The Value of Engineering Design Research

UK Study

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AUTHORS FOREWORD

The research presented within this paper was first envisioned at the Design Society Rigi Meeting 2023 in Paris, France. During Science Day, where attendees include the Design Society Board of Management, Advisory Board, Special Interest Groups and Chapters Leaders and other invited guests including representatives of SNCF Research (host of the meeting), it was identified that Design Society members can face the challenge of justifying the value of engineering design. This value has been harder to justify in recent years with a lack of visibility of the impact of engineering design. This value is important to state to increase the chances of securing research funding for design society members, and to influence policy and strategy on funding of engineering design research in the future as is an aim of the charitable company.

An opportunity was identified to analyse the outcomes of the UK Research Excellence Framework (REF) 2021 data to identify key examples of the value of engineering design and use this to create case studies that can be used by all Design Society members in the future. A future goal of this research is to use this small research project as a preliminary study to identify if this method of enquiry was appropriate and valuable. Future research projects may include using other databases as identified by Design Society members, or to create a database using the Special Interest Groups to create a database of worldwide case study examples.

Due to the nature of this research enquiry. This study is only focused on impactful research provided by engineering design researchers and therefore does not represent the Design Society community in whole at this time. The outcomes of this research do not intend to exclude any individual or institutional contribution or to purposefully exclude recognition for their efforts.

This research is the first of its kind, directly funded by the Design Society Special Interest Group Fund and we hope that the value of the outcomes will encourage others to apply to this fund to conduct similar research for the benefit of Design Society members worldwide.

If you have any questions about the creation of the report beyond that detailed within the methodology section, please contact **admin@designsociety.org**

ACKNOWLEDGEMENTS

The authors would like to express gratitude to the Design Society board of management for the opportunity to conduct this research and for those who contributed to the embodiment of the proposal at the Design Society Science Day. A special thanks should be made to Professor P John Clarkson and Professor Emeritus Panos Papalambros for their support in the application of the research funding to conduct this project.

SECTION 1

INTRODUCTION

The following section details the purpose and methodology of this white paper. Detailing the data collection process and how data will be represented throughout this paper.

INTRODUCTION

PURPOSE

The Research for Excellence Framework 2021 impact database contains around 200+ case studies on impactful engineering design research from institutions in the United Kingdom. Whilst this database is a comprehensive collection of impactful research, it is hard to build a holistic understanding of the direct impact engineering design research has had, and how the research has influenced different research fields and industry sectors. This project aims to help identify key case studies to support this understanding and to create a database easily accessible to identify further examples.

METHODOLOGY

Towards the aim of creating a database of engineering design projects, documents from the UK Research for Excellence Framework were downloaded and a evaluation process was created. This evaluation process included an inclusion and exclusion criteria and a coding schema.

In order to determine an appropriate coding schema, 202 articles were downloaded and reviewed by the author of this study, identifying key themes and words from each. If the study did not have direct impact or was loosely related to engineering design the documents were excluded. Following this first exclusion criteria the number of suitable studies was 115. An example of how the key themes were chosen can be found in Figure 1. *

***Themes that were extracted are subjective to that of the author of this study.**

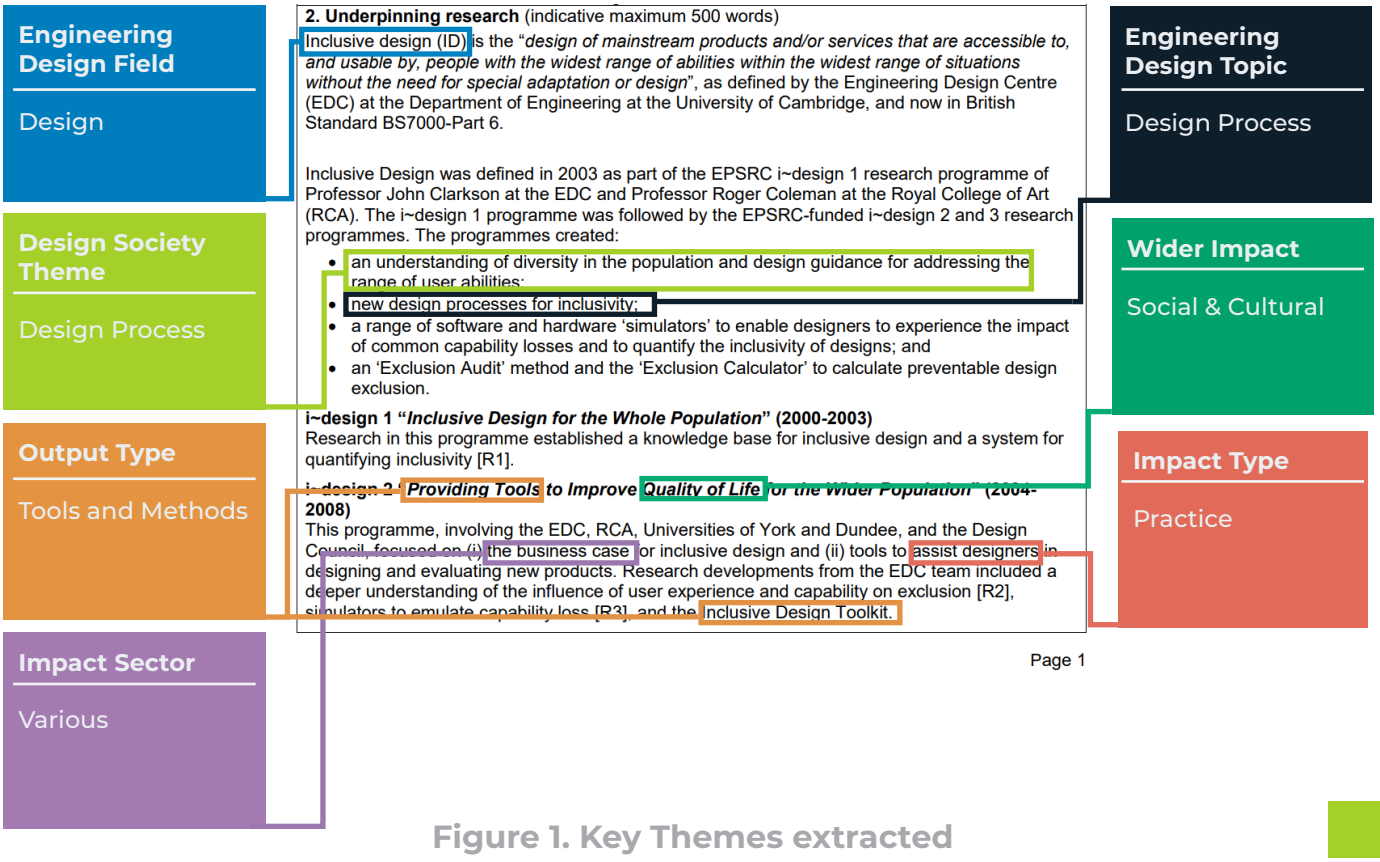


Figure 1. Key Themes extracted

The final data categorisation was made in 6 categories. The categories created were:

1. Engineering Design Field
2. Impact Type
3. Engineering Design Topic
4. Output Type
5. Wider Impact
6. Design Society Special Interest Groups

Details of the separate categories can be found in Appendix A and a description is given below.

Engineering Design Field

Categorising the data by overarching themes found in engineering design such as Design, Engineering Management and Manufacturing to determine a wider understanding of the countries focus.

Impact Type

Categorising the data by the immediate impact within engineering design I.e., does the data impact on the practice of design, is there immediate impact on a business or organisation, primarily this is determined by mention of a company or immediate economic impact.

Engineering Design Topic

This is an add on to the design field, providing more detail of the specific topic within engineering design in which that data relates to.

Output Type

The Output Type is linked with the impact type and wider impact, highlighting what the research has produced to allow for impact.

Wider Impact

Wider impact details where the research has made impact within a wider setting, looking at the four main categories; Economic, Social, Cultural and Environmental.

Design Society Special Interest Groups

The Design Societies special interest groups are used to best assign the impact studies to the relevant research groups. Whilst many of the special interest group topics could apply to a singular case study, the primary focus of each project has been categorised has been chosen. To avoid over complication of the database and the best fit SIG has been selected.

Impact Sector

The impact sector categorisation details which industry the research has made a directimpact on, some case studies may have more than one impact sector therefore they willfall under various

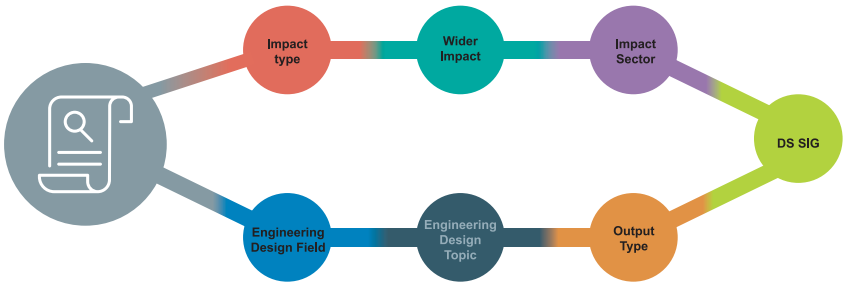


Figure 2. Data representation example

SECTION 2

THE DATA

Section 2 highlights the data, providing statistics on the industry, engineering design field and wider impact.

Some explanation on what this means and recommendations on how to address gaps and further strengthen areas in which the UK is excelling in.

THE DATABASE

An Excel spreadsheet has been creating showing the categorisations for all 115 case studies. The database also includes an overview section where the distribution between each category can be found.

The data can be found at:

https://doi.org/10.15129/1b87f1a8-64eb-4814-8fae-33a56e091757

RESEARCH DISTRIBUTION

From the REF'21 impact case study database, 115 case studies were deemed relevant to the engineering design discipline. Categorised into one of three overarching themes shown below.

Engineering Design (48%)
Manufacturing (18%)
Management (34%)

ENGINEERING DESIGN

Engineering Design research encompasses case studies where impact from research has enabled the development product, systems, methodologies, toolkits and/or novel technologies or techniques.

MANUFACTURING

Manufacturing research encompasses case studies where the research has improved upon existing manufacturing processes, developed methods of manufacturing and/or research that has enabled the develop of new manufacturing technologies within an engineering design context. This theme is the looser of the three, whilst there is a larger amount of impact of manufacturing research, the research in this report relates to manufacturing research that directly impacts on the development or creation of a product, such as additive manufacturing for prototypes.

MANAGEMENT

Engineering Management research studies encompasses case studies where research has enabled to development on systems for monitoring, risk assessment, management techniques, supply chain, or the management of infrastructure.

Table 1. Distribution of key themes across the UK

	Engineering Design	Manufacturing	Management
England (78%)	39%	16%	24%
N. Ireland (2%)	-	-	2%
Scotland (11%)	5%	2%	4%
Wales (9%)	4%	1%	3%

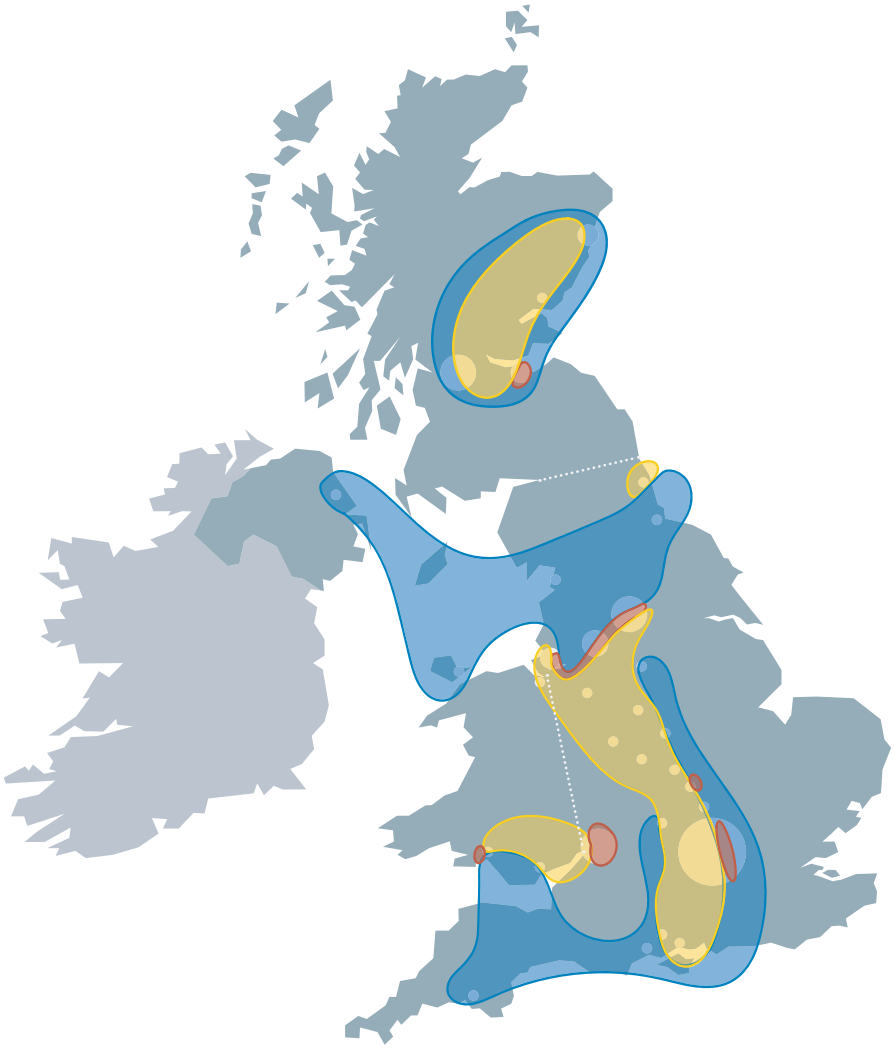


Figure 3. Research theme distrubution across the UK

From the REF'21 database, 59 institutions across the UK had contributed impactful engineering design research.

Figure 3 shows the distribution of the research impact across the UK, with majority of the three research categories falling within England (78.00%). Table 1 summaries the distribution of the research across the UK.

England homes 46 out of the 59 institutions that have contributed to the REF database, therefore it would be a challenging task for the rest of the UK to attempt to compete with England for majority of share within engineering design research.

North England has a high impactful contribution of management research with a small contribution of impactful engineering design research. Central and south England (including London) have significant impact in design research. South England primarily has an impact in engineering management research.

Scotland tends to focus its research into engineering design, within the central belt with contributions to engineering management. Impactful manufacturing research has been conducted in the east coast of the country.

Northern Ireland has a focus on Engineering Management research, however with only 1 institution mentioned in the REF'21 database, it is hard to obtain an accurate picture of the true contribution and impact in which Northern Ireland has.
South Wales has a high contribution towards design research whilst North Wales has a tendency to focus on engineering management research.

TOPICS AND OUTPUTS

Beyond the initial engineering design field categorisation, the data has been further categorised into engineering design sub-topics and output types, enabling us to see what topics are being commonly researched and the outputs that have made impact in recent years allowing for the identification of gaps in both topics and output types.

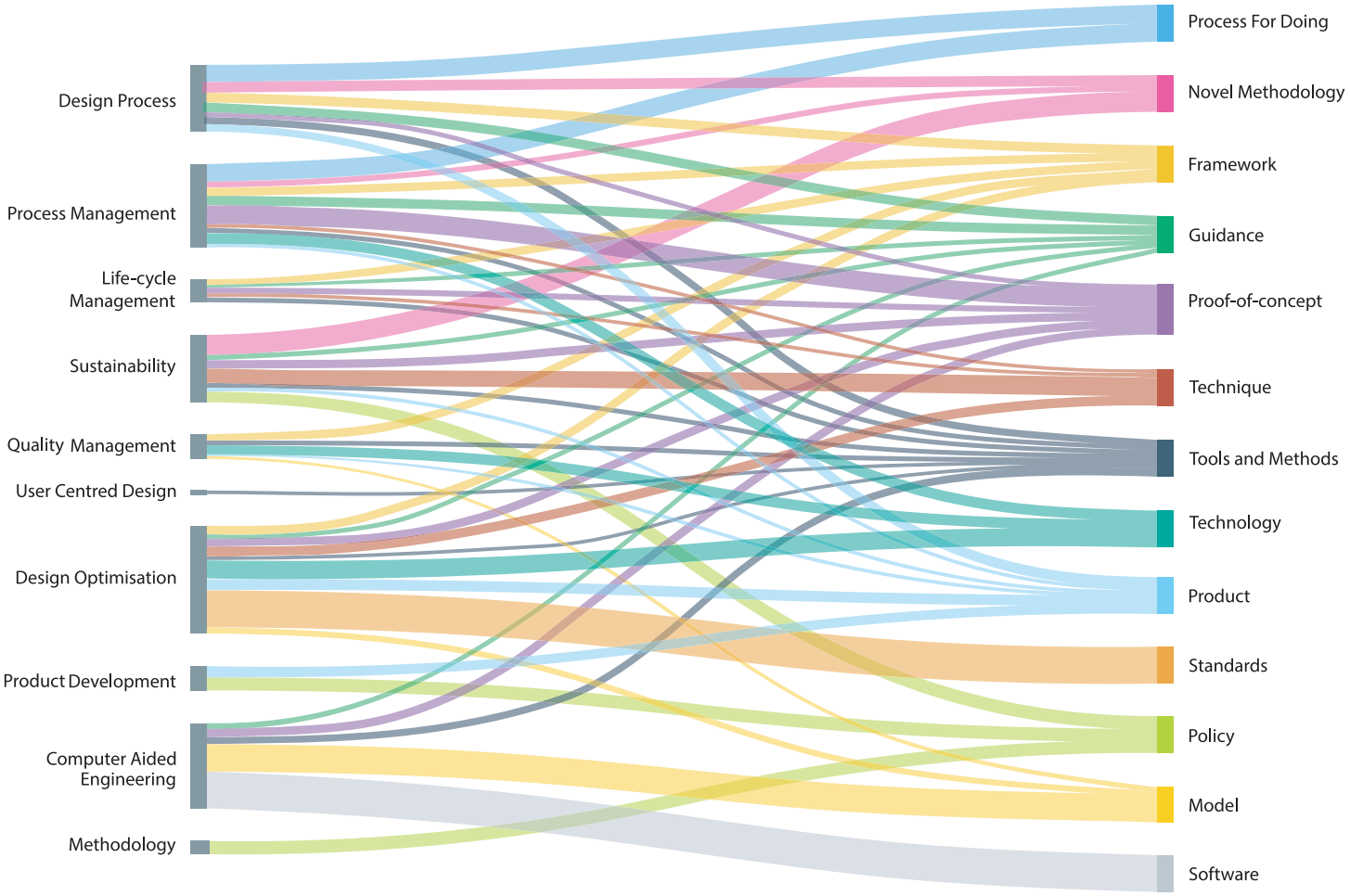


Figure 4. Engineering Design Topics and the related outputs

The data was used to create an Alluvial Diagram illustrating the sub-topics and their various output types, as shown in Figure 4. These subtopics and output types have been further separated by their respective overarching theme of design, engineering management and manufacturing as shown in Figure 5.

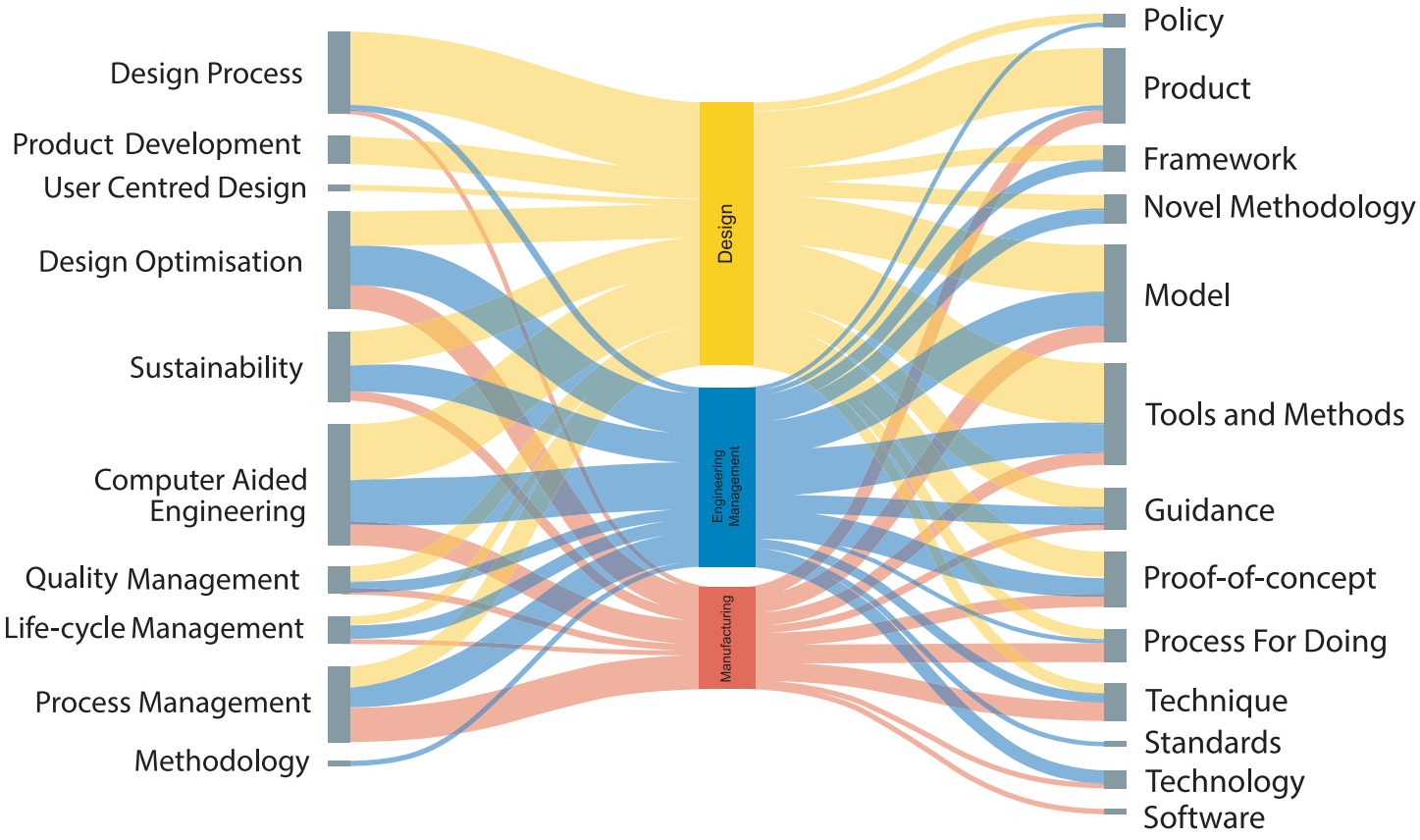


Figure 5. Engineering Design Topics via key themes

Computer Aided Engineering (CAE) has the highest share of engineering design topics (22%) within the REF'21 database. With majority of the outputs being computer models (62%) for testing, and validation. An unsurprising result considering the advancements and the development of both computer aided design and manufacturing software and its common use within industry and academia. With the recent advancements in virtual and augmented reality, research in these areas could further strengthen impact in the computer aided engineering field.

User centred design is the sub-topic with the least impact, only holding 1% of the case studies, with the beginning of research into industry 5.0, where the interactions and involvement of humans in the automation process, could provide an area for focused research and a higher share impact.

IMPACT TYPE

An important consideration to consider related with impact, is determining whether the studies are making impact in either; Practice – influencing the way an activity is conducted, Business/Organisation – the studies bring economical change to one or more businesses/ organisations, or Governance – the research influences and shapes, guidance, standards or policy in a specific sector and discipline.

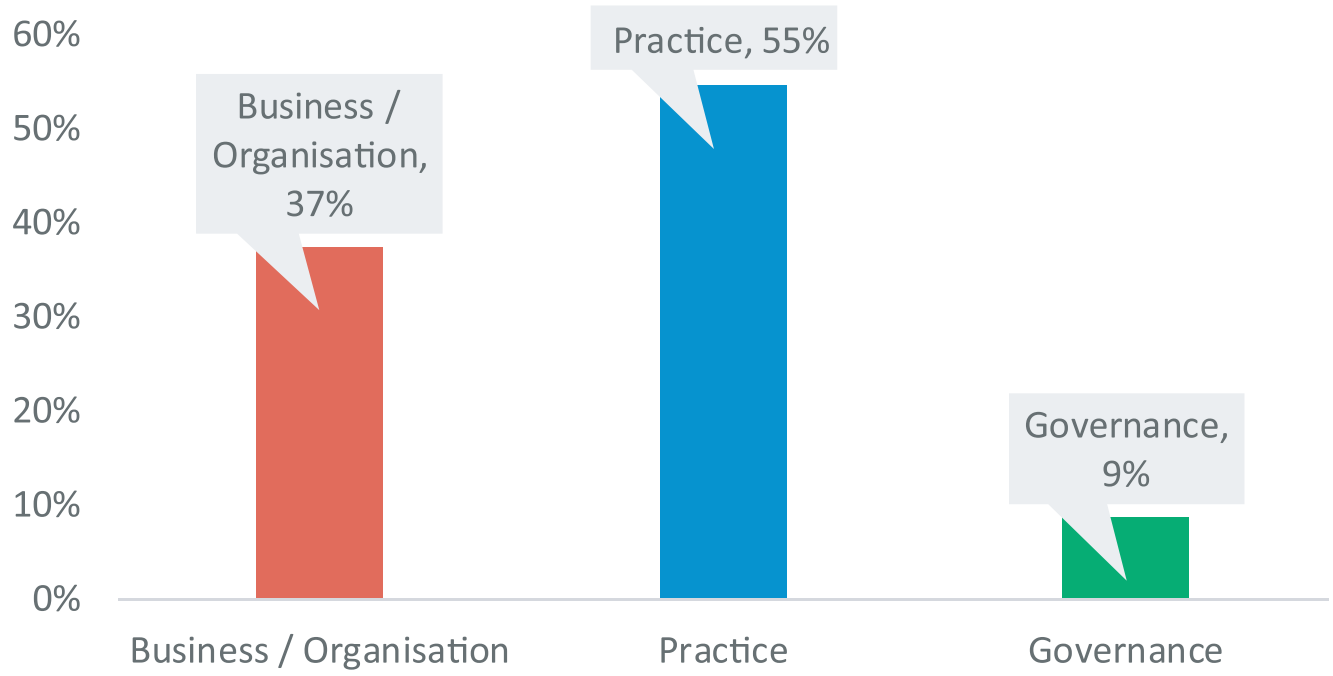


Figure 6. Impact type distribution

Figure 6 displays the share of the three impact types across the 115 case studies. Practice holds the highest share of 54% followed by business at 37% whilst governance only holds 9% of the share. This suggests one of three things, either little research is being conducted in this area, which is highly unlikely, or the REF boards do not view governance as an impactful area – this is also unlikely, meaning that it is the way in which institutions are measuring governance impact.

Computer aided engineering again holds the highest percentage of impact within practice at 22% whilst the lowest percentage of share is in User centred design at 1%, similar to the data from the Topic and Outputs discussion, however this is 100% of the user centred design category, this shows a clear gap in impactful research coming from user centred design. A case study is displayed representing this on page 22.

WIDER IMPACT

To help further understand the impact of engineering design research, 4 additional categories have been created to understand the wider impact. These are based on Paul Rodgers et al. (2022) What Design Research Does..., The four categories are explained below, figure 7 summarises the categories. Each case study had the opportunity to be given two of these categories, a primary and secondary.

Economic

Economic impact, is impact that allows for; business opportunities, improves or impacts customer experience, cost reduction , and /or rethinking strategies for organisations.

Cultural

Cultural impact is when the research impacts on the worth of activities - enhancing learning and skills development, and/or enhancing knowledge.

Environmental

Environmental impact is when the research allows for the development of sustainable solutions, protecting biodiversity and landscapes, and/or the improvement of builtenvironments.

Social

Social impact is when the research allows for the improvement to; quality of life, community benefit, and/or diversity.

Figure 7. Wider Impact Categories

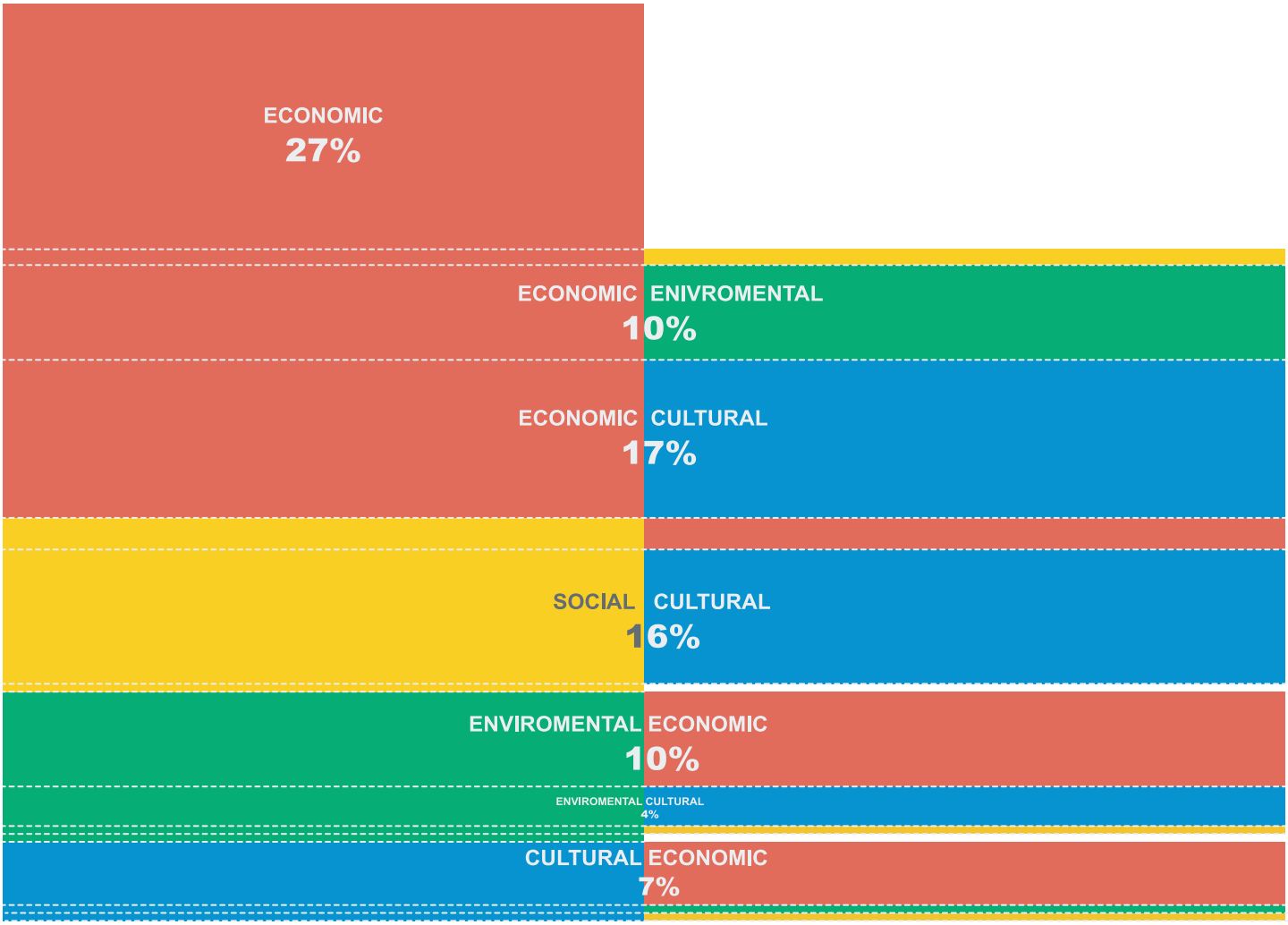


Figure 8. Wider Impact Distribution

Figure 8 displays the breakdown of wider impact. Economic impact has the highest share of impact with 56%, pairing this with the data from practice and business / organisation it signifies that in recent years impact is being measured through monetary gain.

There is a lack of environmental impact however as a primary category with only 17% of all studies falling into this category. With the recent COP26 and COP28 conferences and the implementation the United Nations Sustainable Development Goals researchers across the world have begun to focus their efforts on sustainability research.

It can be expected based on current trends throughout the field that social and cultural impact will begin to grow, an example of this is the development of Industry 4.0 and the beginning of Industry 5.0, researchers are looking at ways to better enhance the integration of technology into practice and daily lives whilst taking into consideration how humans will interact with automation.

SECTOR IMPACT

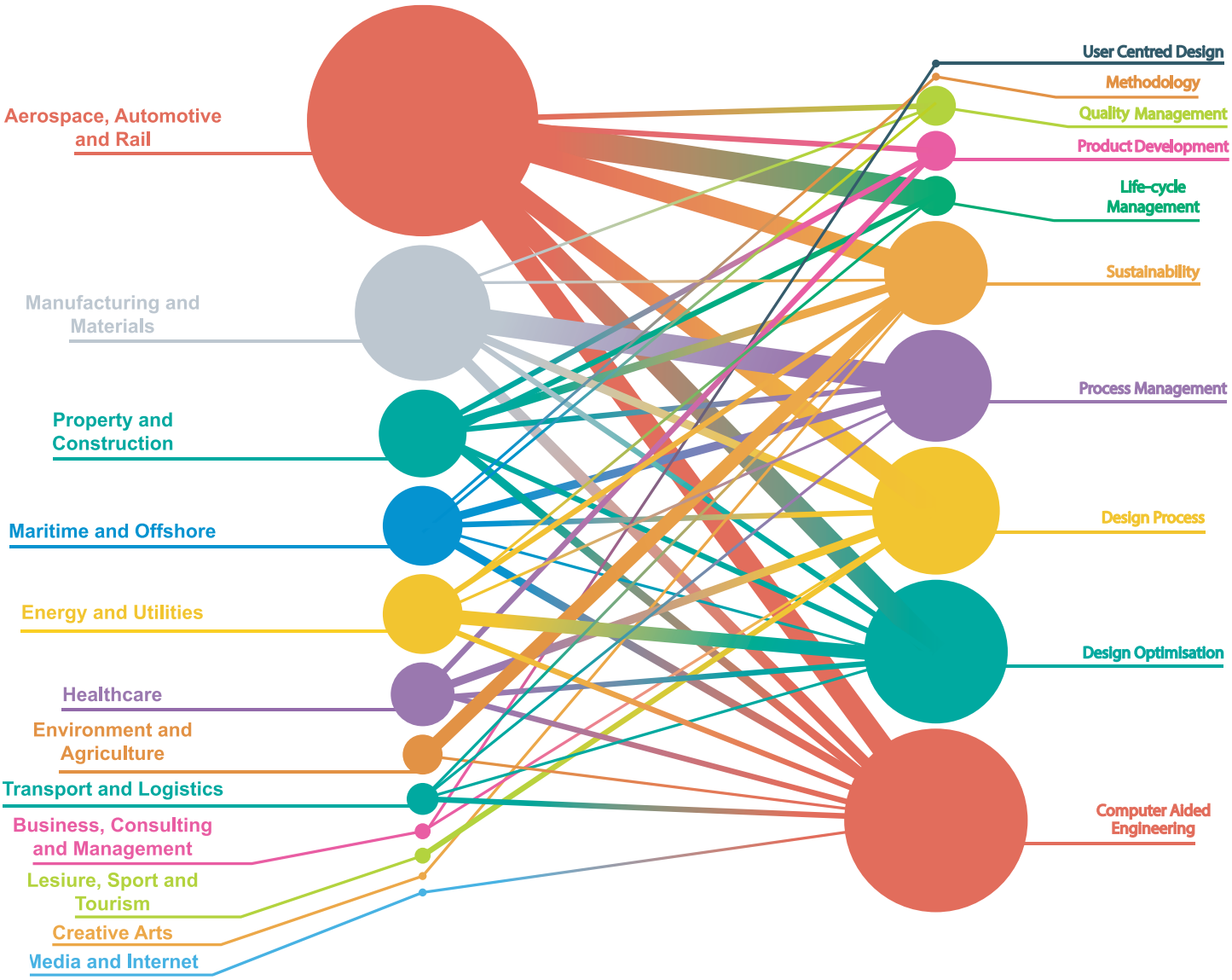


Figure 9. Sector Impact

Sector impact is represented in Figure 9, a chord diagram with the sectors on the right half of the sphere and the topics on the left half of the sphere.

Aerospace, Automotive and Rail is the sector with the highest impact holding 29% of all case studies, this sector also holds the highest share of computer aided engineering topics alongside design optimisation.

With the recent developments in healthcare related design and energy, it is expected that these topics will hold a higher share of the impact case studies in the next REF.

SPECIAL INTEREST GROUPS

Highest impact contributions to a specific SIG: Sustainable design (28%) – lines up with 28% environmental impact studies (17% primary, 11% secondary). Data-informed design holds 14% share – lines up with the computer aided engineering (23%).

However, there is a number of SIGS in which there is no associated impact study such as cognitive design science and collaborative design. To maximise engineering design impact, it is recommended that a SIG designed to focus on impact is created, or SIG's look for common ground between each other and collaborate.

This report can act as a guiding document to identify where impactful research is perhaps not being readily shared and the SIGs can play a role in ensuring this impactful research methods and outcomes are visible. A future research project may be to identify the impact of the Design Society community publications in a similar method. This will allow the Design Society board of management to strategies on ways it can best support its members.

Table 2 details the share of impact between the different Special Interest Groups.

Table 2. Distribution of share between the SIGS

	Share
Sustainable Design	28%
Data-informed Design	14%
Robust Design	10%
Health Systems Design	10%
Design Practice	9%
Risk Management Process and Methods in Design	9%
Product Service Systems	7%
Decision Making in Design	5%
Design Process	4%
Design for Additive Manufacture	3%
Human Behaviour in Design	2%
Design Theory	1%
Cognitive Design Science	0%
Design Education	0%
Design Creativity	0%
Design Sketching	0%

WHY THE DATA IS THE WAY IT IS

The data shown on the previous page is not reflective of the true impact that the individual SIG's produce, instead it answers a proposed question. If all impact from the SIG's came from the United Kingdom, what would this look like?

WHAT DOES THIS MEAN?

The data is not saying that the Special Interest Groups do not produce impactful research. Instead it is an attempt to highlight gaps and areas for institutions in the United Kingdom to tailor research efforts.

This also an opportunity for the Design Society to assess the way in which impact is currently measured in the SIG's. It is an opportunity for SIG's to created workshops and projects focusing on the the ways in which we measure and determine impact.

CONCLUSIONS

The REF'21 database represents a small quantity of engineering design-based research in the UK deemed impactful. From this, we can establish what the UK community deems important and an accurate representation of impact. The categories created by this research can help amplify research impact in all areas by identifying related and relevant methodology. The authors have identified gaps in the current REF outcomes and look to solidify this knowledge for future trends of the REF.

CURRENT TRENDS

The following topics are strong and appear frequently in the REF:

- **Computer aided engineering**
- **Design optimisation**
- **Design Process**
- **Process Management**
- **Sustainability**

Meaning, these are likely topics that will continue to frequently pop up in the REF databases.

Impact trends that is most likely to be accept is economic, 55% of the case studies all made economic impact for businesses and/or the government. Within this wider impact economic / cultural impact holds the highest share (30%), meaning that research that has not only economic impact but impact that also changes working cultural and or practice.

With the UK's investment into Sustainability based research and achieving net zero goals, it is assumed that Environmental impact research will be more likely to be accepted, but incorporating this with either cultural or economic impact this is more likely to be accepted. As discussed earlier, Computer Aided Engineering based research has a high share of the REF'21 database, this is topic which is likely to continue holding a high share of the database, however, to allow innovation and new research to develop outputs should differ from computer models. Research into methodologies may prove useful especially with the advancement of industry 4.0 and the beginning of industry 5.0.

WHAT IS LACKING?

User centred design research is lacking in terms of impact, this is a surprising outcome due to the amount of user centred research coming from institutions from the UK such as The University of Strathclyde, University of Cambridge and University College London. Whilst a case study is displayed in this report, a reason for the lack of impactful research may be due to the way in which we are measuring impact, as discussed above, a majority of the case studies have economic based impact, however it is hard to measure economic impact when it comes to applying user centred design research. The case study below measures impact through adoption, by measuring how many companies are employed the methods detailed in the research. More research into ways of measuring impact is required.

RECOMMENDATIONS

Based off the results of this study, a few key recommendations are suggested.

DS SPECIAL INTEREST GROUPS

The Design Society would likely benefit from the creation of a new special interest group, that focuses on measuring and analysing impact from Engineering design research. Other suggestions are to create initiatives that promote collaborative working between the SIGS to best achieve and maximise impact.

IMPACT WORKSHOPS / RESEARCH

It is recommended that institutions begin looking into the ways in which they can collect and measure impact, the simplest form of measuring impact is monetary gain, however this is not relevant to all forms of engineering design research.

Other ways to help determine impact is by hosting workshops that allow institutions, industry and governance to actively network and collaborate with one another to identify impact. Grant funding is a key to enable these opportunities in the UK design community.

SECTION 3

CASE STUDIES

The following section will highlight and detail some case studies and their impact on design engineering. These case studies are only a snippet of the actual research conducted. For further information on the details of the research, please refer the REF21 impact case study database.

UNIVERSITY OF CAMBRIDGE

DESIGNING FOR INCLUSION

Prof. John Clarkson
Dr. Patrick Langdon
Prof. Simon Godsill

DESCRIPTION

The University of Cambridge developed a toolkit (Design Process including tools and methods) for the purpose of improved designing for inclusion. The process includes tools such as; simulators that allow designers to better experience the quality of life of individuals and experience in any losses in capabilities one may face allowing the designers to quantify the level of inclusion their design may bring. The tools also include an 'Exclusion Audit Method'[1] and the 'Exclusion Calculator' to allow designers to calculate and prevent any form of design exclusion.

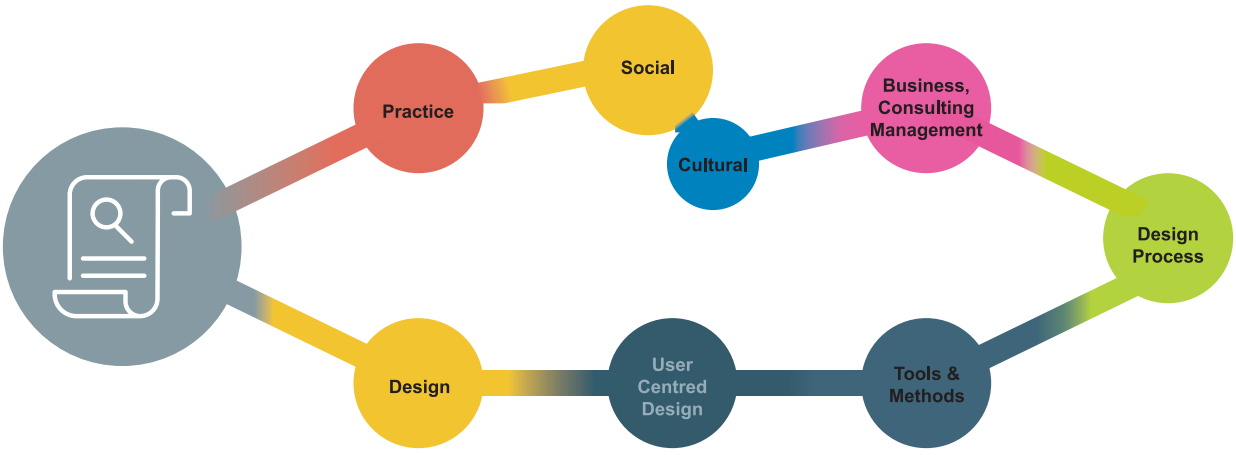
IMPACT

The process and tools have been adopted by several companies around the world including by not limited to:

BBC Heathrow P&G Royal Bank of Scotland

As of July 2020, the toolkit has been adopted by 1,000 companies and individual designers across the world. The toolkit has also been adopted and taught in schools and higher education institutions across 10 countries.

An example of how the toolkit has been applied can be found at P&G, who used the toolkit to make a number of revisions to its herbal essence product line to become more inclusive by adding tactile symbols onto their bottles to cater for those with reduced vision. Other examplescan be found with companies such a nestle who were able to identify issues with one of theirproducts and adapted the design accordingly.



University of Southampton

CLEANER, SAFER, SMARTER MARITIME

James Blake et al.

DESCRIPTION

The University of Southampton has contributed to the World Shipbuilding and shipping industry through extensive research in an array of categories. They developed computer aided engineering models, that allow for the detection of various factors affecting a ships energy consumption and allows designers to optimise ships and become more design efficient. Other models that detect structural integrity and failure points were also developed by Southampton. Their research also includes risk assessment methods for capsizing in small boats (<15m). Southampton also have an extensive research effort in the development and implementation of autonomous vehicles for seafloor mapping.

IMPACT

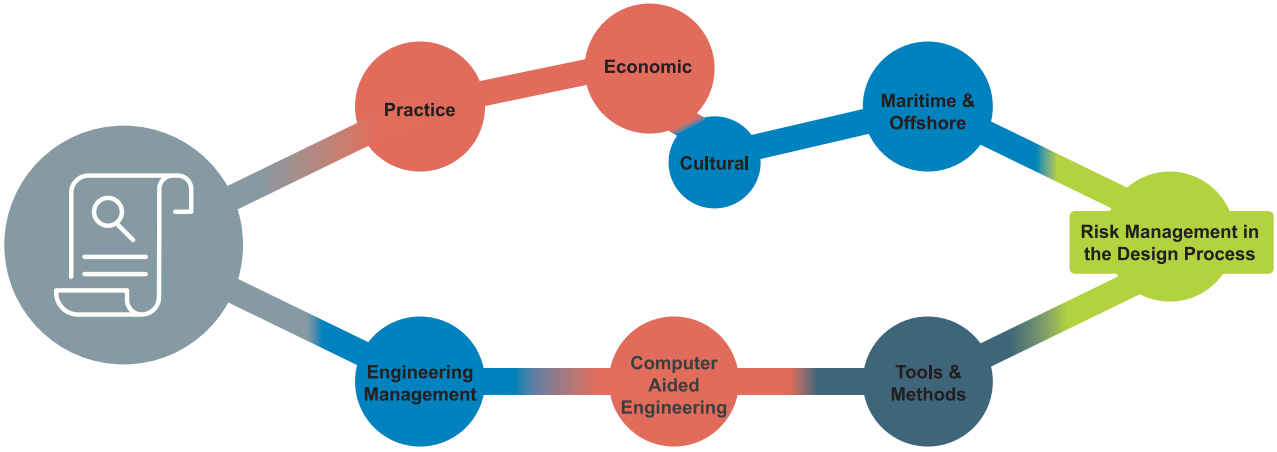
Southampton's research has made several impacts in terms of sustainability, process optimisation, business and economic growth in the United Kingdom and improved designs. Examples of their impact are as follows:

Shell shipping and maritime adopted their models on ship energy consumption and allowed the company to say more than £30 million and reduce their carbon emissions by 200,000 Metric Tons.

Lifeboats

Southampton were also to implement structural integrity models into manufacturers who are able to reduce the design and manufacture time by more than 6 weeks faster than the industries standard.

Southampton's further research impacted on guidance, regulation's and, practice in countries such as the United Kingdom and China, allowing for safer and optimised design practices in both countries. An example of this can be found in the development of composite lifeboats deployed by the Royal National Lifeboat Institution (RNLI)



Aston University
BIRMINGHAM UK

ENDOSCOPE-I

Mark Prince

DESCRIPTION

The research at Aston University has been conducted into healthcare products and the development of imaging capabilities using existing technologies such as smartphones and small optical cameras. The university also implemented several design processes into existing organisations to scale up businesses and allow them to use rapid prototyping techniques such as SLA printing.

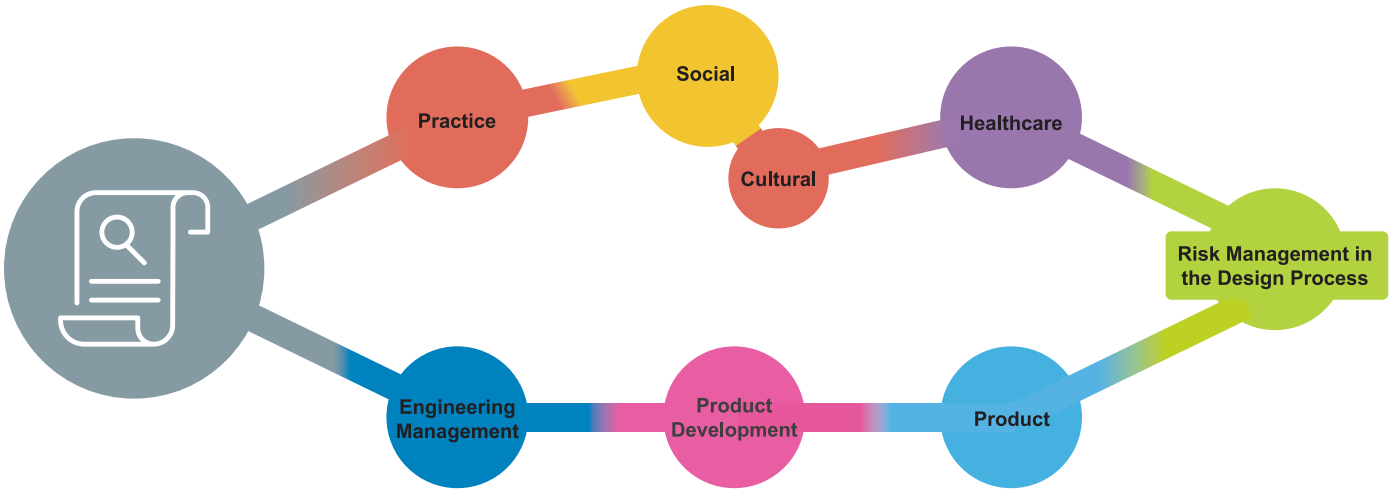
IMPACT

Aston University used a series of design techniques to develop low -cost and advanced equipment for the optical health community.

NHS

The research allowed for creation of cost-effective endoscopy equipment that is not only affordable but compact, the research also allowed for the delivery of remote based consultancy between clinicians and patients. The endoscope-I product line has allowed for the NHS to save resources, time and more effective communication.

Aston universities research also allowed for the development of the only personal protective equipment device that allowed for the nasendoscopy procedures to be conducted safely during the covid-19 pandemic.



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APPENDIX A

ENGINEERING DESIGN TOPIC LIST

Engineering Design Topic		
Topic	No	Percentage
Computer Aided Engineering	26	23%
Design Optimisation	21	18%
Design Process	18	16%
Process Management	16	14%
Sustainability	15	13%
Life-Cycle Management	6	5%
Product Development	6	5%
Quality Management	6	5%
Methodology	1	1%
User Centred Design	1	1%
Collaboration	0	0%
Supply Chain	0	0%

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