kester et al. , 2014). However, this contains the risk of being too much or too little diversification. In addition, portfolios have been found to have a skewed balance towards more incremental over radical developments (Cooper , 2013), which can lower the company’s overall impact to their market and the success they can expect. This diversification has significant impact on the resources that are distributed as it is the purpose of Portfolio Management to distribute them (Daniel et al. , 2014) such that they are not given to those projects that deviate too far from the company’s strategy and objectives. As previously mentioned, the first part of the Portfolio Management process is the investigation into new ideas and potential projects. Conventionally, these are purely financial measures (Cooper , 2013), (Costantino et al. , 2015), (Daniel et al. , 2014). These may deliver the required understanding of certain aspects but they do not deliver the whole picture. Furthermore, by only using financial measures to investigate an ideas merit can lead to only those that carry the least financial impact being selected (Cooper , 2013); which con-

ventionally form the incremental projects, not the radical ones. This will lock SMEs into a cycle of investing only in the ideas of least risk and financial requirement and will set their trajectory to be incremental over radical, lowering their possible growth. Several of these additional key pieces of information that cannot be represented by a financial measure such as risk (Kester et al. , 2014). Therefore, by limiting ones view to only those aspects that can be represented by financial measures creates a metaphorical self-imposed cloud over the idea, whereby the financial aspects are close and clear but several others are obscured and unknown.

Innovation can be thought of as the creation of something new (Blake and Hanson , 2005) through exploration followed by exploitation (Markman et al. , 2009); however, this is simply a generic concept and has no specificity in relation to the environment in which it is found. Therefore, innovative SMEs need to take care when aligning themselves with a particular market (Van Der Duin et al. , 2014) to ensure their innovation is received as desired. The context in which innovation is to occur is critical as it has the potential to spawn different entrepreneurial trajectories (Garud et al. , 2014), several examples of innovation context are shown in Table 1. These are noted in two forms, selection effects and strategic choice effects (Autio et al. , 2014); with the differentiating factor coming from which side of the project start they fall. This demonstrates the criticality of ensuring the definition and maintenance of context throughout the process; which is even more critical for an SME to remain focused towards their defined goals.

Further contextual considerations of the in-

novation process include: type of innovation, organisation, industry and country/culture (Ortt et al. , 2008). These can be decomposed to identify the difference between the types of context. Firstly, the type of innovation has been defined by its characteristics of being incremental (Hoeft and Kline , 2014), radical (O'Connor and Rice , 2013) or transformational (Herskovits et al. , 2013) and where it is to take place (Bellantuono et al. , 2013). Additionally, the organisation can be said to be centralised, decentralised (Cormican and O'Sullivan , 2004), functional (Kihlander and Ritzén , 2012) or organic. Furthermore, the industry can be described as being high-tech (Stevens , 2014), supplier-driven or fast moving (Chesbrough , 2003). Finally, the country/culture could be egalitarian or authoritative. Taking these different types of context and comparing them back to those already identified from (Autio et al. , 2014), parallels can be seen in their exposition. Via the adoption of the appropriate context at several points throughout the innovation process, SMEs can make a process designed more generally to be usable in their specific application. In Figure 1, a synthesis of these different contexts according to focus on the market and the technology (Ortt et al. , 2008), the organisation conducting the innovation and any institutional rules or social requisites for the target market is presented.

Through the application of the appropriate context to innovation, the risk can be reduced (Khurum et al. , 2014) to the SME. Such specific risks to the innovative technology in question can be contextualised with respect to the categories in Figure 1, highlighting the aspect of the process that carries the most risk and which there-

Source	Context
(Autio et al. , 2014)	Industry and technology
	Organisational
	Institutional and policy
	Social
(Poirier et al. , 2015)	Taxonomy of industry
	Institutional
	Organisational
	Project

Table 1: Types of innovation context

Figure 1: Innovation contexts.

fore requires extra research in order to better understand and reduce it. Risk is of critical importance to Portfolio Management (Daniel et al. , 2014); this is so the risk of a project can be balanced to its reward (Kester et al. , 2014). However, it is common to find only the projects that present low risk being selected (Cooper , 2013) leading to only incremental changes. Therefore, by presenting a deeper understanding of the risk present, these can be mitigated and overcome rather than being avoided.

3 SME Innovation Portfolio Management Process Model

It can be seen that the key to advantage for SMEs is the process of generating new ideas and developing them such that they commit their limited resource to the projects that will deliver the highest level of return possible over small, incremental gains. However, if they are to do this effectively, the process of selecting ideas needs to be done correctly to ensure their limited resources are committed to the idea that will deliver the best return. One way in which they can ensure the correct idea is backed is through the generation of multiple ideas; meaning there is an increased number to select from, however there are still no guarantees. During this ideation process, significant learning can be conducted such that later decisions become easier due to an increase in knowledge. This learning process is key as it is required to reflect the reality of the idea to deliver the required information to enable effective decisions. However, this is often limited with the SME environment as process as more ah-hoc, with this being “off the cuff” each time

and relying on different data being used in a unique way. In addition, Portfolio Management relies on financial measures to drive its decision making.

In combination these two limitations can have significant impact on the investigation and evaluation process and ultimately the selection of the idea to take further. Firstly, the ad-hoc nature of the SME process results in a disparity in information collection; with different information collected each time, comparison between ideas can be difficult, even impossible. Second, relying only on financial measures, as is often the case with Portfolio Management, delivers an understanding only based on money which can both circumvent significant pieces of information and result in the lowest impact project being selected over those that possibly present a larger return for a larger investment. Furthermore, the context of the environment where the process is to occur is of critical importance. Utilising the contextual relevance for the idea can lead to a deeper understanding of it. In addition, the contextual risks to the idea can be understood leading to the correct mitigation actions being planned and associated with it before the development path is selected.

This presents the possibility for improvement. Utilising a wider range of information, not only financial measures, delivers a deeper understanding. Furthermore, by expanding this range of information to include other aspects in a defined way would deliver a repeatable process delivering the same information each time an idea is investigated. This makes the comparison process repeatable and the outcomes more valid. Also, placing the idea within the correct

context and identifying the relevant risks further increases the understanding of the idea.

The proposed Portfolio Management process is focused around a Directed Research Approach. This directs the research to capture required information for new ideas while also understanding the relevant context and risk. By conducting it in this way, the same information is captured for each idea such that they can be directly compared to others, whilst understanding the context in which it is to exist and the related risks. This makes the process highly repeatable, resulting in equally detailed and valid information. For SMEs who rely on their agile nature to remain competitive and adapt to any changes in their environment, this light touch structure is key to ensure that the required information is collected in a way that is not overly prescriptive while also being relevant. By utilising the captured information for each identified idea, they can be directly compared to each other, meaning the decisions reached are based on more than an ad-hoc process and “gut feeling”. This ultimately means the decision, as to which idea to pursue, can be trusted due to the use of a repeatable process.

To allow for the creation of this proposed framework, an ethnographic research approach was utilised. This requires prolonged periods of embedded research in the area under observation (Pink et al. , 2010), such that people’s behaviour can be clarified and motivations understood (Kashimura et al. , 2014). Therefore, this work was positioned to observe and improve upon the processes of the SME when conducting investigations for the benefit of their portfolio. Through such positioning of the research, it would be able to identify and present a solution

closer to that required to deliver the necessary improvements.

This proposed Directed Research Approach is aimed at the product push approach. For this, SMEs do not wait for the users to dictate the need for a new technology or capability (Lamb et al. , 2009), they actively search for opportunities to create a new one and let the users move to it. This can often be the main draw of the SME to a market to replace the incumbents. A reason that such an approach would be taken is the limitations of the current technology are so engrained in the day-to-day operation, it is not seen as a drawback and users would not identify this as an area that requires changing. Whereas, by using the product push approach, these limitations can be addressed and highlighted to users to draw them to the new product. Parallels can be drawn to the adoption of Portfolio Management and ideation in the search for the next innovation that will deliver significant returns of the company and protect its future. The product push approach in this instance delivers the ability for defining the next generation of product to be pushed onto the market to deliver the next generation of capabilities.

3.1 Directed Research Approach

There is a strong link between the ideation process and the front-end of innovation, in which both are predicated on the generation and the understanding of ideas. Furthermore, it is understood that the knowledge gained during this front-end work is of greater significance as it can inform later development. Therefore, three front-end of innovation frameworks were inves-

Framework	Phase	Purpose
(Tidd and Bessant , 2013)	1	Search for opportunities
	2	Select course of action
	3	Implement procedure
	4	Capture benefits analysis
(Westland , 2008)	1	Opportunities
	2	Competencies
	3	Market entry
(Conway and Steward , 2009)	1	Cross functional linking
	2	Opportunity coupling
	3	Dualism

Table 2: Innovation structuring frameworks

tigated as to their process and the information they require to be collected. These frameworks, their phases and the purpose of each phase are shown in Table 2.

Each of these frameworks can be seen to have several phases that align with common purpose. Therefore, these are synthesised into a single framework made up of three main phases of research of State of the art, Course of action and Business case.

The first main phase called State of the art is to understand the current competing products that are on the market. This understanding is to include such aspects as the capabilities of these offerings, any intellectual property that is protecting them and any known issues or limitations to both their users and manufacturers. The second main phase called Course of action is to capture the ways in which the development could proceed. This captures information on the possible routes forwards, of which there could be many, and the requirements for these solutions. These factors can be a useful indication for

the viability of the development. The final main phase is the Business case which is focused on understanding the implications of the proposed development. Several can be possible for a single idea depending on the number of courses of action there are available. This phase is to focus on capturing information on the market which it is to enter, protection possible and associated costs and value to the customer.

To implement the proposed Directed Research Approach, the required information for each phase must be captured from an appropriate source. In Table 3 the required information capture for each phase is presented along with possible sources.

In addition to collecting information, in relation to the idea and its potential development path, the risk towards it and the context it is to exist within need to be understood. For the State of the art the risk is from the technology (Ignatius et al. , 2012). This is presented from the competing technologies (Martinsuo and Poskela , 2011) as they are already positioned rel-

Phase	Required input information	Indicative source
State of the art	Existing technology	Technical information sheets
	Capabilities	End users, technical information sheets
	Existing IP	Patent search engine
	Known issues	End users
Course of action	Possible routes forward	Developers, management
	Requirements	End users
Business case	Target market trends	Market analysis reports
	Potential IP	Patent search engine
	Cost of development	Costing analysis
	Value to the customer	End users

Table 3: Required information capture sources

ative to the customer and will command market share. The required context is from the industry and technology; this will focus the attention of the organisation towards the current companies operating in the market (Cohendet et al. , 2015), legislation (Brem and Voigt , 2009) and any distribution routes. Further to this, the context of the technology will deliver extra focus towards the competing technologies (Cruz-Gonzalez et al. , 2015), their capabilities and what is perceived to be required to attract customers to move away from existing technology. This draw can be critical to a product push approach as launching a new product into the market with no draw to drive acceptance would be difficult; there has to be an underlying need met to act as the driver. During the Course of action main phase, the risk is focused towards the innovation itself as positioning a radical technology via product push approach is inherently risky. Further to this, the criticality of the social context is evident due to the increased number of interactions that are required to make a new development successful. These new interactions likely will have formed

with a number of different partners in a new network containing the required core competencies to make the development a reality. It is noted how a network comprising of individuals with specialist knowledge increases the effectiveness of the innovation (McAdam et al. , 2008) and can fill gaps in the SME, however this drastically changes depending on its context (Cruz-Gonzalez et al. , 2015). Finally, during the Business case main phase, the risk is that of the market, as this new technology will be entering into a market that will potentially have several existing offerings from other established organisations that are trusted by consumers (Partanen et al. , 2008) which it will need to replace/displace via the product push. This could also be where the SME creates a new market for their innovation. For either case, it is critical to capture information to the required level of detail about this new market (Cruz-Gonzalez et al. , 2015), any existing companies (Kollmer and Dowling , 2004) and the potential take-up of any new offering (Chiesa and Frattini , 2011). This phase has several layers of context to be considered; organ-

isational (Ortt et al. , 2008), institutional and social. The organisation context is one that is decided in day-to-day operations and can be rationalised by any changes required in order to operate (Cormican and O’Sullivan , 2004). Additionally, the institutional and policy context can be applied through an understanding of the formality of the SME and the way in which it fits into the relevant market and any legislation (Markman , 2008) that is present in the geographical region in which they operate/are to operate (Autio et al. , 2014). This is summarised in Table 4.

By utilising the proposed Directed Research Approach main phases, structure can be given to the investigation process to ensure that the required information is collected for each idea along with the risk and context. This results in information that is available for comparison to other ideas as well as to plan mitigating actions for risks while understanding the context in which the idea resides. This in effect creates a scaffold structure which any SME will be able to adapt to their own procedure to remain flexible, the inherent advantage of the SME (Leithold et al. , 2016), while moving away from their conventional ad-hoc nature (Laforet , 2013). Having this repeatable information means all ideas can be evaluated relative to each other in a repeatable way even without complex decision processes.

As can be seen in Figure 2, there are several phases in the Directed Research Approach. These are divided into two distinct groups of main phases and secondary phases. First, the Ideation phase is focused identifying which ideas to research and making the decisions based on

all options available as to which to investigate at that time and is classed as a secondary phase. Next, the Research phase, which is made up of the State of the art, Course of action and Business case is defined as a main phase as this is where the focus of this approach lies in researching and understanding ideas. Following this, there are the two remaining secondary phases, the Selection phase uses the results of the main phase and compares them to the results from the other investigations conducted such that the final secondary phase, the Development phase, can initiate development on a new idea. Therefore, the secondary phases be a way in which to enable the main phase to operate successfully and to provide the required level of information to begin the process and to utilise it such that development can begin.

In addition, Figure 2 demonstrates several distinct groups of inputs along the main path of the Directed Research Approach. Firstly, the information group relates to any input into the approach which contains any information such as a stimulus of collected information. The risks group contains the main risks to the idea at hand. Contexts, as with the risk group are those which should be considered during the investigation into the idea. The resource group contains any form of input into the approach such as people. Finally, the methods group contains the required decision making methods utilised by the company.

Furthermore, Figure 2 highlights the appropriate people within the company who will both own phases as well as those who will work on them. For the first three phases, the company’s strategic management will own the phases and

Phase	Risk	Context
State of the art	Technology	Industry and technology
Course of action	The innovation	Social
Business case	Market	Organisational
		Institutional and policy

Table 4: Risk and context summary

Figure 2: Directed Research Approach.

what occurs in them. This is because they will decide which ideas to investigate, oversee the research and utilise the results to select which to pursue. The final phase, the Development phase, is overseen by a project manager, as at this point actual development work is being conducted in a conventional process. Under the manager of each phase there is also the phase operative who is the person who will conduct the work required. During the Research phase this person is classified to be a researcher as they will investigate the idea and feed back to the company's strategic management. During the Development phase, the operative is a developer as they will utilise the research conducted and information gathered to create the final product or service. They will report to the project manager overseeing the process. In addition to the phases, there are several elements covered in Figure 2. All elements appearing through the phases defined in this process are fully identified and discussed briefly in

Table 5.

3.2 Application Case Study and Evaluation

To demonstrate the Directed Research Approach, five ideas generated by the SME during the Ideation phase were used. These ideas had the required information, risks and context captured during the Research phase and was evaluated during the Selection phase using an internally defined process such that a prioritisation was created. To evaluate the Directed Research Approach, four members of staff from the SME were used to personally evaluate the ideas and create their own priority in which they believe they should be tackled. The number of participants was limited by the number of staff within the SME and the sensitivity of the ideas prevented exposing them wider for evaluation. Even with this small number of participants this

Phase	Element	Description
Ideation	a	Idea identification: This is where the new ideas to investigate are identified
	a1	Internal stimulus: The ideas can be from an internal stimulus
	a2	External stimulus: The idea can also be from an external stimulus such as industry engagement
	b	Research initiation decision: This is a decision gate as to which idea is to be researched
	b1	SME decision maker: This person is responsible for making the decision as to which idea to research
	c	Task assignment: Here the task of conducting the research is assigned to a member of the SME
	c1	Research constraints: These are added to the research such as time or effort limits
	c2	Pool of resources: These are required to conduct the research such as time of others
Research: State-of-art	d	State of the art: The phase whereby the current technology offerings are investigated
	d1	Information collection: Here information is collected as per Table 3
	d2	Technology risk: Here the risk posed by the opposing technology is investigated and included
	d3	Industry and technology context: Here focus is placed on the industry operating the current technologies as well as the opposing technologies themselves
Research: Course of action	e	Course of action: For this the various ways the development could proceed is investigated
	e1	Information collection: Here information is collected as per Table 3
	e2	Innovation risk: Here the risk is posed by the innovation itself
	e3	Social context: Based on the increased number of social interactions required
Research: Business case	f	Business case: Here more financial and market based information is collected to form a business case
	f1	Information collection: Here information is collected as per Table 3
	f2	Market risk: The risk is formed by the market that the new technology will be entering
	f3	Organisational, Institutional and Policy context: Formed on the day-to-day operation of the SME and how it will fit into its new market segment
Selection	g	Collate idea information: For this step, information collected as part of this investigation is collated as per the three main phases
	h	Comparison and review process: Here the information for the idea in question is analysed in comparison to the other ideas researched previously
	h1	Decision methods: For this, a number of decision making methods can be used such as our own (Pashley et al. , 2017)
	h2	Pool of reviewers: From the available staff in the SME, those able to review the collated information are selected and assigned reviews to conduct
	i	Prioritisation of ideas: Based on the review process, the available ideas are prioritised
	j	Development decision process: Here the decision is made as to which (if any) ideas should be taken further to development
	j1	SME decision maker: The decision maker for the SME utilises the presented information to decide on which path forward to take
	j2	Pool of resources: From the pool of available resources, assignments are made to the selected idea(s)
Development	k	Development process: Here the idea selected is taken forwards and its development begins

Table 5: Elements of Directed Research Approach (as per Fig. 2).

Idea	Ranking
A	Vehicle test rig
B	Coordinate measuring machine
C	Novel sensor
D	Metrology system integration
E	Testing turbine blades

Table 6: Used ideas

still represented 25% of the entire company and therefore presented a significant relative sample size. With the priority from the participants, a comparison was conducted into their order to understand the repeatability of the Directed Research Approach even when using basic evaluation techniques. For the presented five ideas, there are a possible 120 different orders in which the ranking could be presented, therefore achieving a similar order from the participants would demonstrate how the Directed Research Approach leads to repeatable decisions. The ideas used for this evaluation are summarised in table 6.

The roles of employees used as part of the testing are shown in Table 7.

The participant’s ranking of the presented ideas is shown in Table 8.

To understand the differences in the rankings generated, the variance of each Ideas positions was calculated. The ideal case would be a variance of zero as this shows all participants placed the idea in the same position.

From the variance values shown in Table 9, the levels differ over the ideas presented. Ideas A through C demonstrate a low variance of less than 1. This demonstrates an understanding across all participants as to the priority of these

ideas. However, ideas D and E present larger variance values; this is due to the roles which the participants play within the SME and therefore their experience and understanding influencing their rankings with certain positions significantly affecting the result. In the case of idea D, the majority of positions place it close to the bottom of the list in either position 4 or 5. However with one participant placing it at number 2, the variance was greatly affected. Idea E was similar; but two of the positions were significantly different to the rest, leading to the larger variance value.

4 Discussion

Before this approach, the SME utilised an ad-hoc process of information capture of attributes that were deemed to be important at the time. These pieces of information were then reviewed and utilised to make decisions, again in an ad-hoc way based on “gut-feeling” and intuition to define the direction their portfolio was to advance. Now, by utilising the Directed Research Approach, information, risk and context is collected in a consistent and repeatable way that makes them directly comparable to one another. The confidence displayed by the SME and its management in the understanding of the ideas

Participant	Role
1	Applications support engineer
2	Software developer
3	Software developer
4	Mechanical designer

Table 7: SME roles of employees participating

	Participant			
Idea	1	2	3	4
A	2	2	4	3
B	5	3	5	4
C	1	1	1	2
D	4	4	2	5
E	3	5	3	1

Table 8: Participants rankings of presented ideas

Idea	Variance
A	0.92
B	0.92
C	0.25
D	1.58
E	2.67

Table 9: Idea variance

and the order in which they are placed in the ranking is increased; meaning they select opportunities to proceed with a clearer picture of the risk, context and the ideas.

Utilising a company accepted decision making technique using the same information, the ranking is slightly different to that given by the participants; this is shown in table 10.

From the ranking shown in table 10 and comparing it to these given by the participants in Table 8, there are distinct similarities. Furthermore, one of the participants matched the ranking via their understanding alone based on the presented information. This demonstrates a clear link between presenting information in a structured way and the ability to deliver a believable ranking of ideas. It is also important to note that the SME had sufficient confidence in the ranking to select Idea C for further development and are currently investigating routes to the required funding to conduct the project. In addition, subsequent low levels of investigation are also being conducted into Idea D to scope out how the project would proceed if it were selected for development.

The Directed Research Approach to investigate opportunities for a company's portfolio was developed within an SME. This can therefore instil the limitation of applicability to the wider world and similar companies due to the level of involvement and specificity towards the particular SME. To investigate the wider applicability of the proposed approach, several experts in the field of business investment were engaged. The selected experts were from The University of Bristol Research and Enterprise and Development section. Each of these organisa-

tions is focused on the investigation into potential business opportunities which they can invest in. These experts were presented with the proposed approach and the results from the testing within the SME and were asked to comment on the inclusion of all required data points and their source, the risk and context identified and the applicability of this approach outside of the SME.

When asked about the collected information and the sources selected the responses pointed to a general coverage of key points; However, aspects could expand to include the performance of the idea at hand (if any physical prototypes had been made). With respect to the sources of this information it was noted how in all cases the user will be subjective and the challenge faced is to not allow this to impact the process.

Next, when asked about the identified risk and context per opportunity additional aspects were identified that could be useful to understand. This included continuity of resources and the availability of skills within the company.

The final question asked if this same approach would be as applicable outside of the SME again, the general responses were that it would be. Some points made were how in different application areas or sectors, users would be "pre-calibrated" to utilise different language or terms and therefore an initial translation phase would be required to ensure the required understanding. In addition, in several areas, there are systems defined already to utilise the captured information, such as those by Innovate UK. Therefore, by introducing a new way to capture information repeatedly, the way in which that information was used would also require adjust-

Idea	Ranking
A	4
B	5
C	1
D	2
E	3

Table 10: Actual idea ranking

ment.

Based on the captured points above, several deductions can be made. Firstly, and most importantly, how the Directed Research Approach can be utilised outside of the environment and sector in which it was designed to operate. This is due to the spread of the information which is captured, its sources and the understanding of risks and contexts. However, due to the experts' experience in engaging with such projects and companies searching for resources, additional questions are asked and further information is desired to complete the picture in their minds such that differentiations can be drawn and decisions made. However, in the context where the proposed method was devised, an inherent knowledge of the ideas is held and the current state of the company as to skills and resources such that these points are not required to be researched. Therefore meaning, sufficient information on these ideas is held generally by all those involved and that captured via the approach proposed, adds to that such that the decisions can be made.

For other companies, including SMEs in other sectors and environments than this work, this has several implications. Firstly, the generic formulation means an understanding of the idea

can be obtained following a simple conversion of language and terminology to that which they are used to. Furthermore, they will have information already captured and understood about their company due to working in it; such as the resource availability and skill set at their disposal. Then by adding to this knowledge via the collection of information in relation to an idea with the Directed Research Approach, they will create a more complete understanding of an idea which can be utilised in a comparison process with other ideas to select their path forwards. Furthermore, by utilising the complete process outlined by the four phases of the Directed Research Approach yields the ability to follow a scripted set of actions with clear ownership such that ideas can be generated, researched, selected from and enacted. From here, additional ideas can be generated and the process begins again, allowing for continual and controlled evolution of the company's portfolio.

5 Conclusions

This research was initiated due to the need of a highly innovative SME requiring a consistent and repeatable method of capturing information for use in decision making as to the develop-

ment path they should select. Based on this, the Directed Research Approach was created by synthesising innovation structuring frameworks with identified risk and context. This was designed to allow for simple information collection for multiple opportunities to enable effective cross-comparison between them, to deliver the optimal path forwards. This information is to be joined with information already held by the users relating to the company itself and any prior work on the idea in question to create a complete picture. However, the Directed Research Approach is significantly more than a simple indication of which information to collect and where to collect it from. It includes several defined phases to lead the company through the generation of new ideas, researching them by defining the relevant information and directing selection prior to development.

For the SME that initiated this work, the impact was profound. Their conventional process involved an ad-hoc approach to information capture and decision making, meaning the repeatability and consistency were questionable. For an SME with several potential development paths this results in uncertainty as to the future state of their portfolio and the strategic direction of travel. Thus, creating a new decision approach delivered increased confidence in ranking by reducing uncertainty via consistent information capture. This was demonstrated via rankings with low variance during testing and the selection of one of the potential ideas to be invested in further. Furthermore, the defined four phase approach delivered a structure to the entire process from ideation to development, not just the collection of information.

In addition to the effects on the SME, the Directed Research Approach has wider applicability as demonstrated by the captured opinions of experts in the field. This shows how the same process of structured information capture as used within the SME can be utilised by any company conducting investigation into the available opportunities to advance their portfolio with minor alternations for language and terminology used. For SMEs in a similar position as the one which initiated this research, applying this approach could lead to similar increases in confidence in captured information and rankings, ultimately for the benefit of their portfolio and future.

Furthermore, by following the outlined Directed Research Approach, a process for the SME can be defined. Firstly, they will follow a prescribed series of phases including Ideation, Research, Selection and Development with defined inputs which will aid in tracking their progress. In addition, each of the phases will carry clear ownership and reporting lines for those who conduct the work required. Through this structure of phases, inputs, ownership, reporting lines and the process this creates, the Directed Research Approach can be deployed by any organisation, SMEs who require structure without being restricted as to their processes in order to guide them from ideation to development.

Acknowledgement. This work was supported by EPSRC under Grant EP/G037353/1 (IDC Systems) and iMETRUM Ltd. Additionally, we would like to thank the reviewers for their time and feedback. We are finally grateful for the understanding and patience of the editors during

these testing times.

References

- Abbassi M., Ashrafi M., Sharifi Tashnizi E. (2014). Selecting balanced portfolios of R&D projects with interdependencies: A cross-entropy based methodology. *Technovation*, 34(1): 54–63.
- Autio, E. et al., (2014). Entrepreneurial innovation: The importance of context. *Research Policy* 43(7): 1097–1108.
- Behrens, J., (2016). A Lack of Insight: An Experimental Analysis of R&D Managers’ Decision Making in Innovation Portfolio Management. *Creativity and Innovation Management* 25(2): 239–250.
- Bellantuono, N., Pontrandolfo, P. and Scozzi, B., (2013). Different practices for open innovation: a context-based approach. *Journal of Knowledge Management* 17(4): 558–568.
- Blake, M.K. and Hanson, S., (2005). Rethinking innovation: Context and gender. *Environment and Planning A* 37(4): 681–701.
- Brem, A. and Voigt, K.I., (2009). Integration of market pull and technology push in the corporate front end and innovation management-Insights from the German software industry. *Technovation* 29(5): 351–367.
- Brink, T., (2016). Governance of Innovation and Growth in Sme Networks. *International Journal of Innovation Management* 20(3): 1650052.
- Chesbrough, H.W., (2003). The Era of Open Innovation. *MIT Sloan Management Review* 44(3): 35–41.
- Chiesa, V. and Frattini, F., (2011). Commercializing technological innovation: Learning from failures in high-tech markets. *Journal of Product Innovation Management* 28(4): 437–454.
- Cohendet, P. et al., (2015). Knowing Communities in the Front End of Innovation. *Research-Technology Management*: 46–54.
- Coldrick, S. et al., (2005). An R&D options selection model for investment decisions. *Technovation* 25(3): 185–193.
- Conway, S. and Steward, F., (2009). *Managing and Shaping Innovation*, OUP Oxford.
- Cooper, R.G., (2013). Where Are All the Breakthrough New Products?: Using Portfolio Management to Boost Innovation. *Research-Technology Management* 56(5): 25–33.
- Cormican, K. and O’Sullivan, D., (2004). Auditing best practice for effective product innovation management. *Technovation* 24(10): 819–829.
- Costantino, F., Di Gravio, G. and Nonino, F., (2015). Project selection in project portfolio management: An artificial neural network model based on critical success factors. *International Journal of Project Management* 33(8): 1744–1754.
- Cruz-Gonzalez, J. et al., (2015). Open search strategies and firm performance: The different moderating role of technological environmental dynamism. *Technovation* 35: 32–45.

- Daniel, E.M., Ward, J.M. and Franken, A., (2014). A dynamic capabilities perspective of IS project portfolio management. *Journal of Strategic Information Systems* 23(2): 95–111.
- Van Der Duin, P. a., Ortt, J.R. and Aarts, W.T.M., (2014). Contextual innovation management using a stage-gate platform: The case of philips shaving and beauty. *Journal of Product Innovation Management* 31(3): 489–500.
- Eilat, H., Golany, B. and Shtub, A., (2006). Constructing and evaluating balanced portfolios of R&D projects with interactions: A DEA based methodology. *European Journal of Operational Research* 172(3): 1018–1039.
- Garud, R., Gehman, J. and Giuliani, A.P., (2014). Contextualizing entrepreneurial innovation: A narrative perspective. *Research Policy* 43(7): 1177–1188.
- Gupta, S. and Maltz, E., (2015). Interdependency, dynamism, and variety (IDV) network modeling to explain knowledge diffusion at the fuzzy front-end of innovation. *Journal of Business Research* 68(11): 2434–2442.
- Henriksen A. D., Traynor A. J. (1999). A practical R&D project-selection scoring tool. *IEEE Trans. Eng. Manag.* 46(2): 158–170.
- Herskovits, R., Grijalbo, M. and Tafur, J., (2013). Understanding the main drivers of value creation in an open innovation program. *International Entrepreneurship and Management Journal* 9(4): 631–640.
- Hoarau, H. and Kline, C., (2014). Science and industry: Sharing knowledge for innovation. *Annals of Tourism Research* 46: 44–61.
- Ignatius, J. et al., (2012). The impact of technological learning on NPD outcomes: The moderating effect of project complexity. *Technovation* 32(7–8): 452–463.
- Kaiser M. G., Arbi F. El, Ahlemann F. (2015). Successful project portfolio management beyond project selection techniques: Understanding the role of structural alignment. *Int. J. Proj. Manag.* 33(1): 126–139.
- Kashimura K., Tsukada Y., Kawasaki T., Kitagawa H., Maruyama Y. (2014). Design approach based on social science for social innovation business. *Hitachi Rev.* 63(9): 548–559.
- Kester, L., Hultink, E.J. and Griffin, A., (2014). An empirical investigation of the antecedents and outcomes of NPD portfolio success. *Journal of Product Innovation Management* 31(6): 1199–1213.
- Khurum, M., Fricker, S. and Gorschek, T., (2014). The contextual nature of innovation - An empirical investigation of three software intensive products. *Information and Software Technology* 57: 595–613.
- Kihlander, I. and Ritzen, S., (2012). Compatibility before completeness - Identifying intrinsic conflicts in concept decision making for technical systems. *Technovation* 32(2): 79–89.
- Kock, A., Heising, W. and Gemünden, H.G., (2015). How ideation portfolio management influences front-end success. *Journal of Product Innovation Management*, 32(4): 539–555.
- Koen, P., Bertels, H.M.J. and Kleinschmidt, E.J., (2014). Managing the front end of

- innovation-part II: Results from a three-year study. *Research Technology Management* 57(3): 25–35.
- Kokshagina, O. et al., (2016). Portfolio Management in Double Unknown Situations: Technological Platforms and the Role of Cross-Application Managers. *Creativity and Innovation Management* 25(2): 270–291.
- Kollmer, H. and Dowling, M., (2004). Licensing as a commercialisation strategy for new technology-based firms. *Research Policy* 33(8): 1141–1151.
- Laforet, S., (2013). Organizational innovation outcomes in SMEs: Effects of age, size, and sector. *Journal of World Business* 48(4): 490–502.
- Lamb, C.W., Hair, J.F. and McDaniel, C.D. (2009). *Essentials of Marketing*, South-Western.
- Lee, N., Sameen, H. and Cowling, M., (2015). Access to finance for innovative SMEs since the financial crisis. *Research Policy* 44(2): 370–380.
- Leithold, N. et al., 2016. Optimising NPD in SMEs: a best practice approach. Benchmarking: An International Journal, 23(1), pp.262–284.
- Liao, Y. and Barnes, J., (2015). Knowledge acquisition and product innovation flexibility in SMEs. *Business Process Management Journal* 21(6): 1257–1278.
- Markman, G., (2008). Research and technology commercialization. *Journal of Management Studies* 45(Dec.): 1401–1423.
- Markman, G.D., Gianiodis, P.T. and Phan, P.H., (2009). Supply-Side Innovation and Technology Commercialization. *Journal of Management Studies* 46(4): 625–649.
- Martinsuo, M., (2013). Project portfolio management in practice and in context. *International Journal of Project Management* 31(6): 794–803.
- Martinsuo, M., Poskela, J., (2011). Use of evaluation criteria and innovation performance in the front end of innovation BT. *Journal of Product Innovation Management* 28(6): 896–914.
- McAdam, R., O’Hare, T. and Moffett, S., (2008). Collaborative knowledge sharing in Composite New Product Development: An aerospace study. *Technovation* 28(5): 245–256.
- McAdam R., Reid R., Shevlin M. (2014). Determinants for innovation implementation at SME and inter SME levels within peripheral regions. *Int. J. Entrep. Behav. Res.* 20(1): 66–90.
- McNally, R.C., Durmuşoğlu, S.S. and Calantone, R.J., (2013). New product portfolio management decisions: Antecedents and consequences. *Journal of Product Innovation Management*, 30(2): 245–261.
- Meifort, A. (2015). Innovation Portfolio Management: A Synthesis and Research Agenda. *Creativity & Innovation Management* 25(2): 251–269.
- Mishly, M.A., Tereso, A., (2016). Preliminary research plan towards a project and portfolio management framework to support

- innovation-driven SMEs. *Proc. of 3rd International Conference on Project Evaluation: 247–253.*
- Mitchell, R., Phaal, R. and Athanassopoulou, N., (2014). Scoring methods for prioritizing and selecting innovation projects. *Proc. of PICMET 2014 - Portland International Center for Management of Engineering and Technology: Infrastructure and Service Integration* 907–920
- O'Connor, G.C. and Rice, M.P., (2013). A Comprehensive Model of Uncertainty Associated with Radical Innovation. *Journal of Product Innovation Management* 30: 2–18.
- Ortt, J.R. and Duin, P. a. Van Der, (2008). The evolution of innovation management towards contextual innovation. *European Journal of Innovation Management* 11(4): 522–538.
- Partanen, J. et al., (2008). Social capital in the growth of science-and-technology-based SMEs. *Industrial Marketing Management* 37(5): 513–522.
- Pashley, D., Tryfonas, T., Crossley, A., Setchell, C. (2017). *Journal on Advances in Intelligent Systems* 10(3/4): 327–344.
- Patanakul, P., (2013). Key drivers of effectiveness in managing a group of multiple projects. *IEEE Transactions on Engineering Management* 60(1): 4–17.
- Pink, S. et al., (2010). Ethnographic methodologies for construction research: knowing, practice and interventions. *Building Research & Information* 38(6): 647–659.
- Poirier, E., Staub-French, S. & Forgues, D., (2015). Embedded contexts of innovation. *Construction Innovation* 15(1): 42–65.
- Poorkavoos, M. et al., (2016). Identifying the configurational paths to innovation in SMEs: A fuzzy-set qualitative comparative analysis. *Journal of Business Research* 69(12): 5843–5854.
- Purificato, M., 2014. The Open Innovation Paradigm in Electric Vehicle Industry: A Case Study of Tesla Motors Table. LUISS Guido Carli.
- Reidolf, M., (2016). Knowledge, Innovation and Technology Across Borders Knowledge networks and the nature of knowledge relationships of innovative rural SMEs. *European Journal of Innovation Management* 19(3): 317–336.
- Sperry, R., Jetter, A. (2009). Theoretical framework for managing the front end of innovation under uncertainty. *Proceedings of PICMET: Portland International Center for Management of Engineering and Technology: 2021–2028.*
- Staniewski, M.W., Nowacki, R. and Awruk, K., (2016). Entrepreneurship and innovativeness of small and medium-sized construction enterprises. *International Entrepreneurship and Management Journal* 12(3): 861–877.
- Stevens, E., (2014). Fuzzy front-end learning strategies: Exploration of a high-tech company. *Technovation* 34(8): 431–440.
- Tian, Q. et al., (2005). An organizational decision support system for effective R&D project

- selection. *Decision Support Systems* 39(3): 403–413.
- Tidd, J. and Bessant, J., (2013). *Managing Innovation: Integrating Technological, Market and Organizational Change*, Wiley.
- Trotter, P.J., (2011). A New Modified Total Front End Framework for Innovation: New Insights From Health Related Industries. *International Journal of Innovation Management* 15(5): 1013–1041.
- Westland, J.C., (2008). *Global Innovation Management: A Strategic Approach*, Palgrave Macmillan.
- Daniel Pashley** is Production Controller with iMETRUM Ltd. in Bristol, UK. He holds an EngD in Systems from the University of Bristol and a BSc and MSc in Computer Science from the University of Lincoln.
- Theo Tryfonas** is Associate Professor of Smart Cities and Urban Innovation with the University of Bristol, UK. He holds PhD and MSc degrees from Athens University of Economics and Business and a BSc in Computer Science from the University of Crete in Greece.
- Andy Crossley** is a Senior Lecturer in Project and Performance Management at the University of Bristol, UK. He is a Chartered Civil Engineer with a BSc and an MBA among his qualifications.
- Chris Setchell** is the Director of iMETRUM Ltd. He holds a PhD in computer science from the University of Bristol and has previously held a postdoctoral research post with the Department of Computer Science there.
- Stylianos Karatzas** is Research Project Manager with the University of Patras in Greece. He holds a PhD and MEng from the University of Patras and an MSc from the University of Bath.