



Select Committee on Science and Technology

Corrected oral evidence: Off-site manufacture for construction

Tuesday 24 April 2018

3.25 pm

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Members present: Lord Patel (Chairman); Lord Borwick; Lord Fox; Lord Griffiths of Fforestfach; 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.

Evidence Session No. 1

Heard in Public

Questions 1 - 8

Witnesses

Professor Jeremy Watson CBE, Vice-Dean of Engineering Sciences and Professor of Engineering Systems, University College London; Phil Wilbraham, Expansion Programme Director, Heathrow Airport; Professor Jennifer Whyte, Director of the Centre for Systems Engineering and Innovation, Imperial College London.

USE OF THE TRANSCRIPT

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

Examination of witnesses

Professor Jeremy Watson CBE, Phil Wilbraham and Professor Jennifer Whyte.

Q1 **The Chairman:** Good afternoon to our witnesses. Thank you for coming to help us with this inquiry today. Also welcome are those to whom we often refer as members of the public, but shall I say interested observers? I will start by asking you to introduce yourselves from my left so that we get it on record. If you want to make an opening comment, please do so before we start asking you questions that might help us with this inquiry.

Professor Jeremy Watson: I am professor of engineering systems at University College London and vice-dean of engineering sciences. I am concurrently the chief scientist and engineer at the Building Research Establishment—BRE. I split my time between those two. Previously, I spent some time with Arup as its global research director and was also in government as chief scientific adviser to the Department of Communities and Local Government, or the Ministry of Housing, Communities and Local Government, as I should say now. I spent most of my life as a practising electronic engineer in the manufacturing sector and moved into academe more recently. I also served as president of the Institution of Engineering and Technology last year, which was a formative and interesting thing to do.

I come to this whole challenge space from the point of view of inter- and multi-disciplinarity. In the concepts around construction you can draw some interesting analogies between different sectors; sectors that we believe perform well in cost and risk management. I might cite the electronics industry, ship manufacture and so on, where there is a very tight supply chain, both in the knowledge that is shared up and down it and open-book policies with respect to technology and costs. For example, you find that people who are competitive in the marketplaces share common technology platforms and understanding, and industry associations that are very strong and which set research agendas and so on.

For the construction industry we have a fantastic opportunity to transfer some of the culture and technology across from some of the more well-formed manufacturing industries to replace some of the craft activity and the fitting at the last minute in buildings where things are not necessarily designed precisely before they are assembled, and the assembly sequence and pattern at a systems level are not prescribed exactly in many cases. We can transfer some of that information across and use digital methodologies.

Chairman: We have a lot of questions to come and it was whether you wanted to make a short statement about yourself.

Professor Jeremy Watson: I am sorry. I thought you meant about the problem.

Chairman: Thank you very much. I do not want you to have to repeat it when we ask the questions.

Professor Jennifer Whyte: I am a professor at Imperial College London in the Department of Civil and Environmental Engineering. I have a Royal Academy of Engineering Laing O'Rourke chair in systems integration. I also lead the Centre for Systems Engineering and Innovation that has themes around production systems, infrastructure interdependencies and life cycle of infrastructure. I am involved in the Alan Turing Institute/Lloyds Register Foundation programme on data-centric engineering. I am a co-curator of the World Economic Forum Engineering and Construction Transformation Map.

Phil Wilbraham: Many thanks for inviting me here this afternoon to talk a little about how Heathrow Airport is using off-site manufacturing. I have worked at Heathrow for about 20 years. I am currently the Heathrow programme director for expansion, which means I am accountable for delivering the third runway and all the infrastructure that goes with it. Before that, I led the construction on terminal 5. I worked on that project for 10 years, and then I led the construction on terminal 2. I am a civil engineer. I am also involved with Constructing Excellence, where I am a co-chair, and I am also co-chair of i3P, which is an infrastructure innovation port.

My real interest at the moment is the third runway at Heathrow and how we can do more off-site manufacturing and use our logistics hubs. We intend to set up four of them around the country to consolidate loads, to assemble things that have been made in factories around the hubs and to bring things efficiently to Heathrow—to reduce the number of people we need constructing and assembling at Heathrow and to ensure that we use the full supply chain around the country as we expand Heathrow.

Q2 **The Chairman:** I will kick off with the first question. What factors make people decide that the construction of anything or a major part of it could be off-site? Who makes that crucial decision when you have architects, civil engineers and others involved? What is it that makes them choose off-site?

Professor Jeremy Watson: My immediate stab at that would be where you have regularity and standardisation in the item you are constructing from modular sub-elements, and where there is a cost saving, it might be the architect but, equally, it might be the engineer who recognises the opportunity for the client of off-site manufacture for cost and risk reduction.

Professor Jennifer Whyte: I think clients play a big role here and Phil will expand on that, I am sure. With off-site manufacture it is really important that you have the manufacturing expertise brought in earlier in the process. It is inefficient when design work has been done and it has to be done again. You end up doing it once in situ and then with an off-site methodology. It is important for off-site manufacturing to bring in that expertise around how things are made, manufactured and assembled earlier in the process.

Phil Wilbraham: I completely agree with that. It is really important to have an early decision that one is going to use some off-site

manufacture. That decision probably comes from the client or the client's representative, so either the client themselves or the project manager, the programme manager and so on. It is so important that the first stage of the design is carried out with off-site manufacture in mind, because otherwise designers will generally design the way they always have and we will get the same answer. It is really important to brief the designers to think about how they are going to design in a component-led way, because the real win here is if components are made in factories and they are the same again and again, and those components can be produced and used as the building or civil engineering infrastructure is constructed and assembled on site. Early decision-making probably has client or project management involvement.

There will be pull sometimes from the engineer, the architect or the supply chain when they have done this before. At the moment, because it is still quite a new idea, it needs some early input from the client. On a major piece of infrastructure some targets probably need to be set to enable the teams to understand that this is important. Of course, the reason we are doing this is, ultimately, to reduce cost and time and to get better quality and better health and safety, because it is safer to make things in a factory than it is to make them on-site.

Lord Fox: At the moment would you say that scale is perhaps the driver for considering off-site manufacture, in that making it on-site becomes much harder if it gets bigger? Is there also a political dimension? I do not want to drag you into the particular project you are involved in, but clearly spreading across a supply chain is possible when you do it off-site. Do political and scale considerations tend to be the drivers at the moment?

Phil Wilbraham: There are both those drivers. Scale is really important because if we deliver Heathrow's expansion the same way we delivered Heathrow's terminal 5 and terminal 2, we will be looking after about 15,000 colleagues on-site at peak during the construction. At terminal 5 it got up to about 8,000 or 9,000. We do not think that is a sensible scale to be operating a construction site. Therefore, to reduce that scale we need to do more work in different places. One of our drivers is to reduce the scale of what we do on the construction site.

The Chairman: When I asked the question I should have declared my interests. May I remind my colleagues that when you speak for the first time you should declare your interests? You do not have to do it again after that. I have no interests to declare in relation to this inquiry.

Lord Fox: May I belatedly say that I have no interests related to this inquiry.

Lord Hunt of Chesterton: As regards interests, I am a fellow of the Royal Society, an honorary fellow of the Institution of Civil Engineers and I have a consulting company. I wanted to say that I did some research at the BRE back in the 1970s on how people got blown over when they went near tall buildings, so I have a connection.

What I was surprised about your three replies was that none of you

said—which I thought you might have done—that with off-site you may be able to be more accurate and do things that are more complex and different from what you do when you are doing it on-site. Would you like to comment on that?

Professor Jeremy Watson: For me that was in the risk reduction. It was rolled into the more predictable assembly. Certainly, as you say, at BRE we have examples of domestic buildings that have been built off-site and assembled very quickly. In a visit we had the other day, visitors observed cracks in the traditionally built buildings after three months, but the ones that were made off-site fitted perfectly, exactly because the pieces were designed according to manufacturing techniques. I completely agree with you on accuracy and repeatability and I think that reflects in risk and cost reduction.

Lord Maxton: Building the third runway is your major concern, but you have other clients as well. I have heard airports jokingly described as “shops with runways”. You obviously have other clients. How do they fit in to the overall pattern of constructing?

Phil Wilbraham: You are absolutely right that there are other companies that build things at Heathrow and they develop shops, hotels and those sorts of things. Currently we require them to use some of our methods and encourage them to use others. For instance, at the moment we have a logistics hub at Heathrow—Colnbrook Logistics Centre—where we consolidate things, and if you are building a hotel you have to use our logistics system so that we know what is coming on- and off-site. The criticality at Heathrow is that we have 78 million passengers being served there and the building of a hotel or runway cannot get in the way of that huge operation. We need to control trucks coming into and off the site at Heathrow. We do that through consolidating loads. In that situation we will ask our partner to work with us. In the future, with our logistics hubs around the country, we want to share that knowledge and encourage people to use those. If there is a better way of building a hotel by making more of it in the Midlands, or whatever, one hopes that that will be used by the people who will come along as our partners to develop the rest of the infrastructure.

Q3 **Lord Renfrew of Kaimsthorn:** What are the main drawbacks to off-site manufacture for construction?

Professor Jeremy Watson: In the first instance there will be a cost element because we do not yet have the economies of scale. There are issues around standardisation reuse versus bespoke pieces and there is a whole scale of cost benefits and potential disadvantages there, but in the long term, when the whole system is geared up to do this as a norm, there are very few disadvantages.

Lord Renfrew of Kaimsthorn: Is not transportation sometimes a problem?

Professor Jeremy Watson: Indeed. Going back to BRE, one particular building was put up that required 60-tonne loads which were too large for some of the motorways so we had to choose the route. Again, that is a

case of systems design, how you break it down and what granularity of the modularity you are seeking. The smaller you get it—think of Lego blocks—the more flexible you can be with the solution. Also, manufacturing close to the point of consumption, as was said by Phil, is absolutely key. We do not want one big factory off-site in the middle of the country and an overloaded infrastructure. There are some so-called pop-up factories these days. For some domestic buildings, for example from Bill Dunster's ZEDfactory, they will put up a temporary manufacturing unit and take it down again when they have finished.

Lord Renfrew of Kaimsthorn: I see. That is interesting.

Professor Jeremy Watson: I hope I have answered some of those questions.

Professor Jennifer Whyte: The opportunities outweigh the drawbacks. There are a lot of opportunities around safety of workers, quality assurance, speed, productivity, reduction of waste, and greater traceability of materials. There is a need to do off-site well and thus a need to make decisions up front and to get tolerances right, so that when things come to be assembled on-site they fit together. There is a need to consider maintenance and maintainability. All these push us to think through the life of assets at that early phase so that when we are putting buildings together we have an idea about how we are going to get into bits of the building to maintain it.

That all pushes towards designers needing a greater understanding of manufacturing, assembly, maintenance and operational activities so that they can consider these up front in design. I completely agree that that is partly about thinking in terms of components and platform approaches to design. We are seeing some very good innovative thinking about that in the sector at the moment. Bryden Wood, for example, has done some work on that with the Centre for Digital Built Britain. In the Centre for Systems Engineering and Innovation that I lead we have research looking at design for manufacture and assembly and the processes needed to ensure that designers appreciate materials, maintenance and operation phases.

An example of that is on the Heathrow terminal 5 roof subproject. We did quite a lot of research on that. That was a location where I saw designers and subcontractors working together to understand materials and therefore being able to use standardised products and be quite innovative in the way that they thought about them and put them together.

Phil Wilbraham: One example of a potential drawback is that the factory will work at a particular speed and the construction site at another. There have to be really good logistics between the site and the factory and the hub or whatever, because the factory will want to work at the speed it wants to work at to be efficient, to make it cheaper, but you have to tie that in with how fast you can build on-site. There are extra logistics, and construction becomes about logistics and assembly rather than the traditional construction where there are lots of people doing their different trades on-site, as Jeremy was saying earlier. We need to change the skill set of people and for them to understand that it is about

logistics and assembly rather than about trades coming to site to finish things off.

The Chairman: That leads nicely to Baroness Morgan's question, but Lord Griffiths first.

Lord Griffiths of Fforestfach: To what extent are architects part of the drawback? Successful private companies—the tech giants, say—can splash out on new campuses and so on, and they can attract the best architects who are going to make statements. But if you are constructing a public sector building and the taxpayer is ultimately financing it, and you are subject to the audit office and so on, to what extent, in the end, will this engineering process drive a wedge between these two worlds?

Professor Jeremy Watson: Architecture has to be viewed on a scale. At one end you have the signature architects—the Fosters of this world—and we admire their work and they are wonderful. At the other end you have the real pragmatic architects who are doing, as you say, the public works or even domestic buildings and so on. The signature end, going back to my Arup days, is a little averse to anything that drives the way it designs things. It is their idea and has to be uniquely theirs. As you reduce the granularity of the modular approach, so you get to more and more flexibility. In Japan, there are examples of high-rise blocks which use the same apartment preassembly but offset by a certain number of degrees, so as you go up the building you get the corkscrew effect and it does not look like a prefabricated approach. With a pragmatic approach to architecture somewhere on that scale, you will have architects who will adopt that and celebrate it and say, "We are into modular construction. We are proud of this. We are experts in this area". At the other end I think there will probably be a slow transition. There are interesting changes, and I guess Jennifer can speak to this. Modern computer-aided design tools which drive building information modelling and allow parametric design allow you to take a design feature, adapt it in scale or rotation or whatever and create subassemblies you can make from that. In fact, that is quite close to what architects like to do.

Another point you raised was very interesting and I hope we will have a chance to talk about it a bit later: the concept of in-life total cost, not just capital cost versus running cost. Ownership models, of course, drive minimum capital costs and never mind how much it costs to run. As Jennifer said, maintainability is really key. If you can build instrumentation and sensors now we have the digital internet of things, you can tell how well the building is working and perhaps arrange—I hesitate to use the words PFI here—a sanitised version of PFI which feeds back the performance of the building to allow a contract to be satisfied.

Lord Fox: It strikes me we are not waiting for anything to be invented to make this happen. Prefabs existed a long time ago, so what on earth has stopped this from happening in the natural/market way? Is it the balkanisation of the construction industry? Is it snobbishness about prefabs? What is the major impediment?

Professor Jennifer Whyte: I would argue it is that you cannot change technologies of production without changing business and procurement

models. We have known that for a while. Joan Woodward was doing work on that in Imperial in the 1950s.

Lord Vallance of Tummel: If it is to do with procurement and this, that and the other, why does the UK seem to be behind the race versus a number of other countries? Is there a differential in terms of the procurement between, say, Japan or Germany or wherever and ourselves? Is it planning agreements? What makes us behind the race?

Phil Wilbraham: I think it is the way you set up your project, your programme, at the start. Procurement is part of it, but you need to set it up such that you have a team around you who understand that things can be done in this way. You need some early technical input so that you can understand that things can be done differently; otherwise, people will follow the traditional route. The traditional route of our procurement means that generally you do a little bit of design and another designer comes along and they follow the traditional route.

Going back to what we are taught at university, generally we are taught to do things in situ and on-site. There is an education piece here as well and we cannot just turn a tap as a client from going on-site to off-site. There needs to be an understanding in the supply chain of what that means as well. There are a number of things, but a good starting point is a client who wants to do things in a slightly different way and getting the right technical experts around them such that the procurement can follow at the right pace in the right way. I do not think there is anything from our perspective whereby procurement ultimately stops this change. It is a matter of small changes on all sorts of things.

Lord Vallance of Tummel: Has any other country got it right?

Professor Jennifer Whyte: There are pockets of excellence in the UK as there are elsewhere. The Singaporean Building and Construction Authority (BCA) brought their construction industry over to Imperial precisely to learn about design for manufacture, assembly and integrated digital delivery. Singapore does a lot of this, but it recognises that there are excellent projects in the UK. The question is: given that there are people doing this, why is everybody else not following? That is a question about business models and procurement models which really enable this.

Q4

Baroness Morgan of Huyton: I should declare my interests. I am a non-executive director of Countryside Properties plc and vice-chair of King's College London. We have already touched on some of this. It would be really useful if you could expand for us on the issue of skills. In what we are talking about, how different is the skill set from the traditional skill set? In the new skill set where are the gaps and the opportunities? What is the good and the bad in the story of the gaps that we have currently in skills and what we would have in the future model?

Professor Jeremy Watson: We have come from a world of craft and fitting. There was a time in manufacturing when we built steam engines and locomotives where things were not built precisely and you had to file and adjust, and tolerances were not understood in the same way. We are still there in construction at the moment. What we will see is a diminution

of the fitting element, because, as Jennifer said, if the tolerances are right, things will fit together. Of course, it would be disastrous if the tolerances were not right because we would still have fitting and modular construction. You really have to have it right first time. I think there will be a migration more towards design skills and perhaps some of the manual skills will go in to these regional factories, where they can still be used in a similar way, but, equally, there will be an upskilling towards systems engineering and design.

Professor Jennifer Whyte: We believe that systems engineering is important in this new environment. We are beginning to look at providing CPD around systems engineering out of Imperial and through UKCRIC—the UK Collaboratorium for Research on Infrastructure and Cities. I would say that there is a need for a fundamental research base here as we move to more digital fabrication techniques. There are opportunities around technologies such as AI and robotics as we move forward that I think it is important we have the research base to support. It is not a one-off transition in a sense. There is a transition that is required and that is about business/procurement models. There is also the skill base that is going to support advanced manufacturing approaches to construction as we move forward into 2030, 2040, 2050.

Baroness Morgan of Huyton: How do we excite young people who are currently at school in thinking about this future? I ask that particularly because I have to leave early to speak about women in STEM, so I am wondering if there is something I can take from here. Seriously, it strikes me that in many ways this is potentially attractive to people who are not currently attracted to this industry. Is there any evidence of that yet and what are the lessons for how we try to encourage young people at an early age to think about this?

Professor Jennifer Whyte: I think the built environment is extremely exciting to young people. They get the idea that this is about their houses, the roads that they walk on, the schools that they go to and, if they are unlucky enough to go to hospital, the hospitals they go to. They understand this is really about the world that they live in. The opportunity to make that at a higher level of quality and to be able to think through how we put that together and how we operate and maintain it long term is exciting to young people, so I think there is real opportunity to excite them about this.

Professor Jeremy Watson: User-centric design is really interesting. As you bring the user into the simulation of what it is going to be, there is much more creativity associated with the process rather than it just being delivered and not being quite what you expected.

Professor Jennifer Whyte: There is a lot of cool technology that can play into that. Artificial intelligence and robotics are cool areas of technology that begin to connect with this world.

Phil Wilbraham: The other side of this is we still spend too much time explaining what fun it is to be on a construction site. That is not the point. The point is there is some really interesting work to create something that is extremely easy to build. We need to trade the bit at the

first stages of the work rather than pictures in magazines of people in hardhats, which is what we still seem to trade. People creating things on screens would be a much better way to explain—to my kids anyway—that it is not all about muddy boots and those sorts of things.

Lord Hunt of Chesterton: You did not answer at all the question about what is wrong with the UK in housebuilding. The French are building twice or even three times as many houses as we are. One argument is that in France—and I have been on committees looking at French nuclear—they have centralised teams or the administration des ponts et chaussées for the roads. Do you not think that the planning structure and organisational structure of the UK fails to match up to this pretty efficient system in France where the houses come out and they are built and do not fall down? My wife designed our own one in France and it works very well. You have not answered that question. You have said there is expertise here and there and so on.

Professor Jeremy Watson: That is a political question, I think, because it reflects back to Napoleon's time. Napoleon did some good things.

Lord Hunt of Chesterton: Tell us what you think.

Professor Jeremy Watson: When I was at DCLG as its chief scientist we had regional spatial planning. Somebody had a global idea of how the UK should be laid out. That seemed like a good idea to me—unpolitically, just from a rational point of view—and if you have linear assets such as rail lines to build, you plan that holistically. We are a tiny country, after all, so why would we not think holistically? That, mapped out into the rest of the space we are discussing, will articulate some of the problem. We need to have some sort of centralised pull towards some of these outcomes.

Lord Hunt of Chesterton: Does that correspond with your idea of comparing the UK with other countries?

Professor Jeremy Watson: In as much as I know anything about other countries, which is not as much as colleagues, I am sure, if you look at the extreme of China; the Chinese achieve some amazing projects using off-site manufacturing in infrastructure, for example, deployed at very high rates. Obviously, they have access to huge amounts of finance. That is the other key thing. For us, we need a more coherent view collectively of where we are heading. That should be our response to it and ensuring that we have the investment available to create the momentum.

Phil Wilbraham: That is a key point because there needs to be enough of this, particularly in civil engineering and infrastructure, where it is worth while for people to invest in their factories such that there is throughput. The price will come down only if there is throughput. There is a virtuous circle. If we get started on this and encourage people to use off-site manufacture, the factories will be created and will fill and everyone will realise that that is a cheaper, quicker and safer way of doing it and it will move. However, it will take a big push and it takes the bigger clients. Government clients are the big clients in that situation. They are the ones that need to help us get to a point where these

factories become efficient, because if there is not efficiency in the factory, this will not be cheaper, and we will go back to doing it the way we have always done it.

Lord Maxton: I think what is being argued is: what is the planning problem? Is it that planning permissions are not being given?

Phil Wilbraham: I think there is enough knowledge of the infrastructure workload now. It takes a long time to come through and I think it is key that the public sector clients that look after that have a will to move to this type of way of doing it. It will not come from a private sector client doing something different because, to be honest, everyone else will carry on as they are. With our four logistics hubs we are talking about two other programmes with the aim of those programmes coming with us on that journey, so the hubs become really busy and the factories around them become really busy. That is fairly early work and we are keen to ensure that this gets embedded and becomes a legacy.

Lord Maxton: I should declare that I do not have any interests.

Baroness Young of Old Scone: I declare my interests as chancellor of Cranfield University, chairman of the Woodland Trust, which has an interest in wooden buildings, and honorary fellow of the Royal Society of Edinburgh. Lord Griffiths stole my question, so I dreamt up another one and then you answered it before I could even get that far, so I am left with the scrapings of what I want to ask. It is really about this business of scale-up. Where are we on the trajectory of scale-up? Is it really tiny and it is going to need an exponential increase to get to these levels of efficiency in the off-site manufacturing process, or are we halfway there? Where are we on the growth curve?

Secondly, on the idea of the Government as a driving client, my experience of public sector buildings of various sorts is that Governments are only too keen to step back and let some other agency run with the design concepts because they do not want to have the egg on their face if it all goes horribly wrong. What do we need to do to get the Government to act as a large-scale responsible client to help drive this? Should that be in public sector commercial buildings—non-housing—or is housing a good place to start?

Professor Jeremy Watson: Housing for me is where we have the real gap in capacity against the objectives the Government have, and we are massively underperforming there. There is quite a lot of investment going on in various housebuilding companies and in some of the case studies that we have submitted they have been able to demonstrate benefits. At BRE we have a number of full-scale houses that were built on-site that people live in to try them out. This type of off-site manufacture can be quite small scale. It can be done in pop-up factories or in small local units. I guess that contrasts with, say, Laing O'Rourke which has a factory in Steetley working on very large concrete reinforced structures, which are very specialised and more bespoke. There is a whole spectrum and that is probably less advanced but some countries are leading edge. At the housing end we are probably just a procurement gap away from doing much more of it because it is not that difficult to set up.

There are some other interesting points you raised about the Government's interventions, and those of you who have looked at building information modelling—BIM—which of course was mandated as of April last year or the year before, will know that government procurement above £5 million-worth has to use building information modelling, which is an essential ingredient for what we are talking about today. It is an essential ingredient but it does not specify off-site manufacture in itself. The point there is that the procurement rules can be very effective. The residual question around procurement when I started thinking about it—it sounds great, the Government procures against certain requirements—is: will the private sector follow, will shareholders of public companies say, "The Government are doing this so why are we not?" I do not see much evidence of that at the moment and that deserves some research and understanding.

Lord Vallance of Tummel: May I follow that up a little? Sticking with the private sector for a moment, on the face of it we are saying that off-site manufacturing of houses can be cheaper and better so you would think that if the market was operating as markets usually do and you can produce something that is cheaper and better and there is no demand for it apparently, or no supply of it, what is standing in the way? This is the bit I do not really understand.

Professor Jennifer Whyte: I would argue that the forward understanding of the work pipeline is really important here because of the up-front cost of investing in the facilities to produce off-site. We start to see some volumetric production in the housebuilding industry, but that forward understanding of the pipeline is crucial when you are putting in that capital investment.

Lord Vallance of Tummel: I can see that, but if the demand is there at the end user—in other words, you have something which is cheaper and better and therefore there should be the demand—why does the production not follow it? If you are putting any new product in you have to take the risk of building a factory to produce it. That is part of the game and it is like any manufacturing game. I do not see the difference here. I cannot see quite what is holding this back unless it is a whole concatenation of architects, different trades, public sector procurement, planning, whatever. Is it in that area?

Professor Jeremy Watson: It is probably in planning and development with developers sitting on land and not developing, that sort of thing, and the marginal—if that is the right term—cost of the risk, "Why would I take the risk when I know I can build it with a team of people doing craft and fitting?", and not necessarily having a perception of the extra margins. The construction sector has been living with tiny margins for years.

Lord Griffiths of Fforestfach: Is there a prejudice against prefabs, going back to the early post-war days? Is that part of that atmosphere of caution?

Professor Jeremy Watson: I have not perceived it personally but I have not necessarily been working in the right sector to perceive the

client view. I reflect on the fact we do not like wooden-framed buildings as they have in the US which are essentially prefabbed panels. Culturally, we like brick-built buildings. But you can still have brick-built buildings with brick facades that look just like a house but with off-site manufacture.

Professor Jennifer Whyte: I would say something about the availability of the skill set to deliver in this way.

Lord Fox: Professor Watson, you helpfully provided a briefing before this meeting, which is an on-the-record document. Under "Government actions" you say there may be no immediate burning platform to change technology. You have just been talking about massive underperformance in building housing, and we know that to be true. What constitutes a burning platform if massive underperformance in housebuilding is not a burning platform?

Professor Jeremy Watson: I was thinking from a business point of view, the housebuilders may not see anything that drives them.

Lord Fox: That needs to be clarified given that this is an on-the-record document. Now you have said it, the meaning becomes clear.

Professor Jeremy Watson: If there is a way that I can modify and resubmit, I will do that. I apologise that the meaning was not clear.

Lord Griffiths of Fforestfach: I should have acknowledged an interest that at one stage I was a mentor to someone on an executive development programme in Laing O'Rourke. May I come back to Lord Vallance's question? I think it is really interesting. If, for example—and I know you were in the retail business—you could see ahead a stream of income, and you have figured out what your costs would be, you could say that you either do it or you do not. To what extent in this area—and since my colleague on my left said planning permission is much easier in the north than in the south—is it government intervention in the market through planning permission that makes predicting the medium- to longer-term demand much more difficult than it would be if you just had a normal market?

Lord Maxton: Is not the problem that the planning permissions are not given by central government but by local government?

Professor Jeremy Watson: It is.

Lord Maxton: If I want to build a new conservatory on my house, I have to go to a planning committee and get planning permission.

Professor Jeremy Watson: I would reflect on what I said before, that there is value in taking a central view with the correct local democracy to balance that, naturally. Yes, I think that is the point I would make there.

Baroness Young of Old Scone: May I go back to Lord Fox's excellent burning platform search? I feel the need for a burning platform. Will the skills issue become a burning platform? Everyone is predicting with Brexit that all these wonderful bricklayers are going to go back to wherever they came from and we will end up with a lack of traditional construction skills.

Is that wishful thinking or is that not going to be a burning platform?

Professor Jeremy Watson: It could very well be. I do not know whether we truly appreciate that. Certainly to be able to do what we are doing at the moment at the cost we are doing it will not be possible because the wage expectations might be different between the different nationalities and so on. That could well become a margin driver for companies to have to look for ways of cost reduction.

Phil Wilbraham: In certain parts of the country that will become a driver and already is. At Heathrow we have started work with Lord Blunkett, who is running our skills task force for us. We are looking at what the need for skills will be as we construct the new runway at Heathrow. Again, it is trying to look into the future, as we have been here, as to what those skills will be and to work out how we can create those skilled people around Heathrow, so working with the local education colleges, et cetera, to ensure that we are skilling people up in the right way so they will be able to work at Heathrow in the future. It is a simmering platform, to be honest. At the moment we are still able to carry on as we are and maybe it will start to really catch fire in about 10 years' time. It seems to keep on simmering and people are putting it out rather than it taking light.

Lord Fox: Is the fact that the developers effectively control supply keeping the platform from setting fire? If the supply was to meet the need rather than the developers' ambition, the platform would be on fire because there would not be the skills and the supply chain to deliver the hundreds of thousands we need. Is it the developers who are maintaining control over the supply?

Phil Wilbraham: From my perspective at Heathrow we ought to crack on and develop as quickly as possible and we will add fuel to the fire.

Professor Jeremy Watson: I believe that has been a major issue in housing and the Government are looking at interventions to cause the release of land for development. I agree with you. If you had the step change in demand that would tend to drive it, I think.

Professor Jennifer Whyte: The only thing I would add is that 10 to 15 years ago, when I was in an innovative manufacturing research centre, we were looking at housebuilding in terms of single-family dwellings, and yet what I observe in innovative approaches to housebuilding in the UK at the moment is these multi-storey student accommodation blocks, for example. HTA Design is doing some of the volumetric blocks in Wembley. It has the tallest modular building in Europe. That is really where innovation is happening, in residential that is multifamily, which is of a reasonable height and is in urban areas. That is quite a different problem to crack from the suburban problem.

The Chairman: Baroness Young, did you have a question?

Baroness Young of Old Scone: I did, although I think it has been answered. I must admit with that last remark I suddenly had Ronan Point in the back of my head—multimodular, high-rise, east London. Are we better at it now, do you reckon? You are clearly too young to remember

what Ronan Point was.

Professor Jeremy Watson: Thank you for that. I take it as a compliment.

Baroness Young of Old Scone: I was thinking of your colleague actually.

Professor Jeremy Watson: Clearly, I am not.

Q5 **Lord Kakkar:** May I return to the question of research and development? You have mentioned certain areas—AI, robotics and so on—but what else might be needed in this area? I am particularly interested in how much the university departments are doing in this area. How much of a focus is there on fundamental research to drive this area of economic activity? Are the research councils involved in it? Is UKRI going to have a lead role in this? Are there going to be challenge funds that focus on developing the knowledge base to develop this area and make it truly productive for our economy?

Professor Jeremy Watson: Jennifer is from Imperial and I am from UCL, and UCL East out at the Olympic Park has put up a large robotics laboratory that is sponsored by the civil, environmental and geomatic engineering group, which is very interested in on-site automated construction from off-site manufactured pieces—how to put them together, which is a point we have not really covered today. For example, in Japan, to reduce injuries on-site and to increase the speed of working, you can use robots very effectively for construction. Jennifer mentioned UKCRIC, which is a £140 million investment the Government made with match funding from industry, which is putting together the capital infrastructure to enable a number of universities, including Cambridge—Jennifer can articulate which ones, I am sure—to put together a capability for doing research with and across the patch in that sort of area. Under the industrial strategy fund, UKRI and others are playing a key part in connecting universities with research technology organisations such as BRE and others to put together an integrated capability of people who understand the early technology readiness levels with those who interpret technology in practice and the practitioners as well.

I am certain there is more that can be done but the Government are getting it. Perhaps we need to make sure that it is under some sort of collective umbrella that is being not so much managed as ensuring that communications happen so we do not reinvent wheels.

Lord Kakkar: I should also have added at the beginning that I have no interests to declare. How does the R&D you describe in our country compare with the global research effort in this area? How competitive are we compared to others?

Professor Jennifer Whyte: It is interesting because my focus has shifted east, I guess. I have been in Hong Kong at the construction productivity event where they invited some of us over to talk to them. We have been hosting Singapore and both Hong Kong and Singapore are doing substantial things in practice, but are also interested in this in a

research capacity. We work with the University of Hong Kong. There are interests in this area in Switzerland, where they are doing a lot of work on digital manufacturing. In Germany, there is a lot of good work being done on digital, and in the US of course. The UK is seen as a leading player in digital because of the investment that the UK Government have made as a client into Digital Built Britain.

Professor Jeremy Watson: We were seen as the leader in building information modelling until very recently. We were quite brave in the government procurement policy around building information modelling, which gives us a lead-in ramp to being expert in off-site manufacture.

Professor Jennifer Whyte: The EPSRC has invested over many years in the manufacturing area and so we have a capability in the universities. Indeed, some of that capability was built through the innovative manufacturing research centres that it funded 10 years ago, so there is capacity. It is really important to sustain the research base and refresh it towards that next generation of technologies.

Lord Kakkar: What actions need to be taken to achieve exactly that: to refresh and to retain that established base?

Professor Jennifer Whyte: I think some of the actions are beginning to be taken through the industrial strategy challenge fund. I was pleased to hear that there are calls coming out through the EPSRC, through Innovate UK and through the ESRC indeed on the back of some of the larger investments. It is important that small-scale experiments are happening across the UK and there is a network and they are co-ordinated in some way. We also need the ability for some of the excellent researchers in universities across the UK to do work in this area and to help propel us forward.

Lord Kakkar: Does any of this research effort in our universities, or indeed in industry more generally, depend upon European funding or is it all specifically domestic funding?

Professor Jeremy Watson: Absolutely. I used to be the UK representative on the European Construction Technology Platform and we were seen as key thought leaders in the research area. We instigated a €2 billion public/private partnership on low-energy buildings called E2B, and I believe also a similar project around infrastructure, which I was not part of but which my colleague Terry Hill at Arup started. The UK benefited enormously from the funding that was available—and still does, I guess—from agendas that we had helped shape. The partnerships with major companies, which we all know very well, such as Bouygues and others in the UK and ACCIONA in Spain and so on, are doing collaborative research and sharing outcomes.

Lord Hunt of Chesterton: What you have just said is interesting, but of course something this Committee has looked at is that after Brexit we may participate in certain programmes but we will lose our leadership role, and you see this across the board. What I was going to say is this has to be implicit in thinking about buildings and walls and so on, but of course a hugely important part of housing is energy. Most new small

houses have independent energy. Is that desirable or is it just because individuals want to do it like that? The Government are very concerned—we all are—about energy use. The way we are doing it, by comparison with German public housing, is quite different. How do you see that?

Professor Jeremy Watson: We are on the cusp of an amazing revolution which at BRE we have demonstrated through building three or four houses which have photovoltaics on the roofs, with batteries—we have heard about Elon Musk and Tesla batteries—with 10 kilowatt hours of storage which, say, in the south of England you can easily get on anything other than the darkest winter's day. You store the energy during the day when most people are out and use it in the evenings. You can almost achieve zero energy imports. When it is even sunnier, you can be exporting that energy. The feed-in tariff is very small and has been reduced after those early heady days of whatever it was—nearly 40 pence a unit. Nevertheless, if you can use the energy you create—and these are all modular concepts so modular roofs which have built-in photovoltaic cells that do not look like unsightly photovoltaics but look like roof tiles—those are available now. There is a long way to go on cost-reduced energy storage and management because the volume is not there yet, but with the increase in the use of electric cars that technology will come across into the built environment. We could see a real transformation in terms of distribution and energy and very much more autonomy and, I would say, resilience as well from the grid system, and give the grid operators the flexibility to adjust the balance of power so they do not have to increase the rating of conductors.

Lord Hunt of Chesterton: Will the same factories be used for the energy systems as for putting together the beams?

Professor Jeremy Watson: The assembly, say, of roofs, would involve the inclusion of photovoltaic devices built into prefabricated roofs, but not the semiconductor manufacturing; that is probably done somewhere else.

Q6 **Lord Fox:** You have mentioned en passant the industrial strategy and the industrial strategy challenge fund. A key element of the industrial strategy is sector deals. What should be included in the construction sector deal to bring to fruition the promise that we see from off-site manufacture?

Professor Jennifer Whyte: It is a hard question to answer because, of course, we do not have the sector deal draft in front of us.

Lord Fox: I am not asking you to draft it.

Professor Jennifer Whyte: I would push the argument that it is important to have in that the higher-skills agenda and that is around PhD students, around the knowledge economy; it is around sustaining and developing capabilities to be competitive in our manufacturing processes. The question about international comparisons is well made because we are not the only country that has noticed the opportunities and the benefits of off-site.

Professor Jeremy Watson: I would also cover the other end of the skills scale, so continuing professional development, the uplift and maintenance of skills, people changing their engineering jobs to match the changing technology. That requires the professional institutions and universities to be offering, perhaps by distance learning, ways of getting on top of these new technologies without taking huge amounts of time out of the working day.

The other thing for the challenge fund would be funding at scale, serious demonstrators. We tend to build something that is not quite enough to convince everyone. We need something that cannot be denied—the O2 Arena or something of that sort of scale—which uses a particular approach and clearly demonstrates well-evidenced measured benefits which can pull the momentum through the industry.

Q7 **Lord Vallance of Tummel:** It seems to me that rather than just a sector deal you are looking for a holistic strategy. You have governmental issues of planning regimes, public procurement and developers' motivation, various vested interests in threatened professions such as architecture and various trades as well, and you have the R&D and technology bit of it. You have a whole host of stuff here. There is a risk that you end up—I should not be answering this question—sorting some of the things that go naturally into a sector deal without taking a holistic view of the whole environment in which this operates. Is that right?

Phil Wilbraham: I think there is a lot to change, ultimately. All change needs to be taken in bite-sized chunks. The important thing is that the sector deal picks up some of the points you make. It probably will not pick them all up but, ultimately, people will start using those things and move on to the next point. All that will not change in the next five years. It will be a steady process. Also, we would want to bite off the things that are easier to do first. It is easier to do off-site manufacture with relatively small bits of, say, concrete and steel and do that really well and prove that it works and make it completely and utterly digital. You could work on some bits that can really be done well and prove they work on a normal site, in a normal development. I agree with you that to try to solve all this in a oner is not possible, so we have to pick bits off and different people have to attack different bits.

Lord Vallance of Tummel: But if you do not tackle the market inefficiencies, because it seems to be full of them, no matter what you do elsewhere, you are not going to crack it.

Lord Mair: I ought to declare my interests. I am a fellow of the Royal Academy of Engineering and of the Royal Society and emeritus professor of civil engineering at Cambridge. Laing O'Rourke collaborates with my university. I am also president of the Institution of Civil Engineers and I chair the Science Advisory Council for the Department for Transport, which is a major infrastructure provider. I am sorry, this will not take too long. I should also say that I am a consultant to Laing O'Rourke, but I do not have any involvement with its off-site manufacture. I am primarily a consultant to it on underground matters—tunnelling and so on.

My question is really about the distinction between buildings and other forms of civil engineering infrastructure. We have touched on that and, obviously, Phil, your world at Heathrow is not only about buildings and what you are currently addressing, but most of the discussion has been about buildings. I would like to hear from the three of you about the potential for off-site manufacture in our other forms of civil engineering infrastructure.

Phil Wilbraham: I think there is a potential in civil engineering just as much as there is in buildings. In the past, we have probably done more in buildings, but if you go back to the terminal 5 days, we determined that we should precast 60% of our concrete. It was not the flat concrete but all the other concrete. We set a target and we built river walls out of precast units. People said, "You'll never do it", and a lot of people said we were mad, but we did it and those river walls are still there 14 years later and they do not leak. There is a mindset here as well as proving the case. Certainly for civil engineering, it is so embedded that you design it, you do your reinforcement, you build it on-site, et cetera, and we need to un-embed some of that. With the civil engineering that we are about to embark on at Heathrow, we will be setting targets about how much of it is going to be precast and whether that is precast in a factory. Earlier we built a little factory near Heathrow. There are different ways of doing it. We could build a little factory near one of our logistics hubs. There are lots of different ways of getting at it. It will encourage designers to think differently. Ultimately, you get fewer wet trades on-site and hopefully no hot trades on-site. That is where all the trouble comes, all the danger is, all the joints are and where the problems come later in maintenance, et cetera. In civil engineering there is massive opportunity, but I do not think it has been tapped in to as much as in the buildings. In the buildings it is more obvious and you can see bits of it on the back of trucks. For a long time people have been trying to do their mechanical and electrical—M&E—off-site. We have done that. You put them into big modules and you put it all together and that is great. Again, that is quite simplistic and there is a lot more we can do to bring together bits of buildings.

I was at Laing O'Rourke's yard and they have whole bits of a side of a building coming out now. You can see the bits of the building sitting in the yard ready to go to London and they will be literally installed. That is a combination between civils and buildings. The last multi-storey carpark we built at Heathrow was 80% built in a factory and there you have the same thing again and again—repetitive—and it is built much more quickly, and it is much safer and much higher quality. Ultimately, it will be cheaper. It is back to the scale question; we need scale to get it cheaper.

Lord Mair: Do you think in general that the mindset all around the country at present, if it is thinking at all about off-site manufacturing, is thinking about buildings, and there are all sorts of other projects—local authorities—which are not buildings, and that is probably the biggest barrier?

Phil Wilbraham: There is more progress in buildings. If you ask where we are on the scale, we are probably 10% to 20% in buildings and 5% to 10% in civils. There is a great example on the A14 at the moment where a huge viaduct is being built alongside where it is being put up. There are little pockets of the civil engineering world.

Professor Jennifer Whyte: I would bring in examples from Crossrail. Custom House is an example of prefabrication being used on major infrastructure projects. Both with buildings and infrastructure there is the problem of how you sequence the people you bring in to do the work. If you bring designers in ahead of fabricators, you can end up with an in-situ solution that you are trying to solve post hoc.

Q8 **Lord Borwick:** First, I declare my interest as a property developer, mainly of housing sites but also other developments. May I ask about public procurement yet again because we have touched on it on several occasions? The November 2017 Budget said that the Government were going to encourage off-site construction, particularly in transport and health, and the Department for Education, Ministry of Justice and Ministry of Defence would all adopt a presumption in favour of off-site construction by 2019. How many of those will achieve it?

Professor Jennifer Whyte: There are some good early signals. There is the work that Bryden Wood has done with the Ministry of Justice, which builds on the work that it has done with it on Digital Built Britain. Digital and off-site are not quite the same thing, but they often go hand in hand, because they allow you to think about building, or indeed about infrastructure, in terms of components, and you can start to think about how you fabricate those. There are good early signals that there is the potential at least for government departments to seize the opportunity for the efficiency savings and all the benefits that we know off-site brings.

Professor Jeremy Watson: That is very likely. Government can provide some very useful signposting, and the infrastructure of research and capability can naturally ease a rather conservative and slow industry towards better places. It is also moving incrementally because not only are we doing off-site manufacture but the component manufacturers are also coming along quite well. You are starting to see the parts from which buildings are made being very much more accurately made, with much more standardisation, repeatability and so on. That is driving it top-down and bottom-up at the same time. It is not such a bad position in that way, but some big projects will drive further through.

There is one point I did not get a chance to respond to Lord Mair on and that is around infrastructure. You know much better than I do that things such as tunnel linings, footbridges for motorways and all sorts of similar things have been made for years in prefabricated off-site ways. An opportunity that emerges is that by tracking materials through their life you can do closed loop and you can use materials at the end of their life as well, particularly steel, which is typically melted down, with a huge use of energy and huge inefficiency. We can potentially start to think of a national Lego kit for putting things back together in different ways. That

is where modularity and the tagging of materials with smart devices can assist.

Lord Hunt of Chesterton: One of the critical factors, presumably, in getting more efficient and effective building programmes is for the customers to be educated as to what they should expect and what they should ask for. Look at us here in Parliament: we do not know very much and yet we are making decisions. Similarly, members of councils and all sorts of industries are making very important decisions about this or, for example, Heathrow or the Olympics. Do you think that more could be done to educate or to inform, to show them other countries before they make their decisions? My feeling is that we have not done very well in creating intelligent customers, particularly for this area.

Phil Wilbraham: It is absolutely critical that the people who are making those early decisions know an awful lot about their environment, what they want and what they can see as the outcome, and that they understand how the thing works, how it operates. We sometimes leave these decisions to professional programme managers, who are very good at getting things designed and constructed, but we need capable owners, as I call them, who can really get behind this. I have been fortunate to be at Heathrow for 20 years. The people who operate the buildings have to put up with what I have done. We have great conversations about, "Wouldn't it have been better if ...", et cetera, and the learning you get through people understanding how buildings and infrastructure operate is fantastic. There is a huge piece to ensure that the—

Lord Hunt of Chesterton: Do you do this in the programme that you were talking about at Imperial? Does that have an element of teaching and creating intelligent customers?

Professor Jennifer Whyte: We would be keen to work with major infrastructure owners. We work with the major projects, which are their delivery clients, so they are not the eventual owners and operators, but they are the owners through that delivery process.

Lord Hunt of Chesterton: Are councillors and other people going to universities to get some training? That is what we are talking about, is it not? I do not think it is happening.

Professor Jeremy Watson: I would reflect on it in two ways. When one of my previous employers—Arup—did the King's Cross St Pancras underground we simulated that with virtual reality. You could wear 3D goggles and go up and down the escalators. We could check the signage was right with the client before anything was ever dug in the ground or cut. The other side of it, of course, is the mass training that is needed. Again, at my present employer—BRE—we have an academy. We have put literally thousands of people through CPD modules and training, keeping their skills up and making them fit for purpose.

The Chairman: A quick question from Lord Vallance and a quick answer.

Lord Vallance of Tummel: I do not have another question, but I should declare my interests, which I failed to do before, as chairman of the Edinburgh Business School, which is part of Heriot-Watt University and

which no doubt has an interest in this somewhere.

The Chairman: We overran slightly, but thank you very much indeed for kicking off this inquiry extremely well. Thank you for coming.