Institution: University of Sunderland		
Unit of Assessment: 12 Engineering		
Title of case study: Sustainable Advanced Manufacturing in the North East		
Period when the underpinning research was undertaken: 2000-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Roger O'Brien	Director of AMAP	2015-date
David Baglee	Professor	2000-date
Michael Knowles	Senior Lecturer	2007-date
Ahmed Elmarakbi	Professor	2007-2018
Adrian Morris	AMAP Operations Manager	2008-date
Period when the claimed impact occurred: January 2018-December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

The £11 million Sustainable Advanced Manufacturing (SAM) project is a knowledge exchange, research and business support programme underpinned by a diverse body of research produced in Sunderland's Institute of Automotive and Manufacturing Advanced Practice (AMAP). It has enabled manufacturing SMEs in the North East of England to implement product and process development and adopt new technology. Purposively aligning SAM's scope with the diverse scope of AMAP research has enabled SMEs across the sector to seek research-based support for a broad range of organisational challenges. The effect (enhanced productivity through innovation) is felt by businesses through, for example, improved profitability. SAM has delivered benefits of £2.34 for the regional economy for every £1 of funding.

2. Underpinning research (indicative maximum 500 words)

Research undertaken in the Institute of Automotive and Manufacturing Advanced Practice (AMAP) underpins the Sustainable Advanced Manufacturing (SAM) project. A body of research in three of AMAP's areas of applied research (design, supply chain and process, and advanced maintenance) forms the intellectual backbone of the practical support and advice offered to SMEs through the project. The diversity of the research undertaken has facilitated the strongly adaptive and bespoke, solution-focussed approach in the SAM project. The rationale behind SAM is directly informed by prior knowledge exchange projects such as **Digital Factory** (2003-13), which brought research to bear in training over 6,500 manufacturing employees and consultancy for hundreds of business; and **Engineering Fellows** (2003-6), which developed and embedded research cultures in regional industry by engaging senior industrialists in PhD programmes within their own companies. The body of work that underpins the SAM project and its impact reflects a long-term programme of research in Engineering; consequently, only a small sample of exemplar outputs and grants from each area are described.

Design

Design research at Sunderland has a broad scope, including work on material, product and system design. SAM participants benefit particularly from the Unit's research on computational modelling and simulation in design. Exemplar projects include:

- Research led by Elmarakbi to model the behaviour of new graphene-based materials used in fabrication of nanocomposites **[R1]**. It demonstrated that car bumpers produced with graphene-enhanced composite materials had 40% higher specific energy absorption than traditional composite materials, and has greater stability. A method for forming graphene nanoplatelets was patented.
- The Eco2Trans project, which aimed to increase efficiency and range of electric vehicles. Computer simulation and rig-based prototype modelling demonstrated that it is possible to improve overall energy consumption levels by around 5 to 12% by using a variable ratio gearbox within an electric vehicle **[R2]**

Supply chain and process

AMAP research on manufacturing processes and (primarily automotive) supply chains has created an evidence base used in the SAM project to increase output, reduce waste and

enhance profit margins in participating SMEs. Research on virtual and augmented reality (VR and AR) has had particular application in designing new manufacturing, on-boarding, auditing and customer acquisition processes. Exemplar projects include:

- OPTFEST redesigned modern maintenance technologies and practices from the aerospace and other industry sectors to improve the profitability of the engineering parts of the food processing sector **[R3]**.
- Work by Dixon et al. (2017) revealed inconsistencies in maintenance practice in the automotive supply chain, and how such inconsistency links with organisational cultural development. It resulted in a conceptual tool that guides manufacturers in the automotive supply chain towards a better understanding of how it can best monitor, develop and enrich its own maintenance strategy **[R4]**.
- AMAP research explores the use of augmented and virtual reality (AR and VR) in manufacturing settings. Haddad and Baglee conclude that AR could have a critical role in knowledge transformation and knowledge transfer **[R5]**.

Predictive maintenance

Research on predictive maintenance led by Baglee examines the effect of innovation in maintenance systems, strategies and technology, and the barriers to adopting such innovation. This research has enhanced how participating SMEs approach maintenance.

- DYNAMITE resulted in an infrastructure for mobile monitoring technology and created new for-decision systems incorporating sensors and algorithms. The key features include wireless telemetry, intelligent local history in smart tags, and on-line instrumentation. A novel method AIMMS (Advanced Integrated Manufacturing Maintenance System) was developed to identify factors influencing the implementation of modern maintenance practices, and enable organisations to devise an overall maintenance strategy **[R6]**.

3. References to the research (indicative maximum of six references)

R1 Elmarakbi, Ahmed, Azoti, Wiyao and Serry, Mohamed (2017) *Multiscale modelling of hybrid glass fibres reinforced graphene platelets polyamide PA6 matrix composites for crashworthiness applications.* Applied Materials Today, 6. ISSN 2352-9407.

R2 Ren, Qinglian, Crolla, Dave and Morris, Adrian (2009) *Effect of transmission design on Electric Vehicle (EV) performance.* In: 5th Vehicle Power and Propulsion Conference, 2009. VPPC '09. IEEE, 7-11 Sept 2009, Dearborn, MI, USA.

R3 Baglee, David, Knowles, Michael and Morris, Adrian (2013) *Optimisation of Food and Engineering Supply Chain Technology (OPTFEST): A Case Study.* In: Comadem 2013, 11 - 13 Jun 2013, Helsinki.

R4 Dixon, Derek, Robson, Kenneth, Baglee, David and Wheatley, Alan (2017) *The role of cultural development when improving maintenance practice in the automotive supply chain.* In: COMADEM 2017, 10-13 July 2017, Preston, UK

R5 Haddad, Karam and Baglee, David (2015) *Using Augmented Reality in Manufacturing Firms and its Impacts on Knowledge Transfer.* In: 16th European Conference on Knowledge Management - ECKM 2015, 3 - 4 Sep 2015, University of Udine, Italy.

R6 Baglee, David and Knowles, Michael (2010) Maintenance strategy development within SMEs: the development of an integrated approach. *Control and Cybernetics*, 39 (1). pp. 275-304. ISSN 0324-8569.

Quality indicators: **R1** was funded by the EU Graphene Flagship project and was published in a peer-reviewed Q1 journal. **R2** is a peer-reviewed conference paper presented at an international conference, and has 125 citations to date. **R3**, **R4** and **R5** are peer-reviewed conference papers presented at international conferences. **R6** was published in a peer-reviewed journal and has 40 citations to date.

Grants

Graphene Flagship, EU FP7, 2014-17, €54M (Sunderland: £113k). Graphene Flagship, EU Horizon 2020, 2016-19, €89M (Sunderland: £143k). OPTFEST, UK Department of Trade and Investment, £18k. DYNAMITE, EU FP6, €3.7M (Sunderland: £234k). ECO2Trans, One North East, £314k. Engineering Fellows, One North East, 2003-06, £1.63m. Digital Factory, ERDF/One North East, 2003-2013, £2.3m

4. Details of the impact (indicative maximum 750 words)

In early 2018, Sunderland's School of Engineering, in collaboration with the European Regional Development Fund (ERDF), launched the Sustainable Advanced Manufacturing

project (SAM). This pioneering knowledge exchange, research and business support project leverages the Institute of Automotive and Manufacturing Advanced Practice's (AMAP) industry-facing applied research portfolio and expertise in the service of the regional manufacturing sector. It enables SMEs in the manufacturing supply chain to implement product and process development and adopt new technology, and make sound capital investment decisions. The resulting enhanced productivity through innovation benefits both the SMEs involved and the regional economy. To date the project has received £10.9m in funding. Its continued success is reflected in a recent decision by the Ministry of Housing and Local Communities to extend the project to 2023.

SAM was born out of AMAP's successful and diverse research and knowledge exchange projects, including Engineering Fellows and Digital Factory. Research-based expertise in design, supply chain and process, and predictive maintenance underpins the work undertaken with small and medium sized enterprises (SMEs) to address organisational challenges. It also informs the design and content of SAM's micro-factories where SMEs can visualise and test innovative technologies and processes. The project's leadership and technical staff include University research staff **O'Brien** (Director of AMAP, SAM Technical Lead and SAM Grant Panel member) **Baglee** (Head of Engineering, SAM Steering Committee member and SAM Grant Panel member), **Morris** (Lecturer and AMAP Operations Manager, and SAM Senior Manufacturing Specialist) and **Mehrabi** (Associate Professor of Engineering and SAM Research Lead). The SAM Technical Team, comprising specialist researchers and technical staff at the University, work with SMEs to address organisational challenges In aligning the scope of the project with the (diverse) scope of AMAP's research, SAM enables SMEs across the manufacturing sector to access research-derived support to address a broad range of organisational challenges.

Impact on the North East region

The North East has lowest level of expenditure on R&D of any English region and performs poorly on all principal innovation metrics. There has been underinvestment by the private sector and capability failures where companies lack the skills, resources or other capacities to exploit innovation opportunities **[S1].** Sunderland City Council *"are acutely aware that economic challenges can make companies reticent to invest in the resources, such as staff and equipment, which are necessary for sustainability. Partnerships with research organisations can remove some of these barriers and give SMEs access to knowledge, equipment and facilities that are essential for innovation and their own sustainability"* **[S2].**

An external assessment of the SAM project **[S1]** carried out in October 2020 at the request of ERDF shows that it has achieved this goal, with **significant benefit to the regional economy**. The assessment directly attributes 198 FTE new jobs, additional £20m in sales turnover and £6.6m Gross Value Added to the SAM project. Productivity, measured by Output per Hour (OpH), increased following SAM support by an average of 9.1% to £64.43 (based on participant self-reporting), compared to a sector-level average of £39.25 across the UK and £36.45 at the North East level (according to the Office for National Statistics' 2018 OpH data for the manufacturing sector). **The assessment concluded that for each £1 of funding, SAM delivered benefits of £2.34 for the regional economy.**

The project **supports the strategic development goals of both the City of Sunderland and the wider North East region**. The Business Growth Director of the North East LEP says: "*The North East LEP has identified advanced manufacturing as one of four areas of strategic importance, where our assets and capabilities have strong opportunity for growth. The SAM project aligns with and supports these growth ambitions**. It is a critical activity underpinning our commitment to supporting businesses to capitalise on local research and innovation capability**… SAM provides technology expertise that encourages SMEs to explore new ways of working, and then financial grant support to de-risk their take-up of these technologies. **As a bridge between academia and industry, this is highly effective in enabling research to become commercialized**. The project, built on the foundations of the University of Sunderland's excellent research in advanced manufacturing,*

has confirmed the role of the University in strengthening the regional economy and in removing barriers to innovation" **[S3]**.

The Chief Executive of Sunderland City Council acknowledges the project's relevance to the City Plan, adding: "***The University's research on advanced manufacturing provides the foundations of the SAM project, and underpins its contribution to economic growth in the city and wider region****… Advanced manufacturing is a key part of the local economy, and its sustainability and growth are critical…* ***The importance of this cannot be over-estimated and has been increased as we seek to adapt to the wider challenges and opportunities of a post-Covid post-EU Exit economy****… The SAM project is an exemplar mechanism for enabling these partnerships and is a success because … the University of Sunderland undertakes applied research that is informed by industry needs. The industry-facing nature of their research also brings credibility to the project – essential for demonstrating to SMEs the value of engaging with the project"* **[S2].**

Impact on participating SMEs

SMEs can lack the expertise, resources and space to embrace productivity-enhancing innovation. The SAM project was designed to address these challenges by giving SMEs access to knowledge and facilities arising from the UoA's rich history of academic research, innovation and industry partnerships. SMEs benefit from four strands of support:

- Knowledge exchange projects of up to 15 days with the SAM Technical Team, working with deliberate focus on areas where there is both a specific advanced manufacturing need, and knowledge within the team and complementary University academic staff to address it. Since the project launch, **253 SMEs have received 6,379 hours of bespoke, solutions-focussed support [S4].**
- Grants of up to £50,000 to support the growth of new products and processes. The grant fund operates as an extension to Technical Team support which must have been received prior to applying for a grant. This ensures that the funding enables real and meaningful changes identified by the team as appropriate and realistic, and not simply allocating grants to fund 'nice to have' capital equipment. The UoA's research, in underpinning advice to SMEs and funding decisions, ensures that every penny in grant money delivers impact. **46 SMEs have received grants totalling £1.13m. [S4]**
- Access to industry-leading technology and equipment in five micro-factories, including VR and AR software, a two-material 3D printer, Hexagon Manufacturing Intelligence measuring equipment, and a robotic welding cell. The design of the micro-factories and the selection of equipment drew on knowledge of the state of the art and future trends in Industry 4.0 gained through applied research, and the facilities allow SMEs to visualise and test the advice they receive from the Technical Team before adopting it in their business. Approximately 150 SMEs have accessed this opportunity, and **71% of those who participated in the external assessment said it enabled them to decide whether or not to make a capital investment**. 57% of SME respondents did invest in kit as a result, and 43% said it enabled them to decide against investing **[S1]**.
- Research and development undertaken by SAM research fellows in response to specific SME requirements. **20 SMEs** have benefitted from this support **[S4].**

The project has supported **253 SMEs in the North East Local Economic Partnership region** (County Durham, Gateshead, Newcastle, North Tyneside, Northumberland, South Tyneside and Sunderland); 68% in developed areas, and 32% in transitional areas **[S4].**

The external assessor's survey of all participating SMEs asked about the business outcomes of their participation in SAM. Of the 40 responding SMEs (16% of SAM participants) 56% reported **improved technical capability or understanding**; 44% have **introduced new or significantly improved products**; 41% reported **improved productivity**; and 37% have **introduced new or significantly improved processes**. In addition, over a third of respondents reported **increased production volume** and **improved product quality,** and more than a quarter counted a lasting relationship with the University of Sunderland, increased profit, improved efficiency, improved design capability, and

implementation of new production technology among key benefits **[S1].** Clearly, AMAP's applied research, made accessible through the SAM project, has resulted in improvements in key business performance metrics.

SAM successfully boosted Technology Readiness Levels (TLR), with 65% of SMEs reporting an improved TRL after participation. The average increase in TRL across respondents was 2 points on the scale, indicating that SAM has helped SMEs to move products closer to market. The greatest increase in TRL was one SME that went from TRL 2 to TRL 9 over the course of their participation, indicating their product is now at market **[S1]**.

Each SAM intervention is tailored and unique, but the following examples give a flavour of how the benefits enjoyed by participating SMEs derive from research.

Funky Chunky Furniture make standard and bespoke solid wood products. Its business was growing but the company was not ready for the high disruption and additional cost of relocating to new premises. In June 2019 SAM introduced the company to software integrated workflow along with metrics relating to sequence, frequency and time in all the pertinent steps. Inefficiencies in process were established, lean and efficient designs explored and suggestions for improved layouts established **[S1]**. **By July 2020, the company had experienced growth of approximately 30% (approx. £36k net profit) within their existing premises, with no increase in headcount or overheads [S5].**

Fabrication and machining group **Dyer Engineering Ltd** used SAM support to produce a suite of fully functioning, interactive 'virtual site tours' and 3D scans with a wide range of information relating to capability, process, and live performance data. These are available both on standard screen displays, viewable through a web browser and also as a VR walk-through. **The virtual technology has been particularly valuable in customer acquisition and onboarding new employees in times of social distancing and has saved time and money in asset tracking and site surveys for the installation of new equipment.** Its adoption makes Dyer stand out from competitors as an early adopter and innovator **[S6]**.

SAM advice enabled hygiene solutions manufacturer **AGMA Ltd** to meet the exploding demand for its sanitisers and hand gels linked to COVID-19. SAM expertise helped them identify areas of the business that could be improved through automation and invest in the machinery required to automate the process, safeguarding 30 jobs while increasing output, reducing lead-times and increasing sales. AGMA's Finance Director says "*This would not have been possible had it not been for the support we received from the SAM Project*… ***This support has allowed us to tap into R&D expertise, previously out of reach, and invest in state-of-the-art machinery that will help us compete for years to come*" [S7].**

DLAW Contractors, a relatively new company which manufactures renewable energy solutions, was supported by the SAM project to both identify the machinery it needed in order to improve its manufacturing processes and with grant funding towards its purchase. **This support helped the company to go on to win its largest and most valuable order to date to the value of approximately £300,000 [S2].**

5. Sources to corroborate the impact (indicative maximum of 10 references)

S1 Summative Assessment report by ERS Research and Consultancy
S2 Letter from Chief Executive of Sunderland City Council
S3 Letter from the Business Growth Director of the North East Local Economic Partnership
S4 SAM progress report (Q4 2020) submitted to MHCLG and ERDF
S5 Funky Chunky Furniture case study by its Managing Director
S6 Dyer Engineering Ltd: Applying 360 degree/video technology in manufacturing contexts.
S7 AGMA: Capital investment pays off as agma helps clean up