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Future Ready case studies: conceptual designs facing new global challenges

Casos de estudio de "Future Ready": Diseño conceptual afrontando los nuevos retos globales

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ABSTRACT

Future Ready is a framework developed by WSP to help our designs respond to the rapidly changing world. Future Ready helps our projects to be ready for new global challenges by engaging clients and inspiring designs for the future. By understanding future trends and technologies, it can improve project outcomes through good conceptual design. We present three case studies to explain how we consider future trends, the process followed and the benefits of the Future Ready approach.

The Waterloo Bridge project responded to trends in technology by adjusting the project scope to trial advanced satellite monitoring techniques applied to bridge movements.

In light of trends for healthy transport, the conceptual design of Bromley Heath viaduct refurbish-ment enhanced the use of an existing structure for non-motorised users.

The solution developed for Hammersmith Flyover considered trends in resources and novel mate-rials by deploying Ultra High Performance Concrete on a high profile application.

KEYWORDS: Conceptual design; creativity; inspiration; symposium; future; future trends.

RESUMEN

"Future Ready" es un marco desarrollado por WSP para ayudar a nuestros diseños en este mundo cambiante. "Future Ready" prepara nuestros proyectos para los nuevos retos globales, involucrando a los clientes e inspirando diseños para el futuro. Al comprender las tendencias y tecnologías futuras, puede mejorar los resultados de los proyectos a través de un buen diseño conceptual. Presentamos tres casos de estudio para explicar cómo consideramos las tendencias futuras, el proceso seguido y los beneficios del enfoque de "Future Ready".

El proyecto del puente de Waterloo respondió a las tendencias de la tecnología ajustando el alcance del proyecto para probar técnicas avanzadas de monitorización por satélite aplicadas a los movimientos del puente.

A la luz de las tendencias para un transporte saludable, el diseño conceptual de la renovación del viaducto de Bromley Heath mejoró el uso de una estructura existente para usuarios no motorizados.

La solución desarrollada para el paso elevado de Hammersmith tuvo en cuenta las tendencias en materia de recursos y los nuevos criterios de compatibilidad al utilizar hormigón de ultra alto rendimiento.

PALABRAS CLAVE: Diseño conceptual, creatividad, inspiración, simposio, futuro, tendencias futuras.

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1. INTRODUCTION

The world is facing rapid change. Technology continues to develop at an apparently accelerating rate [1] as illustrated by the oft-quoted Moore's law [2]. The impact of climate change and the need for an effective and progressive response has been recognised internationally in the Paris Agreement [3]. Some resources are becoming scarce and there are moves towards reducing waste and adopting a cir-cular economy [4]. Society continues to adapt and change, with trends such as rapid urbanisation [5] and globalisation [6].

In response to such changes, a need emerges in the design and maintenance of our infrastructure. As engineers, we need to understand the demands, now and in the future, on our infrastructure and provide appropriate solutions. To address the future needs, we have the challenge to become more creative and innovative in how we consider and provide better outcomes from our work. Although creativity can be perceived to be something that is innate, either present or not, some studies suggest that creativity can be encouraged and developed. Various design methods and aides have been proposed to stimulate creativity, including design thinking [7], lateral thinking [8] and TRIZ [9]. Similarly, procedural methods have been proposed to help capture and manage innovation, such as an 'innovation funnel' that seeks to allow idea generation, capture and filter ideas, and develop the most promising [10].

Patterns of divergent and convergent thinking are seen as instrumental in encouraging creativity and thence innovation [11]: divergent thinking is about generating original ideas, expanding the con-ceptual space through synthesis ; whilst convergent thinking is about logically evaluating and finding the best solution from within the range of solutions, a process of analysis to explore the conceptual space [12]. To quote Nobel Prize winner Linus Pauling, « The best way to have a good idea is to have a lot of ideas ».

Civil engineering design relies extensively on codes and standards to provide verification of adequacy, given that it is usually impractical to try out prototypes at full scale. Standards can inhibit inno-vation, since they codify practice that can become obsolete [13] and are time-consuming to update. Designers can rely on experience, heuristics and a knowledge of what has worked before; knowledge re-use from previous projects [14] is particularly useful when time and fees are tight. However, reliance on standards and experience tends to produce backwards-looking solutions rather than necessarily ad-dressing future needs.

Design is typically viewed as proceeding in distinct stages, such as clarification of design task, conceptual design and detailed design [15]. The opportunity to generate value tends to be higher in the earlier design stages when there is greater opportunity to influence the solution [16]. Conceptual design However, the opportunity to influence the first stage should not be overlooked, to ensure that the overall project brief has the optimum objectives; some sources suggest that the project definition phase is often undertaken poorly for construction projects [17].

Future Ready provides a view of the future themes that could affect infrastructure. It helps promote a wider view than can be achieved simply by referring to past practice, thus encouraging divergent thinking that can inspire innovative solutions. It can apply at the different stages of a project, in order to achieve better outcomes from a project.

2. THE FUTURE READY FRAMEWORK

Future Ready is a framework developed by WSP to help our designs respond to the rapidly changing world. It requires our engineers to consider future trends, challenge the means and ends, in order to deliver better outcomes. Through Future Ready, our aim is that our projects are fit for the future as well as today.

At the heart of Future Ready is a constructive challenge of means and ends: of project objectives and delivery. This comprises three main aspects: 1) discussion of objectives and scope with a client; 2) refinement of the conceptual design; 3) review of solutions to realise the concept. These three aspects are illustrated by the three case studies in this paper.

Future Ready draws on the philosophy of divergent thinking. It aims to promote a wider consideration of the possible solution space, by forcing consideration of issues that may not naturally have come to mind. In line with the philosophy of divergent thinking and the innovation funnel, having a wider range of solutions to choose from can help find solutions that may not initially have been considered from a narrower range of ideas stemming from past practice. As such, Future Ready is strongly linked to innovation and idea stimulation and can help to inspire innovative ways of responding to the future trends.

Future Ready can open a way of communicating about project objectives with the client. As noted in the literature, the project definition phase can be poorly defined for construction projects. Sometimes, achieving a better outcome can require exploration and development of the project objectives, and the project brief may have to be developed. Clearly this has to be done jointly and with the agreement of the client.

3. APPLICATION OF FUTURE READY

WSP uses a structured approach to apply Future Ready to projects. The approach includes: research into future trends; staff awareness; tools to apply to projects; and culture change within the organisation.

Our research aims to develop a view of what the future looks like in relation to our projects. Globally, we have classified the trends into four key theme areas: climate change, resources, society and technology. Each of these is further subdivided in trends; a selection is shown in figure 1, although the full list is wider. We have developed statements of what these trends entail, best on the published data, and how we envisage these trends will apply to civil engineering projects. In some cases, such as climate change, there are widely accepted albeit uncertain predictions about changes. For other areas, such as technology, the trends tend to be more vaguely defined.

Staff awareness is key to our Future Ready approach. We aim to provide each person with a clear and consistent view of

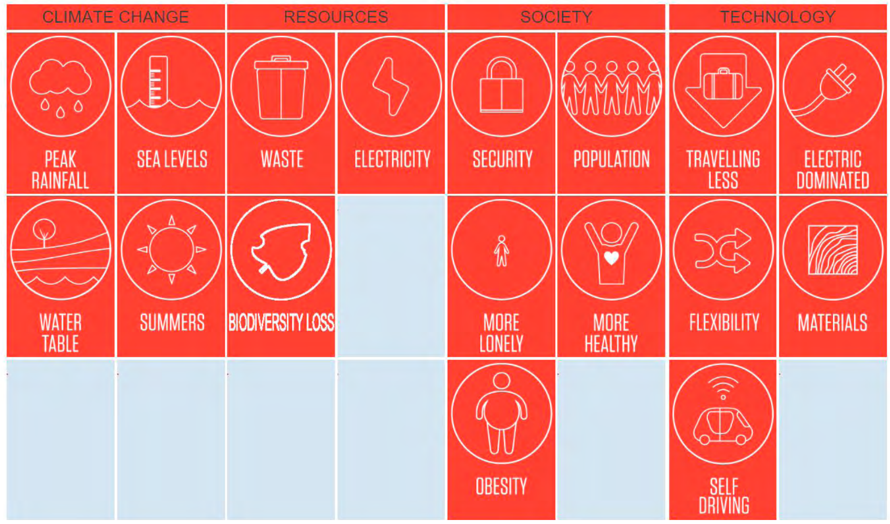

Figure 1. Future Ready themes and selected trends.

what we believe their future world could look like, specific to their country and relevant to their discipline. We engage staff with office presentations, webinars and by providing guidance material.

Application of Future Ready to projects is aided by a set of tools. We provide a checklist which lists the trends and gives examples of how they could apply to our projects. We encourage Future Ready to be discussed as part of initiation workshops with clients. Upon completion of projects, we encourage staff to undertake a retrospective review, to capture lessons learned, topics that can be fed back to the checklist, or projects that could be developed as case studies for the Future Ready approach.

Finally, we aim to embed Future Ready thinking as part of the culture of our organisation. To this end, we have appointed team champions. We engage staff through monthly Future Ready Innovation Labs, that explore a particular question, for example, considering a future of more intense rainfall or a future of loneliness and how this can be addressed through urban design. Future Ready becomes part of our day-to-day business and part of our offering to clients.

We present three case studies to explain how we consider future trends, the process followed and the benefits of the Future Ready approach. The case studies, of Waterloo Bridge, Bromley Heath Viaduct and Hammersmith Flyover, illustrate how Future Ready applies at three of the project lifecycle stages: 1) discussion of objectives and scope with a client; 2) refinement of the conceptual design; 3) review of solutions to realise the concept.

4. WATERLOO BRIDGE

The first case study, about Waterloo Bridge, illustrates how Future Ready was used during the project definition stage in the discussion of project objectives and scope with a client. The bridge, over the River Thames in London, was suffering from failure of some of its bearings. Work was required to understand the bridge movements under thermal and other loading. Future Ready thinking was used to refine the scope of the project, and include a trial of a novel satellite sensing technology with potentially wider applications.

4.1. Project background

Waterloo Bridge is a concrete road bridge carrying the A301 across the River Thames in London. Some of the bridge's abutment bearings had failed despite being installed relatively recently. WSP were asked to provide advice to client Westminster City Council on the management and future remedial works for the structure.

The bridge had a complex articulation system from its original construction, and it was thought that the bearing failures were due to a failure to properly understand the bridge movements. The first stage of the project was therefore envisaged to be a monitoring regime to allow a better understanding of the bridge's true behaviour and to identify the reasons for the bearing failures. The second stage of the project would be the development of the remedial solution, in particular, considering whether the structure's articulation should remain as originally designed or be adjusted based on the measurements of actual behaviour.

4.2. Application of Future Ready

One of the Future Ready trends is climate change. It is anticipated that climate change will lead to increases in extreme temperatures and increases in temperature variations. These effects may need to be taken into account during the second stage of the project to determine the remedial measures; but during the first stage of the project the issue of determining the cause of the bearing problems is thought to be due to the structure not behaving as originally modelled, which is independent of climate change effects.

Our Future Ready trends also include technology developments, and for civil engineering projects, developments in sensing technology is a key trend. We therefore saw an opportunity to use this project not just to gather information about Waterloo Bridge, but also to serve as a trial for novel sensing technology that could have wider benefits in the future.

Figure 2. Aluminum reflector installed on one of the Waterloo bridge piers.

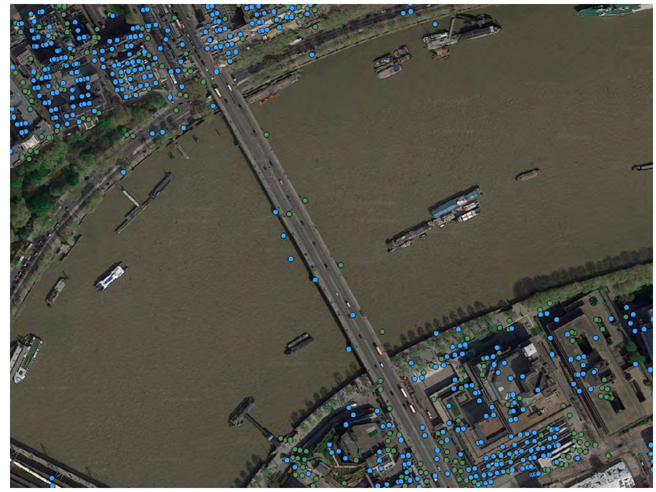

Figure 3. Satellite monitoring data points; green points on the bridge correspond to the corner reflectors.

We therefore proposed and agreed with the client to amend the scope of the project and use two sensing systems on the bridge. The first system was a conventional monitoring set-up using traditional survey stations to take measurements of the movements of certain defined points on the bridge. Shade air temperatures were also logged. In parallel, a second novel system was trialled using data from satellite monitoring.

Under the Future Ready approach, we designed a new system based on the use of the satellite data from the European Space Agency's TerraSAR satellites. It was incorporated with the cooperation of a Cambridge University PhD research project. With this system, imagery is collected each time the satellite passes overhead. Then, by identifying changes between images taken at different times it is possible to determine movements. Corner reflectors fitted to the structure allowed calibration of the points measured using the conventional system, against the same points observed using the satellite data ; see figures 2 and 3.

4.3. Benefits of our Future Ready approach

Our Future Ready approach supported the client's primary objective of safely maintaining this piece of historic infrastructure for future generations to use with an unobtrusive solution whilst supporting the development of novel sensing technology. This project allowed us to validate leading-edge satellite monitoring techniques against more conventional monitoring techniques. Although the research work is still ongoing, it has proven the potential use of this technique for bridge monitoring. Through understanding the future trend, we are able to challenge the objective of the project and achieve a better outcome.

In the future, one potential benefit of satellite technology is that there is no need to install anything on the structure or even to deploy people and equipment to the structure to undertake the monitoring. By the same argument, historic satellite imagery can be retrospectively processed, making this system capable of studying the variation of movements before the system was incorporated. This brings the opportunity of making use of a huge volume of data or the potential for displacement monitoring of assets over large geographical areas at lower cost.

5.
BROMLEY HEATH VIADUCT

The second case study, about Bromley Heath viaduct, illustrates how Future Ready was used during the development of the concept design. The viaduct was too narrow for current needs, particularly for non-motorised users such as pedestrians and cyclists. The project aimed to adapt the viaduct for changes in its use whilst designing out future maintenance. Future Ready thinking was used to refine the conceptual design in response to the overall project objectives.

5.1. Project background

Bromley Heath Viaduct forms a key element of Bristol's strategic road network in South West England. It carries over 55,000 vehicles and 500 cyclists a day. Built in the 1960s, it is a 100m long concrete viaduct.

WSP were commissioned by the asset owner, South Gloucestershire Council to design refurbishment and improvement works for the viaduct. The scheme was envisaged to include a combination of essential, planned and preventative maintenance alongside aspirational improvements using both traditional and innovative concepts.

The key objectives of this project were to provide a wider and safer footway for use by non-motorised users. The viaduct was on a popular route for pedestrians and cyclists but had inadequate provisions for sustainable travel. The existing 2m wide footway was unsuitable for the flow of cyclists wishing to use it and was thought to be deterring potential users.

5.2. Application of Future Ready

One of the Future Ready trends, that of changes in society, includes the trend towards people changing their travel choices. In Western Europe, there are concerns about increasing rates of obesity and encouragement for people to become more active in order to lead healthier lives. Alternatives to the car, such as walking and cycling, contribute to this goal and also can help to reduce pollution in urban areas. This trend was alre-

Figure 4. Bromley Heath Viaduct's widening.

ady encapsulated in the objectives of the project, to provide a wider footpath on the structure. This trend is linked to other, wider, societal trends, including higher quality living and better connectivity; a key aspect of transportation and transport routes in future will be to think about new ways for transport to help improve the quality of life of people in the city or area.

Another Future Ready trend is that of resources, including minimising waste. As usual during the conceptual design stage, potential alternatives were explored. Options for both a new bridge adjacent to the existing one and for widening the existing viaduct were explored. The option to widen the existing viaduct using a cantilever attachment used less resources than the option for a new adjacent bridge ; this approach also had the benefit of a more economic capital cost, indicating a link between more sustainable resource use and economy of cost. After giving due consideration to the site constraints as well as Future Ready trends, the preferred design solution was that of widening the existing footpath and segregating pedestrians and cyclists from the main carriageway, as shown in figure 4.

The Future Ready Society theme also includes a trend towards an increasing usage of our infrastructure, through increasing traffic flows, and also towards a demand for increased availability and reduced time out-of-service. The design considered the road closures that would be needed both to undertake the works and for future maintenance requirements. A number of works were incorporated to help minimise future maintenance needs : for example, permanent jacking plinths and a bearing inspection gallery, not provided during the original construction, were designed and installed. Although these additional elements were challenging to design and construct, they will provide a significant programme, cost and waste savings during future bearing inspections and maintenance whilst also reducing health and safety risks.

Returning to the Resources theme, our Future Ready approach suggests that it can be advantageous to include adaptability in our designs, to help avoid future waste if and when a structure is repurposed in future. The design included spare service ducts in the deck to provide the potential for future technologies to be installed. Adapatability during the temporary construction case was also considered. The design gave the contractor flexibility to avoid existing reinforcement during construction by specifing a zone for strengthening bars, rather than specifying only a single location.

5.3. Benefits of our Future Ready approach

Future Ready thinking has delivered project outcomes that encourage healthy transport trends. The new widened footpath/ cycleway created a safer and more comfortable environment, encouraging people to use healthy travel options. This resulted in an increase in people making active travel choices following the project, according to a survey of local workplaces.

Considering Future Ready trends, thinking about reducing waste and re-purposing existing infrastructure helped steer the design preference towards adapting and extending the life of the existing structure. We considered future demands on the transport infrastructure and included works to minimise future maintenance needs including reducing the need for future road closures.

6.
HAMMERSMITH FLYOVER

The third and final case study, about Hammersmith Flyover, shows how Future Ready was used to review and refine the design solution used to realise the concept. The flyover required strengthening works due to loss of section of post-tensioned tendons, but there were many technical challenges in realising the strengthening given the constraints around the viaduct. Future Ready thinking helped identify a solution to achieve the desired strengthening outcome within the constraints, by making a novel application of Ultra-High Performance Fibre Reinforced Concrete which had not previously been used in such a situation.

6.1. Project background

Hammersmith Flyover is a key artery in western London, carrying the A4, the main route for vehicles into and out of the city centre. It has 16 spans, with 630 meters long concrete precast segmental bridge was an innovative concrete structure when opened in 1961. In 1999, detailed inspections highlighted corrosion of existing prestressing tendons that could compromise the structural integrity of the structure. In 2006, acoustic monitoring was installed to assess the deterioration of the tendons. In December 2011, 6 months before the 2012 Olympic Games, additional analysis revealed an immediate structural risk and the flyover was closed to all traffic, causing severe traffic disruptions.

The challenges given by the client, Transport for London (TfL) were easy to express but hard to achieve: make the existing post tensioning system redundant, maintain existing headroom and maintain traffic on the deck at all times. The structure should be brought as much as possible in line with Eurocode design rules, with the constraint of having the best locations for tendons already occupied by the existing cables.

The design was carried out by a partnership between Ramboll and Parsons Brinckerhoff (now WSP). The develop-

Figure 5. Replacement post-tensioning system on Hammersmith Flyover showing the external "short" tendons anchored by UHPFRC blisters.

ment of the design benefited of the cooperation between all the stakeholders by a contractual system involving the main contractor Costain, and its specialist sub-contractor Freyssinet early in the design process. The background to the project and the solution adopted are described fully in [18].

6.2. *Application of Future Ready*

The repairs were done in two phases: a partial emergency repair first and then complete replacement of the post-tensioning system. It was in this second phase where Future Ready thinking was most significant. The project was a classic case of the constraints and challenges stimulating the need for a creative and innovative solution.

Under the trend of Resources, Future Ready considers novel and innovative materials. Such materials can offer significant advantages in strength, size or performance. However, where they are not covered by existing codes and standards, then it can take additional effort to promote and justify the use of the material.

The overall concept for the strengthening solution was to install a completely new post-tensioning system that rendered the old post-tensioning redundant. However, because this had not ever been envisaged in the original construction, there were no ideal places to install the new tendons and associated anchorages. The new post tensioning system was proposed to comprise two families of tendons: "short" cables, exterior and anchored on Ultra-High Performance Fibre Reinforced Concrete (UHPFRC) blisters (see figure 5) and "long" cables using large units and placed inside central cells.

The material proposed to form the external blisters was UHPFRC. This material has desirable properties from which benefits can be derived in conceptual design : in this case, its high strength allowed the blisters to be made small enough to maintain the required headroom over the road, and allow them to be precast to aid construction. However, UHPFRC is currently considered a novel material in the UK as shown in [19]. Because of its novelty, the use of UHPFRC introduced risks into the project. The absence of national and international standards and guidance, lack of precedent experience amongst designers and contractors, and the absence of satisfactory prior use regarding technical approval, made it harder to deploy.

Hence, Future Ready thinking was benefical to convince the relevant parties that, despite these risks, the use of the UHPFRC was the best solution for the project. Cooperation between all project parties was key to foster the utilisation of new technological opportunities and to ensure all practical aspects were considered. Risks were carefully managed during design and construction, for example, by testing of the UHPFRC blisters.

6.3. *Benefits of our Future Ready approach*

Future Ready thinking helped to deliver a solution to a complex and constrained strengthening problem. It encouraged the use of a novel material, UHPFRC, as part of the solution despite the inherent challenges.

7.
CONCLUSIONS

Future Ready is a framework developed by WSP to consider future trends, challenge the means and ends, in order to deliver better outcomes. Through Future Ready, our aim is that our projects are fit for the future as well as today. Our Future Ready approach includes research into the themes that are likely to affect the future of our projects, categorised into climate change, resources, society and technology. It includes awareness briefings to staff and tools such as checklists to be deployed onto projects; ultimately, we aim to embed Future Ready thinking into our organisational culture.

Three case studies have been presented, showing how the Future Ready approach can be used to provide constructive challenge, widening the potential range of solutions considered, and thereby inspiring more creative thinking that can help encourage innovative solutions. The case studies have shown: challenge of project scope, with the response to emerging sensing technologies on Waterloo Bridge; challenge of conceptual design, with the response to resource scarcity and availability of transport networks, on Bromley Heath viaduct; and challenge of solutions, with the response to novel materials, on Hammersmith Flyover.

Our aim with Future Ready is to inspire every engineer of the organisation to be more creative and use the challenges of each project as opportunities to give extra value to our clients.

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