

# ABSORPTIVE CAPACITY IN INTELLIGENT MOBILITY

A REPORT FOR TRANSPORT SYSTEMS CATAPULT

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**CATAPULT**  
Transport Systems

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# CONTENTS

Executive summary .....	4
<b>1. Introduction.....</b>	<b>6</b>
1.1 TSC and Intelligent Mobility .....	6
1.2 The importance of Absorptive Capacity.....	8
<b>2. Designing an index for the Intelligent Mobility market .....</b>	<b>9</b>
2.1 Why take an index approach? .....	9
2.2 Our approach to developing and index in this study .....	10
<b>3. A focus on three IM market segments .....</b>	<b>13</b>
3.1 Which priority market segments did we focus on? .....	13
3.2 The survey sample.....	16
<b>4. Headline results.....</b>	<b>22</b>
4.1 Regression analysis .....	23
4.2 What do differences in scores mean for survey responses? .....	32
<b>5. Conclusions and Recommendations .....</b>	<b>35</b>
5.1 Have we measured Absorptive Capacity Successfully? .....	35
5.2 Firm level insights.....	36
5.3 What it means for TSC, Innovate UK and wider government stakeholders .....	37
5.4 Recommendations .....	41
<b>6. Appendix 1 – Case studies .....</b>	<b>42</b>
<b>7. Appendix 2 – Survey questionnaire.....</b>	<b>56</b>
<b>8. Appendix 3 – Detailed IM market segments .....</b>	<b>76</b>
<b>9. Appendix 4 – Index development methodology.....</b>	<b>78</b>
<b>10. Appendix 5 – Bibliography.....</b>	<b>80</b>

# EXECUTIVE SUMMARY

As part of its Technology Strategy for Intelligent Mobility, the Transport Systems Catapult (TSC) selected seven specific Intelligent Mobility (IM) market segments to support in the years ahead. Each were selected according to four main criteria (paired into two overarching requirements).

Market segments were chosen that were either:

1. forecast to be large AND where the UK possessed a strong capability; or
2. had a predicted growth rate that was exceptionally high AND where no established market leaders existed at the time.

The resulting seven priority market segments identified in TSC's Technology Strategy were:

1. intermodal smart ticketing;
2. security, resilience, and cyber security;
3. Internet of Things (IoT) asset management (road);
4. monitoring and management systems for road infrastructure;
5. data management and analysis;
6. data collection and communication platforms; and
7. autonomous vehicles.

A 2016 review of the selection criteria by Oxford Economics suggested a number of further areas for TSC to consider.<sup>1</sup> These included the market structures of individual priority market segments, the downstream capabilities of firms to support cost-competitive production, and the extent of Absorptive Capacity in each of the seven priority market segments.

TSC have now commissioned Oxford Economics to undertake a feasibility study to help it understand if Absorptive Capacity could be measured in different IM market segments. Defined as the ability of companies to exploit external information, this study seeks to measure the ability of companies to turn innovation activities into commercial gain.

This feasibility study used four distinct but complementary capabilities identified in the literature to measure Absorptive Capacity: knowledge acquisition, assimilation, transformation and exploitation. A survey of 1,413 firms in three of TSC's priority market segments—autonomous vehicles, data collection and communication platforms, and security, resilience and cyber security—was then used to develop an index measure of Absorptive

Capacity. Analysis of the index helped to test the efficacy of this measurement framework and to gather insights that TSC and wider stakeholders can use to help target support to firms in these priority market segments. Case studies of 11 firms and Innovate UK were also used to shed light on observed trends in the data.

Analysis of the survey data yielded the following key results:

1. Larger firms achieve higher scores—specifically, firms that have revenues of over £10 million or employ more than 50 people on average score higher statistically than comparative smaller firms, especially in their knowledge acquisition and exploitation capabilities.
2. The share of graduates has a bearing on index scores—firms with over 30 percent of graduates score more highly than firms with lower shares of graduates.
3. Firms currently operating in each market score higher than firms planning entry in the next five years—on the face of this, this may point towards supporting potential new entrants who might otherwise struggle to exploit knowledge.
4. Being headquartered in London and the South East is associated with higher index scores—this could be evidence of agglomeration economies developing in these IM market segments, though further analysis would be required to confirm this.
5. Access to skills and talent is the biggest barrier for firms in the sample—closely followed by a perceived lack of support and guidance from government.
6. Firm investment behaviour is important—investing over five percent of revenue in internal and external R&D and in hiring staff with specialist skills is associated with higher index scores.

As a measurement exercise, the absence of an objective test means it is difficult to say with certainty whether our methodology is in fact capturing Absorptive Capacity. However, that it yields results which are plausible and would be expected, a priori, gives some comfort that we are measuring something that is at least closely related to Absorptive Capacity, if not Absorptive Capacity itself.

For firms, the tentative results from this feasibility study suggest some clear actions. On this evidence it would be in their interests to invest more in R&D, hire more specialists, invest in improving their knowledge absorption capabilities, and partner with other firms.

For TSC, Innovate UK and wider government stakeholders, on the other hand, understanding the direction of causality in the potential relationships identified in this study will be very important. Does a higher turnover lead to greater Absorptive Capacity, or does greater Absorptive Capacity help small firms become big firms? Are graduates attracted to firms with high Absorptive Capacity, or do firms have high Absorptive Capacity because they have high shares of graduate staff? These are vitally important questions even if answering them is out of scope for this feasibility study. For TSC in particular, the priority should be to understand the dynamics between Absorptive Capacity and firm size, as this will have important implications for both the types of firms it supports in the IM sector and how it supports them.

<sup>1</sup> Oxford Economics, "TSC Technology Strategy: Economic assessment of the framework for market prioritisation" <[https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2016/03/26105726/Technology\\_Strategy\\_Economic\\_Assessment.pdf](https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2016/03/26105726/Technology_Strategy_Economic_Assessment.pdf)>

# INTRODUCTION

## KEY POINTS

- TSC aims to position the UK as a world leader in Intelligent Mobility (IM).
- It has identified seven priority market segments to support in the years ahead.
- A key factor that will determine whether UK firms can exploit market opportunities and flourish in IM will be how well they take on board knowledge from outside their own organisations.
- This study seeks to develop an index that measures the capacity of firms to do this.
- This index approach has been complemented by qualitative insight gathered through a series of in-depth semi-structured interviews with firms either working in Intelligent Mobility or who have the capabilities to work in the sector.

## 1.1 TSC AND INTELLIGENT MOBILITY

TSC's mission is to help UK businesses to create products and services that enable the world's transport systems to respond to ever-stretching demand. In doing so, TSC aims to position the UK as a world leader in the estimated £900 billion<sup>2</sup> Intelligent Mobility (IM), which uses the latest technology to move people and goods around faster and smarter.

To best ensure delivery against this ambition, in 2014 TSC selected seven specific IM market segments to support in the years ahead. Each were selected according to four main criteria (paired into two overarching requirements).

Market segments were chosen that were either:

1. forecast to be large AND where the UK possessed a strong capability; or
2. had a predicted growth rate that was exceptionally high AND where no established market leaders existed at the time.

The resulting seven priority market segments identified in TSC's Technology Strategy were:

1. intermodal smart ticketing;
2. security, resilience, and cyber security;
3. Internet of Things (IoT) asset management (road);

<sup>2</sup>Transport Systems Catapult, "Tech Strategy", in Transport Systems Catapult <[http://tsctechstrategy.co.uk/wp-content/uploads/2016/04/Tech\\_Strategy\\_Brochure.pdf](http://tsctechstrategy.co.uk/wp-content/uploads/2016/04/Tech_Strategy_Brochure.pdf)>

4. monitoring and management systems for road infrastructure;
5. data management and analysis;
6. data collection and communication platforms; and
7. autonomous vehicles.

A 2016 review of the selection criteria by Oxford Economics suggested a number of further areas for TSC to consider.<sup>3</sup> These included considering the market structures of individual priority market segments, as well as the downstream capabilities of firms to support cost-competitive production, and the extent of Absorptive Capacity in each of the seven priority market segments.

Following this work, TSC has now commissioned Oxford Economics to undertake a feasibility study to help it understand if Absorptive Capacity can be measured in different Intelligent Mobility market segments. Defined as the ability of companies to exploit external information, this study seeks to measure the ability of companies to turn innovation activities into commercial gain. Knowing what drives and underpins Absorptive Capacity will help TSC, Innovate UK and wider stakeholders within government to target support to companies in the seven priority market segments and inform policy. However, further work may be needed to fully understand those drivers, work that is out of scope for this feasibility study.

The remainder of this chapter examines the concept of Absorptive Capacity in more detail and the conceptual framework that has been used to measure it in this study. Chapter 2 then sets out our methodological approach to measurement, while Chapter 3 looks in more detail at the priority market segments that are the focus of this study, as well as the characteristics of the sample of firms from which data has been collected. Chapter 4 gives the headline results of our analysis and, finally, Chapter 5 examines the implications of those results, both from the perspective of a measurement exercise and in terms of what those results potentially mean for policy. Chapter 5 also includes recommended next steps for this study.

<sup>3</sup>Oxford Economics, "TSC Technology Strategy: Economic assessment of the framework for market prioritisation" <[https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2016/03/26105726/Technology\\_Strategy\\_Economic\\_Assessment.pdf](https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2016/03/26105726/Technology_Strategy_Economic_Assessment.pdf)>

## 1.2 THE IMPORTANCE OF ABSORPTIVE CAPACITY

The term Absorptive Capacity was introduced by Cohen and Levinthal in 1990 and originally referred to the ability of a firm to identify, assimilate and exploit external information.<sup>4</sup> It has since been reconceptualised by Zahra and George as “[...] a set of organisational routines and processes by which firms acquire, assimilate, transform and exploit knowledge to produce a dynamic organisational capability”.<sup>5</sup>

By acquiring external knowledge, firms are able to widen their knowledge and bring in new ideas that can aid the innovation process. This can be critical for firms to gain a foothold in fast-evolving, nascent markets. Absorptive Capacity is not only valuable to how effectively firms innovate but also to how they create and sustain a competitive advantage.

Through the knowledge absorption process firms can expand their knowledge pool beyond what is feasible internally. As a hugely valuable strategic resource for a firm, knowledge is valuable in its own right, but its accumulation also adds to the development of organisational capabilities.<sup>6</sup> In other words, the routines and processes involved in absorbing external knowledge for the purpose of innovation can influence the ability of firms to exploit knowledge for other purposes too. This can lead to the development of a diverse set of knowledge-based assets and organisational capabilities, which enable firms to respond more flexibly to fluctuations in their market environment, allowing them to maintain a competitive advantage.

Having UK firms with effective knowledge absorption capabilities is important if TSC is to achieve its aim of positioning the UK as a world leader in the IM market. Both establishing a position in the IM market and having the capability to sustain a competitive advantage will be pivotal if the UK is to cement itself as a world leader.

The definition of Absorptive Capacity given by Zahra and George identifies four distinct but complementary capabilities: acquisition, assimilation, transformation and exploitation.<sup>7</sup> These are defined in Fig. 1 below.

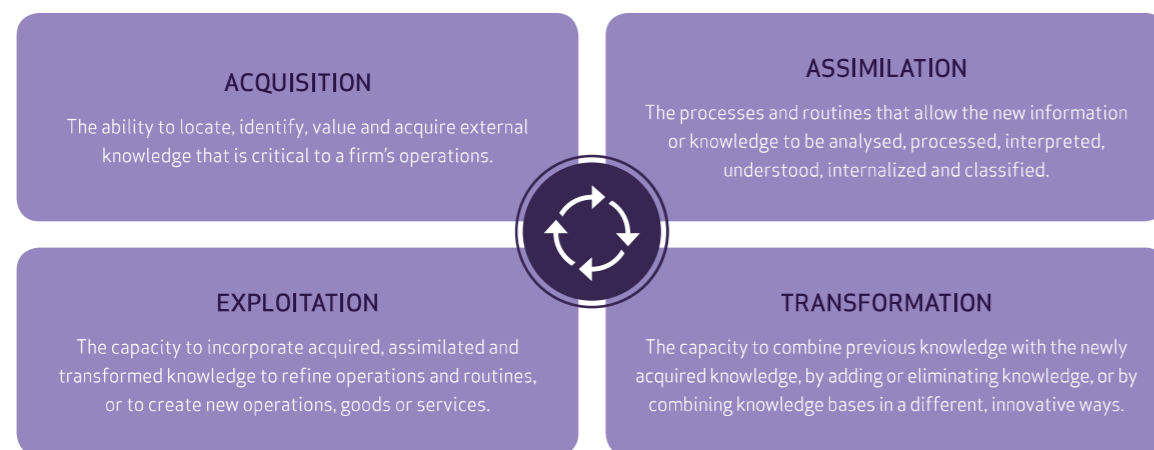


FIGURE 1: Absorptive Capacity and its four underlying capabilities

This provides a clear conceptual framework which has been used in this study to construct an Absorptive Capacity index.

<sup>4</sup>Cohen, W.M., and Levinthal, D.A., "Absorptive Capacity: A new perspective on learning and innovation", *Administrative Science Quarterly*, 1990: 128-52.

<sup>5</sup>Zahra, S.A., and George, G., "Absorptive Capacity: a review, reconceptualization, and extension", *Academy of Management Review*, 2002: 185-203.

<sup>6</sup>Lewandowski, M.S., "Capturing Absorptive Capacity: concepts, determinants, measurement modes and role in open innovation", *International Journal of Management and Economics*, 2015: 32-56.

<sup>7</sup>Zahra, S.A., and George, G., "Absorptive Capacity: a review, reconceptualization, and extension", *Academy of Management Review*, 2002: 185-203.

## 2. DESIGNING AN INDEX FOR THE INTELLIGENT MOBILITY MARKET

### KEY POINTS

- We used an index approach to measuring Absorptive Capacity as this enables us to capture the multi-dimensionality of the concept most effectively.
- There were three steps to the index construction process in this study—designing and testing a survey questionnaire; identifying relevant firms in IM market segments; and designing the index using responses to the survey.
- A survey questionnaire was developed building on approaches taken in the wider Absorptive Capacity literature.
- Using IM market segment definitions and associated key words, North American Industry Classifications System (NAICS) codes were identified and applied to international business directories to identify potentially relevant firms in the UK. Firms were then invited to participate in the survey at random.
- In the survey, participating firms were asked how their offer aligned (or could potentially align) to IM market segments, as a way of filtering out those that were not relevant to the study.
- Responses to survey questions were then used to develop the index measure.

### 2.1 WHY TAKE AN INDEX APPROACH?

A number of approaches have been taken in the wider literature to measure Absorptive Capacity. Broadly, they fall into three categories: measuring 'inputs', measuring 'outputs', and taking an index-based approach.

Input-related measures have generally used research and development (R&D) measures as a proxy for Absorptive Capacity. Examples might include things like R&D intensity (R&D expenditure divided by total revenue), and measures that capture the number of staff working in R&D-dedicated roles.<sup>8</sup> There are advantages to this approach. Firstly, R&D activity is an important indicator of the innovation competence of a firm and therefore its Absorptive Capacity. Secondly, collecting these kinds of input data is relatively straightforward, and they are easily comparable across studies. Despite these advantages, the main drawback of input-type measures is that they are unable to capture the widely accepted multi-dimensional nature of Absorptive Capacity.

<sup>8</sup>Oltra, M., Flor, M., "The impact of technological opportunities and innovative capabilities on firms' output", *Creativity & Innovation Management*, 2003: 137. Zahra, S. A., Hayton, J. C., "The effect of international venturing on firm performance: the moderating", *Journal of Business Venturing*, 2008: 195-220.

Output indicators have usually been one-dimensional in their focus as well— commonly using patent-related indicators, such as the number of patents registered by firms as a means to measure their Absorptive Capacity.<sup>9</sup> Though such measures are a good indicator of innovation competence, they are much more relevant to some sectors, like manufacturing where patents are common, than others, making it difficult to use these measures to look at Absorptive Capacity across different industries.

Index-related measures are increasingly being used in the literature in an effort to overcome some of these weaknesses.<sup>10</sup> Index measures combine indicators associated with the four underlying components of Absorptive Capacity, to capture the multi-dimensionality that input- and output-related measures cannot. The weakness of this kind of approach, however, is that the complexity that comes with combining a variety of underlying measures makes comparison between indices difficult. On balance, given that this is a feasibility study of emerging sectors which have little in the way of directly comparable studies, the benefits of using an index approach were felt to outweigh the drawbacks.

## 2.2 OUR APPROACH TO DEVELOPING AND INDEX IN THIS STUDY

The process for developing an index in this study followed a three step process:

- **Step 1** – Design and test a survey questionnaire
- **Step 2** – Identify relevant firms in IM market segments
- **Step 3** – Use indicators generated by the survey to populate an Absorptive Capacity index

This section sets out each step in detail.

### 2.2.1 Step 1 – Design and test a survey questionnaire

The aim of this first step was to design a questionnaire which sought to measure each of the four capabilities of knowledge absorption as defined by Zahra and George—acquisition, assimilation, transformation and exploitation. One approach could have been to look at knowledge absorption as it relates to specific types of technologies and market segments. However, given the need to design a survey that could be used across different market segments, a general definition of ‘knowledge’ was used.

The process of developing the questionnaire began with a review of the literature to identify questions that had been used in past Absorptive Capacity studies. This was supplemented by a joint TSC and Oxford Economics view on other useful indicators to collect. The resulting survey can be broadly divided into six sections.<sup>11</sup> The first covers company demographics, including turnover; number of employees; region in which the company headquarters are based; and percentage of staff with STEM and other tertiary qualifications.<sup>12</sup> The first section also allows companies to identify to which market segment their goods and services most closely align, and which subsequent subsectors are most applicable to their offerings.

<sup>9</sup> Cockburn, I. M., Henderson, R. N., “Absorptive capacity, co-authoring behaviour, and the organization”, *Journal of Industrial Economics*, 1998: 157–82. Ahuja, G., Katila, R., “Technological acquisitions and the innovation performance of acquiring firms:”, *Strategic Management Journal*, 2001: 197–220.

<sup>10</sup> Jansen, J. J. P., Van den Bosch, F. A. J., Volberda, H. W., “Managing potential and realized absorptive capacity: how do organizational antecedents matter?”, *Academy of Management Journal*, 2005: 999–1015. Nieto, M., Quevedo, P., “Absorptive capacity, technological opportunity, knowledge spillovers, and innovative effort”, *Technovation*, 2005: 1141–57. Flatten, T. C., Engelen, A., Shaker A. Zahra, M. B., “A measure of absorptive capacity: Scale development and validation”, *European Management Journal*, 2011: 98–116.

<sup>11</sup> For the full survey questionnaire, see Appendix 2—Survey questionnaire

<sup>12</sup> Science, Technology, Engineering and Maths

The second section covers innovation activity by companies. Using the Community Innovation Survey as a key input, this section collects information on the input-type indicators of Absorptive Capacity such as investment in internal and external R&D; and hiring of staff with specialist staff. This section also collects information on other measures including the purchase of advanced machinery; and intellectual property assets such as patents.

The next four sections of the survey seek to capture information about each of the four capabilities of knowledge absorption.<sup>13</sup> Questions covering specific barriers to knowledge absorption are also included in the questionnaire.

The survey was designed to be administered over the telephone – a good way of ensuring the right individual within an organisation is surveyed (C-level and direct reports).<sup>14</sup> It was also designed to last 25 minutes, and use a mixture of question types to avoid respondent fatigue. Anonymity of respondents was also used to encourage full and frank answers.

Finally, the questionnaire was tested on a small panel of five TSC-partner organisations to ensure sufficient information to construct the index could be collected within the 25-minute period.<sup>15</sup>

### 2.2.2 Step 2 – Identifying relevant firms in IM market segments

Step two of the design process involved identifying the population of firms from which a survey sample could be drawn. The ideal starting point in an exercise of this type would be to use the Standard Industry Classification (SIC) code system to identify market segments as they appear in national accounts. However, as with many new and emerging sectors, the current SIC code system does not align very well with IM market segments. Instead, relevant companies are split across multiple SIC codes, which also contain firms that are not relevant to IM. This made identifying the true population of companies in these nascent industries, or with the potential to operate in these market segments, particularly difficult. In the absence of this information, the process of identifying relevant companies for the study used the following steps.

<sup>13</sup> See Appendix 2— Survey questionnaire for a brief summary of how questions, sourced from the literature, relating to the four capabilities were selected.

<sup>14</sup> Telephone interviews were conducted by Phronesis Partners, an independent survey provider.

<sup>15</sup> For further details please contact TSC

First, detailed IM market definitions (see section 3.1) were used to identify a list of the closest aligning SIC codes. A set of keywords which, in our view, are synonymous with the types of firms that could potentially operate in these market segments were also identified. Together, these SIC codes and keywords were used to identify a list of North American Industry Classification System (NAICS) codes. NAICS codes have the advantage of being slightly more detailed than SIC codes, and are also widely used by international business directories such as Hoovers and Capital IQ. Any UK companies listed in these directories that met the NAICS code criteria were then considered potentially part of the ‘universe’ of firms that would be relevant for the study. This group was then randomly sampled to participate in the survey.

However, it still remained possible that a fair portion of these firms would not in fact be relevant, despite fulfilling the NAICS criteria. To ensure the survey sample included only companies that really were relevant, a final stage was undertaken to check and account for this.

1. Using the AV market segment as a pilot, a sample of just over 50 AV firms located in the directories using the NAICS code approach was reviewed for relevance to the study, through a search of their company websites. This analysis found that 60 percent of identified companies were relevant.
2. Though encouraging, it remained important to find a way to filter out those that were not well-matched. The survey questionnaire, therefore, was adapted to include a question asking firms which IM market segment best aligned to their goods and services. Specifically, participating firms were asked whether they currently operate in one of the IM market segments, whether they planned to operate in one of the market segments in the next five years, or whether they had the capabilities to operate but were not planning to enter IM. By allowing firms to self-select in this way, those that did not have capabilities to operate in the IM market segments could be filtered out completely from the study.<sup>16</sup>

Four subsectors of the AV market segment were surveyed first as a ‘proof of concept’ before the survey was rolled out fully.<sup>17</sup>

### 2.2.3 Step 3 – Use survey outputs to develop an Absorptive Capacity index

Responses to survey questions associated with the four capabilities of knowledge absorption were then used to develop indicators. These indicators have been combined to give each surveyed firm an Absorptive Capacity index score.<sup>18</sup> Index results were then analysed using regression analysis to test whether relationships that we would expect to hold between Absorptive Capacity and firm characteristics a priori were visible in the data. Regression analysis also allowed to see whether any insights could be drawn about how TSC and wider stakeholders can target support to firms in IM priority market segments.

The next section looks at the specific IM priority market segments that were the focus of this study, and describes the sample of firms that were identified through the process described in Step 2 above.

<sup>16</sup>The survey ended at that point for those firms.

<sup>17</sup>Control systems, localisation and mapping, connectivity and sensing.

<sup>18</sup>For details of our methodological approach to constructing the index, see Appendix 4 – Index development methodology

## 3. A FOCUS ON THREE IM MARKET SEGMENTS

### KEY POINTS

- At this feasibility stage, we have focused on three of TSC’s seven priority market segments: autonomous vehicles; data collection and communication platforms; and security, resilience, and cyber security.
- Each of these market segments were defined at the subsector level to ensure that the study could take as broad a view of each market segment as possible.
- A sample of 1,413 firms was built up of quotas of at least 50 firms in each of the identified subsectors.
- Some 75 percent of companies surveyed had a turnover under £50 million, while 57 percent employed fewer than 100 people. The highest proportion of firms were based in London (27 percent).
- Firms that have more than 30 percent of staff with graduate qualifications accounted for more than half the sample.
- Half of all firms surveyed were currently operating in at least one of the three priority market segments, a further third intended to do so within the next five years, and the remainder had no plans to operate in any of the priority market segments.

### 3.1 WHICH PRIORITY MARKET SEGMENTS DID WE FOCUS ON?

As a feasibility study, only three of the seven priority market segments are in scope at this stage:

1. The autonomous vehicles (AV) market segment—specifically, the market for technologies that enable vehicles to operate without human intervention.
2. The data collection and communication platforms (DCCP) market segment— in particular, technologies that acquire and transmit data for both real-time and offline processing.
3. The security, resilience, and cyber security (SRCS) market segment—primarily, technologies that help assess, monitor, evaluate, report and mitigate risks related to transportation vehicles and infrastructure.

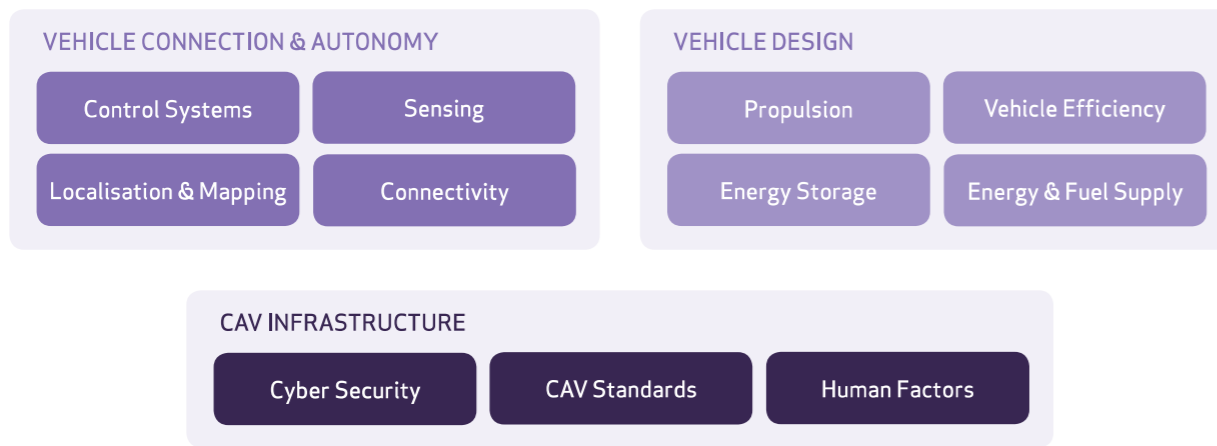
These particular segments were chosen as the starting point for this study because of the overlap they share with other priority market segments. Also, in TSC's experience, firms operating within these market segments tend to be very mixed, in terms of size, location, etc., important factors in our subsequent analysis.

The next sections examine each market segment and their underlying subsectors in more detail.

### 3.1.1 The AV market segment

In the simplest terms, autonomous vehicles are vehicles that are capable of controlling themselves. To do this, a vehicle must be able to perceive its environment, make decisions about where is safe and desirable to move, and do so. It can also be possible for a vehicle to be only partially autonomous, so that some decisions are made by a human driver, and some by the machine itself.<sup>19</sup> The 'Vehicle Connection & Autonomy' cluster of sub-segments relate to on-board technologies which include capabilities associated with SAE Levels 1-5, whilst various other off-board sub-segments are considered, as defined in Fig. 2.<sup>20</sup>

As noted earlier, the broad scope of the AV market segment and its overlaps with a number of other IM priority market segments was part of the benefit of selecting it in this feasibility study. Fig. 2, developed for this project, disaggregates the AV market segment into its key component technologies. The specific components, and by extension subsectors, are highlighted, with the exception of cyber security, which features in the SRCS market segment.



Source: Transport Systems Catapult

FIGURE 2: AV market definition.

As Fig. 2 suggests, an emphasis has been placed on the autonomy components of the market segment in this study, as opposed to the more traditional automotive supply chain. The breadth of the market segment also means that overlaps (such as cyber security and human factors) are only captured in one market segment for the purposes of this study. Finally, the scope of the market segment was limited such that only the 'on-road' AV market is captured. Detailed descriptions of each of the subsectors are provided in Appendix 3 – Detailed IM market segments.

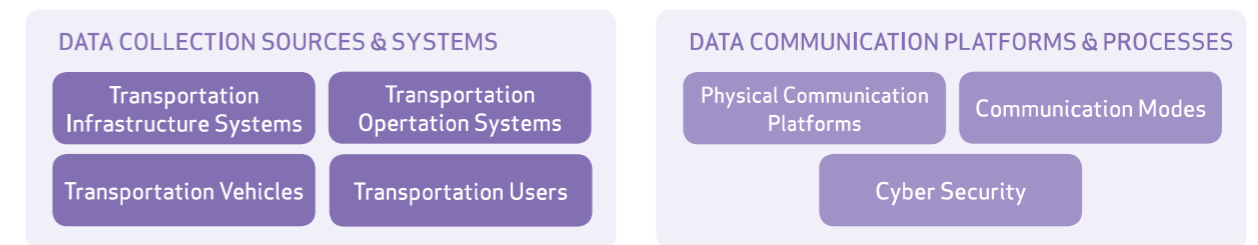
<sup>19</sup>Lloyd's Register Foundation, "Foresight review of robotics and autonomous systems" (unpublished thesis, 2016).

<sup>20</sup>SAE International J3016

### 3.1.2 The DCCP market segment

The DCCP market segment encompasses the real-time collection of data through sensors and CCTV cameras, and the communication process that enables remote access to the data. These systems underpin vehicle-to-vehicles (V2V) and vehicle-to-infrastructure (V2I) communication, and are therefore key enablers to autonomous vehicles operations.

In this study, the DCCP market segment has been divided into two areas—data collection sources and systems, and data communication platforms and process. Fig. 3 below shows the subsectors that constitute both of these areas. Again, the cyber security subsector has been captured for in the SRCS market segment.



Source: Transport Systems Catapult

FIGURE 3: DCCP market definition.

### 3.1.3 The SRCS market segment

Finally, the SRCS market segment comprises a wide range of products and services that reduce the likelihood (security) or minimise the impact (resilience) of disruptions to a transportation system. In doing so, technologies in this market segment help to address both accidental and malicious incidents, as well as natural impacts on the products that they protect.

Products and services in this market segment can be stand-alone (e.g. surveillance and screening equipment, risk profiling analytics) or integrated with other applications (e.g. passenger management services, emergency route-optimisation algorithms). In addition, most products and services in this market segment are transferable to other markets besides transportation.



In this study, the SRCS market segment has been subdivided into three areas—infrastructure security, network cyber security and infrastructure resilience. Again, Fig. 4 shows the subsectors that constitute each of these areas.

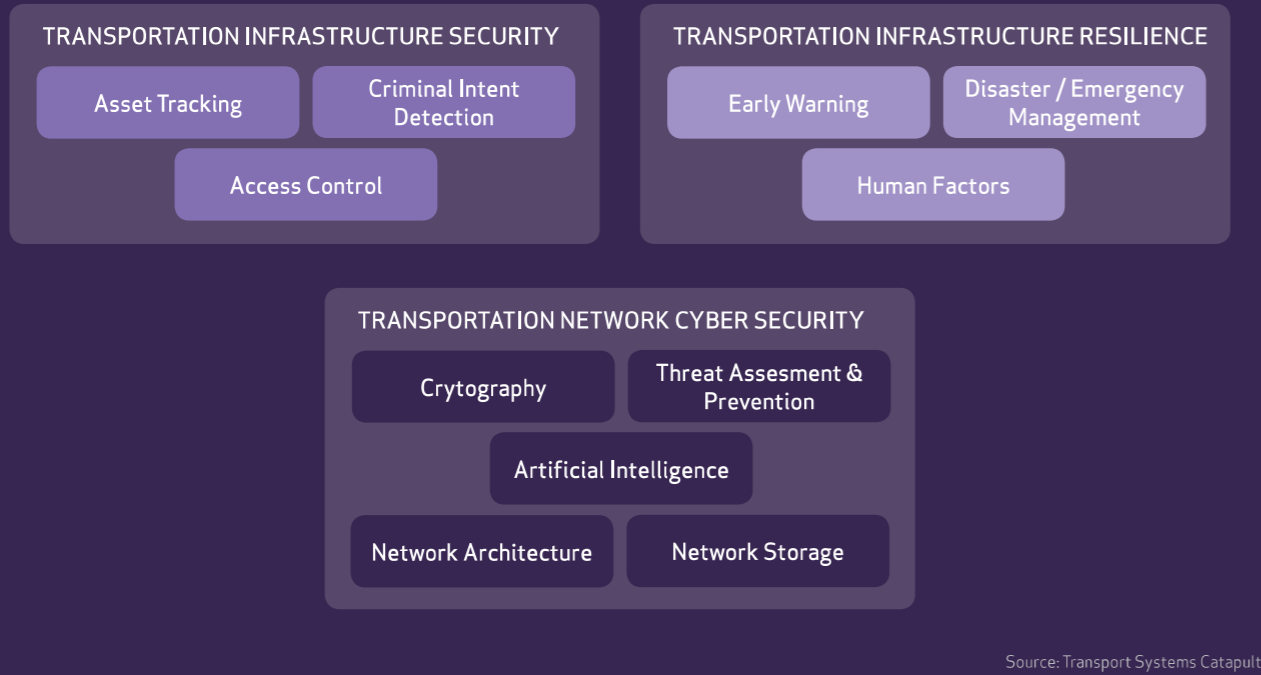


FIGURE 4: SRCS market definition.

### 3.2 THE SURVEY SAMPLE

These market definitions, combined with the process for identifying companies described in section 2.2.2 were used to identify the survey sample.

Running in two phases (the first being the pilot of 200 AV firms) from the end of November 2016 until the first week of March 2017, a total of 3,324 firms were invited to participate in the survey. Of these, 1,977 agreed to participate, of which a further 476 were filtered out by the self-selection question and 88 failed to finish the survey for one reason or another.<sup>21</sup> The remaining 1,413 firms that successfully completed the survey were split across the three market segments as follows.

<sup>21</sup> Respondents who ran out of time for example

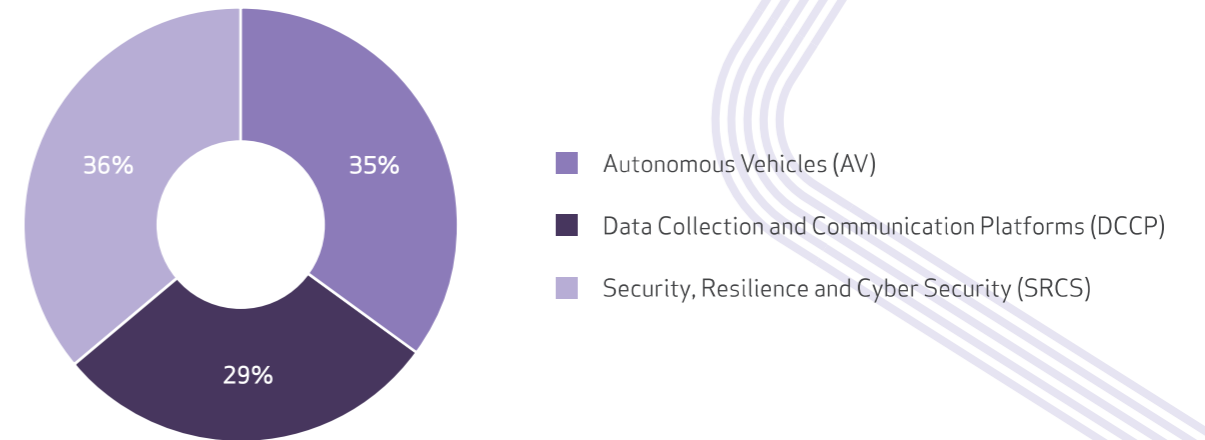


FIGURE 5: Respondents by IM market segment<sup>22</sup>

Subsector quotas, with a minimum of 50 firms per subsector, were used to build this sample.<sup>23</sup> The number of firms selected in each subsector was set in line with NAO sampling guidance on minimum sample sizes.<sup>24</sup>

The demographic characteristics of the sample that were used to inform the index analysis were turnover; number of employees; share of staff with tertiary degrees; region in which the firm’s headquarters is based; and whether the firm is currently operating in at least one of the three market segments, whether they are planning to enter in the next five years, or whether they have the requisite capabilities but no entry plans. These demographic characteristics are described in turn below.

#### 3.2.1 Turnover

Over half of the study sample have turnover under £25 million per annum, rising to just under 75 percent with revenues under £50 million. In the context of the wider technology and transport sectors<sup>25</sup> in the UK, where more than 95 percent of companies have annual turnovers of under £5 million, this suggests a sizeable concentration of large firms in our sample, perhaps reflecting the ability of larger firms to enter new markets relatively quicker than smaller firms.<sup>26</sup> At this stage however, it is difficult to know with certainty.

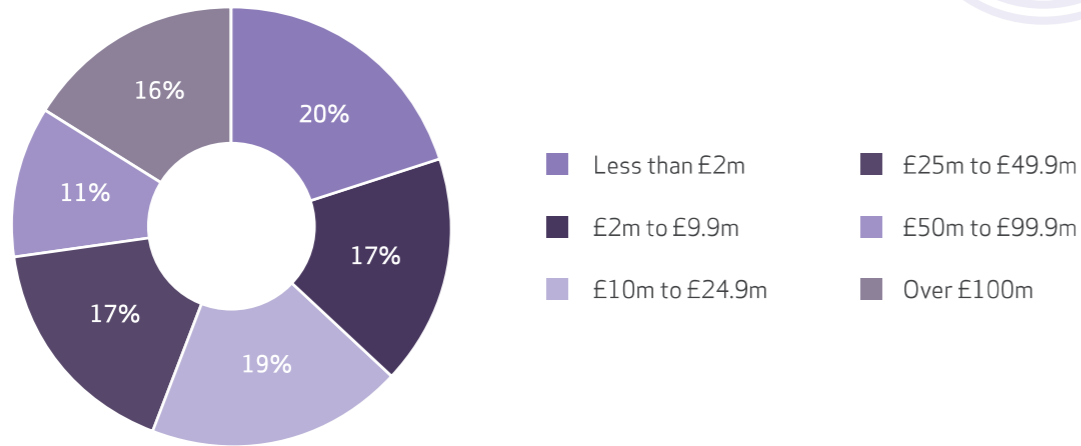
<sup>22</sup> ‘Primary’ market segments were determined for firms operating in more than market segment

<sup>23</sup> Please see Appendix 3 – Detailed IM market segments for detailed subsector breakdowns

<sup>24</sup> National Audit Office, “A practical guide to sampling,” 2001 <<https://www.nao.org.uk/wp-content/uploads/2001/06/SamplingGuide.pdf>>

<sup>25</sup> Includes the following SIC codes; SIC 26 (Manufacture of computer, electronic and optical products), SIC 49 (Land transport and transport via pipelines), SIC 50 (Water transport), SIC 51 (Air transport), SIC 61 (Telecommunications), SIC 62 (Computer programming; consultancy and related activities), SIC 63 (Information service activities)

<sup>26</sup> Sourced from the ONS database; UK Business – Activity, Size and Location

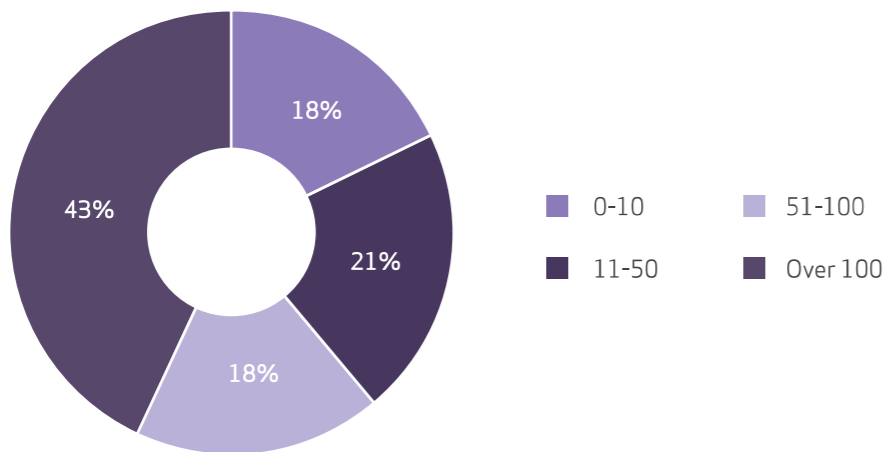


Source: Oxford Economics

FIGURE 6: Firms by turnover.

### 3.2.2 Number of employees

Just over half of the sample firms (57 percent) have fewer than 100 employees. Again, compared to the wider technology and transport sectors in the UK where 99 percent of companies have fewer than 100 employees, suggests a higher concentration of large firms in our sample.

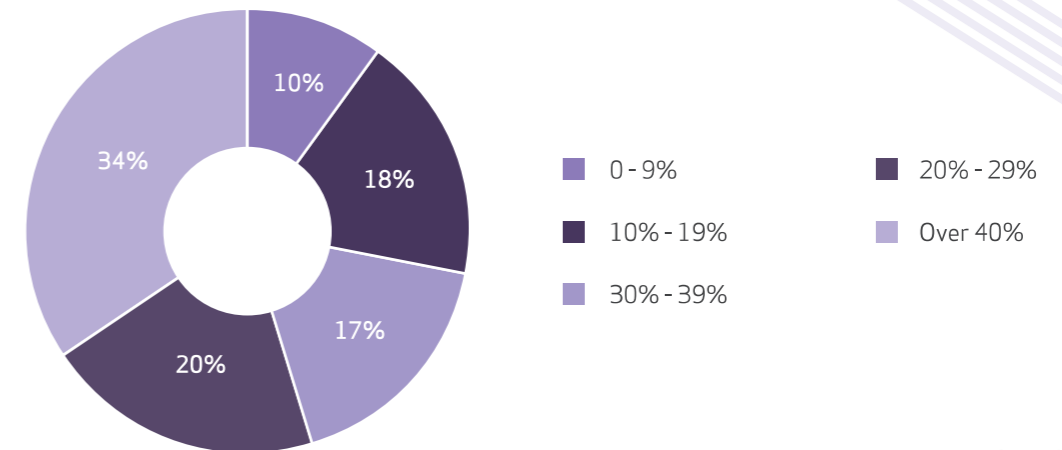


Source: Oxford Economics

FIGURE 7: Firms by number of employees.

### 3.2.3 Share of graduate staff

Given the technical nature of the three market segments, it was important that the survey collected data on the academic qualifications of employees. As Fig 8 shows, a finding that over half the sample (52 percent) have over 30 percent of staff with tertiary degrees is unsurprising, in the context of highly technical sectors.

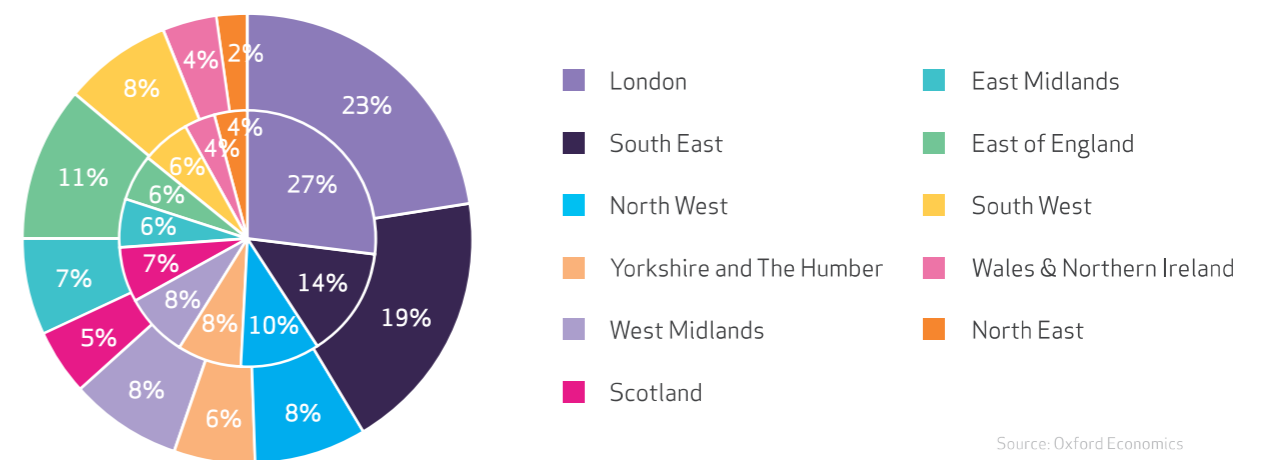


Source: Oxford Economics

FIGURE 8: Share of staff with degrees.

### 3.2.4 Region

By headquarter location, London accounts for highest proportion of firms in the sample (27%) followed by the South East of England (14%). This is broadly in line with national statistics as shown in Fig. 9.

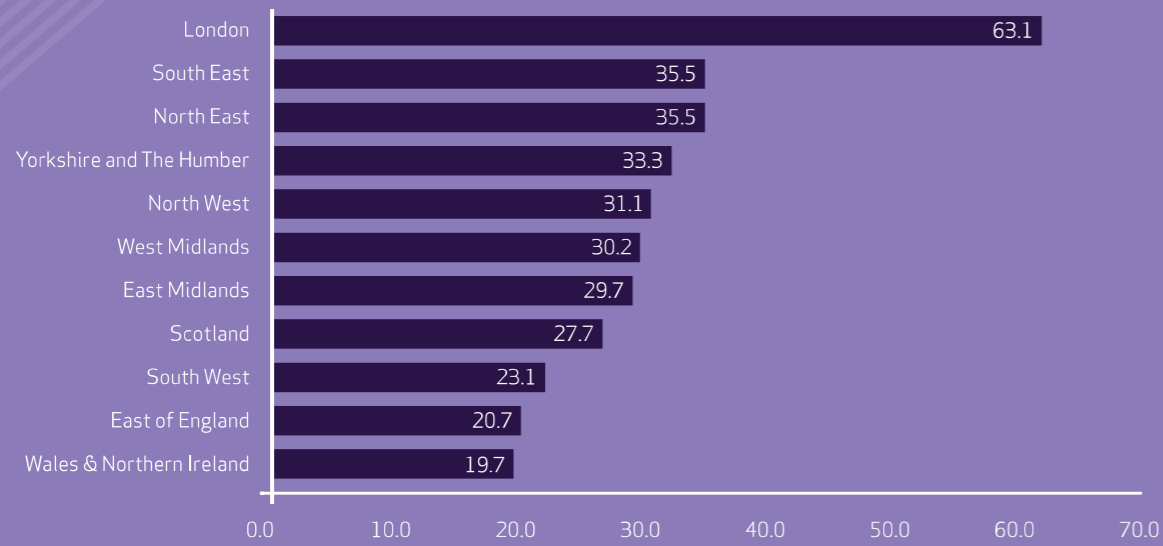


Source: Oxford Economics

FIGURE 9: Number of firms by headquarter location in our sample compared to UK transport and technology firms<sup>27</sup>

<sup>27</sup> Inner ring reflects sample distribution. Outer ring reflects UK transport and technology sector distribution

Taking regional working age populations into account, London still has the highest proportion of firms in our sample. By contrast, on a per capita basis there is a relatively higher concentration of firms in the North East than the raw sample data would suggest.



Source: Oxford Economics

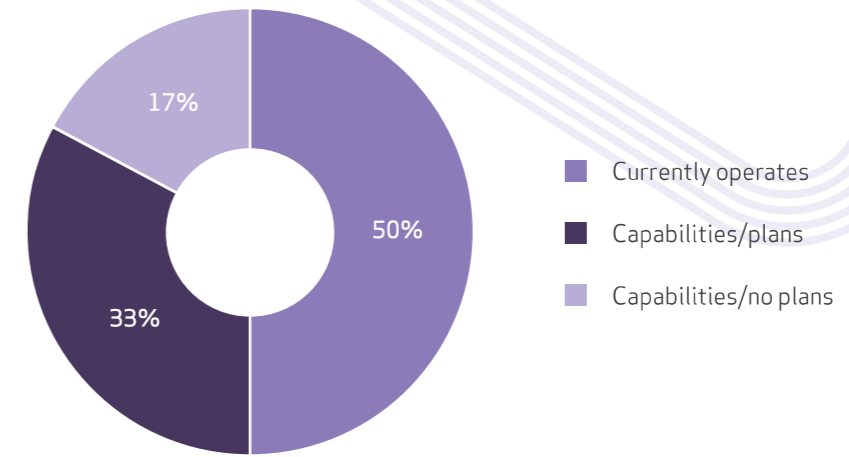
FIGURE 10: Number of firms per million working age population by headquarter location<sup>28</sup>

### 3.2.5 Current operations, future plans and capabilities

Finally, given TSC's remit to position the UK as a world leader in IM, it was important to also get a sense of the potential for new firms to enter the three market segments. Firms were therefore asked to indicate whether they were currently operating in at least one of the three market segments; whether they planned to enter a market segment within the next five years; or whether they felt they had the requisite capabilities to enter one of the market segments but had no plans to do so.

As Fig. 11 shows, some 50 percent of firms in the sample are currently operating in at least one of the three IM market segments.

<sup>28</sup>Using working age population statistics



Source: Oxford Economics

FIGURE 11: Current operations, future plans and capabilities.

For detailed demographic breakdowns at the priority market segment level, please refer to TSC's website.<sup>29</sup>

### 3.2.6 Is the sample representative?

In order to generalise survey results to a wider population, a survey sample must be representative of that population. Normally this requires two conditions—that the sample has been chosen from the population at random, and that population itself is well defined. While random sampling has been used in this study, the true population of firms in each of these three market segments is unknown for the reasons described in section 2.2.2.

Comparisons of the sample with the general population of transport and technologies firms in sections 3.2.1 and 3.2.2 does suggest a higher concentration of larger firms in this study. However, of the total invited to participate in the survey, some 1,347 chose not to. Without knowing the composition of these firms and, crucially, whether their reasons for not participating were directly related to their Absorptive Capacity, it is difficult to say whether the concentration of large firms in the sample has had any impact on our interpretation of the results.

In summary, we cannot say with any certainty whether the sample is representative. However, in the absence of this, the checks built into the process described in section 2.2.2 offers some assurances that we have captured relevant firms in this study.

In the next section, headline index results by each demographic group are presented.

<sup>29</sup>For more details, see TSC's website

## 4. HEADLINE RESULTS

### KEY POINTS

- Larger firms, with either revenues over £10 million or with more than 50 employees, scored statistically higher on our index measure than smaller firms.
- Firms that have more than 30 percent of staff with graduate qualifications also scored statistically higher than firms with lower proportions of these staff.
- Firms currently operating in these IM market segments also performed better statistically on our measure than those planning to operate in these market segments.
- Firms headquartered in London and the South East performed better statistically than firms in other parts of the UK.
- Access to skills and talent was seen as the biggest barrier to firms' knowledge absorption, followed by support and guidance from government.
- A positive relationship was identified between the Absorptive Capacity index scores and investing at least five percent of turnover in internal and external R&D and in hiring staff with specialist skills. In fact, firms investing between zero and five percent of turnover in internal R&D would need to improve their performance in two of the four knowledge absorption capabilities to close the gap firms investing over 10 percent of turnover.
- The weaker demographic groups can close the gap on their respective peers by improving their response to every question in the survey relating to a single component of absorptive capacity by one unit.

The purpose of this study was to understand whether Absorptive Capacity can be measured in different IM market segments. Though we have used an index approach, an approach that has support in the academic literature, the drawback is that interpreting index scores in practice can be difficult. So to give some context, we have done two things. First, we have used regression analysis to test whether there are any relationships between index scores and demographic characteristics, holding all other characteristics constant. So, for example, testing whether being headquartered in London is associated with a higher or lower Absorptive Capacity index scores, taking account of other factors that might also have an effect, such as firm size or share of graduates. Insights from case studies have also been used to bring results to life.

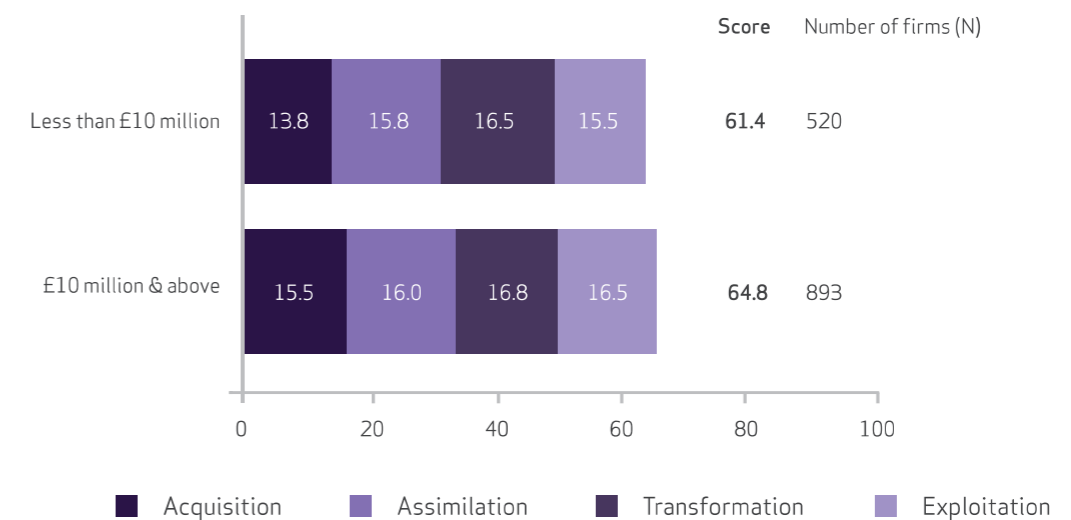
Second, we have looked at the differences in the level of scores between different demographic groups to give a sense of the scale of those differences.

The results of both are presented in this chapter, whilst the next chapter looks at what lessons we can draw from them, both for the measuring exercise and for policy.

### 4.1 REGRESSION ANALYSIS

#### 4.1.1 Larger firms achieve higher scores

Analysis of index scores by firm size, both in terms of turnover and number of employees suggests that larger firms score higher on average than smaller firms. Specifically, our analysis suggests that, holding other factors like share of graduates and headquarter location constant, firms with annual turnovers in excess of £10 million achieve higher scores than firms with annual revenues under £10 million per annum. In addition, the difference between the scores of those two groups is statistically significant.<sup>30</sup> On closer inspection, where these larger firms excel on this measure relative to their smaller peers is in both the knowledge acquisition and exploitation capabilities.<sup>31</sup>



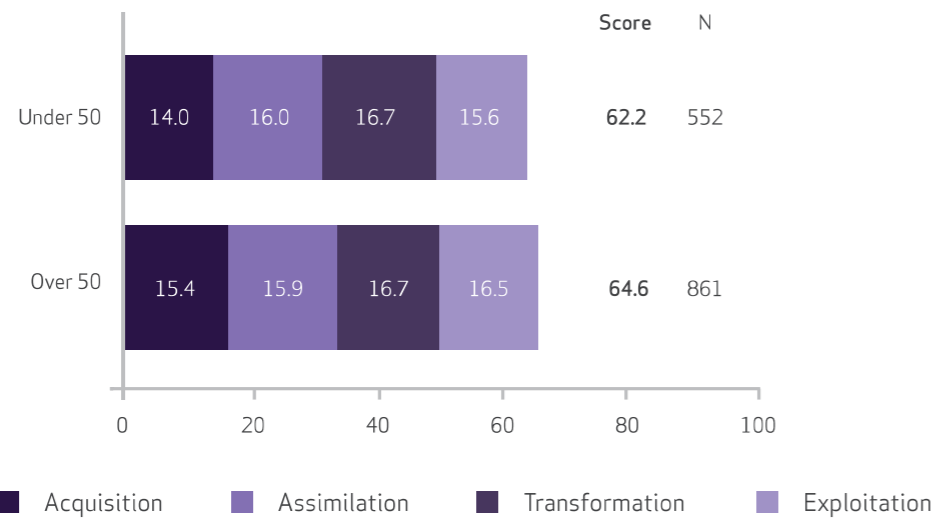
Source: Oxford Economics

FIGURE 12: Index scores by annual turnover.

Similarly, firms that employ over 50 people score higher on average than firms with fewer than 50 employees, with the difference being statistically significant. Again, these differences are largely being driven by the knowledge acquisition and exploitation scores of the larger firms.

<sup>30</sup> At the 10% level. All statistically significant results in this report are at the 10% level.

<sup>31</sup> Differences in the knowledge acquisition and exploitation sub-scores are also statistically significant.



Source: Oxford Economics

FIGURE 13: Index scores by number of employees.

Sectoral analysis suggests that these patterns hold in both the DCCP and SRCS market segments. In the AV market segment however, our analysis suggests that only firms with annual revenues between £10 million and £25 million per annum score statically better than other sized firms. Though this result is statistically significant, we would ideally want to see if it holds in a larger sample of AV firms before drawing any firm conclusions.

CASE STUDY INSIGHTS

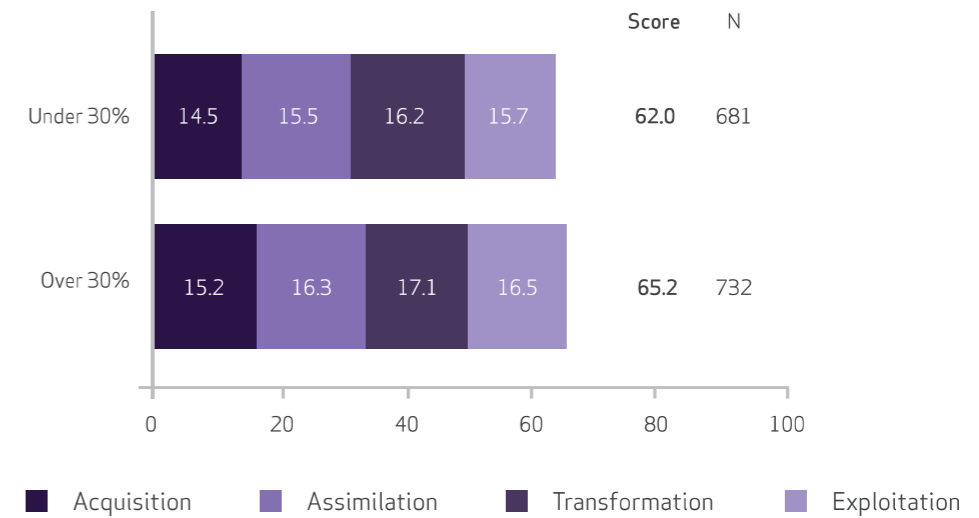
Information from customers and potential customers, research institutions and industry publications are common inputs in the knowledge acquisition activities of firms of all sizes. Primarily, this information gives firms an indication of how demand for their products and services might develop in the short, medium and long term, and therefore what the most effective approaches to product development might be. But with size comes more options. IBM, for example, is able to acquire other firms with specific knowledge, replicating the benefits of that knowledge at scale across its global network. IBM has also built an extensive networks of partner organisations that it works with on specific projects.

Similarly, Ford, the automotive company, has been able to use its wider corporate network to cast a broad net when identifying potential partners to work with, as it looks to exploit opportunities around Mobility as a Service (MaaS). With partners ranging from small companies to local government bodies, the company has demonstrated an ability, and willingness, to look beyond the traditional transport sector in exploiting knowledge.

By contrast, for smaller companies like Immense Simulation and Huq Industries, the primary challenges are firstly around either having the bandwidth to engage in valuable information gathering and knowledge acquiring activities. Secondly, these smaller firms sometime struggle to identify individuals and companies outside of their personal (or investor) networks that have valuable knowledge that could help them exploit opportunities to develop their products and processes and/or, or expose their products to wider audiences.

4.1.2 The share of graduates staff has a bearing on scores

Analysis of scores by share of graduates suggests that, on average, firms with over 30 percent of employees that have degrees score statistically higher than firms with under 30 percent of graduate staff.



Source: Oxford Economics

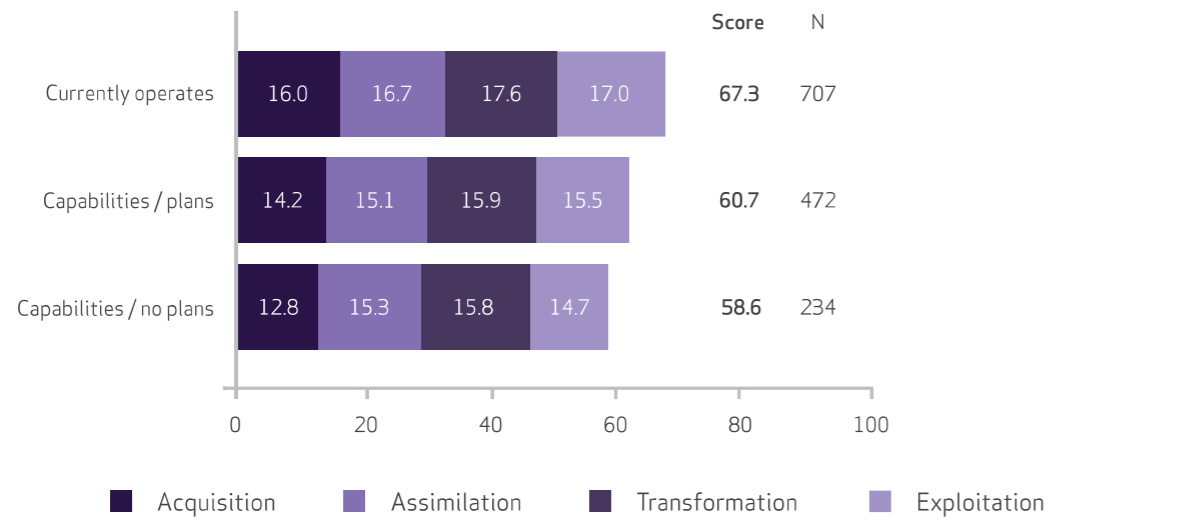
FIGURE 14: Index scores by share of graduates.

Interestingly, comparisons of the two groups show that the higher qualified firms, by share of graduates, score better statistically across all the four capabilities of knowledge absorption relative to their lower qualified peers.

As with the firm size, these results hold at the DCCP and SRCS sectoral levels. In the AV market however, there is little to separate index scores across firms with different shares of shares of graduate staff.

4.1.3 Firms currently operating score higher than firms planning entry

Comparing firms currently operating in at least one of the three IM market segments and those that are planning entry in the next five years, we find that incumbent firms score higher than potential new entrants, and the difference is statistically significant. This result hold across all three IM market segments.



Source: Oxford Economics

FIGURE 15: Index scores by current operations, plans and capabilities.

The literature suggest that firms with prior knowledge are better able to anticipate how markets might develop.<sup>32</sup> In the context of this results, this suggests that by being able to anticipate market developments, incumbents may be better able to protect any competitive advantages that they build in these market segments, potentially to the detriment of new entrants.

CASE STUDY INSIGHTS

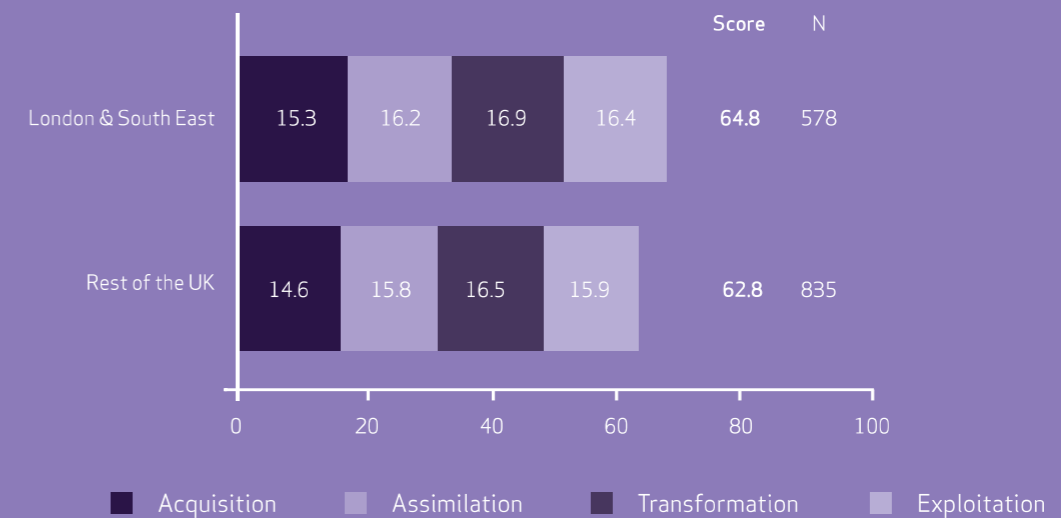
As a start-up company providing an innovative range of smart road studs, one of the biggest challenges that Valerann faces to entering the UK market is in demonstrating the value its products can bring to potential customers. This issue is compounded by regulatory requirements in infrastructure projects that act as barriers to entry for smaller firms trying to break into markets, while protecting incumbents.

In Valerann's view, supporting companies to pilot could help to tip the balance more towards innovative companies planning to enter these markets. Not only does it allow innovative potential new entrants to demonstrate their value, but it also helps them attract more funding from investors, which in turn leads to further product development, raising their chances of successfully breaking into markets further still. Piloting support therefore enables this virtuous circle to develop.

<sup>32</sup>Lewandowski, M.S., "Capturing Absorptive Capacity: concepts; determinants, measurement modes and role in open innovation," International Journal of Management and Economics, 2015: 32-56.

4.1.4 Being headquartered in London and the South East is associated with higher index scores

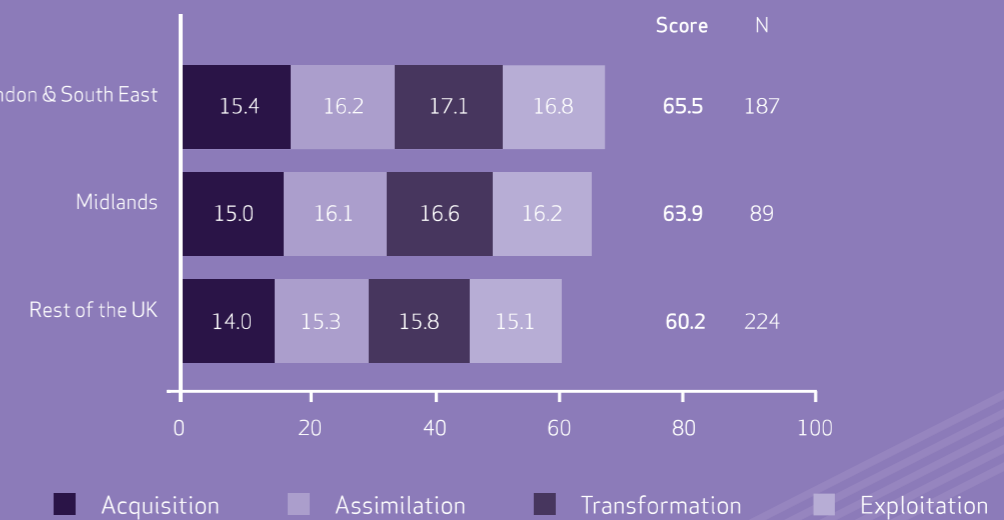
From a regional perspective, firms in London and the South East achieve statistically higher scores on average than firms in other parts of the UK.<sup>33</sup>



Source: Oxford Economics

FIGURE 16: Index score in London and the South East compared to other parts of the UK.

At the sectoral level this result holds particularly strongly in the AV market segment, where the scores of firms in the Midlands are also statistically higher than in other parts of the UK. However, there is no statistical difference in scores between London and the South East and the Midlands.



Source: Oxford Economics

FIGURE 17: Index scores by region in the AV market segment.

<sup>33</sup>Firms in the North East also score poorly relative to firms in other regions, though larger sample sizes would be required to test whether this result holds.

Further research could helpfully explore whether there is a genuine regional effect, or whether in practice the firms choosing to headquarter in London and the South East also have bases of operations outside of those areas. This would somewhat mitigate the impact of this finding.

CASE STUDY INSIGHTS

The role of local networks can be essential in helping businesses build local connections that could help them to develop their products and service offerings. Cosworth Electronics, for example, has been able to accelerate its stakeholder mapping of potential local partners by being a member of Cambridge Wireless—a local organisation that connects 400 companies through a range of networking events, with the aim of stimulating collaborative innovation in Cambridgeshire.

Visteon, the automotive supplier, also takes a local approach to partnering. In its case, the company aims to work with local universities to support the delivery of projects, helping to raise the profiles of those universities in the process. This approach also allows Visteon access to essential skills, an area that is generally challenging for other firms in these market segments (see next section).

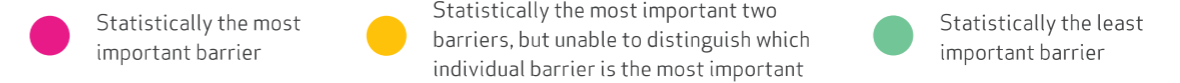
4.1.5 Access to skills and talent, and government guidance and support are the biggest issues

As noted in section 2.2.1, the survey also covered the barriers firms face in their knowledge absorption activities. Four barriers in particular were specified in the survey—culture and ways of working; access to the right technology; access to the right skills and talent; and support and guidance from Government.

From these responses, a ‘barrier index’ was developed to illustrate the relative importance of each barrier for different demographic groups. Statistical analysis was then used to determine whether any observed differences between barrier scores were statistically significant. Fig. 18 shows only the demographic categories where we can draw definitive conclusions about the statistical significance of barrier scores.<sup>34</sup>

<sup>34</sup> In other demographic categories it is more difficult to make definitive conclusions because we cannot, from a statistical standpoint, separate the most important and least important barriers.

DEMOGRAPHIC CATEGORY	CULTURE AND WAYS OF WORKING	ACCESS TO THE RIGHT TECHNOLOGY	ACCESS TO SKILLS AND TALENT	GOVERNMENT GUIDANCE AND SUPPORT
DCCP			●	
Turnover < £10m	●		●	
Turnover > £10m			●	●
No. of employees < 50	●		●	
Share of graduates < 30 percent			●	
Share of graduates > 30 percent	●			
Currently operating in at least 1 market segment			●	
Planning to operate in the next 5 years	●		●	●



Source: Oxford Economics

FIGURE 18: The most and least important barriers to Absorptive Capacity.

As Fig. 18 suggests, access to skills and talent is a particular issue for a broad cross section of firms in these market segments, especially smaller firms. On the other hand, culture and ways of working was found to clearly be the least important barrier for those smaller firms. For larger firms with revenues of over £10 million and for firms that are planning to enter these markets in the next five years, both access to skills and talent and government guidance and support were viewed as the two most significant barriers of the four tested in the survey.



CASE STUDY INSIGHTS

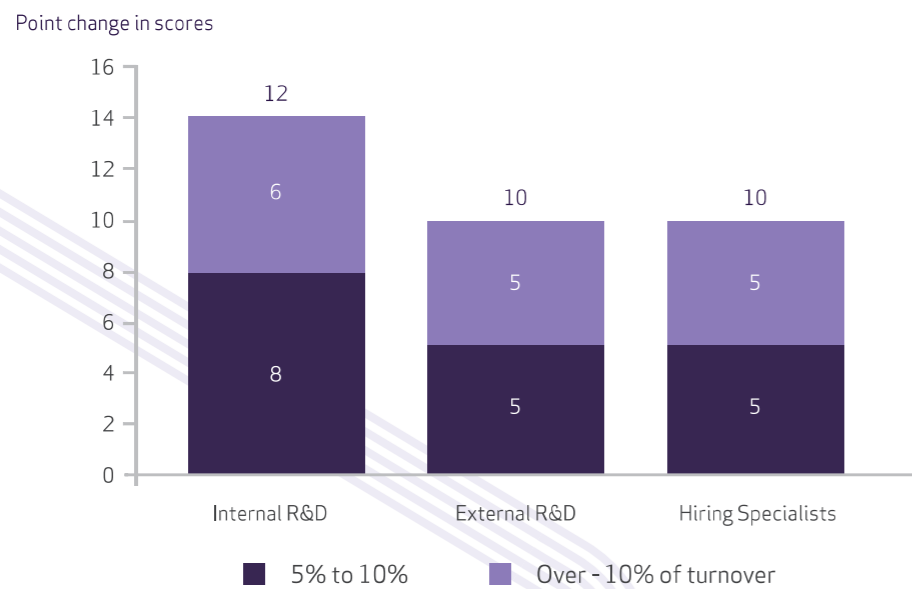
Access to skills and talent is a key limiting factor for Plextek. For the design and technology innovation consultancy, being able to identify the right people is intrinsically linked to the company's ability to grow and to continue to be successful.

In the company's experience, the pool of people with the requisite skills is out of synch with the level of demand for those highly skilled individuals. Compounding this is the perceived reduction in training schemes that were once common in the very largest firms, which has had a knock-on effect in terms of the numbers of skilled experienced hires on the market.

For Inflecto, challenges around accessing skills present themselves in a slightly different way. For the Sheffield-based bespoke software development company, the cost associated with hiring skilled people, combined with challenges it faces as a small software company raising finance, is a key limiting factor for the company.

4.1.6 Firm investment behaviour affects their scores

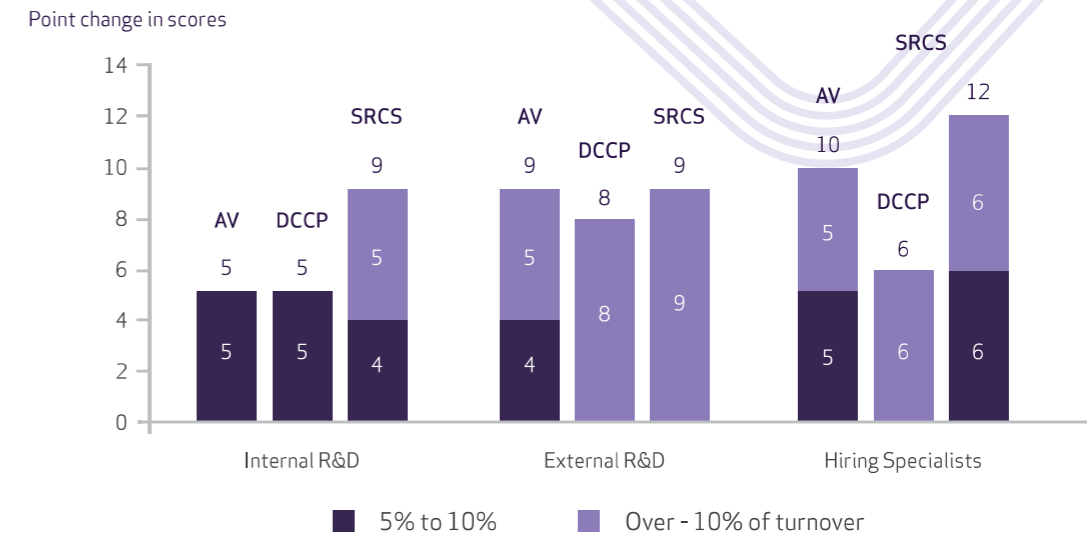
Also noted in section 2.2.1 was the use of the survey to capture firms' innovation behaviour. Using those questions, we were able to test the impact on index scores of investments in internal R&D, external R&D and hiring staff with specialist skills, all for the purposes of innovation. From a baseline of investing between zero and five percent of turnover in each of these areas, Fig 19 shows the point impact that these investments have on index scores.



Source: Oxford Economics

FIGURE 19: Impact of R&D and hiring investment behaviour on index scores.

The positive relationship between these investments and index scores is also found at the market segment level, as shown in Fig. 20.



Source: Oxford Economics

FIGURE 20: Impact of R&D and hiring investments on index scores at the market segment level.

CASE STUDY INSIGHTS

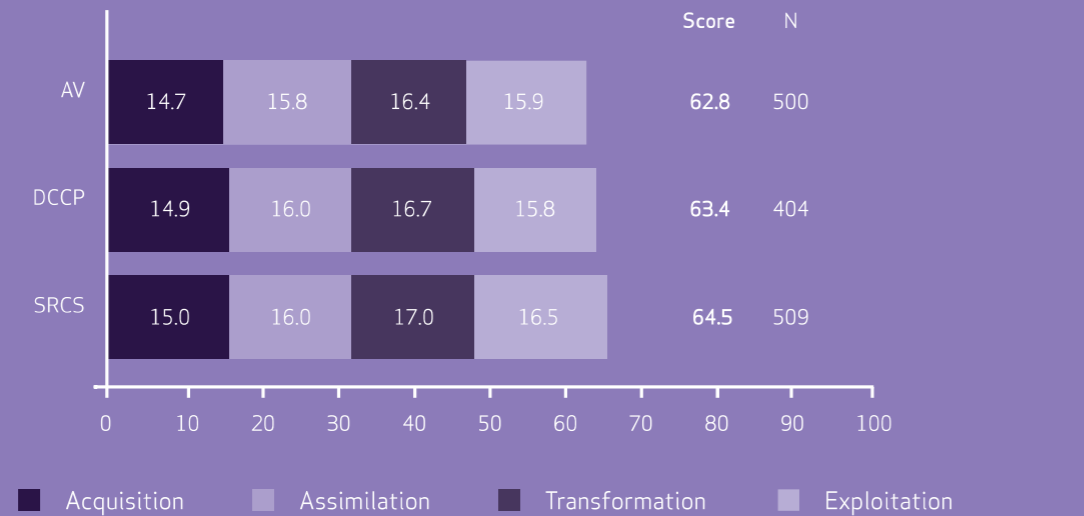
Innovate UK, the innovation agency, works with companies and partner organisations by co-financing risky R&D projects, incentivising companies to invest in promising research that they would be unable to justify on their own. De-risking projects in this way helps to enable innovation, with the aim of meeting the agency's long term objectives of creating UK jobs and driving economic growth. For projects involving large companies the agency contributes 50 percent of R&D costs, rising to 70 percent for SMEs, and projects are awarded through competitions for funding. The year-long process for setting the scope of competitions demonstrates the agency's own knowledge absorption process, beginning with feedback from industry about potential plans for research. This feedback is then discussed internally and synthesised into themes, within the context of government policy. Themes are then refined through a process of consultation with a wide range of stakeholders until, finally, a smaller number of competition areas are determined.

TRL, the research company, also uses a competition format to decide which internal R&D projects to fund. The competition starts by a call for ideas for projects from a small number of research areas. In planning and delivering winning projects, staff are encouraged to work cross-divisionally, to help enhance the flow of knowledge and idea across the company and to encourage joint working.



### 4.1.7 Market segment-level evidence is mixed

Finally, at the market segment level, this evidence suggests that firms in the SRCS market segment achieve higher scores than firms in the AV market segment. However, the difference in scores between firms in both market segments and DCCP firms were not found to be statistically significant.



Source: Oxford Economics

FIGURE 21: Index scores by market segment.

### 4.2 WHAT DO DIFFERENCES IN SCORES MEAN FOR SURVEY RESPONSES?

In practice, what does it mean to find differences in index scores that are statistically significant? While the literature points to using index measures to capture Absorptive Capacity, their interpretation can be complex.

To conceptualise what differences in scores could mean, and to give a sense of scale to those difference, we have looked at how much lower scoring firms would need to change their responses to close the gap to their higher scoring peers. So, for example, whether they would need to collect information from a wider variety of sources on a more frequent basis (acquisition), or hold more cross-departmental meetings (assimilation).<sup>35</sup>

The first step to answering this question is to reframe the responses to statements in the survey on a zero to five point scale (the first step in the index construction process), and then to tally up the scores if we assume respondents only score in one way to all of the questions—i.e. only ever ‘strongly disagree’, only ever ‘strongly agree’ and everything in between. Fig. 22 show the resulting scores.<sup>36</sup>

<sup>35</sup> See Appendix 2 – Survey questionnaire for the full questionnaire.

<sup>36</sup> This also includes survey responses to statements that captured frequency of activity (from yearly to daily), though these types of responses are omitted from the table for ease

Survey responses	Acquisition	Assimilation	Transformation	Exploitation	Total
‘Strongly disagree’ only	0	0	0	0	0
‘Disagree’ only	6.25	6.25	6.25	6.25	25
‘Neither agree nor disagree’ only	12.5	12.5	12.5	12.5	50
‘Agree’ only	18.75	18.75	18.75	18.75	75
‘Strongly agree’ only	25	25	25	25	100

Source: Oxford Economics

FIGURE 22: Scores that would be achieved from answering all questions with the same response.<sup>37</sup>

As Fig. 22 suggests, a firm that only ever ‘strongly disagrees’ with statements in the survey would get an overall index score of zero, the minimum possible index score. At the other extreme, a firm that only ever ‘strongly agrees’ with statements in the survey would score a maximum 100 points.

From this we can see that:

- Changing all responses from ‘neither agree nor disagree’ to ‘agree’ in one of the four knowledge absorption capabilities individually would add an additional 6.25 points to a firm’s score.
- Changing all responses from ‘neither agree nor disagree’ to ‘agree’ in all four of the knowledge absorption capabilities together would add an additional 25 points to a firm’s score.

We have chosen to focus on a change in response from ‘neither agree nor disagree’ to ‘agree’ because all of the index scores presented are achieved by answering between these two responses on average. Specifically, the index scores presented earlier lie between 48.2 and 74.3 (the respective scores that would be achieved if all questions were answered ‘neither agree nor disagree’ and if all questions were answered ‘agree’).

The second step is to calculate the differences in scores observed between different demographic groups, as set out in section 4.1. These differences can be summarised as follows.

<sup>37</sup> The actual scores will differ slightly from this table due to the re-scaling that takes place after the Principal Component Analysis, used to construct the index, has been undertaken.

Demographic categories	Differences in scores
Turnover: >£10 million vs. <£10 million	3.4
Number of employees: over 50 vs. under 50	2.4
Share of graduates: >30 percent vs. <30 percent	3.2
Capabilities: currently operating vs. planning to operate	6.6
Location: London and South East vs. Rest of UK	2
Internal R&D investment: >10 percent vs 0-5 percent of turnover	14
External R&D investment: >10 percent vs 0-5 percent of turnover	10
Hiring specialists investment: >10 percent vs 0-5 percent of turnover	10

FIGURE 23: Differences in scores by demographic categories. Source: Oxford Economics

Finally, to get a sense of the scale of these differences, we ask—how would the responses of firms that get lower scores have to change to close the gap to firms that have higher scores? The results of this analysis suggest:

1. Changing responses to the survey from ‘neither agree nor disagree’ to ‘agree’ across all four capabilities of knowledge absorption would be enough to close the gap for all firms with lower index scores (since this would add 25 points to their scores).
2. For firms with turnovers less than £10 million, changing their responses from ‘neither agree nor disagree’ to ‘agree’ in one of the four knowledge absorption capabilities would be enough to close the gap to their larger peers.<sup>38,39</sup>
3. The same applies if firms with under 50 employees or firms with fewer than 30 percent of employees with degrees were to close their respective gaps.
4. Likewise for firms headquartered outside of London and the South East.
5. By contrast, firms planning to operate in these IM market segments in the next five years would need to do a little more than change their responses from ‘neither agree nor disagree’ to ‘agree’ in one of the four knowledge absorption capabilities to close the gap to firms currently operating in these market segments.<sup>40</sup>
6. In addition, firms investing between zero and five percent of turnover in internal R&D would need to either change their responses from ‘neither agree nor disagree’ to ‘agree’ in two of the four capabilities, or change responses from ‘neither agree nor disagree’ to ‘strongly agree’ in one of the four capabilities of knowledge absorption to close the gap to firms investing more than 10 percent of their turnover in this activity.
7. Finally, firms investing in between zero and five percent of turnover in external R&D or in hiring specialists would need to do more than change their responses from ‘neither agree nor disagree’ to ‘agree’ in one of the four knowledge absorption capabilities to close the gap to firms investing more than 10 percent of their turnover in those activities.

These results taken together with the survey questionnaire, suggest that there are things that weaker firms can do to improve their index scores. In the next chapter, we look at what these, and other results from this chapter, mean for this measurement exercise and for policy.

<sup>38</sup>Since the additional 6.25 points that comes with changing those responses would be more than enough to close the current 3.4 point gap.

<sup>39</sup>Technically, not all firms responded ‘neither agree nor disagree’, so these results serve more to illustrate the point than be definitive.

<sup>40</sup>Since the 6.25 boost in scores would not quite be enough to close the current 6.6 point gap.

## 5. CONCLUSIONS AND RECOMMENDATIONS

### KEY POINTS

- Without an objective test, it is difficult to say definitively whether this feasibility study has met its objective of measuring Absorptive Capacity in these IM market segments.
- However, that the index measure yields plausible results gives us some comfort that the study is measuring something that is at least closely related to Absorptive Capacity, if not Absorptive Capacity itself.
- For firms, the tentative results suggest that it would be in their interests to invest more in R&D, hire more specialists, invest in improving their knowledge absorption capabilities, and partner with other firms.
- For TSC, Innovate UK and wider government, understanding the direction of causality between the different potential relationships identified in this feasibility study will be key to targeting effective support.
- For TSC, the immediate priority should be to understand the dynamics between size and Absorptive Capacity.
- As a measurement exercise, widening the scope to include more IM market segments may add the most value, by helping to establish an index baseline across TSC’s seven priority market segments.

The purpose of this feasibility study was to understand whether Absorptive Capacity could be measured in different IM market segments, and if so, whether it could be used to draw any valuable insights for IM firms, TSC and other stakeholders.

In this concluding section we consider whether the study has met these objectives.

### 5.1 HAVE WE MEASURED ABSORPTIVE CAPACITY SUCCESSFULLY?

To really judge whether the index approach taken in this feasibility study has been successful in capturing Absorptive Capacity requires an objective test. One example test would be to benchmark the results of this study to other industries that are known to have high levels of absorptive capacity, by applying our methodology to those industries. Unfortunately, working within the confines of this feasibility study means that this has not been possible. Therefore, it is difficult to say with certainty whether the objectives of the study have been met.

However, in the absence of an objective test, the closest we can get to understanding whether Absorptive Capacity has been captured in this study is to see whether it yields plausible results that one would expect a priori. For example, it would be reasonable to expect that larger firms, which generally have more resources, or firms with greater shares of graduate staff would be better at absorbing knowledge. Likewise, we would also expect, and the literature confirms, that engaging in relatively more R&D is positively related with Absorptive Capacity. To find these results hold true in this feasibility study therefore gives some comfort that we are measuring something that is at least closely related to Absorptive Capacity, if not Absorptive Capacity itself.

If we assume that Absorptive Capacity is indeed being measured, what do these tentative results mean for firms, TSC and wider stakeholders?

## 5.2 FIRM LEVEL INSIGHTS

Though proving sample representativeness is difficult, the headline results offer a number of interesting insights about the characteristics of firms that do relatively better on our index measure. Specifically, these firms tend to be larger, both in terms of turnover and number of employees, have high shares of graduates, and tend to be headquartered in London and the South East. Clearly some of these characteristics are difficult for individual firms to change in the short term. Also, given that this study only gives a snapshot of Absorptive Capacity in these market segments, we cannot be sure whether these characteristics are driving Absorptive Capacity, or whether having Absorptive Capacity results in firms that tend to share these characteristics. While understanding these causality questions is out of scope for this feasibility study, these results do in any case point to some actions that firms could take for the benefit of their knowledge absorption, and by extension innovation, activity.

First, investment in R&D to develop new and improved products and processes appears to be important. In fact, this research suggests that firms should be prepared to invest significant shares of their revenue in this activity, in excess of five percent, if they are to reap the full benefits.

Second, hiring specialists appears to be an important step as well. Though this report finds access to skills and talent is a significant barrier for firms, innovative approaches, such as partnering directly with universities, should be more carefully considered by firms in these market segments.

Third, for the most part, firms with lower scores need to focus on their performance in at least one of the knowledge absorption capabilities to close the gap to their higher scoring peers. This might be, for example, seeking out new sources of knowledge; encouraging more cross-departmental working and encouraging more training and continuous learning; or supporting the development of prototypes and focusing on marketing of new products.

Finally, partnering arrangements between different types of firms (e.g. large and small) may lead to spillover benefits for firms, and help to raise the overall standard of knowledge absorption across IM market segments. In any case, it is likely that partnering will become increasingly important if firms, research organisations, TSC and other public sector stakeholders are going to effectively solve the challenges presented by IM and, in doing so, position the UK as a global leader in the field.

## 5.3 WHAT IT MEANS FOR TSC, INNOVATE UK AND WIDER GOVERNMENT STAKEHOLDERS

The tentative results of this feasibility study also suggest some areas where targeted support by TSC, Innovate UK and wider government stakeholders might add value. However, getting a better understanding of the causality behind some the relationships identified in this report will be of vital importance in understanding which policy tools would be most effective.

### 5.3.1 R&D and skills

This analysis has shown a clear association between R&D investments and Absorptive Capacity, and between the share of graduates and the Absorptive Capacity. From a snapshot view like this it is difficult to say definitively whether firms have high levels of Absorptive Capacity because they engage in more R&D activity and attract more people with graduate qualifications, or whether firms that invest more in R&D and hire more graduates do so because they have high levels of Absorptive Capacity. That being said, assuming the causal relationship runs from these behaviours to higher Absorptive Capacity, which is not unreasonable, would suggest that these behaviours should be encouraged. Collaborative research funding which encourages firms to invest in R&D themselves, for example, would be one approach though there may be others.

Also, as hinted in Fig. 24 and Fig. 25 below, raising the profile of universities, their research and their potential for working collaboratively to deliver projects could also be a value adding exercise by TSC, particularly if it allows firms greater access to skilled labour.



### 5.3.2 Regional effects

The study also identified a ‘London and South East effect’ in scores though, again, it is difficult to establish causality. If being located in London and the South East (and the Midlands for AV firms) does drive higher scores, this might be evidence of firms gaining additional advantages from clustering in these regions. Fostered in the right way, these agglomeration benefits, as they are known in the literature, may lead to these areas becoming better able to attract talent, to develop strong supply channels for firms located in them, while allowing the flow of information and ideas between those firms to flourish. The downside however, is that these benefits might come at the expense of other regions, even though there might be a net benefit overall.

If, on the other hand, firms are clustering in London and the South East because they have higher levels of Absorptive Capacity, then regional policy should focus on supporting firms in other regions to raise their performance in at least one of the knowledge absorption capabilities. As these tentative results suggest, doing so may help to close the gap.

In either case, TSC, Innovate UK and wider government stakeholders may have to decide whether a policy goal of encouraging regional clusters is more important than supporting firms located outside of developing clusters, or vice versa. Though it may be that both are desired policy aims.

### 5.3.3 Size and current market operations

Finally, this study has demonstrated an association between firm size and Absorptive Capacity, and between firms that are currently operating in these markets and Absorptive Capacity. Understanding whether being large, either by turnover or by number of employees, or currently operating in a market is a driver of Absorptive Capacity, or whether firms become larger or are in these markets because they have high levels of Absorptive Capacity is vitally important to TSC and other stakeholders.

If being large, or currently operating in a market is a driver of Absorptive Capacity, then that would give TSC and others a clear mandate to invest in markets and research areas where there are either large numbers of larger firms, or where there are established incumbents. Doing so, by the definition of Absorptive Capacity, would result in firms being more able to capitalise on the outputs of that investment. However, for TSC in particular, this approach may conflict with one of its criteria for supporting priority market segments, namely where the predicted growth rate is exceptionally high and where no established market leaders exist at the time.

On the other hand, if firms become larger because they have high levels of Absorptive Capacity, this would suggest supporting smaller firms where this evidence suggests they are weakest—in their knowledge acquisition and exploitation capabilities, or in other words, the two outward facing capabilities. From the survey, as Fig. 24 and Fig. 25 show, supporting these smaller firms to access new knowledge from research institutions and universities, and helping to them to gather insights from other sectors could be a valuable first step for TSC and other stakeholders. Working with them in the first instance to gauge what would be most useful would also be sensible.



Source: Oxford Economics

FIGURE 24: The percentage of firms gathering information from particular sources (by turnover).



Source: Oxford Economics

FIGURE 25: The percentage of firms gathering information from particular sources (by number of employees).

Supporting these smaller firms to also exploit opportunities, either through marketing support and raising their profile, or through making piloting easier would also be beneficial.

If firms are also attracted to these markets because they have high levels of Absorptive Capacity that would suggest supporting potential new entrants across all knowledge absorption capabilities. However, in practice it may be more difficult to identify exactly who these firms are.

In both cases, using research funding criteria that encourages firms of different sizes and capabilities to work together could be a useful tool in raising the overall standard of knowledge absorption in IM market segments.

### CASE STUDY INSIGHTS

Broadly, the views of case study participants regarding what might constitute helpful interventions in the sector by TSC and wider government fall into five categories, each of which can be influenced by TSC, Innovate UK and wider government actions and policy:

1. Playing a co-ordination role—bringing together stakeholders including firms, infrastructure owners, and central and local government bodies, and incentivising them to work together. All of these parties have a stake in the success of IM, but they often work in isolation. This co-ordination could also help smaller firms identify and navigate potential new markets. **As a neutral third party with the responsibility of helping guide and inform IM stakeholders, TSC is ideally placed to play this role.**
2. Supporting innovative companies to pilot products and enter markets—helping to reduce barriers to entry in the process. Linked to the co-ordination role, reducing barriers by simplifying the plethora of regulatory hurdles that are currently put in place by different bodies should be part of this. **TSC's plans to continue developing a series of Enabling Capabilities within the framework of the Integrated Test Environment (ITE), should help to support companies in this area.**
3. Helping to raise the profile of SMEs and innovations within university departments, and promoting the UK in general as a place to do business—among other things, this would help to attract international companies, which in turn could lead to greater partnering opportunities for UK firms and research institutions, leading to additional spillover benefits. **Through the IM Accelerator, TSC is well placed to support SMEs with business support expertise and networking opportunities. Its University Partnership Programme and Academic Engagement framework can also help to bridge any gaps between industry and academia.**
4. Working with industry to encourage investment—for example, to improve connectivity in rural areas, which will be vital for fully autonomous vehicles to operate. **Collaborative funding models used by Innovate UK would be one way of encouraging this activity.**
5. Providing more research funding—in particular to support the development of new high risk idea, as distinct from collaborative funding that is intended to speed up or scale up ideas that are already in development. **Wider government funding can also clearly play a role.**

### 5.4 RECOMMENDATIONS

This feasibility study raises a host of interesting questions and potential next steps for TSC, Innovate UK and other stakeholders, both in terms of its objectives as measurement exercise and in terms of targeted support.

As a measurement exercise, there are two main options for where to go next. First, the study could be expanded to include additional IM priority market segments. Or, it could be used to look more deeply at one or two of the market segments that has been the focus of this feasibility study. On balance, expanding the survey to include other priority market segments, providing a baseline index measure across seven of TSC's priority market segments in the process, may be the best approach. A potential third option could be to conduct this exercise in a different market that is known to have high levels of Absorptive Capacity, as a way of providing an objective test to these results.

In the longer term, this exercise could be repeated on a semi-frequent basis, every two to three years for example, to see whether TSC, Innovate UK, or other stakeholders' measures are feeding through to firms on the ground. A key advantage of repeating this exercise is that a time series of results can be obtained which can enable the direction of causality to be empirically tested. However, it will take a number of years to establish a sufficient time series for this analysis.

In fact, for TSC, Innovate UK and wider government stakeholders, these tentative results suggest an immediate priority to understand the direction of causality in some the relationships identified in this report. For TSC and its approach to supporting the sector, understanding the dynamics between size and Absorptive Capacity is the most pressing question posed by this research. It should therefore look to answer this question sooner rather than later, potentially through further in-depth qualitative research with firms of a mix of sizes.

## 6. APPENDIX 1 – CASE STUDIES

### CASE STUDY 1

## COSWORTH ELECTRONICS LIMITED

With a history in Formula One racing, Cosworth Electronics Limited uses engineering and manufacturing capabilities to provide products that improve vehicle and driver performance.

Employing 400 people, mainly in Cambridge and Northampton but also in the US, the company supplies electronics and powertrain products as well as engineering services to vehicle manufacturers. The company also provides a suite of products to the likes of Porsche and General Motors that collect driver related data which drivers, vehicle manufactures and other interested parties can use to monitor performance. The company is also becoming increasingly involved in trying to understand how these data can be transmitted around transport networks in the management of those networks.

Historically, the company has relied on networking as a primary source of new knowledge. As the company has increased its profile in the automotive space, from the relatively closed industry of Formula One, it has taken a more proactive stance to its networking activity. It has done this, for example, through industry organisations like the SMMT, as well as through local organisations and attending industry conferences. To develop the communications capabilities of its products, the company has also been looking to other sectors for insights, such as the defence sector.

Cosworth's approach to what knowledge to acquire, and how to assimilate, transformed and exploit it is led in the first instance by the company's commercial strategy and five year plan. The plan itself is defined in terms of three horizons—the first being around current revenue generation opportunities; the second around pipeline development activities; and the third around technologies that the company believe are going to become important in to future products but which are not well developed now, for example artificial intelligence (AI). All knowledge that is acquired is viewed in terms of these three horizons. With knowledge that fits in the first two horizons the company is proactive about scoping how that knowledge might help it develop products that will help it sustain a competitive advantage. As part of this, it also looks to identifying partners that could help it exploit that knowledge in cases where it has gaps in its own capabilities. For example, Cosworth is currently working with a new software partner in Manchester as a result of this process.

In the third horizon, the company is looking at autonomy and connectivity with a view to identifying the small steps it can take to ideally position itself to capitalise on future opportunities. So when the company comes across a business or a technology or even a person that it thinks can help it bring horizon three into greater

clarity, it tries to bring insights from those sources into its R&D activities. Here, the company's engagement with organisations like Cambridge Wireless, which brings together local electronic and software business, has been particularly helpful in identifying potential partners.

Generally when the company does decide to transform knowledge, particularly around how it does things, a 'champion' within the business is identified and nominated. The role of the champion is to lead the activity by defining who will be affected, who needs to contribute and what further training is required. This gives individuals in the business clear mandates and support to make things happen, while making sure that the process of change and continuous improvement is closely managed. It also helps to make exploitation clear and accountable.

As a company that understands the benefits of partnering, the company believes that government can do more to encourage different types of companies to work together, especially around third horizon-type projects where there is a greater degree of risk. One tool for encouraging such behaviour could be in collaborative research funding, though the Catapults and knowledge transfer networks could also play an important role. As a starting point, roadshows similar to those run by the Centre for Connected and Autonomous Vehicles could be used to identify partnering opportunities between companies with shared interests in these technologies. As an additional benefit, they would also help government to get a better understanding of companies in these nascent industries, which it could use to target support.

## CASE STUDY 2

## FORD MOTOR COMPANY

Ford Motor Company is a global automotive company with annual revenues of \$140 billion in 2015. The company employs around 197,000 worldwide, including over 13,800 in the UK.

In 2016, the company announced the launch of the Ford Smart Mobility, LLC (FSM), a subsidiary that works with Ford's product development, research and advanced engineering, marketing and data analytics teams to develop commercially-ready mobility services and invests in promising mobility-related ventures. As part of Ford's expanded business model to be both an auto and a mobility company, Ford has looked at a number of new opportunities, from car-sharing to a parking service that helps drivers find on-street parking.

The experimental nature of smart mobility projects means Ford can take a more open, collaborative approach to knowledge acquisition. In practice this means that it can afford to think widely about how it can capitalise on acquired knowledge, and who it needs to work with to do so, whether that be a small app developer or a local authority. By contrast, in the wider business the typical approach is to partner with established partners that can match Ford's scale.

To assimilate and understand the value of knowledge, Ford use internal workshops extensively. Generally, the purpose of these workshops are to ensure that the project scopes and objectives are clear, and they are also used as an opportunity to rigorously test the extent to which each project fits with the company's strategic objectives. This helps to bring the potential benefits to the company of projects into sharp focus in their early stages.

But for ideas to really flourish in an organisation of its size and complexity, each idea needs to be sufficiently 'amplified'. Practically, this means that it is equally as important to identify internal experts who can help to develop ideas as it is to find senior sponsors who can spread the benefits of those ideas more widely and get buy-in from stakeholders across the organisation. Again, this underlies the importance of projects having a clear scope that can be easily traced to the company's strategic objectives. It also demonstrates the importance of internal networks in large organisations as key enablers of knowledge assimilation and transformation.

Finally, when it comes to exploiting knowledge, external corporate networks play an important role as well. A good example of this is around piloting projects. Current active testing of pilots with Islington Council, Transport for London and fleet operators across London are testament to this, and to the company's ability to find willing partners to test its innovative products.

Understandably for a company with a global footprint, promoting the UK as an attractive place to do business and to trial new products is one of the key roles that the company feels TSC and wider government can play in the automotive sector. The company also sees these organisations playing a leading role in facilitating conversations between different types of organisations that can influence the development of intelligent transport—beyond the usual OEM / supplier interactions that are commonplace in the sector today.

## CASE STUDY 3

## HUQ INDUSTRIES

Huq Industries is a start-up data analytics company based in Central London. Incorporated in 2015 and employing four people, the company collects anonymised mobile phone data, such as device locations and network interactions, through its proprietary software solution that is distributed through mobile apps. Currently collected from around 20 million devices, these data are used to model consumer behaviour. In the transport sector, the company has used its technology to study behaviour around busy transport hubs, like London tube stations.

Though a young business, experience has taught the company the value of considering exploitation in its search for knowledge to develop its technology. At first, the company acquired knowledge with a view to developing its technology in a way that would be helpful for its distributors, app developers, in their own knowledge acquisition about their own customers. A lack of demand however meant a change in the company's knowledge acquisition focus was needed, ultimately to avoid wasting company resources. Now, the company uses a clear statement of its capabilities which it tests in the market through its personal and investor networks, for example in the finance industry. It then uses feedback from potential customers to modify its technology to fit with their requirements.



The early experiences have also shaped the company's approach to the development process itself. In the very early days of the business, developing decisions focused acquiring knowledge for the purposes of 'building' the solutions themselves. Now, the company increasingly looks to acquire knowledge through partner or simply to buy off-the-shelf solutions which it combines with its own software. Again, this helps to avoid wasteful uses of resources, and allows the company to focus on its core strengths—collecting and processing data large volumes of data and using that to make sense of consumer behaviour.

As a small company, knowledge assimilation and transformation is relatively easy, organic process. The team regularly comes together to judge what feedback is valuable and worth taking forward. The knowledge that is deemed important forms the basis of a 'hypothesis', for example about how the technology might meet the needs of a new industry, such as the market research industry. Having gauged how the technology could add value through market testing, an intensive brainstorming process follows about how the technology might be adapted, resulting in a 'paper prototype' of the solution. This can then again be tested in the market, at which point the process of developing the software begins.

Throughout this process, technology plays an important role. The company uses solutions like Trello, the digital pin board service, to capture ideas, and road mapping tools to clearly tie those ideas to a central, shared vision of what it is trying to achieve. Capturing ideas like this means that the company can and has revisited ideas, which it has then used in later developments. It also makes what are the genuinely new ideas and what ground has already been covered in brainstorming sessions. The challenge is then to prioritise which ideas to pursue. The company uses a model of partnerships with industry experts in its exploitation strategies. These partnerships, and the input that they bring, help to prioritise ideas for development and to maintain a focus on exploitation through the development process.

Embedding technology in its knowledge absorption process has been a conscious move by the company to preserve its culture. While it accepts that with growth will come the need for more structure around its knowledge absorption activity, it believes that making technology central to the process will help to maintain an open, creative and fast moving culture as it grows.

As a young business in a nascent industry, the company sees knowledge dissemination as a potentially important role for government. A particular challenge the company faces is lack of understanding in the market of its value proposition. Through publishing studies, the public sector, as an increasing buyer of these sophisticated data analysis capabilities, can play a direct role in educating companies and individuals, including potential investors, in the benefits of these technologies.

## CASE STUDY 4

### IBM

With revenues in excess of \$80 billion dollars and operating in over 150 countries, IBM is a leading global cloud platform and cognitive solutions company with significant operations in the UK.

With a long history dating back to the late 1800's, there are numerous examples in the company's past of moving into new markets, divesting of others, while maintaining a continually focus on the future needs of customers. For the company, staying ahead of market and societal trends is core to its survival.

External knowledge is therefore fundamental to the long term success of the company. As such, it uses a number of methods to acquire valuable knowledge. First, the company commits significant resources, of around \$6 billion annually, to internal research and development. This allows it to develop cutting edge technologies which it eventually brings to the market. The Watson suite of products is an example of this.

Its global and financial footprint also gives the company more options in its knowledge acquisition, including an ability to acquire companies which possess knowledge that fits with its business objectives. In the last 15 years alone, IBM has acquired over 100, mainly software, companies for this purpose. Its global footprint in particular allows it to leverage the technologies associated with each acquisition at scale, taking advantage of economies of scale in the process. On some occasions, the technologies the company is seeking to acquire are in fact people and know-how, as it did when it bought PricewaterhouseCoopers consulting business in 2002.

In many cases however, the company looks to acquire knowledge over a particular time period or for the development of specific product. In these situations, rather than make a 'buy' or 'build' decision the company choose instead to partner with organisations that hold that knowledge. The company has developed a network of over 1,000 such companies in the UK that it works with, many of which are simultaneously also customers, suppliers or competitors. In fact, IBM rarely acquires a company that it does not already have an existing business relationship.

Underlying its knowledge absorption activity is a continual interaction between the need to exploit market opportunities and the acquisition or creation of knowledge in order to do that. This is reflected in the main sources of knowledge coming from either internal research and development, or the customer facing parts of the business. Customer facing staff are constantly trying to understand the direction their customers businesses are heading in, what challenges they face now and might face in the future, and the technologies that will help to meet those challenges. All of this is fed back into the development cycle. The need to think about how knowledge can be exploited is also evident in IBM's business case process. These help to ensure that the exploitation opportunities associated with external knowledge are clearly articulated from the start.

Finally, in a business where change is such a big part of the way the company operates, reviewing the skill base and skill mix is also key to survival. In transforming and exploiting knowledge, that means re-training staff or allowing them to leave the company, as well as hiring new people with the requisite skills and capabilities. This ability to 'reinvent' itself is an essential attribute that drives the company's ability to adapt to a changing external environment.

In the company's view, technological progress has the potential to have a profound effect on transportation. To best manage that transition, government can therefore play an important and leading role setting the agenda by defining a clear vision of the future of transport. One that will necessarily be different from transport of today.



## CASE STUDY 5

## IMMENSE SIMULATION

Immense Simulation (ImSim) is a company that was spun-out of the Transport Systems Catapult in 2015. The company was borne out of the need for advanced modelling and analytics capabilities in Intelligent Transport. It employs 14 people and specialises in large-scale detailed simulations of cities to understand how people move around them, and how best transport systems can support that.

At the moment, the company operating model involves working with partners to offer products and services as initial proof of concept pilots. In the medium term the company's offerings will move more towards simulations that can support a range of customers, from Mobility as a Service (MaaS) providers through to planning authorities as they plan logistics around autonomous vehicles.

To acquire knowledge, the company is engaged in a number of Intelligent Mobility fora. These include its continuing work with the Catapult, collaborative partnerships, and through involvement in innovation networks such as the Knowledge Transfer Networks. The company also has strong links with academia. In addition, the company has taken active steps to expose itself to knowledge from outside the traditional transport industry through its recruiting process, by hiring people from the e-commerce, defence, aerospace and property industries.

While the company has access to a wide range of sources of knowledge it struggles with finding the capacity needed to make the most out of them. At the heart of this struggle is a fundamental tension between short-term goals of generating revenue to remain operational, and the longer-term need to build market leading products and to be sustainable. As a young growing company, this is somewhat compounded by the process the business is going through to develop its own cultural approach to how it acquires knowledge, and how it decided how to action that knowledge.

That being said, being a small team of 14 people means that the knowledge that is acquired can be assimilated relatively quickly. Insights are shared across the company, either by email or on sharing forums within the company. Staff are then able to give their views about how those insights fit with product development, though the company acknowledges the need for more structure around these processes as it grows.

ImSim's agile approach to product development, which is based around testing and experiments, lends itself well to knowledge transformation. New insights are incorporated as new test cases for example. Agile approaches are also applied when the company goes about changing how it does things. By using small trials, for example in their test reporting, the company is able to see what works, and adapt their processes accordingly. In both its product and process development, the company sees its main challenge coming from the need to formalise and standardise how it goes about these activities, and how its people integrate new ways of working into how they work.

In its approach to knowledge exploitation, ImSim often use collaborations with project sponsors as a way of driving their understanding of the benefits of its products. This way, sponsors and the wider travel and transport community can see the benefits of their products early on. It also allows them to see the benefits of working collaboratively as a form of procurement, as opposed to the traditional long procurement processes used in the sector which involve detailed up-front specifications that, in the worst case, can stifle creativity.

Facilitating partnerships between SMEs and large companies and/or enabling inter-company sharing of resource would be, in ImSim's view, helpful roles for government. Especially in early technology areas where there is no immediate commercial driver, or where investments are more speculative. Making it easier to navigate what support is already available, and disseminating guidance material on a range of topics that are important to small and growing SMEs (such as how to go about raising private finance for example) would also be helpful. Finally, ImSim feel that having government-backed lead customers or pilot customers would be particularly helpful for small businesses as they would allow them to earn revenue while at the same time demonstrating the value of their products.

## CASE STUDY 6

## INFLECTO

Inflecto develop software solutions for companies in a range of sectors, including transportation and healthcare. Established in 2006 and based in Sheffield, the company employs 3 people and develops bespoke software solutions for companies that are unable to find off-the-shelf products.

The bespoke nature of their projects means that knowledge acquisition is an important part of how the company develops its offer. Depending on the problem, the company's typical approach is to review published white papers and academic material in order to enhance its stock of knowledge. Where possible, the company also tries to contact the authors of papers to gather further insights.

To assimilate knowledge, first, the company's lead developer takes responsibility to review developments in the technology industry, for example through attending web conferences. New insights are then fed back to the rest of the company, where staff have access to online resources, like Pluralsight (the on-demand technology learning platform), to build up their own knowledge and expertise. This is a continual process for the company as it tries to understand how new developments in the sector can be incorporated into its products.

For Inflecto, transforming knowledge by combining prior expertise and experience of software development with new insights is key to its business model. Typically where it does identify insights or market developments that it considers valuable, it uses small trials as a way of understanding how best to incorporate them with its software. Staff then come together to decide whether the trial has been a success and is worth taking forward.

Over the last year, the company has been through a process of documenting all of its processes as part of its successful ISO9001 accreditation. Formalising its processes in this way, including around how it uses knowledge, has been a helpful exercise for Inflecto. In the company's view, documenting its processes can and will continue to help the company maintain a consistent approach to the way it uses knowledge to develop its software solutions, especially as the team grows in size.

However, the biggest barrier the company faces to growth is funding. In its view, securing funding for small software businesses is more difficult than it is for local manufacturing companies. The company puts this down to funding approaches that favour the types of companies that employ large numbers of people, coupled with a lack of understanding about the value that software businesses like Inflecto can bring. In Inflecto's experience, regulations and red tape also make attracting funding from government initiatives more difficult for a small companies. It believes the UK can learn from other countries, like the US, about how to best support innovation by small businesses.

## CASE STUDY 7

## PLEXTEK

Plextek is a design and technology innovation consultancy which employs around 75 employees, and works with clients to overcome engineering challenges. Customers typically come to Plextek when they have an engineering problem that they are unable to solve using off the shelf products or systems, or who require an optimised, integrated solution. In Intelligent Mobility, the company has worked in a number of areas—it has helped design radar sensor technologies for autonomous vehicles and communications technology for unmanned vehicles; it has delivered projects that involve communicating and processing data between different places; and it has a portfolio of work around cyber security that closely relate to its data collection and communication work.

Solving client problems in innovative ways requires Plextek staff to be engaged in the latest developments in their fields. Knowledge acquisition is therefore an integral part of how staff at the consultancy operate. Keeping abreast of the latest university research and subscribing to engineering journals, publications, and trade press are the most common forms of knowledge acquisition, supported by personal desk research. Some staff members belong to professional bodies, such as the Institute of Electrical and Electronic Engineers (IEEE), the Institute of Engineering Technology (IET) and the Institute of Physics (IOP).

Staff are also organised into groups, each with different technical themes such as signal processing, communications systems and smart sensor systems. This makes assimilation of acquired knowledge easier, while also helping to push the company's capabilities in each of those topic areas. Employees are also encouraged to share insights relevant to their group or across groups through staff newsletters, through internal blogs and through external blogs on the company's website.

Plextek also employs a small number of people in specific sectors who are responsible for talking to people in those sectors to gather insights. These staff typically have backgrounds in those sectors and are therefore better able to understand the key challenges both now and in the future. Matching these challenges with the skills the company has in solving problems is a fundamental part of its business model. Working across different sectors also means that Plextek is able to take insights from one sector and use them to innovate in others.

Transforming and exploiting knowledge, both to deliver projects and to improve the way it does things is, in the company's view, an important factor in maintaining a competitive advantage. The company sets each group annual goals around improving its capabilities in specific areas, and gives them the space outside of their project work to achieve those goals. It also reviews past projects to identify process developments it can make, which can then be implemented and exploited for commercial gain. For example, its experience of developing hardware and software solutions (and the blurring boundary between the types of engineers involved in both) has led it to develop a process whereby a much broader range of engineers are now involved in the development of new software. This way, more diverse views can feed into the software development process, which could potentially mean developing software that can be applied more widely.

As a business that is heavily reliant on the quality of its people, finding the right people is a significant barrier for Plextek. In fact, the company sees the hunt for skills and talent as its biggest barrier to growth. At the heart of this issue, in the company's view, is a significant mismatch between the demand for highly qualified people in science and technology, mathematics, physics, electronics and software engineering, and scarce supply. Experienced engineers trained at larger firms used to be typical recruits for the company, though even these are in increasingly short supply, possibly as a result of larger firms scaling back their training programmes. As a result Plextek has developed its own apprentice and graduate training schemes as a way of accessing talent.

In terms of a role for Government, the company sees a lot of spillover benefit from the research funding models that are typically used in the defence sector, where there is a greater focus on funding early research. This compares to the collaborative research funding approach typically used in transport and most other sectors which, in the company's view, is more focussed around bringing already promising technologies to market quicker, rather than funding new, speculative and therefore more risky ideas that can have greater potential.

## CASE STUDY 8

## TRL

TRL is an independent research organisation that provides evidence-based research that supports innovation in all forms of surface transportation.

Owned by a non-profit distributing foundation (Transport Research Foundation), the company was first established in 1933 as the UK government's Transport Research Laboratory, and was privatised in 1996. It now has more than 1,000 clients across 145 countries and employs over 300 people, mainly across three divisions—an infrastructure division, a transportation division and an engineering and technology division. The company's ownership structure also means that any profits made are ploughed back into independent research.

The company offers a wide range of products, from software typically used by local and road authorities in their transport modelling and traffic management activities, to crash testing related products. The company also engages in internal research-led projects which can either be in early stage technologies, where it might partner with a university, or to support products at stages five or six of the technology readiness index. In Intelligent Mobility, the company's most important area of work is on autonomous vehicles and in managing the safety and cyber security risk that might come with them.

As a research intensive organisation, knowledge acquisition plays an important role in the company's day-to-day operations. Employees take an active interest in seeking out new information in the course of the work they do, through reading academic journals, attending conferences or through other channels that best suit their interests and specific areas of work. With a broader agenda around autonomous vehicles, for example in terms of artificial intelligence and machine learning, staff are encouraged to look outside of the transport sector as well.

The process the company uses to allocate profits to new research demonstrates an innovative approach it takes to knowledge assimilation and transformation. At the core of the 'reinvestment' process is an internal competition, which TRL uses to generate a shortlist of options. The competition starts by a call for short proposals for projects in a small number of research areas, from the heads of each of the company's three divisions (the Chief Scientists). Research topics are usual early technology areas that are at too early a stage to be funded by the company's traditional clients.

Proposals set out the project scope, objectives and expected outcomes. Staff are also encouraged to work cross-divisionally, to help enhance the flow of knowledge and idea across the company and to encourage joint working. Winning proposals are then chosen by Chief Scientists and TRL's Academy Director. One of the ideas that was proposed and is currently being delivered is the application of machine learning techniques for traffic management.

To maintain a focus on the exploitation of knowledge during this process, exploitation plans are also developed when projects are launched. Getting teams to think about exploitation at an early stage helps to maintain a balance between blue sky thinking and return on investment. They also provide a way of closely managing projects during their implementation. Finally, at the end of project the lead researcher gives a presentation to the company covering what was achieved and next steps, which again helps to share knowledge across the company.

As a research intensive organisation, part of the role that TRL sees for government is in providing additional funding to get early stage research ideas off the ground. Government could also add value to the innovation process by raising the profile of SME's and innovations within university departments, and generally bringing companies, academics and research institutions together in areas of applied research.

## CASE STUDY 9

## VALERANN

Valerann is a start-up company dedicated to solving some of transports most pressing challenges.

Employing 10 people in the UK and Israel, the company's vision is for roads to sense, communicate and react to the world around them, capabilities that will become increasingly important as the connected and autonomous vehicle market grows. Starting with a range of smart road studs to enable smarter roads, the company aims to eventually provide predictive analytics services which can be used to monitor road safety and ensure more efficient usage of the road network.

Knowledge from potential infrastructure customers about their strategies and intentions, and therefore future needs, has been an essential component in the company's product develops process. Valerann has used this knowledge and combined it with insights from other sectors to ensure it is using the most suitable technologies in its product to best meet those future needs. For example, in developing communication capabilities for its products, the company looked to the water infrastructure sector for ideas because the challenges there are similar—the need in water management to collect data from pipeline infrastructure.

Initially however, the company struggled to build a network of contacts and industry experts from which it could acquire knowledge. Identifying potential customers, to show how its range of products could help solve pressing future challenges, was also difficult. At one stage the company even considered engaging a professional 'expert network' service provider. In the end, personal connections with the London Business School's alumni network, and attending infrastructure conferences and events gave the company the platform it needed to engage potential design partners and customers.

As a small company, knowledge sharing within the company is relatively easily done. Typically, the CEO, CTO and the Business Development Director meet on a frequent basis to discuss knowledge they have collectively acquired and the implications for product development. Usually, these conversations centre around the industry's direction, the needs of potential customers, and the trade-offs involved in developing their products to fit with what they have heard. As a key part of the company's decision-making process, the outcomes of these conversations are documented and shared across the company, via email. This allows others to feed in valuable input, and it helps to maintain a free flow of information within the company. The documented output of this process also helps to build corporate memory, and is used in the on-boarding of new members of staff. However, the company acknowledges that the time commitment required by this process will make it more difficult to maintain in its current form as it grows.

Though the company's profile with key partners and customers has grown in the last year, the biggest barriers it has faced in bringing its products to market is regulation. Specifically, the onerous requirements placed on firms in the tendering process for infrastructure projects, and the long time lags involved, has been an issue. One example of these requirements that the company has faced is a requirement to evidence four or more government-funded projects, each with a minimum contract value of £250,000. Barriers like this, in the company's view, have the potential to completely exclude smaller, more innovative companies from entering the market. This then has a knock on effect on those companies' ability to attract funding from investors, which in turn hampers further product development. As a result, the company has been forced to consider alternative go-to-market strategies to distribute its products. Partnering with larger more established players and providing equipment as a value added service, is one such strategy.

In Valerann's view, market entry support for smaller, younger companies could be an invaluable role that organisations like TSC and the wider government could play. Facilitating greater co-ordination of different local and central government bodies, are all whom are facing similar pressing challenges but either have different standards and regulations, or are being excluded from infrastructure industry conversations all together, would also be helpful.

## CASE STUDY 10

## VISTEON

Visteon is a global electronics supplier to the automotive industry. The company designs, engineers and manufactures vehicle cockpit electronics products and solutions that support connected and autonomous driving and employs approximately 10,000 employees and reported sales of \$3.16 billion in 2016.

The company takes a very pragmatic approach to its knowledge absorption. As an example, it is increasingly looking at developing business relationships with technology companies, academia and companies from other industries, as part of its longer term vision to develop new, innovative products. Connected and autonomous vehicles and the infrastructure required for them to operate is one area where it is taking this approach.

The company first uses its own understanding of the technologies and capabilities that will be needed to capitalise on opportunities in these new areas, to identify potential partners where it has gaps. It then proactively networks to engage those partners, for example through the Automotive Electronic System Integration Network (AESIN), a network of automotive electronics supply chain companies that Visteon chairs. The UK Cite Project is one such example. This project brings together a range of partners to develop an environment in the Midlands where connected and autonomous vehicles can be tested. Project lead by Visteon, these partners include the original equipment manufacturer (OEM) Jaguar Land Rover; infrastructure owners including Highways England, Coventry City Council, West Midlands Combined Authority; companies from other sectors including Siemens, Vodafone and Huawei; and Coventry University and the Warwick Manufacturing Group (part of the University of Warwick).

This specific example demonstrates two things. The first is that the company actively engages and works with universities in exploiting knowledge, and the second is its willingness to work jointly with infrastructure owners.

In fact, the company has a long history of working with universities in a collaborative way, and takes a proactive approach to working with local universities. Generally, it sees a number of advantages of working with universities to exploit knowledge. First, it allows the company to access skills and talent that are in short supply in the market place. By exposing universities to real world, live issues, it also indirectly allows the company to influence what students learn, in a way that makes them more attractive recruits. By the same token, it gives universities a chance to develop their offerings to industry, on commercial terms that industry finds attractive. However, in Visteon's view there is still more that some university partners can do to take a more commercial approach to projects, particularly around delivering within project timescales.

Encouraging infrastructure owners to work more collaboratively with companies is, in Visteon's view, a valuable role that government can play. Especially in cases where exploiting knowledge requires real world piloting, as will increasingly be the case in Intelligent Mobility. Tied to this is a role in raising awareness of available sources of funding for such projects, and cutting red tape around accessing that funding.

Finally, raising awareness about the UK's attractiveness for testing connected and autonomous vehicle technology is something that the government should continue to do in the company's view. Especially as the UK has not ratified the Vienna Convention, which makes testing easier here compared to other European countries.

**CASE STUDY 11****INNOVATE UK**

Innovate UK, the UK's innovation agency, is an executive non-departmental public body sponsored by the Department for Business, Energy and Industrial Strategy (BEIS). The agency works with companies and partner organisations by investing in risky R&D projects.

For projects involving large companies the agency contributes 50 percent of R&D costs, which rises to 70 percent for SMEs. De-risking projects in this way helps to enable innovation, with the aim of meeting the agency's long term objectives of creating UK jobs and driving economic growth. From its perspective, the key to the agency's investment strategy is enabling R&D in areas that companies and partners consider promising but deem too risky to justify investing in now, mainly because of the long term nature of the benefits.

Therefore, the vast majority of support the agency offers is around collaborative projects where there is no current end customer. Typically, these projects involve consortia of companies, large and small, working together with universities and/or other research organisations. The agency then reviews the outcomes of projects, rather than the companies and partners themselves. One of the benefits for companies, who might already have supplier/ customer relationships, is that joint working in this way helps to strengthen working relationships or enable new relationships to form, a particular benefit for smaller companies.

To get Innovate UK funding, consortia submit proposals to Innovate UK, as part of agency run competitions. The process of setting the competitions themselves demonstrate the agency's own consultative approach to knowledge absorption. Throughout the year, agency staff attend conference, industry events and workshops, and use them as opportunities to talk to industry about R&D funding that is available. As a bi-product, companies talk to the agency about their own plans, and projects they are thinking about over the next year and beyond. Collectively, this knowledge gives the agency a broad picture of the direction that industries are heading in, how that fits with government policy objectives, and therefore early ideas about where targeted funding might add the most value. These ideas are discussed internally and filtered down into emerging themes, which the agency tests with industry advisory panels comprising experts and option formers; academics; and representatives of SMEs and large companies.

At this point, Innovate UK hosts its own events with up to 300 companies to seek their views on these themes, in terms of potential commercial opportunities, UK capabilities and areas where targeted investment would be most welcome. It also commissions its own market research and seeks further advisory panel input. Together, all of these inputs are used to refine the themes into a smaller number of priority areas for investment in the upcoming year, which form the bases of competitions. Winning projects are then led and project managed by industry and monitored by Innovate UK.

Like companies, the agency faces its own challenges and barriers to effectively discharging its functions. Since 2007, Innovate UK has invested over £1.8 billion supporting innovation and has helped more than 7,600 organisations with projects. As an organisation of only 300 people, having sufficient time to focus on the whole process, from gathering insights to running competitions and monitoring projects, can be challenging. Identifying companies that could add values to projects, particularly harder to reach small companies, and making sure industry is generally aware of the funding that is available to them also has its challenges.

In spite of this, Innovate UK's competition process and framework gives it a platform to encourage different types of companies to work together. Its exposure across sectors also allows it to bring stakeholders in different sectors together around common challenges, like battery technology, in a way that individual companies or industry groups would struggle to do by themselves.

## 7. APPENDIX 2 – SURVEY QUESTIONNAIRE

### INTRODUCTION

Intelligent Mobility (IM) uses the latest in technology, communications and data processing to move people and goods in faster and smarter ways. The Transport Systems Catapult (TSC), part of a network of technology and innovation centres in the UK, has a specific role to drive Intelligent Mobility in the UK and to support companies within the sector.

As part of its work, TSC has commissioned this survey to understand the ability of companies in the UK to create new products and services, refine operational processes, and develop new business models by using external knowledge.

This survey breaks down the end-to-end process of knowledge adoption into four distinct phases—knowledge identification, assimilation, transformation, and exploitation. Each of these will be explained in more detail during the survey.

#### Why you?

This survey is aimed at companies which operate in the Intelligent Mobility market or those which the TSC believes could potentially benefit from the Intelligent Mobility market in the UK. Since the survey focuses on their general abilities to adopt new knowledge, rather than the specifics of the knowledge itself, it does not require companies to divulge any confidential information.

#### Q1 What is your job title?

- Owner/Founder/Chairman
- Chief Executive Officer/Managing Director
- Chief Financial Officer/Head or Director of Finance
- Chief Information Officer/Head or Director of IT
- Chief Innovation Officer/Head of Product or Service Development/Head of R&D
- Chief Marketing Officer/Director or Head of Marketing
- Chief Operating Officer/Director or Head of Operations
- Chief Strategy Officer/Director or Head of Strategy
- Chief Technology Officer or other Head of Technology
- Other C-level or direct report – please specify \_\_\_\_\_
- Other, please specify \_\_\_\_\_

#### Q2 What is your company's annual turnover?

- Less than £2 million
- £2 million to £9.9 million
- £10 million to £24.9 million
- £25 million to £49.9 million
- £50 million to £99.9 million
- £100 million to £499.9 million
- £500 million and above (please specify) \_\_\_\_\_

#### Q3 How many people does your company employ in the UK?

- 0–10
- 11–50
- 51–100
- 101–500
- Over 500 – please specify \_\_\_\_\_

#### Q4 Please estimate the proportion of employees who hold a degree or higher qualification (e.g., BA/BSc, MA/PhD)

- None
- 1%–9%
- 10%–19%
- 20%–29%
- 30%–39%
- 40%–49%
- Over 50% – please specify \_\_\_\_\_

#### Q5 Please indicate up to three of the most popular degree subjects:

- Engineering
- Science and technology
- Maths and Statistics
- Computer science
- Social policy
- Management
- Other subjects – please specify \_\_\_\_\_

**Q6 In which region is your UK headquarters located?**

- Scotland
- Wales
- Northern Ireland
- England—North East
- England—North West
- England—Yorkshire and the Humber
- England—East Midlands
- England—West Midlands
- England—East of England
- England—London
- England—South East
- England—South West

**Q7 Is your company's global headquarters outside of the UK?**

- No
- Yes – please specify \_\_\_\_\_

**Q8 What is your company's main activity?**

**Q9 In the below key Intelligent Mobility market sectors, which of the following statements applies most to your company's operations in the UK?**

	Currently operates	Capabilities / plans	Capabilities / no plans	N.A.
Autonomous Vehicles market, specifically the technologies that enable vehicles to operate without human intervention. Examples include control systems, environment sensing, localisation, mapping and connectivity systems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Data collection and communication platforms that communicate position and traffic conditions. Examples include condition monitoring, sensors, cameras and GPS systems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Security, resilience, safety and cyber security technologies that help assess, monitor, evaluate, report and mitigate risks. Examples include control, risk engineering and cyber security systems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q10 Which of the following subsectors relate most closely to your company's products and services?**

Choose all that apply

**Autonomous Vehicles**

- Control systems – for example, integrated software systems which enable autonomy, system management and operator assistance.
- Localisations and mapping – technologies which use computational techniques to construct a vehicle's local virtual environment and position the vehicle within the mapped environment.
- Connectivity – technologies that allow vehicles to share data with other vehicles, and the infrastructure that facilitate autonomy and off-board processing.
- Sensing – which includes optical and scanning technologies that gather environmental information (radar/lidar) in addition to internal condition monitoring.
- Propulsion – including the optimisation of traditional internal combustion engines as well as new developments in electric and fuel cell propulsion and the associated control systems which manage such high power density devices safely.
- Energy Storage – such as novel battery chemistries, rapid energy transfer devices such as capacitors and mechanical storage in flywheels.
- Energy & Fuel Supply – Technologies related to the provision of energy for recharging facilities and the generation and distribution of energy sources.
- Vehicle Efficiency – Particularly cutting-edge design techniques and technologies including low power consumption electronics and lightweight vehicles structures.
- CAV Standards – These include legislative, regulatory and standardisation authorities which may influence policy makers and define the boundaries that CAV manufacturers operate in. These include insurers and certifiers of autonomous control system.
- Human Factors – cognitive analyses technologies that reduce the impact of transportation disruptions due to human error.

### Data Collection and Communication Platforms

- Transportation Infrastructure Systems – Including systems applicable to multiple transport modes, which gather data to support the maintenance of infrastructure and increased traveler safety.
- Transportation Vehicles – For example, V2V applications such as location sensing, V2I applications such as asset tracking, and on-board vehicle condition monitoring.
- Transportation Operation Systems – Including data collections, such as traffic management and environmental data, which contributes towards strategic-level transport systems management.
- Transportation Users Systems – systems which allow for dynamic pricing and smart ticketing systems by amalgamating user generated information and journey information.
- Physical Communication Platforms – technologies that enable physical telecommunications infrastructure; for example, antennas and communications masts and mobile communication platforms such as smart phones and other connected devices.
- Communication Modes – a broad category which include short-range such as radio and Bluetooth, long-range satellite communications and digital cellular communications.

### Security, Resilience, Safety and Cyber Security

- Asset Tracking – for the purpose of reduced disruptions, for example the management of fleets of vehicles through GPS and CCTV video monitoring, or the automated tracking of goods through RFID tagging.
- Criminal Intent Detection – Security technologies to deter and prevent the likelihood of criminal and/or terrorist incidents, including boarder protection devices such as metal detections at transportation hubs (airports, rail stations, etc).
- Access Control – Technologies that prevent the occurrence of malicious disruption by individuals, such as card readers.
- Early Warning – systems intended to notify people in the event of emergencies, such as fire alarm systems and other alarm systems in transportation hubs.
- Disaster / Emergency Management – including risk assessments and traffic modelling activities, and maintaining supply chains in response to natural disasters such as floods required predictive modelling and technologies specific to search and rescue, such as UAVs and ROVs.
- Cyber Security – Technologies which enable the encryption of wireless and wired communication to maintain their privacy and integrity, including:
  - Threat assessment and prevention – including encryption techniques for currency transfer and network architectures, learning algorithms for real-time and adaptive protection of digital infrastructure systems;
  - Network architecture – software defined networks and distributed systems for network security and resilience; and
  - Network storage – Cloud Security service and Storage Area Network security techniques.

### Q10A Which of the following subsectors relate most closely to your company's products and services?

Please select only one

#### Autonomous Vehicles

- Control systems – for example, integrated software systems which enable autonomy, system management and operator assistance.
- Localisations and mapping – technologies which use computational techniques to construct a vehicle's local virtual environment and position the vehicle within the mapped environment.
- Connectivity – technologies that allow vehicles to share data with other vehicles, and the infrastructure that facilitate autonomy and off-board processing.
- Sensing – which includes optical and scanning technologies that gather environmental information (radar/lidar) in addition to internal condition monitoring.
- Propulsion – including the optimisation of traditional internal combustion engines as well as new developments in electric and fuel cell propulsion and the associated control systems which manage such high power density devices safely.
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- Energy & Fuel Supply – Technologies related to the provision of energy for recharging facilities and the generation and distribution of energy sources .
- Vehicle Efficiency – Particularly cutting-edge design techniques and technologies including low power consumption electronics and lightweight vehicles structures.
- CAV Standards – These include legislative, regulatory and standardisation authorities which may influence policy makers and define the boundaries that CAV manufacturers operate in. These include insurers and certifiers of autonomous control system.
- Human Factors – cognitive analyses technologies that reduce the impact of transportation disruptions due to human error.

### Data Collection and Communication Platforms

- Transportation Infrastructure Systems – Including systems applicable to multiple transport modes, which gather data to support the maintenance of infrastructure and increased traveler safety
- Transportation Vehicles – For example, V2V applications such as location sensing, V2I applications such as asset tracking, and on-board vehicle condition monitoring
- Transportation Operation Systems – Including data collections, such as traffic management and environmental data, which contributes towards strategic-level transport systems management
- Transportation Users Systems – systems which allow for dynamic pricing and smart ticketing systems by amalgamating user generated information and journey information
- Physical Communication Platforms – technologies that enable physical telecommunications infrastructure;

### Security, Resilience, Safety and Cyber Security

- Asset Tracking – for the purpose of reduced disruptions, for example the management of fleets of vehicles through GPS and CCTV video monitoring, or the automated tracking of goods through RFID tagging
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- Disaster / Emergency Management – including risk assessments and traffic modelling activities, and maintaining supply chains in response to natural disasters such as floods required predictive modelling and technologies specific to search and rescue, such as UAVs and ROVs
- Cyber Security
  - Threat assessment and prevention – including encryption techniques for currency transfer and network architectures, learning algorithms for real-time and adaptive protection of digital infrastructure systems;
  - Network architecture – software defined networks and distributed systems for network security and resilience; and
  - Network storage - Cloud Security service and Storage Area Network security techniques.

**Q11** Whilst your responses to this survey are entirely anonymous, TSC would like to develop a list of companies that are either operating in IM currently, or have the plans and/or capabilities to operate in the sector.

**Would your company object to being added to this list?**

- Yes
- No

**Q11A** The purpose of this project is to encourage decision makers to act. This is best achieved when industry challenges relate to real people and companies. We would like to give you the opportunity to carry out a short face-to-face interview to discuss the findings of the final report. With your permission TSC and Oxford Economics would develop this into a case study which will feature in the report and be read by senior Intelligent Mobility stakeholders from across Government and Industry.

**Would you want to take this opportunity?**

- Yes
- No

**Q12** During the last three-year period, did your business invest in any of the following, for the purpose of current or future innovation?

**Choose all that apply**

- Internal Research & Development (creative work undertaken within your business that increases knowledge for developing new and improved products and processes)
- External Research & Development (same as above, but performed by external organisations, including companies within your group, and purchased by your businesses)
- A merger with another business or part of another business, which increased turnover by at least 10%
- Hiring employees with specialist skills
- Bringing innovative products and services to market – please specify:

**Q12X1**

- Changes in product design
- Changes in process design
- Changes in business models
- Launching new products and services



**Q13** For each of the innovation-related investments in the previous question, please estimate the size of the expenditure as a percentage of total revenue over the last three-year period. Include both internal costs and purchases from outside of the business.

	None	0%–4%	5%–10%	10%–24%	25% or more
Internal Research & Development	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
External Research & Development	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mergers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
New hires with specialist skills	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Market introductions of innovative products and services	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

#### Q13 Other

Please Specify

- Internal Research & Development \_\_\_\_\_
- External Research & Development \_\_\_\_\_
- Mergers \_\_\_\_\_
- New hires with specialist skills \_\_\_\_\_
- Market introductions of innovative products and services \_\_\_\_\_

**Q14** Did your business acquire any of the following last year, for the purpose of current or future innovation?

Choose all that apply

- Advanced machinery, equipment, hardware or software for innovation, such as design modelling software, additive manufacturing equipment, including 3-D printing
- Intellectual property (purchases or licensing of patents and non-patented inventions, know-how and other types of knowledge from external organisations)
- Knowledge management and collaboration software to encourage the sharing of ideas across the company

#### KNOWLEDGE ACQUISITION

Knowledge acquisition is defined as a company's general ability to identify, value, and acquire external knowledge, which it uses to develop new products and services, refine operating processes, or develop new business models.

The following questions will focus on your company's knowledge acquisition activities.

**Q15** Which of the following sources does your company use to gather information?

Choose all that apply

- Customers
- Suppliers
- Other companies in your sector
- Companies in other sectors
- Research institutions
- Universities
- Trade or professional bodies
- Public sector bodies
- External experts

#### Q15X1

Choose all that apply

- Within your sector
- Outside of your sector

**Q16** Please indicate how often your company engages with the information sources you selected in the previous question.

Choose one answer per row

	Yearly	6-monthly	Monthly	Weekly	Daily
Customers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Suppliers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other companies in your sector	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Companies in other sectors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Research institutions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Universities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Trade or professional bodies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Public sector bodies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
External experts within your sector	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
External experts outside your sector	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q17** Please indicate how strongly you agree or disagree with the following statements about your company.

Rate on a scale of 1–5, where 1 = Strongly disagree, 3 = Neutral, and 5 = Strongly agree.

	Strongly disagree 1	2	Neutral 3	4	Strongly agree 5
Digital information systems are used to gather information from external sources to develop new products/ processes/business models (e.g., customer or supplier data, or research systems used to search relevant patents and journals).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
We have staff with specific responsibility for gathering external information for the purposes of product/process/business model development.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees are rewarded for using information sources within our industry such as industry journals, market reports, foresight reports, conferences, etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees are rewarded for using information sources from other industries such as industry journals, market reports, foresight reports, conferences, etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q18** How strongly do you agree that ready access to information from customers, suppliers and external partners is acting as a barrier to your company's ability to identify, value and acquire new knowledge?

Rate on a scale of 1–5, where 1 = Strongly disagree, 3 = Neutral, and 5 = Strongly agree.

1	2	3	4	5
				

**KNOWLEDGE ASSIMILATION**

Knowledge assimilation is defined as a company's ability to absorb external knowledge by analysing and fully understanding its value, and where it best fits within the company.

The following questions will focus on your company's knowledge assimilation activities.

**Q19** With regard to assimilating new, external knowledge within your company, please indicate how strongly you agree or disagree with the following statements.

Rate on a scale of 1–5, where 1 = Strongly disagree, 3 = Neutral, and 5 = Strongly agree.

	Strongly disagree 1	2	Neutral 3	4	Strongly agree 5
Ideas and concepts are communicated effectively across departments/teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Different parts of the company work well together to solve problems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tools are used to spread knowledge across the whole organisation (e.g., knowledge management systems, intranet, internal studies, best practice guides).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Face-to-face, cross departmental/team meetings are used to exchange new developments, discuss problems and/or achievements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Temporary exchanges of personnel between departments/teams are encouraged.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q20** Please indicate how often your company engages in the following activities.

Choose one answer per row

	Yearly	6-monthly	Monthly	Weekly	Daily
Ideas and concepts are communicated cross-departmentally.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Different parts of my company work together to solve problems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Face-to-face cross-departmental meetings are held to exchange new developments, problems, and achievements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Temporary exchanges of personnel between departments/divisions/teams are supported.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q21** Please indicate how strongly you agree or disagree with the following statements about your company.

Rate on a scale of 1–5, where 1 = Strongly disagree, 3 = Neutral, and 5 = Strongly agree.

	Strongly disagree 1	2	Neutral 3	4	Strongly agree 5
Information flows quickly, e.g., if a department/team obtains important information it communicates this to all other departments or teams	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees from diverse departments/teams get along well when communicating with each other on a cross-departmental basis.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There is informal contact between employees of all levels and departments/teams.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees know who possesses specialist skills and knowledge, and for whom certain information is of special interest.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees willingly share their knowledge, information, and experience with their colleagues.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
We employ staff whose specific responsibilities include ensuring knowledge is spread across the organisation.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees are rewarded for sharing their knowledge, information, and experience with their colleagues.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

## KNOWLEDGE TRANSFORMATION

Knowledge transformation is defined as a company's ability to combine its current knowledge with new, external knowledge.

The following questions will focus on your company's knowledge transformation activities.

**Q22** When transforming new, external knowledge within your company, please tell us the extent to which you agree with the following statements.

	Strongly disagree 1	2	Neutral 3	4	Strongly agree 5
Employees engage in further training and continuous learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees share and combine ideas cross-departmentally/across teams	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q23** Please indicate how often employees at your company engage in the following activities.

	Yearly	6-monthly	Monthly	Weekly	Daily
Employees engage in further training and continuous learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees share and combine ideas cross-departmentally/across teams	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q24** Please indicate how strongly you agree or disagree with the following statements about your company.






Rate on a scale of 1–5, where 1 = Strongly disagree, 3 = Neutral, and 5 = Strongly agree.

	Strongly disagree 1	2	Neutral 3	4	Strongly agree 5
We quickly adopt external knowledge for use in product/service development.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees link existing knowledge with new insights when developing new products or processes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
We emphasize the systematic reuse of insights from past projects.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Our employees transform new knowledge into valuable information for our company.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees share new knowledge and make it accessible and available.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Strongly disagree 1	2	Neutral 3	4	Strongly agree 5
Learning capabilities are a competitive advantage for our company.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees are able to effectively apply new knowledge in their practical work.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees are encouraged and given time to experiment with applying new ideas.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees are rewarded for successful knowledge transfer.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q25 How strongly do you agree that levels of investment in staff training and development are acting as barriers to your company's knowledge transformation activities?**

Rate on a scale of 1–5, where 1 = Strongly disagree, 3 = Neutral, and 5 = Strongly agree.

1	2	3	4	5
				

**KNOWLEDGE EXPLOITATION**

Knowledge exploitation is defined as a company's ability to incorporate new, assimilated, and transformed external knowledge to create new goods and services, or ways of doing things, including new business models.

These final questions will focus on your company's knowledge exploitation activities.

**Q26 Please indicate how strongly you agree or disagree with the following statements about your company.**

Rate on a scale of 1–5, where 1 = Strongly disagree, 3 = Neutral, and 5 = Strongly agree.

	Strongly disagree 1	2	Neutral 3	4	Strongly agree 5
We have introduced new or significantly improved commercially successful products/ services based on our research in the last 3 years.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
We have introduced new or significantly improved processes for producing or supplying new products/services in the last 3 years.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Strongly disagree 1	2	Neutral 3	4	Strongly agree 5
We have introduced new or significantly improved business models in the last 3 years.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
We support the development of prototypes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
We convert innovative ideas into patents, new publications and/or copyrighted materials.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
We implement innovations successfully through effective change and project management.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
We evaluate the commercial potential of new innovations (e.g., through carrying out market research).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
We measure the contribution delivered by innovations (e.g., in terms of improved performance, revenues, cost savings).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
We support the launch of new products/ services with effective marketing.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
In the last 3 years we have implemented technologies and tools to accelerate innovation (e.g., advanced manufacturing equipment).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Employees are rewarded for successfully launching innovative new goods and services.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Staff are given specific responsibilities for ensuring exploitation of knowledge.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Management are good role models regarding the exploitation of knowledge.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q27 How long are the typical or average product development cycles in the subsector(s) in which your company operates?**

- 0–2 years
- 2–5 years
- 5–10 year
- More than 10 years – please specify \_\_\_\_\_

**Q28** Please estimate the percentage of your company's turnover in the last financial year that was derived from products and services, or business model innovations that were:

	% of turnover
New to the market	
Only new to your business	
Significantly improved	
Unchanged or marginally modified	

**Q28DK**

- Don't know
- Not applicable

**Q29** Please estimate the percentage of your company's cost savings in the last financial year that were derived from process improvements that were:

	% cost savings
New to the market	
Only new to your business	
Significantly improved	
Unchanged or marginally modified	

- Don't know
- Not applicable

**Q30** At this moment in time, does your company have any new products/services that

	Yes	No
Have been abandoned	<input type="checkbox"/>	<input type="checkbox"/>
Are still under development	<input type="checkbox"/>	<input type="checkbox"/>

**Q31** How strongly would you agree that levels of investment in sales and marketing, advertising and promotion are acting as barriers to your company's ability to exploit knowledge?

Rate on a scale of 1–5, where 1 = Strongly disagree, 3 = Neutral, and 5 = Strongly agree

1	2	3	4	5
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



Q32 In each of the four stages of knowledge adoption, how strongly do you agree that the following factors are acting as barriers for your company?

Rate on a scale of 1–5, where 1 = Strongly disagree, 3 = Neutral, and 5 = Strongly agree.

	Knowledge acquisition	Knowledge assimilation	Knowledge transformation	Knowledge exploitation
Culture and ways of working	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree
Access to the right technology	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree
Access to the right skills and talent	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree
Guidance and support from government, trade, and professional groups	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree	<input type="checkbox"/> 1 - Strongly disagree <input type="checkbox"/> 2 <input type="checkbox"/> 3 - Neutral <input type="checkbox"/> 4 <input type="checkbox"/> 5 - Strongly agree

Q33 Please describe the actions, by your company or outside agencies, which would most help you to be more effective in the Intelligent Mobility sector.

#### SURVEY QUESTIONS RELATED TO THE FOUR ABSORPTIVE CAPACITY CAPABILITIES

Questions used in our survey related to the four capabilities of Absorptive Capacity were developed from a literature review, predominantly using Flatten et al (2011). The authors of this paper undertook an extensive literature review exercise using articles in ten management journals to identify related research streams that were similar to or overlapped with at least one element of Absorptive Capacity. This was expanded by using keyword searches that related to these research streams in electronic databases such as Science Direct and JSTOR to identify further articles not published in their 10 chosen management journals. These research streams were then aligned to the capability of Absorptive Capacity for which there was the greatest degree of similarity/overlap. Of the 269 papers studied, 33 were identified to contain a research stream that aligned to at least one of the Absorptive Capacity capabilities. Their initial pool of questions with which to measure Absorptive Capacity were developed from these 33 research streams.

Three rounds of pre-testing were conducted to assess the quality of their chosen questions. This included two tests with business executives and one with academic experts which identified any questions that needed to be modified, eliminated or added. Following the application of their survey, factor analysis was undertaken to further refine the list of questions that were used in their measure of Absorptive Capacity.

## 8. APPENDIX 3 – DETAILED IM MARKET SEGMENTS

### THE AUTONOMOUS VEHICLES MARKET SEGMENT

Sub sector	Definition
Control Systems	Technologies and processes that enable real-time intelligent control of vehicles or systems. This ranges from traditional low-level safety-rated servo control (brakes, steering, and powertrain) to complex event processing, decision-making algorithms and agent based control (cyber-physical systems).
Localisation and mapping	Technologies enabling an understanding of the local environment (e.g. 'where am I and what is around me?'). This includes imaging techniques ranging from satellites to on-board HD video. This also includes technologies and techniques which enable location positioning and an understanding of the environment, such as computer vision.
Connectivity	Ability to connect different systems, travellers, goods, infrastructure with the goal of establishing 'ubiquitous connectivity' across different ranges. This field encompasses vehicle-to-vehicle communication platforms and protocols to data privacy and infotainment.
Sensing	This sector surrounds electronic hardware and data processing software which enable internal and external environmental awareness. This includes optical and radar techniques to understand the wider environment, in addition to internal condition monitoring.
Propulsion	This field encompasses traditional internal combustion engines, which a focus upon the optimisation of such systems. This also includes new developments in electric and fuel cell propulsion and the associate control systems which manage such high-power density devices safely.
Energy storage	In support of novel propulsion technologies (e.g. hydrogen fuel cells and electric traction motors) the storage of energy is a separate field of research which is essential for vehicle range. These technologies take the form of novel battery chemistries, rapid energy transfer devices such as capacitors and mechanical storage in flywheel, for example.
Energy and fuel supply	Technologies related to the provision of energy for recharging facilities and energy the generation and distribution of energy sources.
Connected and Autonomous Vehicles (CAV) standards	These include legislative, regulatory and standardisation authorities which may influence policy makers and define the boundaries within which commercial CAV manufacturers operate. These include the certification of autonomous control systems which inform insurers and software manufacturers.
Human factors	Design techniques which aim to place the human at the centre of the vehicle, transportation system or service design, thus improving the user experience.
Vehicle efficiency	Cutting-edge techniques and technologies which utilise the potential design changes in relation to connected and autonomous vehicles. These include low power consumption electronics and lightweight vehicles structures, for example.

### THE DATA COLLECTION AND COMMUNICATION PLATFORMS MARKET SEGMENT

Sub sector	Definition
Transportation Infrastructure Systems	The collection of data from distributed Internet of Things (IoT) assets in relation to transport system infrastructures. These include systems applicable to multiple transport modes, which gather data to support the maintenance of infrastructure and increased traveller safety.
Transportation Vehicles	This sub-sector concerns data collection methods and their associated technologies in relation to vehicles. For example, these range from V2V applications such as location sensing, V2I applications such as asset tracking, and on-board vehicle condition monitoring.
Transportation Operation Systems	This sub-sector includes data collections, such as traffic management and environmental data, which contributes towards strategic-level transport systems management.
Transportation User Systems	As a source of data, these systems contributes towards dynamic pricing and smart ticketing systems by amalgamating user sentiment and journey information.
Physical Communication Platforms	The sub-sector includes the enabling physical telecommunications infrastructure; for example, antennae and communications masts and mobile communication platforms such as smart phones and other connected devices.
Communication Modes	This sub-sector collates communication modes into broad categories which include short-range such as radio and Bluetooth, long-range satellite communications and digital cellular communications.

### THE SECURITY, RESILIENCE AND CYBER SECURITY MARKET SEGMENT

Sub sector	Definition
Asset Tracking	The tracking of assets in relation to the transportation of goods and people in relation to reducing the likelihood of disruptions. This concerns the management of fleets of vehicles through GPS and CCTV video monitoring, or the automated tracking of goods through RFID tagging.
Criminal Intent Detection	Security technologies to deter and prevent the likelihood of criminal and/or terrorist incidents. These include boarder protection devices such as metal detectors at transportation hubs (airports, rail stations, etc.)
Access Control	To prevent the occurrence of malicious disruption by individuals, access control technologies, such as card readers, are required at transportation hubs to control the flow of people.
Early Warning	These systems are intended to notify people in the event of emergencies. These include firm alarm systems and other alarm systems in transportation hubs.
Disaster / Emergency Management	The planning and management of people and traffic to account for emergency services will reduce the impact of transportation disruptions. This includes risk assessments and traffic modelling activities, and maintaining supply chains in response to natural disasters such as floods required predictive modelling and technologies specific to search and rescue, such as UAVs and ROVs
Threat Assessment & Prevention	A range of techniques which perform threat assessment such as malware reverse engineering and threat analytics. This also includes prevention techniques, such as next generation firewalls, which combine traditional firewall technique with deep packet inspection and network filtering.
Network Architecture	Novel new approaches to building more resilient and secure networks, which include software defined networks and distributed systems.
Network Storage	This category includes systems and service offerings to secure network data including Cloud Security service and Storage Area Network security techniques.

## 9. APPENDIX 4 – INDEX DEVELOPMENT METHODOLOGY

The process of constructing the index measure started with survey responses to questions associated with the four capabilities of Absorptive Capacity being used as the basis for indicators for the index. Specifically, responses were combined into four sub-indices using Principle Component Analysis (PCA). This Appendix explains this process in more detail.

### DATA

Questions in the survey that focused firms' capabilities in each of the four capabilities of Absorptive Capacity were scaled from one to five. With the exception of Question 16, these responses were used for the PCA. For question 16 (sources of knowledge), responses were first combined and normalised separately to account for the fact that not all sources are relevant to different firms, and that 'daily' contact may not always be appropriate. So for example, acquiring knowledge from 'trade or professional bodies' on a regular basis may be less relevant to some firms than others.

The normalisation process for this question started with scores from each source of knowledge being summed together for each firm. These scores were then split into 5 percentiles. The percentiles were then scored 1 to 5 with the lowest percentile given a score of 1 and the highest percentile given a score of 5.

Combining and normalising this question in this way meant, using the earlier example, that we avoided 'penalising' firms (by giving them a lower score) for either not acquiring knowledge from trade or professional bodies or, when they did, for not doing so on a daily basis.

The resulting score was then used in the PCA.

### PRINCIPLE COMPONENT ANALYSIS (PCA)

Principal Component Analysis, or PCA, is a procedure for identifying a smaller number of uncorrelated variables, called "principal components", from a large set of data. The goal of PCA is to explain the maximum amount of variance with the fewest number of principal components.

To carry out the PCA procedure, we analysed the first principle component to determine the weightings that each question should have in the index. The first principal component is the linear combination of responses that has maximum variance (among all linear combinations), so accounts for as much variation in the data as possible. The weights given to each of the responses then involved calculating the eigenvalues and eigenvectors of the variance-covariance matrix  $\Sigma$ . The purpose of this is to weight the responses according to the correlation between them. Using the first principle component helps to ensure that the index is as representative as it can be of the underlying responses.

PCA identified that the weights were similar across each of the sub-indices, which could be an indication that the survey questions were designed coherently and that firms responded consistently across the questions.

### CALCULATING THE FINAL INDEX

Before running the analysis, PCA standardized the variables by subtracting its mean score from each question and dividing it by its standard deviation. The calculated weights for each question which were then multiplied by each standardised question response and summed together to get the first principle component. Each of these four indices were then re-scaled to be between zero and 25 so the final score summed to 100.



## 10. APPENDIX 5 – BIBLIOGRAPHY

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# ABSORPTIVE CAPACITY IN INTELLIGENT MOBILITY

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A REPORT FOR TRANSPORT SYSTEMS CATAPULT

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