



Select Committee on Science and Technology

Corrected oral evidence: Off-site manufacture for construction

Tuesday 1 May 2018

3.25 pm

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Members present: Lord Patel (Chairman); Lord Borwick; Lord Hunt of Chesterton; Lord Kakkar; Lord Mair; Lord Maxton; Baroness Morgan of Huyton; Lord Renfrew of Kaimsthorn; Lord Vallance of Tummel; Baroness Young of Old Scone.

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Questions 17 - 23

Witnesses

Dr Mark Bew MBE, Chairman, PCSG Ltd, former Chair of the Industry-Government BIM Task Group between 2012-16, and Strategic Adviser, Centre for Digital Built Britain; Mark Enzer, Chief Technical Officer, Mott MacDonald.

USE OF THE TRANSCRIPT

This is a corrected transcript of evidence taken in public and webcast on www.parliamentlive.tv.

Examination of witnesses

Dr Mark Bew and Mark Enzer.

Q17 **The Chairman:** Good afternoon, Dr Bew and Mr Enzer, and thank you for coming today. Could you start by introducing yourselves so that we get it on the record? If you want make any opening remarks, please feel free to do so. Otherwise, we have questions to ask you to help us with our inquiry.

Dr Mark Bew: Good afternoon. I chair a company called PCSG Ltd and we are in the space of digital engineering to the built environment. I chaired the government and industry BIM Task Group between 2011 and 2016 and I continue to be on the board of the Digital Built Britain programme, which has carried on from there. I spent most of my career in construction, either as a contractor or a designer. I was on the board of Costain and Scott Wilson, and I am an engineer by training.

Mark Enzer: I am the chief technical officer at Mott MacDonald where I am responsible for professional and technical excellence, which I drive generally through our internal professional networks. I have an interest in build off-site and DfMA, as a number of years back I worked in Anglian Water for seven years and introduced what they call product-based delivery, which in effect is a predecessor of DfMA—design for manufacture and assembly.

Q18 **The Chairman:** I will start with the first question. What leads a client to decide whether the project they have, whatever that is, might be suitable for off-site construction, and who are the clients?

Dr Mark Bew: From my point of view, there are a number of considerations that you would want to look at when it comes to off-site construction. Clearly, a repeat asset lends itself to an off-site componentised approach. Schools, hospitals, prisons, residential properties and some infrastructure where there are repeat components lend themselves to that scenario.

The challenges are that people immediately want to have variations. At what level do you standardise those components? In some industries the componentisation happens at a very low level, and we sometimes end up with platform-type approaches, such as in the automotive industry, where we have lots of different components built into standard platforms and then into lots of different products. That level of maturity does not yet exist in the construction sector, and building that is key. That is one reason why we have not yet seen many clients take that on board.

The other challenge for a lot of clients is that their day job is not building things, it is running a business. A supplier choosing a DfMA route or a traditional route is not their problem, and we need to find a way of encouraging it to be their problem and to become part of their selection criteria.

Mark Enzer: I have just a couple of things to add to that. If a client is looking at an individual project, or one project at a time, there might be

some project-specific needs that would drive the decision to go with DfMA—design for manufacture and assembly—and off-site manufacture. A classic example would be if the site is particularly constrained and there is real advantage to spending a short amount of time on the site. Delivering components that are effectively ready-made reduces disruption to the public and can work in a constrained site. That might be a driver for a specific project choosing off-site manufacture.

It is also important to note that many clients do not just have individual projects that they want to deliver but have programmes of projects that are sometimes quite similar. In that case, standardisation is a driver of an approach where they design once and build many times, which drives a much more productive way of delivering.

I just wanted to extend the question beyond individual projects to programmes of many projects.

The Chairman: At what stage does a client, whether you are talking about architects, design contractors or others, decide that a project is suitable for off-site manufacture?

Dr Mark Bew: Always as early as possible. One challenge is finding a design team that is capable of designing for manufacture. If you go to a traditional architect or engineer, you are likely to get a traditional result. By far the bulk of the industry is currently configured to deliver traditionally. We see some parts of the market starting to understand the benefits of design for manufacture in quality and cost and speed to site. That is encouraging, but it is a very small capacity. It is quite interesting that we are starting to see an emerging capability, but there is very low capacity, and incentivisation and creating awareness among clients that these opportunities are available are key parts of any intervention in the future.

Mark Enzer: Building on what Mark said about the decision being taken as early as possible being better, off-site manufacture will always fit somewhere in a delivery process, which might begin with something such as strategy and move into planning, outline design and detailed design, and then the construction, operation and maintenance.

The later the decision is taken in that delivery process to do off-site manufacture, the more it will probably cost and the less benefit will accrue. It is very important to design the end-to-end delivery process around off-site manufacture rather than just bolting it on as an afterthought. Certainly, if most of the rest of the delivery process has been traditional, a design has already been produced and a contractor has bid against that particular design, going for off-site manufacture is unlikely to deliver the kind of productivity and cost savings that one would hope for, whereas if the end-to-end delivery process has been designed with DfMA in mind, the productivity benefits can come.

The Chairman: If you want to increase the number of buildings being manufactured off-site, whether they are prisons, schools or hospitals, who is the key person you have to educate or influence?

Dr Mark Bew: The key is to create capacity in the market. Currently, anyone who opens a factory to build components carries all the risk of building those components, and if the market does not take up the opportunity to procure those components due to all the factors that we have just described, they fail.

The costs of a factory and labour mean that overheads overtake takings. Finding ways of maintaining the market for those components so that we can get the volumes up to pay for the overheads and invest back into new components is the key. A whole variety of people along the value chain need to be aware of this intervention. Clearly, the client needs to be encouraged primarily. Then the specifiers, designers, engineers and the commercial teams who are in the chain of decisions down through this process need to be aware of the benefits, and supportive of them, to the point where an order is placed in that factory with a DfMA design that goes to site.

Baroness Young of Old Scone: I was really taken with the Mott MacDonald evidence, but it appeared to me to hint at the fact that there is no great evidence base as yet of the benefits of off-site manufacture. There are a lot of theoretical benefits and downsides, but do we have a really substantial evidence base yet? If not, what should be done about that?

Mark Enzer: We do not have a substantial evidence base, but we have enough of one to be quite convinced that design for manufacture and assembly off-site can deliver genuine savings. To get a more substantial evidence base, we need to do more of it. We have seen evidence in the water industry, transport, energy, so in most of the major sectors of economic infrastructure, to convince us that there is some genuine benefit in going down this route.

Baroness Young of Old Scone: Is there some process that we need, because presumably people are not going to jump unless they see the evidence that persuades them?

Mark Enzer: Evidence is part of it, and an element of leadership is needed, which in many ways goes back to the previous question: who needs to change to bring about industry change? Leadership is required throughout the value chain. At one end, there needs to be leadership in client organisations to commit to what is quite a big change. As I explained, the whole delivery process needs to change, not just the construction part of it, and that takes real leadership in a client organisation.

But that is not enough. There needs to be change in the procurement departments, because generally procurement departments have grown up believing that the route to value is the lowest price against a particular specification, whereas DfMA points to value that comes from lower whole-life cost and better outcomes for customers. Procurement has to change, and that is a big change.

As Mark indicated, the supply chain itself also needs to change. If we join that up through the whole value chain, a lot of change and a lot of leadership is needed, and that is tough.

Dr Mark Bew: Part of the challenge is the fact that the current value chain is incentivised to spend against man-hours rather than outcomes, so it is incentivised in reverse to reduce the costs and to standardise. We need to look at the incentivisation and contractual relationships all the way through the supply chain to ensure that everyone is focused on the same outcomes.

At that point, we can start to create a new market, in effect. There is a bit of a challenge here where we have the traditional market and a DfMA outcomes-based market and the journey in the middle between one and the other. We need to be in one or the other for it to work properly. Otherwise, we will never create a market for enough components to get the unit price down.

Lord Vallance of Tummel: I know nothing about this market, but from what you are saying there appears to be a case for vertical integration of the supply chain? Does anybody do the lot?

Dr Mark Bew: Some are getting closer, but very few do the lot. If you go back to when I started in the mid-1980s, a lot of tier 1s had the lot. They had all the sub-contractors, project managers and designers. Trafalgar House, Tarmac, Laing O'Rourke and those sorts of organisations were vertically integrated.

The challenge with that is that you end up with lots of layers of overheads and profit in each part of the organisation, which adds up to a non-competitive position because clients have got into the habit of taking the lowest cost of each package within the project, adding them up and saying that is the cost of the project rather than looking at the project in the round. Effectively, that is what happened when we moved from traditional contracting to design-and-build contracting in the late 1980s/early 1990s.

Lord Vallance of Tummel: Are you are saying that it is more expensive to have something that is vertically integrated, or is it a failure of marketing?

Dr Mark Bew: There is a big difference between the tender cost and the outturn, and you need to look at both numbers. They are not the same number, and pricing costs are not the same numbers either. Once you unpack those, you see that vertical integration gives you a lower cost at the end.

Mark Enzer: Just this morning, across at the Institution of Civil Engineers, there was the launch of Project 13, which in many ways speaks exactly to your question. That is a movement within the infrastructure industry to transform the industry into something that is more vertically integrated; not necessarily vertically integrated by one organisation being vertically integrated but by many organisations coming together in an enterprise to be more integrated. At the heart of that is the role of the integrator—that is exactly what they call it—whose

job it is to pull things together. That delivers precisely what you were getting at.

Baroness Morgan of Huyton: I was fascinated by what you said about moving to whole-life valuation, but how on earth do we make that happen? It is not just about lots of little bits of evidence, is it? It is quite a transformational way of doing procurement and management of huge projects. What should we suggest is the way forward to demonstrate how we need this significant shift?

Dr Mark Bew: There are a number of steps in a journey, not just one. As Mark said, an industry that is 10% of GDP is going to take some moving. It is a big issue. To go to the end game a little more and step back, the three numbers that we are interested in are the capital cost of the asset, the operational cost of the asset and the cost of delivering services through that asset, whatever it may be.

If we look at the ratios, at the moment there is roughly £90 billion of capex in the UK—40% is public and the rest private; £122 billion to £125 billion on services and £400 billion to £500 billion on delivering services—the cost of doctors, nurses, train drivers and so on.

If we can make our assets more efficient and deliver more with the resources that are delivering the services, ultimately we can put more money back into the capex, which starts to create a virtuous circle. To do that—and the Green Book investment process allows us to do that—we need good-quality evidence. We do not have that at the moment. We also have a very long timescale for the life of an asset, so we need to gather that data over a long time.

Clearly, as we start to gather better-quality data with measurements and things like sensors, we will have better insights as to how assets perform and consumers consume those assets. That is some way off but that will give us the evidence to do exactly what you have just described: to self-learn from how we do it.

Baroness Morgan of Huyton: Is that built into the system now? Are people starting to gather that?

Dr Mark Bew: We are slowly edging that way, yes. We have started that journey.

Baroness Morgan of Huyton: Who is “we” in that situation?

Dr Mark Bew: Certainly when it comes to public procurement we are starting to procure data with assets. It is not perfect, but it is the first step in that process. It will start to improve as time goes on. We are seeing the 5G and sensor standards start to become more common, so it will be easier to gather that data.

In the short term, in order to create some steps we have to do some things in the next five and 10 years. We should look at how we can encourage and incentivise the use of standard components and greater skills in design teams to be able to configure those components. That is something that we can do now, and we should look at incentives for enabling that.

Q19 **Lord Borwick:** In the first question we asked about the advantages of the system, but you carefully, and helpfully, answered on both the advantages and the disadvantages, which is a much more balanced answer.

Can I ask more about some of the drawbacks of this process? Are there any financial drawbacks both on cash flow and on other aspects of it? Can you talk a little more about the trend towards making everything the same: identical houses, identical blocks, which is fine for prisons but may not be what customers want in a housing development?

Dr Mark Bew: Some are less bespoke than others, that is for sure. Let me answer the second question first. A great thing about the UK is we have fantastically diverse architecture. We still have good architects in this country and we must not lose that; it creates us and our identity. For the sake of the quality of life of our citizens, we must not get to a cookie-cutter world where everything looks the same. That would be absolutely catastrophic. We see some nations that are heading in that direction. Poor-quality architecture has an impact on social outcomes and mental health and those sorts of things. We know from work that Mind and Shelter have done that the quality of residential accommodation has a big impact on mental health. Mental health is one of the biggest bills in the NHS budget, so we do not want to go down that route. I do not sign up to cookie cutters or standard architecture. We need diversity in our architecture and it needs to work for us.

There is absolutely no reason why standard components cannot also lead us to high-quality architecture. If we look at the automotive industry, standard components make up lots of different vehicles. If you look at a BMW 3 series, the underlying chassis and assembly for that is a 2 series, a 3 series, a Mini and something else, so four cars with all those components. I think you can get 3 million combinations in a 3 series. There is no excuse for going down the route of completely consistent architecture. I would absolutely agree with that.

On the disadvantages around finances, you mentioned cash flow, and I alluded to the same thing. There is a very different cash flow profile to opening a factory, buying materials, buying labour and having stock sitting in a yard. All the tier 1 contractors' balance sheets are geared to not doing that and to letting someone else do it. They need to change and there needs to be a different model for the design of their balance sheets and their operating models.

We have seen some organisations start that journey. Laing, for example, has factories as well as contracting elements. The big challenge, if you can afford and fund the investment around the factory and the labour and materials, is to keep utilisation up, otherwise you run out of cash. That is a fact of life. We have to be able to create a market where we can not only keep the capacity matched with the demand but we can get enough capacity through the machinery to invest in new product in the future, because the first ones we design will not be good enough and we will need to iterate them over time.

The incentives that we should be offering and the leadership from government, as Mark said, should be around enabling that market to exist. We should not tell them how to do it; they know how to do it. We should create a market for them to be able to thrive.

Mark Enzer: Can I add to a few of those points, not so much on the financial side but regarding other potential drawbacks? Some people would suggest that manufacturing can stifle innovation. I am not quite sure why that should be the case, because manufacturing does not seem to stifle innovation in the automotive or aerospace industries, but people certainly mention it.

There is also potentially an initial cost, because there is a lack of manufacturing capacity to do all the things that we might want to do, and that might require some attention to address it. There is a potential concern about being tied to one particular supplier rather than having a lot of choice in the supply chain. That is a potential drawback.

There are another couple of drawbacks, which are in effect the other side of a benefit coin. I would point out that those are to do with quality and adaptability. On the quality side, to make design for manufacture and assembly work, there needs to be much higher quality, which you can get in a factory. Some might say that it is too tough to aim for higher quality or that it is easier to bodge a job, so why even try for quality in the first place? I do not subscribe to that argument, but it is an argument that is made.

There is also the question of the ability to change things later on. In this country we have been used to being able to change things when we are on-site. There has been enough flexibility to redesign while we are building it. That luxury, if you can call it that, goes away with design for manufacture and assembly. I would say it is a good thing to design it properly first and assemble it on-site, but we lose flexibility, and some would say that that is a disadvantage.

Lord Borwick: You mentioned the automotive industry. In 1900 you bought the chassis and had a coach builder build the body on it. Henry Ford came along with this brilliant idea of doing it all in the factory. It was only when he invested the money to make the factory that automotive engineering took great steps forward and cars became better and cheaper proportionately. Is that a valid comparison?

Dr Mark Bew: There is a saying—I am sure it is attributed to Henry Ford—and it goes back to the client conversation we had earlier, “If I’d asked the client, he would have asked for a faster horse”. There is some of that in here. A catalyst such as Henry Ford or digitisation—there are a number of them that we could identify—is the key. We know that fundamentally it is the right answer. We need to catalyse it now. He is a really good example of that. The client is always right, but sometimes he needs to be helped to understand what is right.

Mark Enzer: It is quite interesting that manufacturing in the automotive industry has gone through another few revolutions since then. We could point to lessons learned and driven by Toyota in automotive

manufacturing. There are other manufacturing analogues such as shipbuilding and aerospace. Maybe the good news in all this is that all those analogues exist and we can learn from what they have already been through. It is quite odd in a way that construction should be coming to this party quite so late. A lot of the lessons are already very well learned.

Lord Vallance of Tummel: If you take the analogy of shipbuilding, or whatever, is a reason why things did not change very quickly the vested interests of the various trades and professions? Are there strong vested interests here? I would have thought architects, for example, would not do too well out of this, because there would be fewer of them around. Construction firms might not do too well out of it either. From experience I know that if you change things on-site it costs you an arm and a leg, and that is probably where the construction firms make a lot of their money. Are we up against vested interests in the professions and the trades?

Dr Mark Bew: Absolutely. That is exactly the point I made earlier. We have a new world and we have where we are now. We have to unpick where we are now. This combination of old and new, which is where we find ourselves at the moment, is the worst of all worlds. You have the costs of the new world and the disbenefits of the old. The leadership point we are making is that we have to make a step and do something different. The emerging strategies for manufacturing, digitisation, productisation and those sorts of things are where we have to be heading now. We have to work out the right intervention to move us from here to there, otherwise we will be left with those vested interests.

The challenge, though, is that we have existing demand and capacity, and we have to keep going while we create this new machine in flight and transfer to it. We cannot stop building schools, hospitals and roads, so how do we make that transition? So far we have been trying to fix the old model with the building information modelling and digitisation programme and the existing interventions in manufacturing. We now need to work out how we get to the new model, otherwise we will stay where we are.

- Q20 **Lord Hunt of Chesterton:** How can building information modelling and other digital technologies be used in conjunction with off-site manufacture? Does this facilitate or necessitate? In our previous discussions, I at least, and I think many of us, have been thinking of rather large buildings—large schools, hospitals and off-site modelling—but there is an enormous amount of building in Britain by quite small builders who could be more progressive. Is it like going to the supermarket rather than manufacturing it yourself? Is there a trend towards the use off-site manufacturing where lots of contractors could go and get modelling and building help and so on? We are thinking of a big contractor with his own big factory, but could wholesale off-site manufacture in some senses be something that lots of smaller building businesses could make use of?

Dr Mark Bew: There are two important issues there. One is the digitisation of the sector to help manufacturing and the other is capacity growth and components. Certainly, when contractors have built factories and started to generate products, the competition is unwilling to go to them because they are the competition and they want to avoid them and go somewhere else. As a contractor, growing a market outside your own market is very challenging, which is why most of the tier 1s came out of that market in the 1980s and 1990s. Having stand-alone businesses that make these components is a likely area, because you become expert in those components rather than a jack-of-all-trades. That is happening in other sectors.

Lord Hunt of Chesterton: Is that happening?

Dr Mark Bew: It comes and goes, unfortunately, because we end up with this cyclical financial market that we described earlier. The first thing that happens in a downturn is that the factories run out of work, the overheads become unaffordable and they are shut down. We have been through that loop lots of times already, and we try to avoid that.

One way to look at that is to start consolidating spend from many builders into a fewer number of manufacturers. That is what we see in the automotive industry. There is only one Bosch and one Dunlop. Dunlop make all the tyres and Bosch make all the injectors and what have you. That sort of thing needs to happen for the market to grow. That is where the digitisation process comes in. If those components are available digitally and can be found digitally, we can start to create an online market. The most famous online aggregators are systems such as Amazon and eBay where you type in concrete, plank, column, stairs, pump, or whatever it may be, and there is a whole array of components that you can procure and drag off and put into your design, and away you go. Those kinds of procurement aggregators are likely to be part of the equation when it comes to growing this market. Whether the Government should intervene in that aggregation strategy or not is a decision that needs to be made.

Mark Enzer: Building information modelling—BIM—is a huge enabler of design for manufacture and assembly. As we go forward, it will almost become a necessary enabler of it. It is very difficult to imagine an efficient approach to off-site manufacture that does not use information modelling. We should see that as a great opportunity and not just in the building and assembly part of it, because information ends up being the golden thread that joins up the overall delivery process, and any loss of information in that delivery process is a loss of value.

We can see the same kinds of information being very relevant in the logistics, which is a key part of design for manufacture and assembly and a key enabler for its success. It is not just about the delivery. It gets into the operation, the maintenance and use of the assets, and, again, information ends up being a golden thread that runs through all that. I would see BIM as being a key enabler to start with, but it is just the beginning of something that is of even more value when we recognise the information that sits behind it.

Lord Maxton: Does what you are proposing necessarily mean changes in planning laws? I think that is at the heart of a lot of this. Planning is of course a local government function, not a national government function, whereas in other countries it tends to be a national government function. Do we need changes in the planning laws?

Dr Mark Bew: There are a number of touch points into here. Whether it is a direct touch point is a different question. We lack and are in need of high-quality data in the planning process. Digitisation of data on mapping, floods, demographics, people flows, and other data available for the planning process is a key enabler in gaining transparency in planning and those sorts of things.

Do we need it to encourage DfMA? Possibly, but it is not one of the first places I would start, unless there was a specific need, as Mark says, for things such as logistics. If there are particularly sensitive places, you could you look at the part of the planning process for deliveries through small villages and those sorts of things, but it is probably a peripheral issue rather than a direct issue.

The Chairman: Mr Enzer, do you have any comment?

Mark Enzer: Not on planning.

Q21 **Lord Mair:** Can I come back to the barriers to the wider use of BIM? In the context of R&D and evidence, what ought to be done to make BIM much more widely adopted? What are the R&D priorities?

Mark Enzer: When it comes to building information modelling—Mark is really the expert in this, because he defined it all—we are at different stages for different levels of BIM. If we look at the entry level, level 2 BIM, for design and build, would enable the design for manufacture and assembly that we just talked about. Its adoption in infrastructure is quite well advanced now, and we are getting the benefit from that. There is further for it to go and the strategy is to drive the wider adoption of it, but I do not think it specifically needs R&D. In many ways, that has already happened for that level of BIM.

However, as we look forward to more value in greater integration of information across the whole of the delivery process, including the operation, maintenance and use, which I referred to earlier, that needs R&D because that is making use of information in ways that we have not done before. I would say that the answer really depends on which aspect of BIM we are looking at.

Lord Hunt of Chesterton: If we look at the City of London, and the amazing number of buildings that have been built, can we identify the BIM used for each of these? Was off-the-shelf BIM used by the structural engineers and the architects? They have all been successful, as it were.

Dr Mark Bew: If you look around the City of London now at the Walkie-Talkie, the Cheesegrater, the Gherkin, a few famous ones, all those were BIM-enabled or digitally enabled projects where the design was done digitally on a computer.

Lord Hunt of Chesterton: Did they have to invent a BIM system for those buildings or were they standard ones that were already available?

Dr Mark Bew: The building information modelling tool creates an environment in which to create designs and geometry. If you look at the Gherkin, a series of floor plates was designed and a shape and information can be attached to each of those components within the building. The glass cladding or floor plates would have had some information on manufacturing, weight, stress, maintenance, cost, time and those sorts of things. In effect, you should think of building information modelling as a database of drawings and information that describes the design of that building.

The Chairman: You have to do that whether construction is off-site or not.

Dr Mark Bew: Absolutely, yes.

The Chairman: It is a tool.

Lord Hunt of Chesterton: Was this UK software or imported software?

Dr Mark Bew: Unfortunately, not dissimilarly to other markets, we have invented a lot of these things and they have gone to America to be capitalised. The two biggest vendors in the market—Autodesk and Bentley—are both US-based businesses. We have lots of organisations in the UK that are very innovative in new functionalities, but they often get bought and sold very early in their life and taken to the States to be grown. We see lots of acquisitions going on in the sector at the moment. Two UK-originating companies have been sold for just over £1 billion in the last three or four months. It is a very active market.

Lord Mair: Can I come back to the evidence that you both mentioned a number of times and the role of BIM in providing the evidence, particularly in terms of performance of infrastructure assets? You talked about operation, maintenance and use. Presumably, there is a huge opportunity to combine BIM, which is a digitisation of the building or infrastructure, with data that will come from using advanced sensing technologies and so on. Could you say a little more about that, because that would add an awful lot more to BIM when you have the evidence about how infrastructure is in fact performing?

Dr Mark Bew: I will give a really short synopsis of 2011 to now. Back in 2011, the Government and industry came up with a digitisation strategy that was basically rolling out building information modelling into the sector. We took an approach where we had a series of steps or levels. The level 2 intervention that we made was a very small step to take a very big industry along a journey. That step was about engaging suppliers, clients and the standards authorities in a relationship that enabled us to start to create an environment that used data and BIM information to deliver assets. We worked with the core government departments, particularly the MoJ and highways and environment, to become a data-procuring client. We worked with the supply chain to be able to grow capacity within their environments and we helped BSI create a series of standards that could be included in contracts.

That was completed in 2013, and we started to roll out some pilot projects and we did some measurements. When we intervened in the market in 2011-12, we were at the bottom of the market, we were post crash, we had lots of contractors that were very hungry at that point and we had the austerity challenge of “more for less”. We proved that we could deliver assets more cheaply at a capex level, and more importantly we created an awareness in the industry that digital was a useful thing in starting to deliver a more efficient industry. It was a very low-level conversation, but it was the first one.

We now have an opportunity to have a few thousand people in the debate rather than a few tens of people to do exactly what you described on the next step. How can we take this dataset and enhance it, not only with better quality of design and manufacturing information but in its in-service performance, with the sensors and other things that we know about? We can start to ask: “What was my brief? What did I set out to deliver? What did I design? What did I build? And what is operating?” Those three datasets give us the opportunity to feed back and start to learn. Having learning assets will put us in a very different place in a few years’ time, and that is exactly the journey that we anticipate going on.

Mark Enzer: There is enormous potential value down the route of your question when we look at the value of information through the whole life of the asset, not just in the delivery of the new asset. I do not want in any way to denigrate the delivery of new assets. We have a lot of massive assets to deliver, which is important, and increasing the productivity of construction would be very beneficial for us as a nation. The delivery of new assets is clearly a very important issue, and I am sure that off-site manufacture has a part to play.

However, if we look at the wider picture of the performance of the assets in use, where we already have 99.5% of the assets that we need this year, we are only building a very small proportion of that, and the performance of the assets in use is clearly of massive importance. Being able to look at and manage the information through the whole life of the asset—this picks up on Baroness Morgan’s earlier question on whole-life valuation—is clearly a route to even greater value. BIM makes a connection through all this.

One further point to make on this is that when we look at the performance of infrastructure assets through their whole life we can see the performance of infrastructure as a system, which is really about mathematics and the percentage of the theoretical capacity that we are using. However, we also see infrastructure as a service, which is a very different thing when we look at it through the eyes of the ultimate customer and what the outcomes are for them.

When we talk about the performance of infrastructure, we should be talking about both those things: performance as a system and performance as a service, because they are both incredibly important. If we increase the performance of infrastructure, that is likely to have an even bigger effect on national productivity than increasing the productivity of construction alone.

Lord Mair: I have one further question. Presumably, everything you have both been saying applies equally, whether it is off-site manufacture or not, but the ability in the factory to be able to put in various sensors in the same way as in an automotive factory sensors are placed in the car component applies even more readily to off-site manufacture, arguably, than to conventional construction. Is that right?

Dr Mark Bew: I think it does, because the smarts that we put into the components can be used in manufacturing, delivery and operation as well. The benefit will come from that whole-life use of the smarts within the component, because if we can get the performance data of the components back into the front of the process and start to optimise the components, we will see even more improvement. We understand very little about how these assets perform, either physically or from a consumer point of view, and the more data that we can gather on that and the more analytics that we can do, the more we can learn.

Mark Enzer: It is important to see off-site manufacture as part of a number of different related things that together will deliver greater productivity. It is not off-site manufacture by itself. What you say about off-site manufacture being a really good opportunity to get sensors built into the units is exactly right. It is what those sensors are used for in the rest of the life of the asset that will yield even more value. If we see off-site manufacture as part of a suite of measures that we can drive within delivery of new assets to increase productivity, and as part of a bigger picture of infrastructure performance, off-site manufacture has its rightful place. If we see it as the whole of the picture, we will be looking at too small a thing.

Q22 **Lord Kakkar:** Before I turn to the question of overcoming barriers to the adoption of building information modelling, I want to return to something that was said a moment ago about the value of this continuum of data from design through to manufacture, through to construction, and then through to performance and back again. Have business models been developed to capitalise on the value of that information in terms of its application to the domestic market informing infrastructure, construction, building management and so on, in other parts of the world?

Dr Mark Bew: There are lots of fragmented ideas, but nothing has been brought together. A lot of these datasets exist, but they are poorly understood and accessed. You mentioned one on building performance. The building management system datasets are very comprehensive but almost impenetrable, because the standards around them have made them so.

The lack of skills in the operational parts of the supply chain means that there are not enough people who can interpret that data in order to start to make use of it. A lot of people are hiding behind IP, copyright and those sorts of things. The ability to share this information has been a real challenge. As we move into a new contractual model, we need to ensure that the rights over that data enable it to be collaborated in and shared, obviously within the constraints of contracts and security and those sorts of issues, which we clearly have to manage.

We are not seeing any other nation doing massively better than us at the moment. It is probably the reverse: a lot of other nations have taken the UK standards model and replicated them. We see that Australia and Singapore and even the States are using similar standards to us. The standards that we wrote as part of the first part of the programme are in the process of being promoted to ISOs, so it is a great UK story for that part of the market.

We see other sectors starting to do exactly what we were describing. In aerospace, Rolls-Royce is now selling hours of thrust rather than engines. Engines used to be very expensive and unreliable, so they had to be maintained. You had a big capex bill and a big opex bill. Now, because you are paying for the outcome, these two bills have become very small because all the flaws have been designed out of the engines and have become some of the most reliable machinery that we know. It has been the commercial model that has driven that engineering input into the product to drive those flaws out. The time between servicing is enormous compared with what it was 10, 15 or 20 years ago. We see evidence in other sectors and other applications where it has worked well.

Lord Kakkar: Does that mean that you could eventually have an infrastructure project or a major building project with all this kind of data monitoring and you would pay for the performance of the building or the asset rather than, principally, the capital cost of constructing it?

Dr Mark Bew: I do not think that is impossible at all. Stranger things have happened. We should be heading towards those kinds of ideas and opportunities, because it will drive better behaviour. If we can drive more value out of our capex and opex pound and deliver better outcomes to citizens, that is exactly where we should be heading.

There are some good examples. In High Speed 2 we are looking at how we can use these three datasets to predict faults at least six weeks before they happen. An aspiration for that infrastructure is that any fault will be detected well before it becomes an operational issue. Those are the kinds of aspirations that we are driving for now. Whether that turns into, as you describe, a new contracting model for outcomes, I do not know. I know that Sellafield is looking at outcome-based contracting for its contracts, because it has a very long investment in its assets—2,000 years potentially for some of them. Those kinds of scenarios are starting to emerge.

Lord Kakkar: On the broader question of adoption of this type of building modelling system, if I understood you correctly, the principal software technology asset is now owned overseas and has to be purchased by UK participants. Is that correct?

Dr Mark Bew: Yes.

Lord Kakkar: How can the Government, and the sector more generally, ensure proper access? Do all participants in a project need to have access to the same system?

Dr Mark Bew: There are a number of components to this. There is the system that you use to create and hold the information. It is an

application equivalent to Word on your PC. There is some data that drops out the bottom that you share and someone else uses, maybe another copy of Word, to look at the design. The applications that you use come and go; they will get updated every year.

The key thing, the IP and the value, is in the data that sits underneath. Absolutely, we are looking at creating open standards for the data. We want to create a market around better-quality applications so that Word becomes Word 2020 in a few years' time and improves its functionality. What we are really interested in is the quality, the reliability and the security of the underlying data so that we can reuse it for other purposes. That is where the R&D question comes in. How do we drive the quality of this data up? We know what data we need and we already have it, but how do we massively improve the quality and start to join it up with other pieces of data to make sense out of it?

Lord Hunt of Chesterton: The data must be evolving. In the City, the Gherkin will be a big source of new data, will it not?

Dr Mark Bew: Absolutely. The data that you start with at briefing is very thin, and when you hand it over to operations it is very thick. It also grows in fidelity. That is all part of the management process. We have started the journey of understanding that sequence of events. We have a set of very basic standards for sharing that data, but it needs to be developed and improved. The next generation will be how we do that.

Lord Hunt of Chesterton: You talk about outcome costing. It used to be called some other word when a person puts up a hospital and charges the Government per hour, but the whole process, particularly for public sector buildings, has had a pretty negative press. Why are you so positive about it in light of that?

Dr Mark Bew: The interesting thing about the method that you describe—PF1 and PF2—is there was no feedback loop. It was a linear journey, so we learned nothing from it other than we had a very large bill at the end. We have to feed that data back into the front. We missed a vital component. There is masses to be learned from those projects. It was not all good, but some of that learning needs to be fed back in.

Lord Hunt of Chesterton: I notice you do not use the phrase "PFI". That is a no-no now. I understand that "output costing" is a better phrase.

Mark Enzer: May I add to both these points, which I think are connected? We need to look further when we are talking about the outcomes to consider what outcomes we want from infrastructure, and not just from a particular project. We could look to reducing reoffending rates or to improving educational outcomes. If those are the outcomes we want, maybe those are the outcomes that should be rewarded. It has nothing to do with whether you build a prison, a hospital or a road. If the outcomes are what are wanted and the outcomes are what are rewarded, that can open up all sorts of more interesting solutions, which are not necessarily about just building more.

There are many cases where we do not have enough space to build more, so we need to think more cleverly and therefore we should come up with cyber-physical solutions and digital solutions that release more capacity without having to build things. It is important for us to have a whole-life view, because there is a danger that the kinds of sensors that Lord Mair talks about are seen as a cost rather than a value, whereas what they are doing is releasing more capacity and should be seen as a value.

Coming back to your point on the value chain, it is entirely possible for us to see a new value chain that goes from data to outcomes, and built on the basis of better-quality data we can make better sense of that data, which will give us better insights, which means that we can make better decisions and get better outcomes.

There is a direct connection between data and outcomes. What would make sense, with that view of value chain, is to reward the adding of value to information rather than the time spent doing it. We now have a number of cases where the amount of time we spend doing something like design does not make it worth getting paid for by the hour. The most recent example used to take 15 days and now takes four and a half seconds.

We do not want to get paid on an hours-based model for that, but it equates to productivity. That is exactly the kind of productivity we want. The message for me coming out of that is that we must change the business models. It is not a case of just looking at other business models. It is an absolute necessity that we change the business models to release that kind of value.

Q23 Lord Renfrew of Kaimsthorn: I should first declare my personal interests. I am a fellow of the British Academy and an honorary fellow of the Royal Society of Edinburgh. Currently, BIM is used for commercial buildings and infrastructure and perhaps not quite so much for housebuilding. Could you say more about the benefits it could have in the housebuilding sector?

Dr Mark Bew: It is used in housebuilding, but less so, for sure. We see organisations such as the L&Q Group and Laing O'Rourke using it routinely. They have big transformation programmes to enable that, because they have seen the benefits. All these sectors are on a slightly different curve of adoption and on a slightly different timescale. The application is very similar. It is an asset with components and data that can be managed in the same way.

The volume of housing certainly lends itself to using a component-based manufacture approach, and I think we will see it accelerate massively in the future. The challenge with that is going to be ensuring the capacity in factories, as we said earlier, to enable that to be sustained and potentially in the way we distribute and encourage designers and suppliers to use the data in a standard common way. If we end up fragmenting that market through the interventions we make, we will lose the opportunity.

Lord Renfrew of Kaimsthorn: It is potentially very sensitive to downturns in the market, is it not? You have quite a long chain of sequence from the factory to the finished house, and if there is a downturn in the market there is a big investment that is rather hanging fire. Is that a problem that one faces?

Dr Mark Bew: That is a problem across the manufacturing sector. You have a very high sunk cost in factories, materials and equipment. Anything we can do through the intervention that we design here to increase the demand, either for the domestic or the international market, the better. We need to focus on that, because this is a commercial conundrum that we are unlocking here. We know how to do this stuff. The teams and the experience is in the UK. It is scaling that capacity.

Lord Renfrew of Kaimsthorn: I have a very specific question in trying to think through volumetric construction for houses. Obviously, one wants as large a unit as possible to be manufactured and brought on-site. Does the 5-metre limitation on what you can transport by road prevent a difficulty when we are talking about house construction?

Dr Mark Bew: Logistics is a really interesting constraint. If we look at inner city London, one of the biggest constraints on building in London is access underneath the hoist to deliver the components. The bigger we can make those components when they are delivered and the fewer lorries we need to come into London, the better—environmentally, congestion-wise and all the things that go with that—it will be.

We mentioned earlier that we have components, big assemblies and buildings. The strategy for that is always going to be linked to a set of constraints that are managed in the design. If you have a constrained site or constrained access, you are going to have to build a smaller assembly, but clearly you want to make it as big as you sensibly can.

Lord Hunt of Chesterton: You made a slightly cryptic remark about other countries having ticky-tacky houses that are all the same and so on. I do not know whether you are referring to France, but some of these countries are building them at three times the rate we are, and people are quite content with that. As I understand it, those countries have a lot of centres where they can get parts, or they design parts which they keep using year after year, and they have a much higher volume of construction. Presumably part of the limitation of introducing these off-site methods is the financial side in the UK compared with some other countries where there seems to be a longer, more continuous run. Is that improving?

Dr Mark Bew: For sure, France has a bigger demand than the UK. It is a bigger country with more people, so there is more opportunity to grow their market. They are also much more used to having outcome-based methodologies in France.

The particular example of the quality of architecture that I had in mind was Scandinavia, because you see lots of buildings that look very similar, and in China they all look identical, because they are. What the impact of that might be on future generations we will have to wait and see. We

know already from the work done by the mental health people in that sector that there is a correlation between poor-quality or small poorly designed residential accommodation and mental health.

We do not want to save a few pounds here and grow a massive bill over here by making the wrong decision. We do not want to view this as a big experiment. We want to get this right. There are lots of components in the question that you just asked, and we need to understand each very clearly. There is a danger that we solve one problem and create another one that is much worse.

Lord Hunt of Chesterton: In principle, the Government or the Treasury could decide that it is important to have a continuum of building. That does not seem to be very high on the Treasury's list of priorities. It goes up and down.

Dr Mark Bew: Cyclical funding is a challenge. We have seen improvements over the last few years with departments such as highways getting five-year deals rather than one-year deals, which enables them to build long-term projects such as the smart motorways project, for instance, which has been enabled through that strategy. Because the Government have such a low input into the residential market, that is more difficult. Homes England is more of a land-property organisation now and has a small fund of around about 15%, so it provides a smaller lever for government to intervene in that particular market. If you look at prisons and schools, there is a much bigger lever. We are the client for a much bigger number of products and we can start to insist on a standard set of products and designs. It depends on which department you look at, its agenda and its funding arrangements.

Lord Hunt of Chesterton: Dr Bew and Mr Enzer, we are coming to the end of the session. You said something about the BIM software having to be imported. What is the percentage of the cost of a building if you have to buy that software from overseas?

Dr Mark Bew: I mentioned earlier the analogy between the software, tools and labour that you use to deliver it. The cost of the labour, the architect, is much higher than the cost of the software itself. For some SMEs, there is a little bit of a barrier, but not much. Over the last five years, the push back has not been the cost of the software but the cost of training, and, particularly on the part of the manufacturers and SMEs, nervousness that the Government will not stay committed to this direction of travel. These guys can do this. They have the capacity to do it, but they need a medium to long-term commitment so that all their efforts are not wasted, because that would be catastrophic to them.

The Chairman: What percentage of the schools that are built in England, let us say, would use off-site construction?

Dr Mark Bew: I would not know about schools.

The Chairman: Take any example that you know.

Dr Mark Bew: I know of several off-site schools, and there are more now than there were. It is a growing number.

The Chairman: Mr Enzer, do you know?

Mark Enzer: I do not know what the percentage is, but it is a low percentage.

The Chairman: Thank you both very much indeed. It has been an interesting session and we thank you both for coming to give us evidence.