Value by design in Infrastructure Delivery

The role of designer and contractor collaboration in delivering infrastructure value

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1.0

Executive Summary

This research paper examines the role of high-quality design processes in maximising the value which is delivered in infrastructure programmes in the UK. Ongoing investment in economic infrastructure is a priority for the UK government as it underpins our quality of life by providing reliable services, increasing efficiency, and making the UK an attractive place for investment. However, due to the scale of investment, it is essential that major infrastructure programmes recognise and facilitate a broad range of possible value opportunities beyond the core functional requirements. This is to maximise return on investment and leave a legacy for future generations. This is most clearly evidenced in the holistic approach to the London Interceptor sewers of 1867, not only solving the utilitarian problem of the day but providing new public realm and railway infrastructure all of which still benefit Londoners today.

Research indicates that there are six areas where good design can optimise value in infrastructure. Good design can reduce capital cost, reduce operational and lifecycle costs, act as a catalyst for economic investment, create social value, minimise carbon and create long lasting user value. The golden thread between delivering functional requirements efficiently and releasing value is high quality design processes which invest in early collaborative problem solving to define the correct brief, harness a highly skilled workforce and stimulate innovation in the supply chain.

However, the research suggests that there are systematic barriers which are preventing high quality design from delivering best value outcomes. The literature

review undertaken as part of this research has demonstrated that these barriers are primarily based around 3 core themes:

- Process and Information

  Lack of the correct operational and maintenance expertise and knowledge informing project briefs and lack of delivery supply chain knowledge in early project stages.
- Attitudes and Governance

  Lack of holistic understanding of the wider value that infrastructure projects can deliver and how design can unlock these opportunities
- Procurement and Collaboration

  Procurement processes which require design services to be retendered over the design lifecycle of the project, leading to loss of project knowledge and disincentivising designers and contractors to collaborate to deliver best value outcomes.

Semi structured interviews with senior directors in tier 1 contractors were carried out to validate and build on the themes uncovered in literature review. These interviews revealed that the delivery supply chain believes infrastructure briefs are often incorrectly focused on product rather than performance and do not promote design research and innovation in the supply chain. It also revealed the deeply held belief within the construction industry that high-quality design outcomes and best value are most likely to be achieved through collaborative teaming models such as Project 13. The report concludes by making a series of recommendations to industry which may be summarised as:

- Adoption of a plan of work for infrastructure.
- Embed operational and maintenance in project briefs.
- Integrated and diverse leadership teams.
- Government policy in support of collaborative procurement models.

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List of images and figures

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Glossary

RIBA ..... Royal Institute of British Architects
RICS ..... Royal Institute of Chartered Surveyors
NIC ..... National Infrastructure Commission
ICE ..... Institute of Civil Engineers
DfMA ..... Design for Manufacture and Assembly
IPA ..... Infrastructure Projects Authority
GDP ..... Gross Domestic Product
DfT ..... Department for Transport
TfL ..... Transport for London
LUL ..... London Underground Limited
TUCA ..... Tunneling and Underground Construction Academy
ONS ..... Office of National Statistics
SME ..... Small or Medium sized Enterprise

3.0

Report Structure

This report is structured as follows:

- The introduction and background sections set the scene for the design of infrastructure in the UK including the future strategies for infrastructure delivery and design.
- The literature review section summarises the sources reviewed for this research and outlines the initial findings regarding how design creates value in infrastructure delivery.
- The barriers to good design are explored in the emerging themes section which uses the Design Council 'Double Diamond' as a framework for exploring how infrastructure design is impacted by industry attitudes, processes, and procurement routes.
- The original research carried out through interviews with contractors is summarised in the research outcomes section and this is supported with analysis of three case studies.
- Lastly, the report concludes with recommendations to industry on how design may be better understood across the infrastructure sector and what action can be taken to optimise project outcomes through high quality design processes.

4.0

Introduction

4.1 The Civic value of Infrastructure

Infrastructure investment is essential to support UK productivity, meet climate goals and to address decades of underinvestment. The UK government has made the delivery of economic infrastructure a national priority and, through Zero Carbon 2015 legislation and the National Infrastructure Strategy, has also committed to high quality, long term solutions which leave a sustainable legacy to future generations.

However, in addition to solving everyday functional problems, infrastructure has the potential to create significant wider civic and economic value which goes beyond its core function. If thoughtfully designed, infrastructure projects have the capability to transform our cities for the better by making a positive contribution to the environment we live in, becoming catalysts for regeneration and acting as drivers of inward investment.

This can be illustrated by considering two similar infrastructure projects constructed in close geographic proximity in London but conceived and delivered over one hundred and fifty years apart; The Interceptor Sewers of 1867 and the currently under construction Thames Tideway which is due for completion in 2025.

One of the earliest and most preeminent examples of creating wider value through infrastructure is Bazalgette's Interceptor Sewers from 1867. Unprecedented in its

complexity, this transformative project resolved the most pressing issue for Londoners of the day, London's 'Big Stink' of 1858. However, the most significant legacy of this project is the embankments which were required along the banks of the Thames. The construction of these embankments reclaimed twenty-two acres of land from the river and created new public realm along the Victoria, Chelsea and Albert embankments. The embankments also formed the retaining wall to one of the world's first underground railways, the Metropolitan District railway, now the District and Circle lines on the London Underground network.

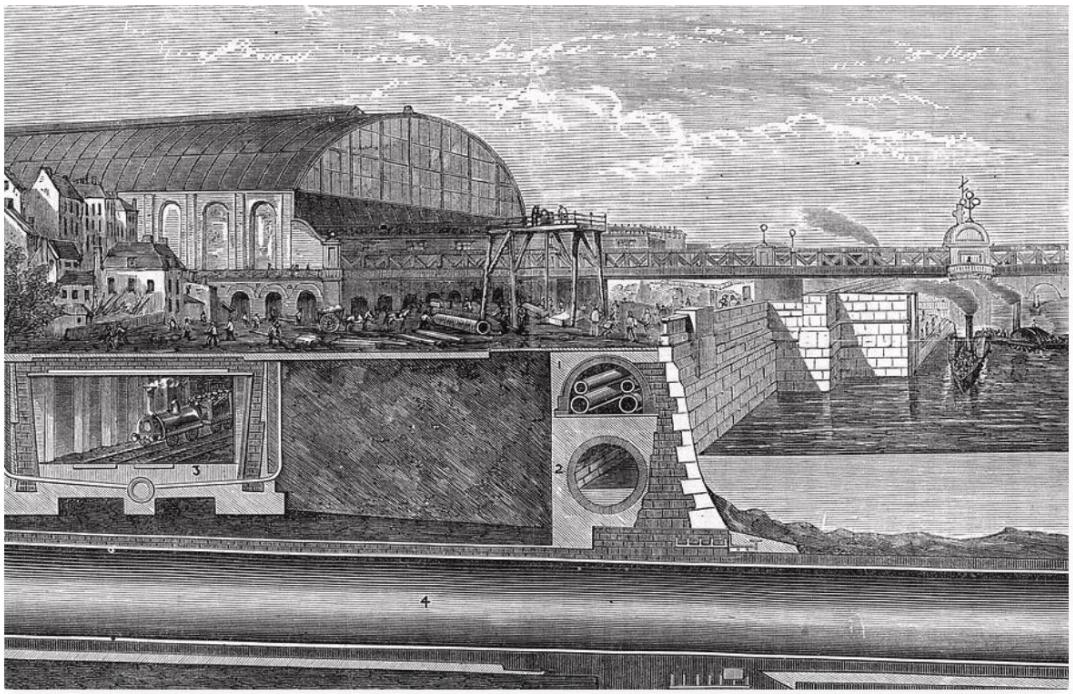

Fig 1: Bazalgette's Interceptor Sewers (Image: Museum of London)

The currently under construction Thames Tideway super sewer is also solving a critical functional challenge of today by expanding the capacity of the existing sewers to prevent overflow of wastewater into the river. However, the project goes much further and looks to seize the broader opportunities offered by the project.

"A range of benefits will remain that go beyond and outlive tunnel construction, including new standards for health, safety and wellbeing in delivering major projects; a rejuvenated river economy and a new public realm for the people of London to enjoy and connect with the River Thames"
(Simms, 2017)

One example of this is new public realm at Victoria Embankment which incorporates access shafts to the sewer below but also provides a new public space on the Thames. This builds on the legacy of Bazalgette and serves to reconnect Londoners to the river over the long term.

Fig 2: Thames tideway at Victoria Embankment (Image: Hawkins Brown Architects)

The lesson to be learnt from these projects is that infrastructure, by nature of its sheer scale and transformative potential, can deliver wide ranging benefits with lasting consequences beyond its core function. The key to achieving this is a holistic design approach and a process which recognises value from early in the project lifecycle and works collaboratively with a broad range of stakeholders to deliver it.

4.2 Research Aims and Objectives

If good design is the key to unlocking value in infrastructure, then how can designers and contractors effectively collaborate with clients to deliver it? This question is central to this research. In particular, it seeks to examine the role of high-quality design in maximising value in infrastructure by identifying opportunities early in the project lifecycle and acting as a collaborative framework for the delivery of those opportunities.

A historical focus on lowest cost over wider value has resulted in a sector where good design and the resulting wider social, economic and life cycle value is often side-lined in preference for programme and cost. Designers and contractors have a particular role to play in collaborating to address this imbalance and delivering a quality legacy in infrastructure. Through literature review and industry engagement, this research seeks to identify the barriers to good design in infrastructure and to engage with industry to identify potential ways to overcome them. The aims of this research are therefore to:

Validate - Through literature review examine the role of design on value creation within infrastructure delivery.

Analyse- Identify current industry blockers which prevent value being achieved through good design.

Recommend - Make an informed series of recommendations to industry which could be adapted and lead to greater value creation through design in large scale infrastructure projects.

5.0

Background

5.1 The context for economic Infrastructure in the UK

5.1.1 Context

This section sets out the context and background to the research. The context of infrastructure design and delivery in the UK is complex and is therefore broken down across the following areas:

- The importance of investment in high quality economic infrastructure in the UK.
- The significance of the infrastructure sector to the UK construction and design industries.
- The future strategy for infrastructure in the UK.

5.2 The importance of investment in high quality economic infrastructure in the UK

5.2.1 Drivers of infrastructure investment

Investment in infrastructure forms a critical foundation of the UK's economy, supporting productivity, economic growth, and quality of life. Ongoing significant investment in infrastructure is also essential in achieving long term strategic environmental goals and developing resilience in the face of the challenges of

climate change. “Given the urgency of the climate emergency and the long lead times and life cycles of infrastructure, the challenge of transitioning these systems over the next 30 years will be immense” (Hardy, 2020). Furthermore, decades of short termism have led to a significant under investment in infrastructure leaving the UK with an asset base of degraded infrastructure which requires upgrading.

5.2.2 Supporting quality of life for a growing population

Ongoing investment in economic infrastructure is essential for improving the UK’s productivity. Without high performing infrastructure, the UK has little hope of improving the productivity of its economy and, in turn, the quality of life of its growing population (Mitchell, 2017). Such is the importance of infrastructure in the UK’s future economic success, it has been identified as one of the five ‘Foundations of Productivity’ within the UK’s Industrial Strategy white paper.

‘Infrastructure is the essential underpinning of our lives and work, and having modern and accessible infrastructure throughout the country is essential to our future growth and prosperity. ‘

UK GOV white paper: Industrial strategy

5.2.3 Environmental goals

High quality infrastructure is also required if the UK is to achieve its long-term environmental policy goals. In 2019 the UK became the first major economy in the world to pass laws to end its contribution to global warming by 2050. The target will require the UK to bring all greenhouse gas emissions to net zero by 2050, compared with the previous target of at least 80% reduction from 1990 levels. The vital infrastructure systems on which the UK relies currently contribute the majority of the UK’s emissions. Transport and energy alone account for around 60% of the UK’s CO2 emissions. (Hardy, 2020). Therefore, investing in decarbonising this infrastructure is essential to achieving Net Zero 2050 goals.

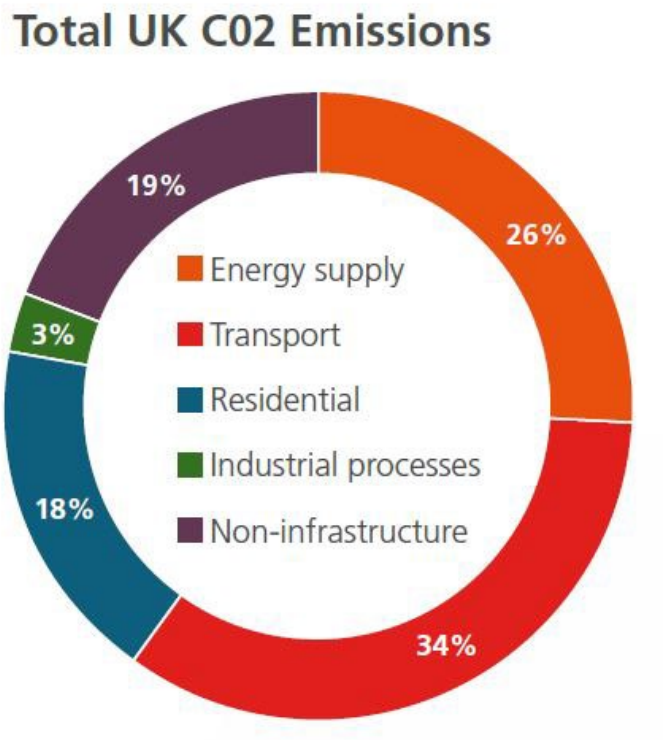

Fig. 3: Economic Infrastructure as a percentage of total UK CO2 emissions (Image Hardy, 2020)

In addition to enabling the UK's achievement of its zero-carbon legislation, investment in infrastructure is also required to adapt it to the challenges presented by climate change such as increased flooding, storms and extreme temperatures. This has most recently, and tragically, been illustrated in the event of the derailment of a passenger train near Carmont, Scotland on 12th August 2020 which resulted in the deaths of three people. An interim report published following the incident identified earthwork slippage caused by rainwater run off due to severe storms to be the cause of the derailment. This illustrates the extent to which unusual weather events due to climate change are putting pressure on rail infrastructure such as earthworks and drainage. "These assets require progressively rising investment accompanied by transformational change in how we manage the network and deploy technology. 'Good' management of climate

change risk involves improved on the ground resilience which will come at significant cost and will take many years to achieve." (Haines, 2020).

5.2.4 Addressing the Economic impact of prior underinvestment

Despite the case for strategic infrastructure investment, a series of factors has led to the UK underinvesting in infrastructure and significant investment in economic infrastructure is now required to compensate for decades of under investment. Principal among these factors is a lack of long-term planning by successive governments which was exacerbated by a steep drop in infrastructure investment in the 1970s and a shift toward privatisation of public services in the 1980s. This is a long-term trend which has led to a fall in infrastructure investment and maintenance. In fact, UK investment in infrastructure relative to GDP has been low relative to other G7 nations since the mid nineteen seventies. While other advanced economies also started scaling back government investment in the 1970s, the UK cut faster and deeper than most between 1970 and 2000, UK government investment averaged 3 per cent of GDP, compared with 4.2 per cent of GDP among all advanced economies. (Bailey, 2020).

FIGURE 2: **The UK government still invests less than other advanced economies**

General government gross fixed capital formation as a proportion of GDP, advanced economies: G7 and advanced country average

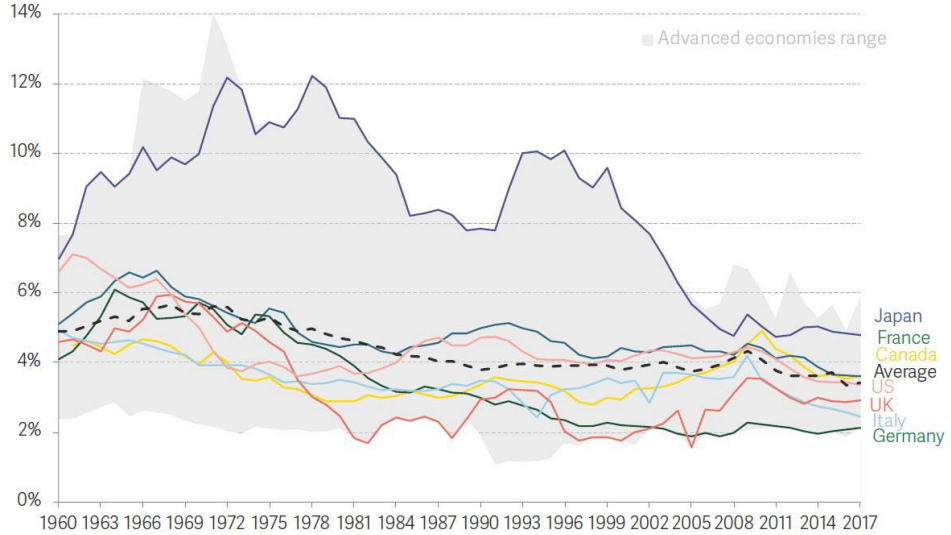

Fig. 4: UK investment in infrastructure as a percentage of GDP relative to other G7 nations (Image: Resolution Foundation)

This under investment has led to a deterioration in the quality of infrastructure and its ability to serve a growing population. It has significant economic impact with a study undertaken by EY (2015) estimating that if these trends were maintained, there could be an annual loss to the UK economy of circa US$116 billion by 2026. In response to this long term deterioration and the associated emerging economic implications, government spending on infrastructure has become a priority, with the 2019 Conservative government manifesto committing to a rise in central government spending on economic infrastructure from £2bn in 2020 rising to £5bn in 2024. (Bailey, 2020).

5.3 The significance of Infrastructure to the UK construction and design industries

Infrastructure is already critical to the UK construction sector with public and private infrastructure investment combined accounting for an ever increasing percentage share of UK new orders since 2010.The impact of significant infrastructure investment is most clearly evidenced in fig. 5 with all-time record UK new orders in 2017 of £70,987 million underpinned with £20.991bn of infrastructure orders. (ONS, 2018)

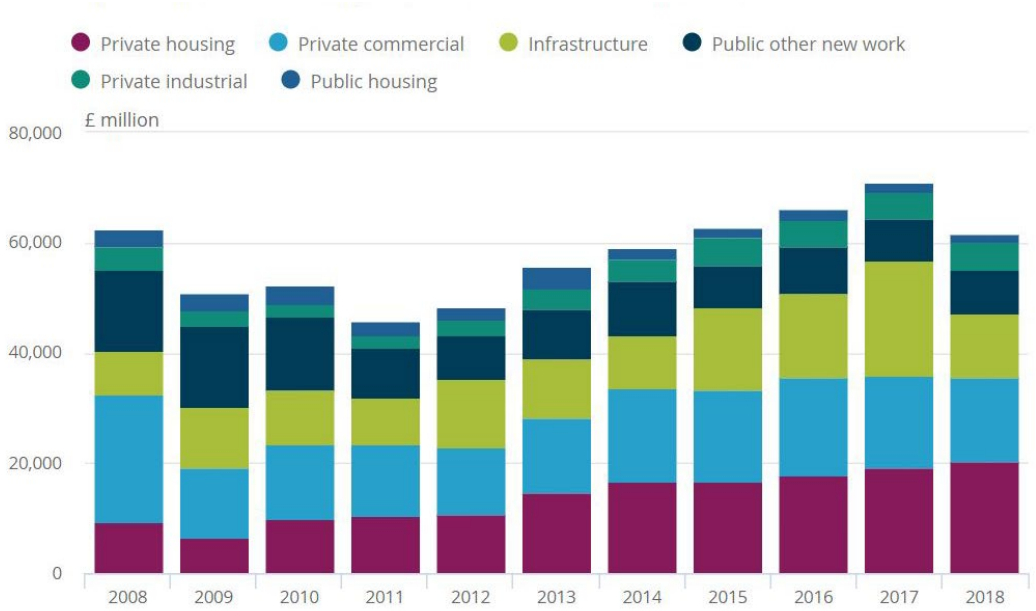

Fig. 5: Construction new orders by sector (Image: ONS)

Analysis of the National Infrastructure and Construction Procurement Pipeline published by the Infrastructure and Projects Authority in June 2020 identifies a pipeline of three hundred and forty procurement contracts across over two hundred and sixty infrastructure projects and programmes due to be brought to market in 2020/21. The collective value of these projects is identified as having an estimated contract value of up to £37 billion.

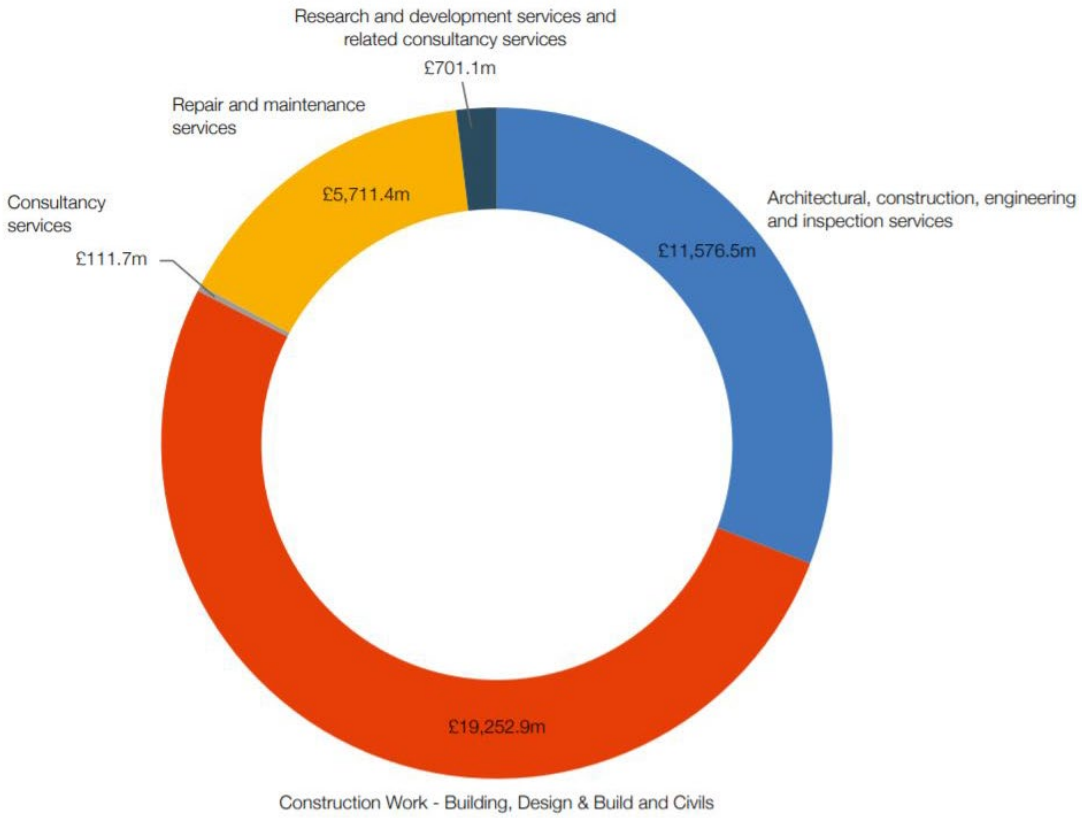

Fig. 6: Procurement Pipeline by work type 2021 (Image: IPA)

The split of how this money is spent is identified in the pie chart above for design and engineering services. This illustrates the trickle-down impact of infrastructure spending not just to contractors but to professional services associated with infrastructure design, engineering and inspection.

5.4 The future strategy for infrastructure

5.4.1 A national plan for infrastructure

A national plan for infrastructure investment, the National Infrastructure Strategy, was published in 2020. This strategy is important not only in setting out spending goals but identifying the national and regional infrastructure needs across the UK and providing a roadmap for a coherent long-term strategy for meeting the UK's infrastructure requirements over the next thirty years. This strategy is based on the analysis and recommendations of the National Infrastructure Assessment published by the National Infrastructure Commission in 2018.

5.4.2 National Infrastructure Commission.

The National Infrastructure Commission (NIC) was established in 2015 to provide independent, impartial advice on the UK's long-term infrastructure needs. The core benefit of this commission is to "address the lack of a long-term infrastructure strategy, siloed decision making in infrastructure sectors, fragile political consensus and short termism. The Commission has addressed these issues by taking a long term, cross-sectoral approach, with in-depth analysis and wide consultation" (Armitt, 2018).

In 2018, the National Infrastructure Commission finalised and published the National Infrastructure Assessment (NIA) which outlines a pathway for infrastructure investment for the next thirty years. This formed the basis for the national infrastructure strategy. In addition to setting out long term, affordable goals for UK infrastructure, the NIA is very clear that the benefits of these will not be fully achieved without also improving how the UK selects and designs infrastructure projects. The NIA's recommendations on infrastructure design are of particular relevance to this research.

The view of the NIC is that good design:

- Saves money
- Reduces risk
- Adds value
- Supports environmental net gain
- Creates a high-quality legacy for everyone

Due to the significant benefits of good design outlined above, a key recommendation of the NIA (Recommendation no. 6) is that good design should be embedded into the culture of infrastructure planning. The NIC proposes achieving this through two key strategic recommendations. Firstly, by ensuring that all nationally significant infrastructure projects have a board level champion and that they use design panels to ensure value is maximised. Secondly, that these projects are designed in alignment with an underlying set of design principles; Climate, People, Place and Value.

'Once a decision is taken, infrastructure needs to be designed and built well...Now is the time to embed design into the culture of infrastructure planning, saving money, reducing risk, adding value, supporting environmental net gain and creating a legacy that looks good and works well '

National Infrastructure Commission (2018): National Infrastructure Assessment

5.4.3 NIC Design Group

The NIC Design Group was established in 2019 to promote and champion design excellence in nationally significant infrastructure projects with a key aim being to put good design at the heart of the UK's infrastructure delivery. The NIC design group has subsequently undertaken a broad range of research which has formed part of the literature review. The findings of this research indicate:

- There are significant benefits to high quality design in infrastructure design beyond aesthetics.
- There is a demand for better design in the way infrastructure is planned and delivered both from the supply chain, stakeholders, owners and the general public.
- There are significant existing barriers to good design both in terms of the attitudes of those delivering it, the understanding of the value of design across a broad range of stakeholders, and the routes used to procure it. (Publica, 2019)

5.4.4 National Infrastructure Strategy

The recommendations of the NIC NIA and those for the NIA Design Group are captured in the National Infrastructure Strategy, published in November 2020. Within this strategy the UK government clearly sets out its intention for good design to be a central tenet of infrastructure delivery.

Good design is also an essential element in securing high performance of infrastructure from the start. In line with the design principles set out by the National Infrastructure Commission (NIC), the government is committed to embedding good design in all infrastructure projects
HM Treasury (2021): National Infrastructure Strategy

It is clear therefore that achieving good design is a priority for the UK government in the delivery of infrastructure over the next thirty years and it has been widely recognised both by the NIC and central government that good design brings significant value to infrastructure delivery. The literature review examines this value in more detail, further interrogating the role of design in delivering the wider benefits that infrastructure can bring and identifying the emerging themes which serve as barriers to the successful delivery of these benefits.

6.0

LITERATURE REVIEW

6.1 Sources of literature review

Due to the broad range of issues to be addressed, the literature review was undertaken across a range of sources which may be classified under four typologies:

6.1.1 Government Research Papers

A review was carried out of policy and research papers relating to infrastructure such as the National Infrastructure Strategy, the Transforming Infrastructure Performance report and the Transport Infrastructure Performance Strategy. This also included review of central government papers relating to the broader topic of the general construction such as the Latham review, the Farmer Report, and the Construction Sector Deal.

6.1.2 Independent government advisory reports

Research from independent government advisory bodies was reviewed including publications by the National Infrastructure Commission and the Design Council. Of particular relevance is the National Infrastructure Assessment by the National Infrastructure Commission and a range of original research carried out by the

National Infrastructure Commission Design Group including 'A Sector Review of Attitudes' and 'The Value of Design in Infrastructure Delivery'.

6.1.3 Professional institutions

A review was undertaken of publications from various professional institutions which play a role in the design and delivery of infrastructure projects. These included the Royal Institute of British Architects, The Institution of Civil Engineers, and the Royal Institute of Chartered Surveyors.

6.1.4 Academic research papers and journals

A review of academic research papers and independent consultancy reports relating to infrastructure was carried out. This included publications by multinational engineering and design consultancies such as Aecom and Jacobs, consultancies such as McKinsey and charitable foundations such as the resolution Foundation. For a complete list of references and sources reviewed refer to section 12: References.

6.2 Defining value for large-scale infrastructure projects

6.2.1 Value in Infrastructure

A key aim of the literature review has been to develop an understanding of the role that design can play in delivering best value outcomes in infrastructure delivery. Fundamental to this aim is an understanding of the complex definition of 'value' with respect to infrastructure. Research indicates that Infrastructure, as opposed to individual buildings or developments, presents a unique value proposition. According to the NIC research paper 'The Value of design in Infrastructure Delivery', this value can be categorised across six areas as illustrated in figure 7.

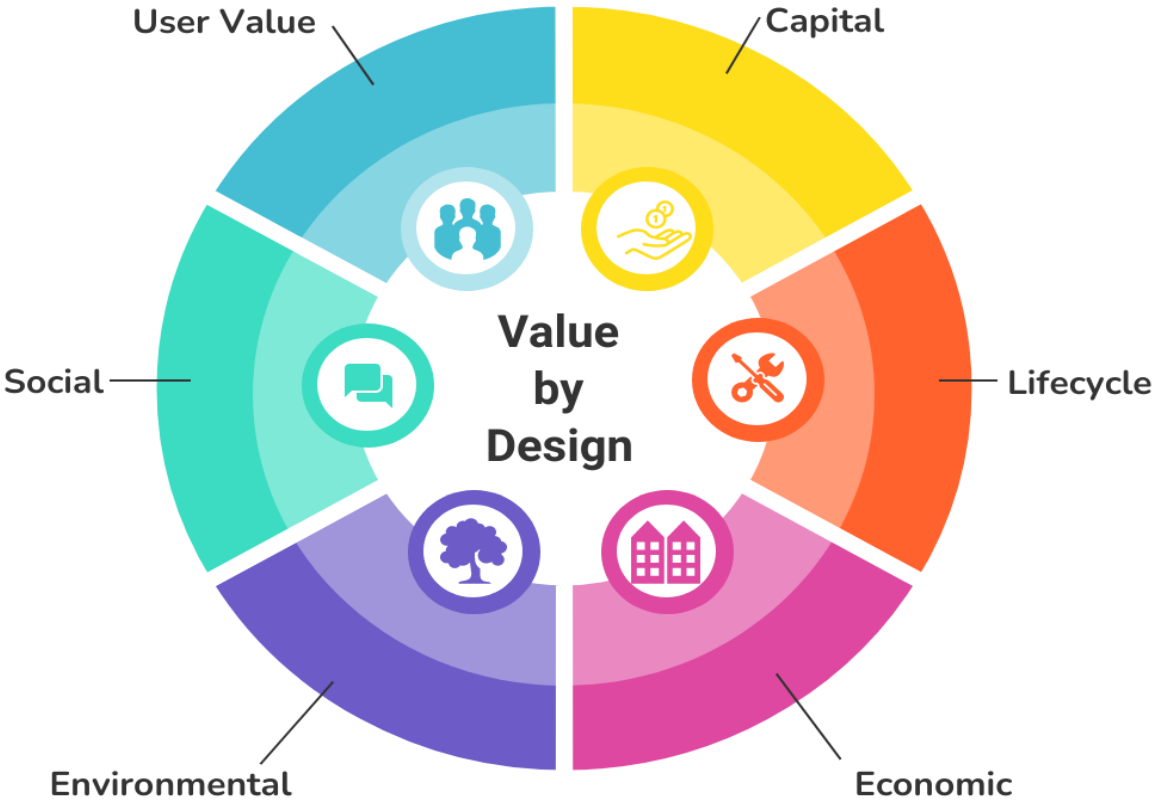

Fig. 7: Six areas where design adds value in infrastructure

6.2.2 Capital Value

Good design can reduce capital expenditure in infrastructure projects across a broad spectrum of areas highlighted below:

- **Project briefing and requirements**

Good design processes allow the correct infrastructure operational, maintenance and delivery expertise to inform project briefs. This serves to focus briefs on outcomes rather than products and allows the market maximum flexibility to meet the project requirements.

- **Scheme Design and Consent**

Good design can de-risk programmes by ensuring the design of infrastructure meets all stakeholder requirements. Using an inclusive design process to get broad stakeholder support of a project vision reduces the risk associated with consents processes.

- **Delivery**

Embedding modern design and construction methodologies into the design early (such as design for manufacture and assembly and economies of scale) ensures the most efficient delivery of infrastructure assets. The scale and repetitive nature of many large-scale infrastructure projects means the role of intelligent design solutions can deliver large savings and programme reductions.

- **Systems Integration**

Design processes which proactively integrate systems and consideration of interfaces early can minimise the programme and associated cost risk for systems interfaces and ensure right first-time delivery.

6.2.3 Lifecycle Value

The long-term lifecycle of infrastructure projects places increased significance on the value which can be measured over the lifetime of the asset relative to up front savings afforded through capital cost reduction.

However, research suggests that the current infrastructure delivery model in the UK is often based on procurement which is focused on lowest capital expenditure to the detriment of long-term value. 'Initial commitments to buying best whole-life value rarely carry through into the actual procurement processes that in most cases focus on the costs of construction. Long-term value is unwittingly sacrificed in the pursuit of short-term costs savings. The result is repeated instances of projects failing to deliver their intended outcomes.' (Mitchell, 2017).

The importance of long-term lifecycle value is illustrated in the DfT's Transport Infrastructure efficiency strategy which places the understanding of whole life benefits as number one in its seven core challenges. *"By providing whole life cost information, more effective decisions can be made about how to balance short and long-term trade-offs, including disruption to our transport network. To underpin this, transport bodies need to harness knowledge about underpinning asset bases to improve asset management"* (Wolstenholme, 2018).

In the context of infrastructure therefore, good design is that which addresses the whole life value issues holistically and balances them against the initial capital expenditure to deliver best value outcomes. Whole life cycle value issues which are particularly relevant to infrastructure include:

- **Material life cycle value**

Investment is design effort at the start of projects can deliver long term value through the identification of opportunities to deliver lower life cycle maintenance and replacement of materials even if initial capital expenditure up front is greater than other alternatives. For example, in the rail sector, the use of slab track over ballast has a higher initial capital cost but potentially a significantly lower life cycle cost over its 120-year lifecycle.

- **Asset Monitoring**

Design solutions which consider and incorporate up-front investment in asset monitoring technology can lead to long term high value outcomes. Through the DfT's Transport Infrastructure Efficiency Strategy, the UK government has made a commitment to invest in embedded remote condition monitoring in new infrastructure to allow future asset maintainers to more accurately anticipate when investment will be required. This will allow for a strategic approach to maintenance which reduces cost, risk, and operational disruption over the lifetime of the infrastructure (Wolstenholme, 2018).

- **Flexibility to meet future requirements.**

Design solutions which allow for ease of future adaptation can deliver value as infrastructure technology changes over the lifetime of assets. Designs which are inherently flexible can allow for conversion to other functions in future. This value is highlighted by the ICE in their systems approach to infrastructure delivery report. Designing assets with a focus on systems integration, which can be adapted to different fit outs over time as systems technology advances, can ultimately deliver long term value for infrastructure owners.

6.2.4 Economic Value

The role of high-quality design in maximising economic value in infrastructure delivery is often underplayed in favour of the direct benefits of the functional infrastructure itself. However, through careful design and engagement with communities and stakeholders, a wide range of opportunities for parallel investment and economic benefits can be maximised.

- **Placemaking and masterplans: The value of a holistic vision.**

Key to this is a design process which enables a diverse team to recognise opportunity for the delivery of wider benefits at an early stage in the design lifecycle. A collaborative design framework which ensures the infrastructure owner works with stakeholders such as local authorities and private developers is critical. Masterplans which build on the opportunities brought about by the infrastructure to create a holistic vision can serve to unify a broad spectrum of stakeholders behind the project and smooth the path to delivery.

An example of harnessing this wider value is the Knostrop footbridge in Leeds which is cited by the NIC in their research report “Value of design in Infrastructure Delivery”. As part of the Leeds Flood Alleviation scheme the provision of a weir was required at Knostrop. However, to enhance the wider value, the scheme incorporated a crossing for walkers and cyclists, encouraging sustainable healthy activities while connecting communities either side of the weir and facilitates

sustainable commuting into the city centre via bicycle. The high-quality design uses the structure of the weir for support which reduced capital cost and risk, while the prefabricated bridge elements were lifted into place over just two days.

The distinctive design helps to create a sense of place and serve as a catalyst for development of a previously low value adjacent brownfield site. Here is a good example of how joined up thinking, and time spent on high quality design upfront in the process, allows the weir infrastructure to harness the wider possible value available by reducing Capex, creating economic value through placemaking and unlocking land parcels, social value through connectivity and environmental benefits by promoting sustainable activities.

Fig. 8: Knostrop Footbridge Leeds (Image: Knight Architects)

- **Driving research, investment, and innovation**

The scale of infrastructure projects can have other significant indirect long-term benefits for national productivity and efficiency. The scale of investment required for infrastructure projects has a role to play in driving research and development within the design and construction industries. Ultimately, this can create a legacy of skills and training which adds value to the economy while also creating a

workforce which has transferrable and exportable skills to redeploy in research, development or future infrastructure projects in the UK or abroad.

A design process which engages with industry early to understand the impacts on the supply of skills within the industry, and therefore allows steps to be taken to mitigate this shortfall, adds significant legacy value. A primary example of this is Crossrail where the use of spray concrete lining technology was selected early in the process, but it was identified that a shortage of skills in this area could risk programme delay. This led to the formation of specialist Tunnelling and Underground Construction Academy (TUCA) to reduce project risk. By the end of 2018/19, it is estimated that TUCA will have generated £49m of Gross Value-Added benefits against an initial investment of £12m, which amounts to a 2.3:1 return on investment (Bigam, 2016).

6.2.5 Environmental Value

The environmental benefits of many infrastructure projects are self-evident as, for example, in the case of mass transit projects such as Crossrail or energy projects such as offshore wind or nuclear. However, an emphasis on design early in the project can enhance the net benefit of these projects by not only maximising environmental benefits through energy efficiency in use but by minimising carbon embodied in materials during delivery.

Again, Crossrail is a relevant example of this value. Through the displacement of car journeys, Crossrail is predicted to provide annual savings of over seventy thousand tonnes of CO2. However, due to the carbon embodied in its construction, the programme is not expected to generate a net saving until nine to thirteen years after opening. However, by developing a design tool which allowed the project to measure and forecast its carbon footprint, the project was able to drive an embodied carbon reduction of approximately eleven percent.

6.2.6 Social Value

Infrastructure projects have the capability to deliver large scale social value by understanding the impact of the project on peoples' lives through its design, delivery and use. This social value can range from wellbeing, physical and mental health, equality, housing, mobility and access to jobs and services. The extent to which infrastructure projects are successful in optimising this value is down to a design process which identifies, assesses and incorporates these benefits in a timely manner in the project lifecycle.

In the research paper 'Before & Beyond the Build: A blueprint for creating enduring social value at scale through infrastructure investments' by Jacobs-Simetrica, a design framework for a people centred design process which allows social value to be optimised in infrastructure delivery is proposed. This includes the use of big data to inform design decisions such as identifying populations and areas most in need of social value improvements and use of co-design to fully engage with and understand the social needs of communities impacted by the infrastructure. It also recommends engagement with social enterprises during design and ensuring that design decisions are assessed consistently throughout the project lifecycle to ensure social value is safeguarded.

Right now, we have a major opportunity to take a look at infrastructure investments through a collaborative and deeply strategic lens and to consider how we leverage these new models and approaches to design, deliver/build and operate infrastructure in a way that could support us to tackle some of today and tomorrow's most pressing challenges. (Alexander, 2020)

6.2.7 User Value

The last aspect of value that infrastructure can deliver is that of user or legacy value. This is the most difficult to measure or assess but is also potentially the area of value with the longest lasting impact. The long design life and national scale of many infrastructure projects results in a significant impact on the lives of those who use or otherwise interact with that infrastructure for decades after delivery.

The potential for poor design to adversely impact communities adjacent to infrastructure has been demonstrated repeatedly during the twentieth century, most obviously with inner city highway schemes in US cities which created severance across communities and ultimately stymied development and inward investment. In this context, the value that good design can deliver is most explicitly demonstrated with the Rose Kennedy Greenway project in Boston. The central artery, an elevated highway scheme through the city centre dating from 1959, was one of the busiest highways in the United States by 1995. It also created severance between downtown and the Waterfront area of the city.

In 1995, a complex infrastructure project known as The Big Dig, commenced and over the course of a decade placed the highway in a tunnel and replaced the route through the city with a new urban park, The Greenway. This is a rare example of a poorly designed infrastructure project ultimately being replaced by a second, even more complex project, simply to undo the legacy of economic and social damage to the city and its communities. It illustrates the need for high quality design to carefully consider the wide ranging and long-lasting impacts of infrastructure projects.

Today, the Greenway has created miles of new urban parks, greenspaces and water features throughout the city centre and significantly improved the quality of life for those adjacent to it. Communities have been reconnected and economic and transportation benefits have also been delivered with journey times reduced and air quality improved.

Fig 9: The Rose Kennedy Greenway, Boston. The former route of the elevated highway is now a linear park. (Image: Rosekennedygreenway.org)

7.0

Emerging Themes

7.1 Defining design in the context of large-scale infrastructure

Research suggests that despite the potential for design to create value as described above, the role of design in infrastructure is often underestimated or misunderstood. Most commonly, design is interpreted erroneously as a matter pure of aesthetics of a finished project whereas the definition, and resultant benefits, is much broader than that. The NIC design task force defines the broader definition of design as:

- Thinking creatively about the processes involved in providing infrastructure.
- Problem solving from the outset of a project.
- Making infrastructure human scale and user friendly.
- Enhancing the environment and improving quality of life for local people and communities (Publica, 2019)

This definition of design is echoed by TfL in the 'Design Idiom for London Underground: '*Good design should be the driver of decision-making, should permeate every level of the organisation, and should, ultimately, be celebrated by everyone. It doesn't have to cost more; it's an approach and an attitude of mind that thinks both broadly and carefully about what we do.' (Brown et al, 2015).*

Furthermore, the understanding of design as a process which adopts a broad approach is identified by the Design Council, the government design advisory body on design, as one of their ten key recommendations on how infrastructure can be delivered to a higher standard in the UK. It recommends that design is an integral part of infrastructure projects and that the concerns of local communities and all stakeholder be part of the design development process. "Holistic thinking is required to ensure that projects are part of an integrated process that fits into bigger strategies such as regional or sub-regional planning" (Design council, 2010).

Once the process of designing and delivering has been completed, good design is not solely about delivering iconic buildings or structures but about the long term functionality, durability and adaptability of the asset which, over the long term, combine to create a holistic value offer. The RIBA report on infrastructure design, Joining the Dots, makes this case clearly:

"Good design is not just about the striking architecture we associate with big, iconic structures, such as the Millennium Bridge or Birmingham New Street Station. It is also about the functionality of places, the durability of built forms, flexibility of function, and value for money "

(Derbyshire, 2019)

7.1.1 Designing the process

The Infrastructure Client Group, with support from the ICE, also recognises the importance of using design to think creatively about solutions from the outset of projects and then collaborate effectively to deliver the right solution. '*Effective teams are networks of collaborative relationships that encourage an exchange of knowledge and capabilities to drive improvement and innovation. Owners should*

take the lead in designing coalitions of suppliers to deliver their programmes and should not allow their supply chains to be the consequence of a series of traditional procurement decisions'. (Mitchell, 2017). In other words, the process of identifying the correct project and proactively working out the best process, procurement methodology and teaming to deliver it, is itself a design process which adds value to the final outcome.

Therefore, understanding this definition of design as a collaborative, problem solving process which delivers tangible benefits to people every day over the project lifecycle rather than an aesthetic outcome is fundamental in understanding how high-quality design can deliver value to infrastructure projects. This raises a key question. If client organisations such as TfL and bodies such as the RIBA and ICE all recognise the value which design brings then why is it so poorly understood within infrastructure delivery? If design is a process which requires ongoing collaboration between owners, designers and contractors, and if so many benefits can be delivered through this process, then why isn't every project doing it?

7.2 Barriers to good design in infrastructure

Research suggests that there are three themes around which the key industry barriers for effective design collaboration may be grouped.

- Process and Information
- Attitudes and Governance
- Procurement and Collaboration

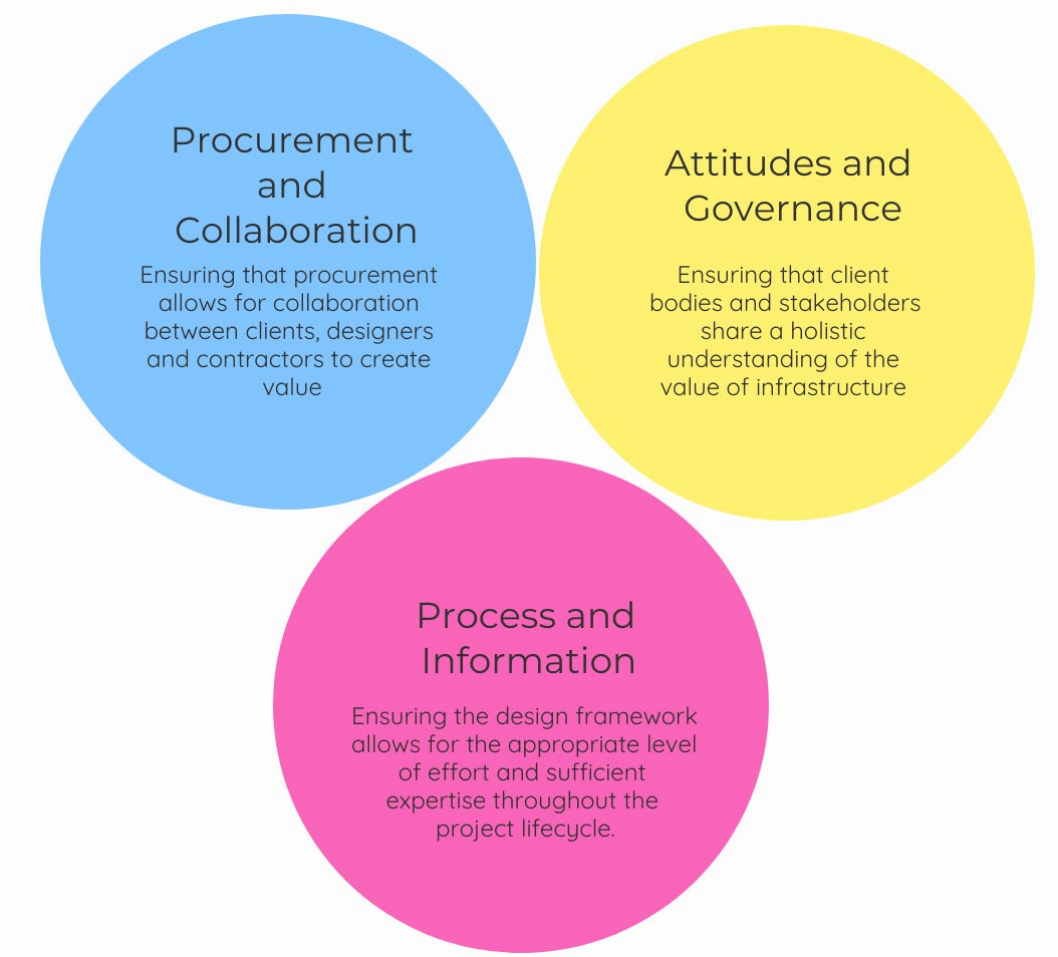

Fig. 10: Barriers to good design in infrastructure: three themes

7.3 Process and information

Research suggests that the process whereby design is developed, and the information available at each stage, is fundamental to maximising value in infrastructure, and that this is particularly significant during project definition and briefing. Engaging in early collaborative problem solving at project outset is critical in identifying the problem to be solved and opportunities for wider value which a holistic solution can provide. Seeking input from the delivery and operational supply chain to inform the project brief is also essential if a successful project outcome is to be achieved. These front-end activities are all part of the design process and cannot be easily added on later in the project lifecycle. To explore this issue further it is worth examining some of the design processes already in use within the design industry and how these relate to the infrastructure sector.

7.3.1 The RIBA plan of work: A linear design process

A traditional understanding of design process which is commonly understood across both owners, designers and contractors is a linear process such as that described by the RIBA Plan of Work. The RIBA Plan of Work is the definitive design and process management tool for the UK construction industry. Initially intended for use by architects to explain project stages to clients, it has evolved to become the industry standard 'road-map' used across both multi-discipline design teams and client bodies for defining design maturity and levels of detail at each design stage.

The plan is broken down into eight stages with each stage having a set task, deliverable and statutory process. Depending on the procurement route followed, a specific procurement activity is also defined for each stage. The plan defines design as a linear process whereby each stage is illustrated with equal weight. At stage 0, the client's requirements are developed with a brief approved at stage 1. Following this the design progresses from concept through to detail design from stages 2 to 4. Stages 5 and 6 cover construction and handover with stage 7 addressing In Use. With this approach, contractors are not generally appointed until stage 3 or beyond depending on the selected procurement route. Maintainers are not appointed until stage 7.

Although it has existed since 1963, only in 2015 was the Plan of Work updated to capture project 'Strategic Definition'. Prior to this, the plan started at project brief and progressed on from there. This has helped to underline a common historic misconception within the design industry that design starts once the client writes and prepares a brief and passes it to a design team to deliver. Even when mending its error, the RIBA Plan of Work 2020 still states that no design team is required for stage 0 and 1, just strategic advisors. However, research suggests that strategic definition is a critical design stage within infrastructure as, beyond this point, decisions may be made and 'locked in' which ultimately provide poor value and cannot easily be unpicked.

Research indicates that with infrastructure delivery, this approach may result in three critical areas of failure which result in poor value outcomes:

- Firstly, a lack of sufficient problem-solving and time spent from the very first stage of the project to identify the problem and inform the brief.

- Secondly, valuable intelligence and value within the operational and maintenance supply chain is not incorporated until too late in the programme.

- Lastly, using traditional building models tends to focus on the civils and built environment which means the integration and design of critical systems is pushed towards the end of the programme leading to increased risk.

This demonstrates that this traditional linear design approach is not fully appropriate for application within the infrastructure sector and more sophisticated models of design delivery are needed to address the multifaceted issues which are unique to the sector. "Delivery remains in the hands of traditionally trained engineers working within organisations using long-established construction industry methods. The consequence of this conservatism is an increasing number of signature projects that are delivered behind schedule, beyond the cost estimate and that fail to meet the public's expectations." (McNaughton, 2020).

Fig 11: RIBA Plan of Work

7.3.2 The ICE systems approach: A V-shaped design process

To address the issues identified with respect to linear design and delivery processes, the ICE has undertaken research which examines an alternative approach which leads with systems design and integration. This research is captured in '2020 A Systems Approach to Infrastructure Delivery: A review of how systems thinking can be used to improve the delivery of complex infrastructure projects'.

A central tenet of the ICE's research is that increasing reliance on data in the 21st century lends itself to a system led approach to design. In the systems approach to design, the civils and build environment envelope is merely a framework within which the ever changing and evolving systems technology will continuously change and be replaced over time. "Physical assets form a platform or 'box' for the data and technology that will provide the infrastructure services on which millions of people depend. This technology will go through many cycles of development during the lifetime of the physical structures that surround it." (McNaughton, 2020). The outcome of the ICE research is a 'V-shaped' process which has eight central principles:

- Think outcomes not edifices
- Close the gap between sectors
- Owners must own projects
- Use the V-cycle process
- Think shovel worthy not shovel ready
- Bake systems thinking and risk management into the project data
- Spread authority through empowerment models
- Data oils the project

Of particular note is the emphasis this research places on upfront design informed by expertise within the delivery and operational supply chain.

"Upfront planning is needed to ensure that major infrastructure projects are politically sustainable, practically deliverable and economically affordable. Better planning also enables owners to halt projects that are not viable. Projects need to embrace 'left-shift thinking', whereby more activity and resources from the delivery phase is pulled from the later stages (right-hand side) of the schedule to the front (left-hand side)."

(McNaughton, 2020).

This research also identifies that it is important to manage all stakeholders who can influence or make claim to the value created by the infrastructure. However, whilst this approach creates a framework for design to maximise capital and lifecycle value and minimise risk by focusing on the design and integration of systems, it does not necessarily provide a clear framework for how wider economic value is captured. While this methodology excels at looking forward towards how systems will be replaced and maintained over time, it is less successful at looking outwards towards interfacing programmes and holistic value creation through economic investment and understanding the wider value of the asset. To use the metaphor from the ICE research, if the civil engineering and built environment is the 'box' into which systems are integrated and replaced over time, into what context does the box fit and how does it act as a catalyst to change that context for the better?

7.3.3 The Design Council approach: A double diamond-shaped design process

A third way of considering the design process in infrastructure delivery is the 'Double Diamond' approach developed by the Design Council. This is becoming a standard framework for thinking about value creation in infrastructure design and is the framework for design preferred by the National Infrastructure Commission Design Group. The Design Council Double Diamond design process illustrates the importance of design from the outset of the project, in defining the problem and developing the project brief (Sykes& Marko, 2018).

It identifies design as consisting of two key phases or 'diamonds' (early collaborative problem solving on the left and iterative design development and delivery on the right) separated by a brief. In the first 'Discover and Define' stages, adequate time is spent up front engaging with suppliers, maintainers and stakeholders to fully understanding the problem to be solved and to inform a brief. This time is also used to identify the wider value which can be delivered beyond the core function of the infrastructure. Thinking of design in this way allows for creative and collaborative problem solving early in the design stage to maximise value. It also allows operational maintenance expertise up front to help define and discover the problem and inform the brief. In the second 'Develop and Deliver' stages, iterative design solutions are developed and tested to ensure right first-time delivery. It also allows sufficient time for iterative versions of design to be tested before refining into the detail of a single preferred solution. There is sufficient time for prototyping to be used to encourage supply chain innovation and achieve economies of scale. "Prototypes give you insight into how your design will be used, before you create a finished version. Physical prototypes are also particularly effective in communicating design ideas to diverse groups of stakeholders." (Design council, 2021). This is particularly relevant to infrastructure where the scale of the projects means that spending time on design upfront on refining elements which can be deployed repetitively across the programme can offer significant value.

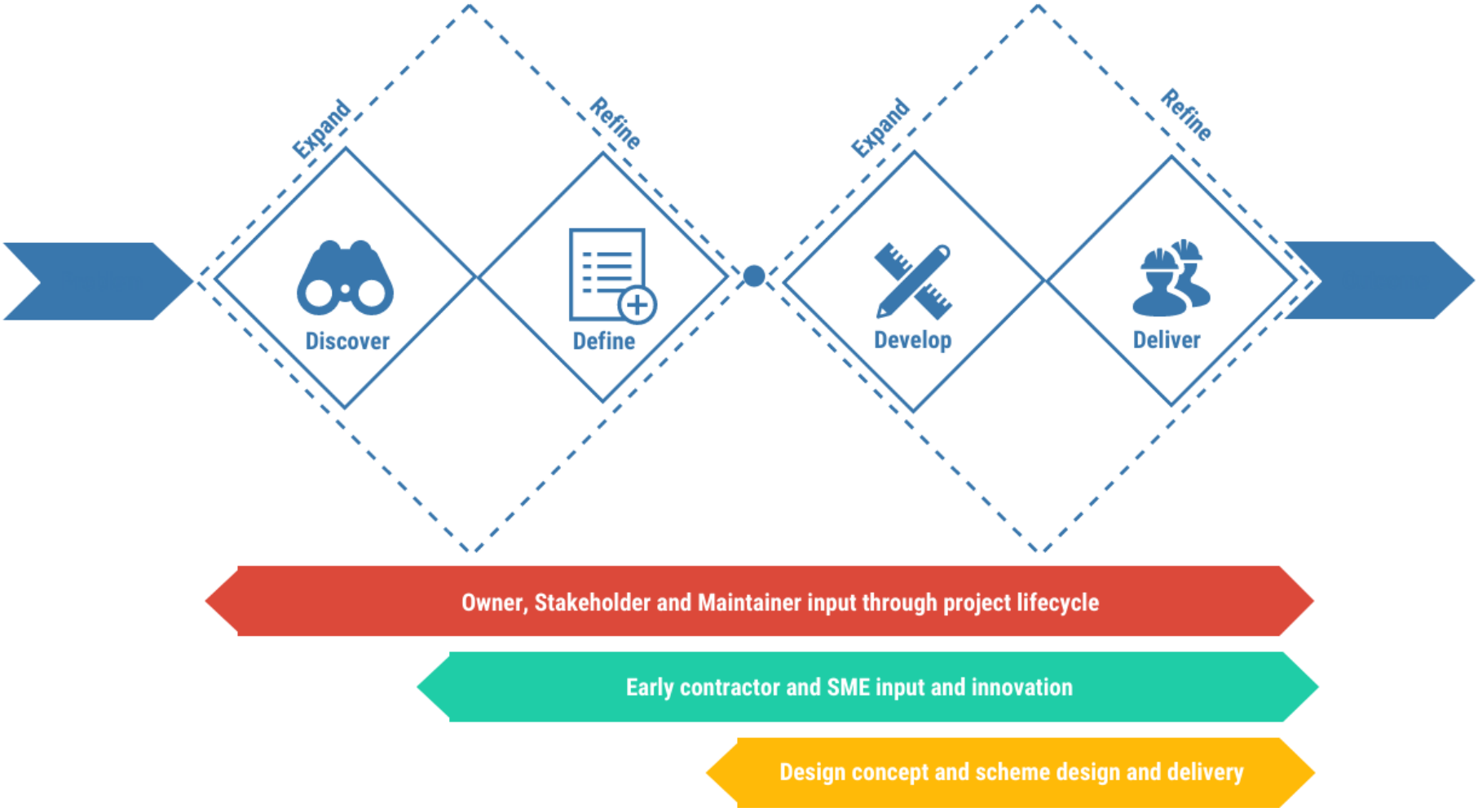

Fig 12: The double diamond design process used to illustrate how early contractor, SME and operational input should be used to inform early collaborative problem solving and inform the project brief. Owner and stakeholder involvement in design throughout the project lifecycle supports informed decision making and high-quality outcomes.

7.3.4 Attitudes and Governance

The second theme which research suggests is acting as a barrier to the delivery of good design in infrastructure is Attitudes and Governance. Research has already been undertaken into prevailing attitudes and understanding of design within the infrastructure sector by the National Infrastructure Commission. This was captured in their 'Design and Infrastructure Sector Review of Attitudes' paper which was published in 2019. This research identified nine areas where poor attitudes and governance is preventing good design outcomes. The NIC research carried out interviews with a broad range of infrastructure professionals to identify barriers preventing the value added by quality design in infrastructure from being understood. These include, inter alia, poor project briefs, lack of champions of design at governance level, inflexible planning policies and a failure to embed design in the day to day work practices of those responsible for project delivery (Publica, 2019).

Further research published by the ICE and the Infrastructure client group as part of the Project 13 initiative reveals that owners and stakeholders often have different attitudes to the value of design and have different methods of governing its delivery. This lack of integration and different attitudes to design ultimately results in stakeholders and owners taking different routes to desired project outcomes.

Infrastructure owners often lack expertise in the wider value created by their assets and use procurement processes to engage design based on achieving the technical requirements at lowest cost. Project delivery teams are subsequently set up to be focused on meeting technical requirements and delivering to a set of fixed milestones without sufficient space for design optioneering or decision making. Project briefs often focus on the narrow technical requirements of projects and do not sufficiently identify the wider opportunities and impacts of

projects, and this is exacerbated by short feasibility stages and a rush to construction.

Of critical importance, the owner's and investor's appreciation of value needs to have progressed from reducing initial price or CAPEX cost to a long-term holistic vision for value that benefits a wide range of stakeholders. (Mitchell,2017)

Stakeholders lack expertise in the technical and engineering constraints of the infrastructure and may use political pressure and statutory processes such as petitioning, design panels and planning consents to influence design quality to achieve wider value. Often the environmental, physical, or cost envelope for the project is fixed at an early stage when the design is immature and subsequent meaningful design change is difficult to retrofit.

At the project delivery stage contractors procured on a lowest cost basis to deliver the functional requirements are also tied into engaging with local planning consents with different priorities which are not captured accurately in the employer's requirements. This 'known unknown' is priced as risk leading to poor value outcomes for programme funders.

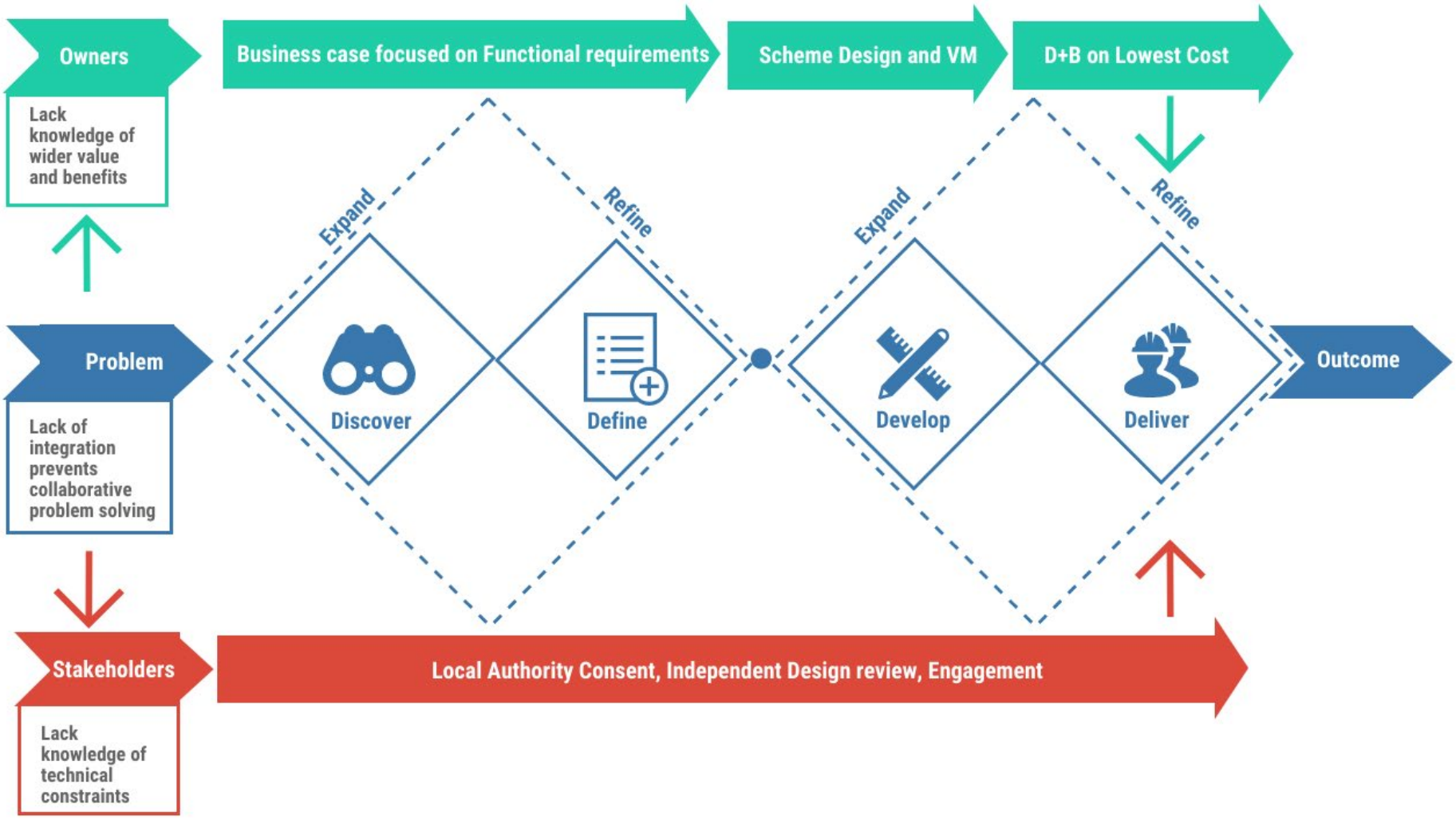

Fig 13: The double diamond design process used to illustrate how different attitudes to the value of design can lead to conflicting requirements being pursued via different avenues. This presents the organisation delivering the infrastructure with conflicting requirements and additional consents and approvals risks which ultimately leads to poor value outcomes.

7.3.5 Procurement and Collaboration.

Infrastructure projects are often developed by re-tendering design services at each design stage. This may result in several different designers being involved from concept through to ITT and project delivery. It is not unusual for one design house to develop designs up to concept design, to be replaced by a second design house for scheme design and then a third design team to deliver the project by supporting a contractor to develop detail design. This has the potential to lead to lack of continuity and loss of project knowledge.

Construction and logistics advice is often provided as an add on to the design and engineering until the point at which a contractor is tendered. Many benefits the preferred contractor could bring through innovation are limited by being late in the programme where they are often outweighed by the cost of redesign or risk of programme extension.

The procurement of projects in this way can also lead to conflicting understanding of the value of design between owners and contractors. Owners spend significant time during concept and scheme design to develop design solutions and then pass them to a contractor with a mandate to deliver further savings on a pain/gain basis. The contractor, in turn, will instruct design teams to save money as a priority through the detail design stage with the result being that finished projects do not meet stakeholder expectations and value is lost.

Ultimately, the team delivering the project is kept separated out from the early design stage where project objectives are identified and collaborative problem solving maximises value. This disconnect results in poor value creation for infrastructure.

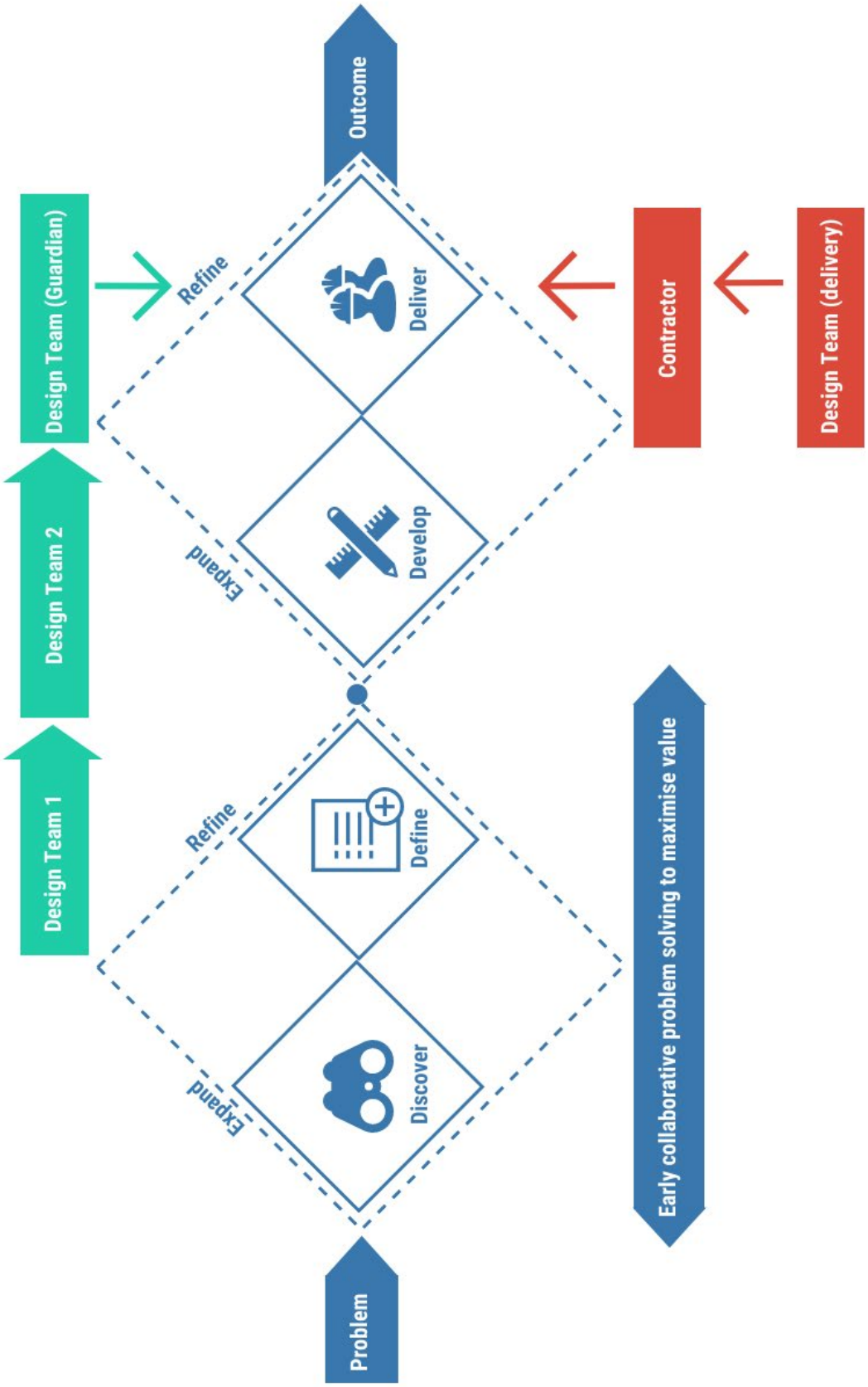

Fig 14: The double diamond design process used to illustrate how owners retender design services over the course of infrastructure projects. This serves to separate out those detailing and delivering projects from the early collaborative problem solving where project objectives and values are established.

8.0

Research Outcomes

8.1 Research Methodology

Semi-structured interviews were held with senior personnel within three tier one contractors. Their experience spans utilities, rail, aviation and highways. The interviews were structured around the three emerging themes explored in chapter four of Process and Information, Attitudes and Governance, Procurement and Collaboration. Further detail on interview discussion topics is contained within Appendix 1. Following these interviews additional research was carried out on three case study projects or initiatives referenced by the interviewees as exemplars of issues relevant to the research.

8.2 Interview outcomes

The interviews undertaken discussed a range of topics which are collated under thematic headings:

- Operational and maintenance input
- Supply chain innovation
- Owner and stakeholder conflict
- Employer integration and ownership
- Time to design
- Alignment of design values

8.2.1 Operational and maintenance input

Interviewees repeatedly stated that the knowledge and expertise used to inform the brief was critical in delivering the final desired best value outcomes. It was noted that infrastructure briefs often focused more on product rather than lifecycle which can lead to late maintainer input and the integration of systems as an add on too late in the design and construction programme.

The long design life of infrastructure (often more than 120 years) results in the consideration of operations, maintenance and replacement early in the design process having the potential to add significant value. It was noted that despite the advantages offered by this, the infrastructure sector was generally poor at considering lifecycle value as a key tenet of the design brief.

Conversely, interviewees offered numerous examples of infrastructure projects where systems handover created project risk by occurring late in the programme. The Thameslink upgrade of London Bridge station was cited as an example where the systems maintainer was only brought onto the project towards the end of the construction programme. This resulted in several knock-on effects. Handover had to happen after the milestone of station opening was reached resulting in work taking place during engineering hours. This further served to extend the handover programme while bringing the added risk of handing over systems in an operational station.

It was noted that a design process which fully engaged operators and maintainers to inform the project brief, and retained them during project delivery, would create significant value by mitigating project risk at the point of handover from the contractor to the maintainer. Furthermore, placing emphasis on maintenance and operations upfront in the project brief would serve to encourage a step change in the perception of infrastructure projects as a provision of a user focused services rather than a series of built outcomes or ‘products’.

These findings echo those contained within the ICE report 'A systems approach to infrastructure delivery' from the ICE. "Projects can easily go wrong if one aspect dominates. In infrastructure projects, this is often the most expensive element – normally the civil engineering. Finishing the bridge, tunnel or building is the overwhelming priority, right up until the point that it becomes clear that there are serious problems in bringing the system, of which it forms merely one part, into service (McNaughton, 2020).

In this instance, the role of design is twofold. Firstly, a process must be designed to ensure the right level of operational and maintenance expertise into the brief to ensure the correct focus on the desired outcome. Owners must clearly define outcomes so engineers and technology developers can deliver for that use (McNaughton, 2020). Secondly, the procurement route must allow sufficient flexibility for the supply chain to achieve that outcome in the best value way possible. Preferably it will incentivise the contractor to give the owner more than just a product and the best value outcome over the lifecycle of the asset.

8.2.2 Supply Chain Innovation

Interviewees emphasised not only the lack of operational intelligence informing briefs but also the lack of sufficient contractor expertise early in the process. In particular it was noted that better value outcomes could be achieved through contractor input and innovation up front advising owners and informing project briefs.

The scale and often repetitive nature of nationally significant infrastructure projects means value offered by contractor innovation such as offsite and design for manufacture and assembly are significant. It was felt that early contractor involvement to advise on the possible delivery solutions would create a culture of early collaborative problem solving with a view to providing best value. Deploying the most innovative and efficient design and delivery solutions should be key requirements of the brief and this would ultimately not only offer best value to

infrastructure providers but also drive research and development within the supply chain in order to gain competitive advantage.

It was noted that developing very prescriptive employer's requirements limited the ability of any supply chain innovation to subsequently add value. At this point redesign to accommodate better value, delivery-led solutions are often not possible within programme milestones or where limited by conditions of planning consent.

In addition, early involvement of SMEs and tier two contractors was seen to be of great value to infrastructure clients as it allows innovation to occur early in the design process and reduces project risk on specialist areas (e.g. tunnelling etc). This also allows for realistic expectations in terms of feasibility, cost and programme for complex high-profile elements as 'dumbing down' of these elements later in the programme due to buildability and budget can lead to reputational risk.

One sector which was held up as an exception by those interviewed was aviation with briefs often informed by contractors and lifecycle cost with a focus on value outcomes rather than a product. The procurement model proposed for the third runway expansion at Heathrow was identified as an exemplar of this approach with the project establishing supply chain principles which embrace off-site manufacturing from the outset and optimise value by promoting supply chain innovation.

8.2.3 Owner and Stakeholder conflict

Interviewees identified conflict between owners and stakeholders over the value of infrastructure and the role of good design in delivering it as being common.
For example, agreeing on the design and responsibility for benefits beyond the core function of the infrastructure asset such as placemaking, connectivity, public realm etc.

It was observed that quite often conflict between stakeholders arises mid contract when a delivery partner has already been appointed. This serves to drive up costs both in terms of programme delay or re-design to resolve differences in terms of design. It was also suggested that this potential conflict increases the risk built into the tenderers prices when tendering for the project. Combined, these offer a poor value outcome for the infrastructure programme. It was noted that allowing sufficient time up front to collaborate on the design of a unifying project vision which gets the buy in of all stakeholders would create better value outcomes.

Also noted was the tension between national programmes and local stakeholders and contexts. Again, aviation was identified as being a leader at understanding local priorities in terms of design whereas the one size fits all approach adopted by national infrastructure programmes not rooted in one particular place often carried a greater risk of conflict with local stakeholder design ambitions.

8.2.4 Employer integration and ownership

Interviewees stated that the most successful projects were these where clients were an integrated part of the delivery team. This ongoing involvement of owner and stakeholders with designers and contractors allows change to be made quickly with appropriate buy in from all parties. It also ensures the team is sufficiently flexible to allow questioning of the design from first principles to ensure best value.

Interviewees also observed that in their experience projects which were delivered under an integrated one team approach between employer, designers and contractors offered better value by avoiding a confrontational blame culture and instead promoted a culture of problem-solving and collaboration. Alliancing models with a shared charter based on values and behaviours and co-located drove better design outcomes by avoiding the ‘siloing’ of disciplines and by promoting a focus on a shared objective rather than the provision of services for a fee.

It was clear from the interviews undertaken that a collaborative procurement model in the vain of Project 13 while addressing many of barriers to good design evidenced by the literature review, also has widespread support among those delivering projects on the ground.

8.2.5 Time to design

A consistent theme of the interviews was that high-quality design outcomes in infrastructure could only be achieved if sufficient time is given for design. The earlier a project can give consideration to how the outcome will be delivered, rather than just what will be delivered, then the better value will be achieved. It was noted that political pressure to progress quickly to the delivery stage and 'spades in the ground' meant that insufficient consideration was given to design in the early stages of infrastructure projects. This echoes the ICE systems approach to infrastructure delivery and its mantra of 'think shovel worthy not shovel ready'.

One respondent referred to this as a culture of 'B+D rather than D+B' i.e. that projects are often tendered first and construction commences without full consideration or understanding of the entirety of the design. Rushing to project commencement dates this also creates uncertainty and risk which can ultimately lead to cost and programme over runs. In this instance, instead of contractor and maintainer innovation being used to inform the brief, the contractor relies on the deployment of 'innovative' construction techniques such as MMC and off-site to reduce risk to meet inflexible project milestones. This has led to a clouding of the industry's understanding of what innovation is.

To truly act as catalysts for innovation infrastructure programmes must incentivise research and development through project briefs and then allow sufficient time upfront within the project programme for design iterations and prototyping to

drive new and innovative methods of delivering projects. Critical to this is tendering on the basis of value added and ensuring that the supply chain shares in opportunities presented through investing in research and development. Currently the construction industry as a whole, not just infrastructure, is caught in a race to the bottom with low margins caused by competitive tendering based on lowest cost. This drives out innovation.

The infrastructure sector, by nature of its sheer scale and level of public investment, presents a golden opportunity to change this. By demonstrating the long-term benefits of investing in research and development, infrastructure projects are uniquely placed to drive for better value outcomes for owners, higher levels of productivity for contractors and cutting-edge design solutions which would provide designers with world leading expertise.

8.2.6 Aligning Design Values

The final theme drawn out from the interviews is that of the unique market position that infrastructure owners in the UK have both in terms of the scale of their pipeline and the relatively limited number of competitors. In practice any potential design or delivery partner within the supply chain whose business is focused on the infrastructure sector should be conscious of delivering on design quality and value if mandated to do so given that there a relatively few 'bridges to burn' within the sector. The implication for design quality is that there is therefore a strong impetus for suppliers to align themselves with the design objectives and values of infrastructure owners in order to develop long lasting relationships built on a working history and common goals, to secure future work.

This will ultimately still fail to deliver high quality design outcomes if the owner's definition of value is not wide enough to encompass the wider value created by their asset and is limited to functional requirements at lowest cost. This can be mitigated, as described earlier, by creating sophisticated client bodies or enterprises which have a holistic understanding of the value delivered through

high quality design, but these may only be set up for limited times for programmes. When they are dissolved valuable expertise and lesson learnt are lost and there is no incentive for suppliers to invest in developing long term relationships.

To harness the opportunity presented by its significant pipeline to deliver high quality design outcomes, owners must become long lasting sophisticated client bodies which champion high-quality design throughout the organisation. Procuring design and delivery by developing an in depth understanding of their supply chains strengths and weaknesses, and developing lasting relationships and sharing risk and rewards with those who best mirror their own understanding of the value of design, will ultimately deliver high quality design outcomes.

9.0

Case studies

9.1 Project 13

Case study summary:

Project 13 is a blueprint for collaboration on infrastructure delivery which encourages collaborative design across employers, designers, and contractors to identify value early and deliver it efficiently. Better value outcomes are achieved by facilitating the correct design advice early in the project lifecycle, creating integrated client bodies to develop and deliver projects and ensuring risks and rewards are shared across infrastructure owners, design teams and contractors.

Description

Project 13, which is an initiative from the Infrastructure Client group and the ICE, was repeatedly referenced during interviews as offering a clear framework for ensuring that design of infrastructure projects could be developed to maximise value. Project 13 seeks to avoid a transactional approach to procurement by forming sophisticated client bodies, or enterprises, at project outset. This enterprise can consist of SMEs, maintainers, contractors, consultants, and stakeholders in addition to owners. This collective group then works as one team to define and optimise value early on including identifying the problem which needs to be solved, identifying wider opportunities for value, and developing a holistic project brief.

Adding value by design

The advantages of this approach in terms of maximising value through design include:

- The enterprise model brings the owner and stakeholders together and speaks for them with one project voice removing conflict and ensuring a shared holistic understanding of the value of design across the client body.
- The process ensures that SMEs and their knowledge is central to the design process from the outset and so harnesses the value that their knowledge can bring.
- Removes layering of design fees and culture of charging by the hour by sharing the risks and rewards across all parties. This encourages design innovation.
- The owner is central to the process and this ensures that operational and maintenance knowledge is embedded in the project brief and design processes early on.

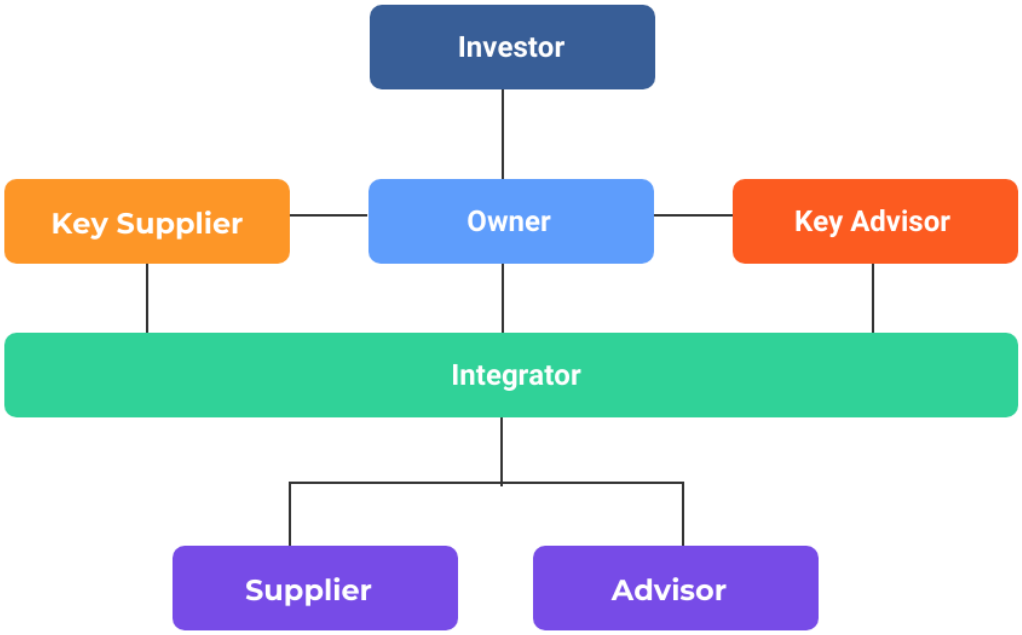

Fig 15: Project 13 Organogram

9.2 Wessex Capacity Alliance

Case Study summary:

The Wessex Capacity Alliance was formed in 2016 to deliver the £602M investment programme for the Network Rail Wessex route. An alliance of client, designer, contractor, and rail systems contractor was used to ensure a fully collaborative approach to a high-risk programme of works with significant complex interfaces and time constraints. This project demonstrates the high-quality design outcomes, capital savings and economic benefits which are possible to be delivered through multidisciplinary design within a collaborative alliancing model.

Description

A Skanska, Aecom, Colas Rail and Mott MacDonald alliance was awarded the contract by Network Rail to design and construct the Waterloo and south west upgrade on the South West Trains network on the Wessex route to Waterloo station. This programme increased capacity at the UK's busiest station by 30%. All members of the alliance signed up to a joint charter which outlined key behaviours and established the equal sharing of risks, responsibilities, and success across all parties.

Adding value by design

This model of delivery allowed design to add value to the programme across several areas:

- Delivering the design through an alliancing model avoided a transactional approach between client, designers and contractors and having allocated

team maximised opportunities for multidisciplinary working. This ultimately delivered a more streamlined and integrated design process *"Fortunately, the nature of working in an alliance highlights the synergies that naturally exist between different disciplines, giving the opportunity to maximise the outcome of every bit of work being done. Its existence has been essential to the success of this project and, perhaps, was the only way of meeting the current and future needs of the route's rail users, the train operator, asset owners and, ultimately, the taxpayer's purse"* Mott McDonald (2018).

- Having an integrated team with a shared risk and success model meant that savings could be delivered by investing time upfront in design. The alliance undertook several design iterations which allowed the contractor expertise to be integrated into the process. This relied upon all parties being willing to invest in time to design but ultimately delivered significant savings. *The mammoth £65M of savings made to date on the WIT required an initial outlay of £250,000 of 'thinking time' to discover these solutions, a luxury perhaps only afforded within an alliance environment where all parties are aligned to deliver the best solutions'* (Mott McDonald, 2018).

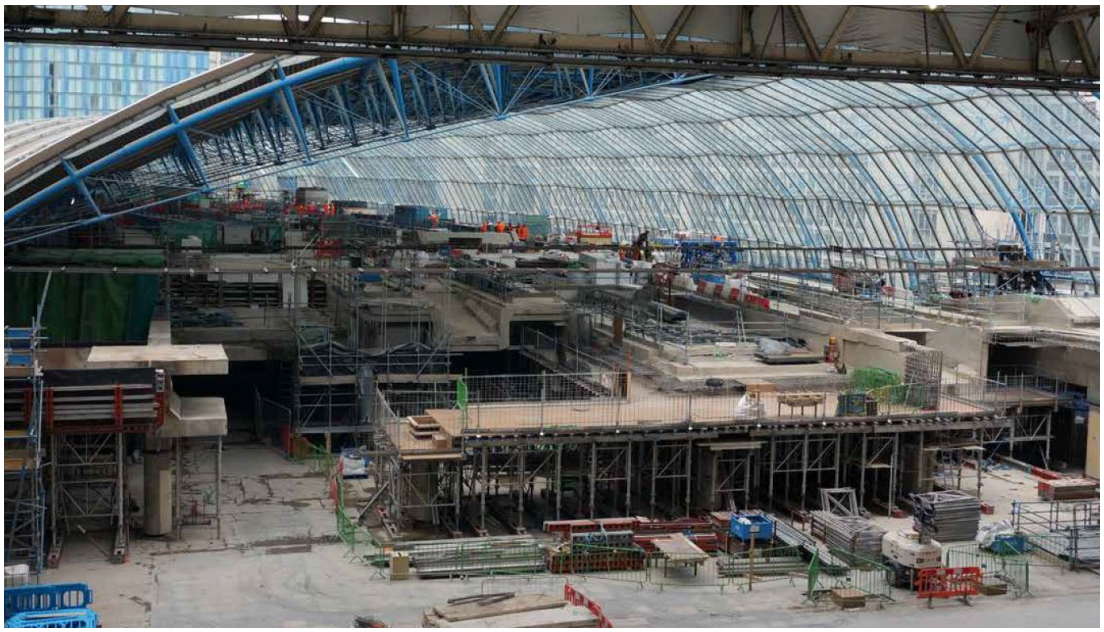

Fig 16: Waterloo station works as part of the Wessex Capacity Alliance (Mott McDonald, 2018).

9.3 The ODA design delivery partner

Case Study summary:

The infrastructure and buildings for the 2012 Olympics represented a nationally significant project to be delivered within a complex stakeholder and technical environment. The selection of a delivery partner model allowed for a clear delineation of design responsibility across client and delivery parties with both sharing the same objectives for success. This case study illustrates how an integrated delivery partner model produced a high-quality design outcome within programme and budget with significant legacy value.

Description

The delivery of the infrastructure required to host the London 2012 Olympic games presented a unique opportunity but daunting challenge. The opportunity went well beyond the chance to host a high-profile sporting event to deliver a transformational project for area, placemaking on a grand scale acting as a catalyst for long term investment and job creation. The challenges were equally daunting, to deliver a nationally significant high-profile project with a finite end date and budget.

Adding value by design

- Central to the successful high quality design outcome from the ODA programme of works was the establishment early in the project lifecycle of design issues such as accessibility, sustainability and legacy as part of the six key criteria against which the success of the programme would be measured. In doing so, the programme established design as a priority for

all stakeholders and partners from project outset this served to align all parties behind a unifying set of strategic design principles.

- High quality design outcomes were also ensured by providing the correct level of design guardianship at board level, with the design director sitting alongside the finance and delivery directors on the executive management board reporting directly to the Chief Executive Officer. This organisational arrangement echoes that called for by the National Infrastructure Commission and reinforces the view that, for value to be optimised, design needs to be sponsored at the highest level within the governance structure.

- Value was also delivered by ensuring the ODA's contract with the delivery partner provided financial incentives to the to deliver the ODA's sustainability, environmental and inclusivity objectives. In this way the reward for delivering high quality design was shared with those delivering the project.

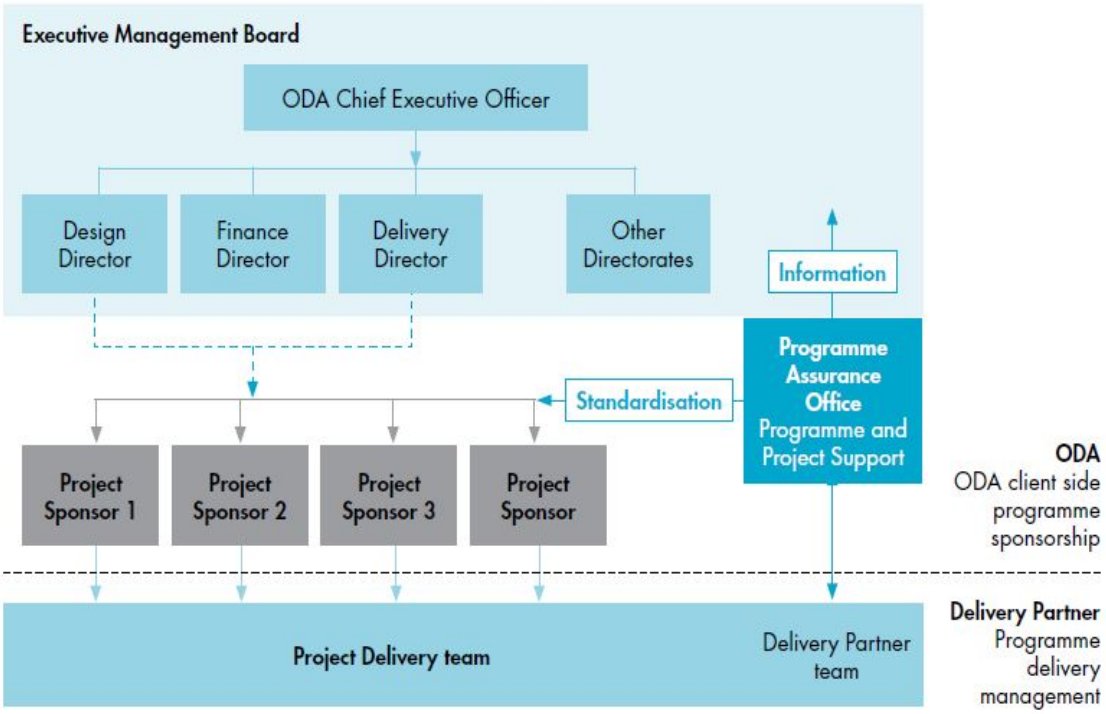

Fig.17: ODA design and delivery organogram illustration senior design leadership (Jacobson 2011)

10

Recommendations

10.1 Research recommendations

The recommendations to industry arising from this research are summarised under the following headings:

- Adoption of a plan of work for infrastructure.
- Embedding operational and maintenance value in project briefs.
- Integrated and diverse leadership teams.
- Government policy in support of collaborative procurement models.

10.2 A Plan of Work for Infrastructure

The development of a multi-disciplinary plan of work specifically designed for infrastructure would offer many benefits. Currently, there is no single framework for the development of design for infrastructure which is consistently understood or applied with a mx of the RIBA plan of work, political processes and consents used to define the design activities and outputs at each stage. As explored in this research, this lack of a universally understood, centralised approach exacerbates barriers to maximising the delivery of best value.

A standardised roadmap which identifies the opportunities and benefits that infrastructure can create, and when in the design lifecycle these should be locked in, would, if widely and consistently adopted, help to safeguard design quality

within infrastructure delivery. If done correctly, it would place emphasis on the time to design and ensure projects allow sufficient time up front to get brief right and produce design iterations over the project lifecycle. It would also allow for a holistic understanding of the infrastructure specific risks and opportunities at each phase of design. This could include identifying and engaging the correct stakeholders early in the project lifecycle and ensuring their views are incorporated into the brief.

A plan of this kind could all bring together the complete range of multi-disciplinary design considerations and identify how and when each of these disciplines can potentially deliver best value for the project. It could also ensure that operational, maintenance and supply chain expertise is identified and engaged at the correct stage in the project lifecycle and that systems integration is considered appropriately from the project outset.

Given the complexity of the issues involves, a framework such as this would be best developed and owned by an objective body which has the capability to draw on the range of expertise required to compile and update the plan. A body such as the National Infrastructure Commission or the Infrastructure and Projects Authority may be appropriately positioned to have the holistic overview to develop this plan. In any event, it would need to draw on a broad range of expertise from across the design and construction industry in addition to stakeholder bodies such as local transport providers, local authorities, and utility providers.

10.3 Embed maintenance, operational and lifecycle value in project briefs and employer's requirements

Project briefs should focus less on products and more on performance, lifecycle and maintenance value and long-term flexibility and adaptability. A key finding from the research is the extent to which poor project briefs limit the value that

good design can deliver in infrastructure. This was identified by both the NIC, the ICE and in the interviews carried out with contractors. Briefs should allow for sufficient flexibility for the supply chain to identify how value can best be provided.

In fact, setting requirements which are too prescriptive can drive up cost and limit innovation. For example, a common prescription in the world of infrastructure is for civils assets to have a design life of 120 years. This can have the impact of driving carbon intensive poor value outcomes which increase capital cost and drive out innovation.

Better value could be achieved if this requirement was a 'looser fit' so it could be met with a holistic approach which not only considers the design life of the asset but also the regime of monitoring, inspection, and repair. This would allow the supply chain to consider more cost-effective leaner solutions that may be possible and would encourage the adoption of supply chain innovation such as digital twinning, remote monitoring, and innovative materials.

Ultimately, by allowing the research and innovation within the supply chain to come to the fore, this would promote a culture of investment in R+D to gain competitive advantage and overall offering the construction industry increased productivity in the longer term.

10.4 Integrated and diverse client leadership teams

Project leadership teams for significant infrastructure projects should be drawn from, or integrated across, both the infrastructure provider and wider stakeholders. This would allow for a more holistic understanding of the role of design, not just to deliver functional requirements, but also to realise wider value.

The research has demonstrated that to maximise the benefits of infrastructure projects, it is essential that opportunities to deliver value outside of the core

requirements are identified and assessed in a timely manner. Having a design process which is iterative and allows sufficient time to explore these opportunities is also essential. However, very often these wider benefits are qualitative and need to be measured against a complex set of nuanced criteria which often conflict with functional requirements or extend beyond the red line boundary of the project.

It is essential that infrastructure projects have a senior leadership team which has both the experience and diversity to understand and assess this complexity. They must have the ability to take a long-term, outward looking view to assess the wider benefits that investing in high quality design outcomes can bring relative to more quantifiable or functional requirements such as cost and programme. Leadership teams drawn from a broad range of backgrounds and stakeholder bodies would also provide for knowledge of local stakeholder requirements and priorities even within the context of national infrastructure projects.

It is noted that the NIC has recommended that a design champion be part of the board of significant infrastructure projects and that this was supported by government in the National Infrastructure Strategy published in 2021. Of course, this is to be welcomed as a step forward in terms of placing more emphasis on the value that design brings to infrastructure projects. However, in some ways this does not go far enough and is misleading in that design quality is siloed off rather than being fully integrated into the culture of a project. In infrastructure projects true quality is only achievable through developing an understanding of both the functional requirements and the site-specific needs and opportunities available. Only then can a set of holistic design responses be developed and tested with respect to these criteria. Ultimately, an only an integrated project leadership team which is empowered to guide this design process and has the knowledge to make the best holistic decisions for the project *and* the place can deliver value.

10.4 Government support for collaborative procurement

The deployment of collaborative models such as Project 13 for nationally significant infrastructure projects should be supported through government policy and legislation. This would create a step change in the way infrastructure projects are designed and delivered which would improve value creation.

Project 13, which proposes the creation of sophisticated integrated client bodies, or Enterprises, offers a pathway for incorporating appropriate practices and technology to deliver the best value outcomes. Most importantly, it proposes a framework for design which allows for the correct knowledge and expertise to inform the project brief at early design stages and allows for the correct level of client involvement as the project is designed and delivered.

This approach allows for the design process to benefit in two principal ways. Firstly, it facilitates early involvement of SMEs, maintenance supply chain and other specialists early in the design process, allowing for specialist knowledge to inform the brief. Furthermore, by moving from a transactional to collaborative approach, it creates a reward system which means reward is based on value added to the outcome rather than services provided to fixed milestones. This is significant as is drives innovation in the design supply chain by focusing on a shared interest in the project outcome rather than the delivery of a service, creating an environment for high quality, innovative and efficient design solutions.

This represents an opportunity for the government to lead by example. Through government support for procurement models that promote early SME and tier 2 involvement, the value of investment in research and development and innovation would be demonstrated on the nation's most significant projects. This would promote collaborative practices and investment in research in the wider construction industry and create a trickle-down impact on smaller projects.

11

Conclusion

This research paper was founded primarily on a question: If good design is the key to unlocking value in infrastructure, then how can designers and contractors effectively collaborate with clients to deliver it? Therefore, the purpose of the research was, through literature review, firstly to demonstrate whether good design does unlock value in infrastructure. Following a detailed review of publications from a range of sources including government, independent advisory and professional institutions it is clear that design has been widely identified as a driver of value in infrastructure delivery.

However, the literature review also reveals that there is no universal understanding across the disciplines or organisations what forms design can take and the range of areas in which it can deliver benefits for infrastructure projects. Too often design value is conflated with delivering an acceptable aesthetic solution for an otherwise functional asset at lowest cost. The infrastructure sector must move beyond aesthetics to understand design as a collaborative and creative process which drives value from the project outset by ensuring the correct leadership and inputs and reduces risk through testing iterative design solutions throughout the project lifecycle. This is ho design can ultimately deliver value by lowering capital and lifecycle cost, promoting inward investment and environmental benefits, and ultimately delivering social and user value over the lifetime of the asset.

The research has revealed that it is very difficult to optimise value in infrastructure without a universally understood definition of design or the benefits it brings being shared across owners, stakeholders, designers, and contractors. This creates

cultural barriers to good design across organisations and disciplines which are exacerbated by procurement models. The three themes which have been used to characterise these barriers were validated through the industry engagement which has been carried out.

On the theme of process and information, it is clear that the industry feels that design is only truly enabled through models which allow the right expertise to define project scope and inform briefs, reflecting the long term design life of infrastructure by providing maintenance and operational supply chain with sufficient voice upfront in the design process.

It is also evident that industry believes that integrated client bodies which include stakeholders and avoid a transactional approach with contractors allow design to add value by reducing project risk and ensuring the outcomes meet the requirements and ambitions of all parties. Equally, ensuring continuity between the early collaborative design work to identify value, and the more detailed design decisions during the delivery stage which can determine whether that value is realised, is critical in ensuring the best outcomes for infrastructure projects.

The conclusion of this research is that the establishment of a standardised framework for design in infrastructure would be of value, not only in establishing a shared framework for design in infrastructure but also in raising the profile of design as a key tenet of infrastructure programmes. Although a step in the right direction, this alone would not be sufficient and would need to be supported with a suite of measures including refocusing project briefs on best value long term outcomes rather than ‘products’ and ensuring the right mix of leadership experience to ensure briefs are ultimately met. What is clear is that there is a strong will both within central government and the design and construction industry to deliver high quality design outcomes in infrastructure. What is now needed is effective action.

12

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Appendix 1

Interview Topics

Value in Infrastructure Design - Semi Structured interviews format

1 - It is proposed to hold semi structured interviews with Tier 1 contractors and their supply chain to validate the desktop research and gain a greater understanding of the issues.
2 - The discussion points below are proposed to provide a framework for the interviews. They are based around the three themes identified in research and are chosen with specific aims as illustrated below.

Discussion point	**Aim**
Process and Information	
The RIBA plan describes designa as linear process whereby a brief is written at stage 1, a concept developed at stage 2 through to delivery at stage 5. Contractors are not generally appointed until stage 3 or beyond depending on procurement route. Maintainers aren't appointed until stage 7. *Research indicates that with infrastructure delivery, this approach may result in valuable intellignece and valuewithin the delivery and maintenance supply chain not being incorporated until too late in the programme. Do you agree with this statement? Why/Why not? In your experience, is the RIBA the standard used?*	Response: Yes/No response and expansion through discussion to test theme validity.
If yes, how do you believe supply chain R+D can create value in infrastructure?	Interviewee to discuss specifically what areas of R+D can add value and how this value is quantified.
In your experience do you know of any example where increased awareness of the opportunities offered by R and D and DFMA at early design stages could add value?	Establish quantative past examples to support study and identify case studies
Can you identify any sun contractors of sub consultants you use who could add value if appointed earlier in the design development stages (e.g. monitoring)	Identify latent potential in supply chains
What should the industry do to improve R+D knowledge at early stages when briefs are being formulated?	Support recommendations to industry.
Procurement and Collaboration	
Research suggests that large scale infrastructure projects are often developed by re-tendering designs services on a lowest cost basis at each design stage. At technical delivery, a design guardian is retained client side while a technical architect supports to a contractor. Contractors only involved post procurement RIBA stage 3 - not where value is created and in adversarial position with design guardian. Contractor is not incentivised to reconsider the design value form first principles – only to reduce costs relative to the existing concept. Technical designer has not been involved with value creation stage but is incentivised to deliver savings and lowest cost services.Do you agree with this statement?	Response: Yes/No response and expansion through discussion to test theme validity.
Have you experience of this in the projects you have worked on? Please give examples?	Establish case studies to support research.
Have you delivered projects where this was not the case and if not, why not? Do you have examples of projects where this was avoided or successfully worked around? How?	Identify potential solutions to inform recommendations to industry
Do you think bidding in an infrastructure D+B bid with a 'challenger' design team offers better value than using an incumbent? Why?	Establish attitude to collaboration/engagement with concept designers and high value outputs v. lowest cost solutions
How do you think contractors could work with designers at earlier stages to ensure value is maximised and avoid conflict at later stages?	Identify alternative procurement models to inform recommendations to industry

Attitiudes and governance	
Infrastructure owners often lack expertise in the wider value created by their assets. Stakeholders lack expertise in the technical and engineering constraints of the infrastructure. These requirements are effectively split out for procurement.Contractors are often procured on a lowest cost basis to deliver the functional requirements but are also tied into engaging with local consents and design panels with different priorities not captured in the employers requirements. Do you agree? If not why not?	Response: Yes/No response and expansion through discussion to test theme validity.
Have you experience of this in the projects you have worked on? Please give examples?	Establish case studies to support research.
Have you delivered projects where this was not the case and if not, why not? Do you have examples of infrastructure projects where the client was a successfully integrated 'one voice' and this was reflected in the works information? Did this lead to better value outcomes?	Identify instances where client bodies were successfully integrated and what value this created
Are you aware of the ICE P13 initiative? Do you believe this model is workable and will add value. Are you currently working in a similar partnership or alliance arrangement?	Test working familiarity with current industry best practice and identify if this is producing 'real world' outcomes which add value.