OFFSITE INNOVATION IN UK INFRASTRUCTURE: THE ROLE OF THE APPROVALS PROCESS IN BOX JACKING PROJECTS

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In the UK civil engineering major roads and rail sectors, novel uses of offsite methods of construction have commonly "required special approval" by governmental body approval processes and Codes of Practice. Understanding the ways that such organisations influence the sector's confidence regarding innovative construction methods and materials could help accelerate their development in the design and construction process, and hence also help maximise the possibilities of modernisation in the sector. By comparing two case studies of offsite precast concrete underbridge box-jacking, one as part of a government authority responsible for motorway contracts and one with a government authority responsible for railways, the differences regarding prioritisation of acceptable risk are explored. The main drivers and constraints for offsite adoption and implementation are investigated and presented. Key challenges during the design and construction period of the projects are identified. These focus on establishing effective communication between clients, designers, contractors and offsite suppliers/sub-contractors when implementing offsite, as well as understanding aspects of the physical integrity of assets that are dependent on the limitations of essential availability, disruption of usage or closure. By considering the differences in approach towards innovation and approval systems for the Governmental approval agencies responsible for motorways and railways, the parties involved can align their programmes of work and methods to help capacitate their clients' needs, facilitating more lean working processes throughout the procurement, design and construction stages.

Keywords: box-jacking, civil engineering, innovation, lean, offsite.

INTRODUCTION AND BACKGROUND

Offsite techniques in the building sector have experienced great developments in the past few decades. Within infrastructure, although distinct benefits have been identified, the transformation has proven lengthier. Many barriers have been identified including the inflexibility of the approval authorities to change and adjust. To help investigate some of these occurring challenges two offsite case studies were analysed.. Forming culverts and under bridges by reinforced concrete box-jacking may not be a completely new and innovative solution in itself but in conjunction with an array of organisational and legislative problems and limitations, this offsite solution can become extremely demanding and complicated to apply. The projects reviewed and compared as case studies in this paper have many similarities, but one major

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difference. First, the same contractor, consultant and subcontractor were involved in both schemes. Secondly, the challenges faced were ground-breaking - in one of the projects the box was jacked into position under a live motorway (Figure 1) and the other was jacked under a live railway line during a precise time-window of 101 hours. In both projects the margin for error was minimal, therefore very strict approval protocols had to be addressed in order to increase confidence so that the governmental approval agencies would authorise the works underneath and around their assets.

Figure 1. RC Box-Jacking under a live motorway

The attitudes of the government approval agencies responsible for motorways and railways (road agency and railway agency) when considering adopting offsite, are compared here to the practical challenges faced on site within these projects. Through this process the industry's beliefs and the government approval bodies' needs are analysed with the objective to identify the reasons for the diverse expectations when innovative construction collaborations take place. An additional objective of the paper is to analyse the process of gaining confidence in an offsite solution whilst going through the common practice approval procedure by identifying fundamental barriers and constraints. The specific aim of the paper is to assist an engineer working for a consultant, contractor or subcontractor to develop an understanding of the prioritisation process of the approval bodies when faced with solutions that are not common practice. It will also contribute towards the maximization of the modernization of the sector via appropriate offsite understanding and implementation.

LITERATURE

Innovation in construction has been a topic of thorough investigation. Due to the scale of the existing literature on the area however, only relevant points to the research area are included here. There have been a series of attempts to identify what drives and hinders innovation (Bossink, 2004; Blayse and Manley, 2004; Gann and Salter, 1998; Koskela and Vrijhoef, 2001). Bossink (2004) identifies the drivers of innovation in construction networks being focused upon environmental pressures, technological capability, knowledge exchange and boundary spaning. These drivers can also be sub-divided into management levels ‘intrafirm’, ‘interfirm’ and ‘transfirm’. This inductive approach allows for a general understanding of the issues from a theoretical

perspective with an incorporation of the management aspect, which is unique. Furthermore, although many terms of innovation are generally defined, Bossink's paper lacks the definition of ‘construction network’ and the more practical research focuses predominantly upon the Dutch construction industry. Blayse and Manley's (2004) approach is far more practical identifying six primary influences. These include clients and manufacturers, the structure of production, the relationship between individuals and firms within the industry and between the industry and external parties, procurement, regulations, as well as the nature and quality of organisational resources. Although these topics are thoroughly analysed the innovation strategy adopting the identified drivers in project work is lacking development. One of the points identified as a hindrance by Dulaimi *et al.* (2002) was the lack of coordination between academia and industry when adopting research in projects, which was ignored by other literature. After having examined in detail how the standards and regulations affect innovation, Gann and Salter (1998) turned to how the standards and regulations affect innovation, considering whether the performance based regulations hinder or drive novel methods of construction. Their analysis predominantly focuses on internal integration of business methods rather than the interaction of the firm with the approval body. Dubois and Gadde (2002) accuse the government approval bodies of ‘hampering innovation’ with their negative influence. However, the responsibilities of the industry were not developed to the same extent.

Box-jacking is not an uncommon practice in civil engineering, with at least seven projects in the UK using this particular method, during the past, 20 years. Therefore, it may be perceived as not particularly innovative. Nevertheless, according to Slaughter (1998) ‘innovation is the actual use of a nontrivial change and improvement in a process, product or system that is novel to the institution developing the change’. Furthermore, innovation can be ‘incremental’ or ‘modular' (Slaughter, 1998). The two projects reviewed faced strict time limitations and needed to overcome a series of extreme technical challenges referring to the alternative options considered and rejected (Allenby and Ropkins, 2004; Ogborn *et al.*, 2011). The technical issues and contractual processes were clearly mentioned in two journal publications that have governed the literature assessed in this research (Allenby and Ropkins, 2004; Ogborn *et al.*, 2011). Regarding the box-jacking schemes involving working under a live motorway, Allenby and Ropkins (2004) identify and analyse the detail of the mechanical system 'anti-drag system' (ADS) used and the methodology employed to minimise disturbance to the running motorway above. The project that involved works under and around a railway may not have had to employ ADS system to such an extent (Ogborn *et al.*, 2011). The challenge was of a different manner because the available time window for works was 101 hours. Therefore, in the rail project there was no option of ‘freezing’ the works if a problem occurred dissimilarly to the motorway project. In addition to the journals above, there are a number of additional conference papers (Allenby and Ropkins, 2006, 2001; Brunsden *et al.*, 2003) that analyse different technical aspects of the box-jacking process but do not contribute any additional information.

RESEARCH DESIGN AND METHODOLOGY

The methodology employed is based on a combination of action research and grounded theory (Dawson, 2009). This blend of methodological approaches allowed the researcher to be flexible with novel issues appearing in conjunction with the emergent data collection process and ongoing literature review (Glaser and Strauss, 1999).

Background Research

Prior to identifying the main aims and objectives of the research, a primary background study through meetings, discussions and site visits was conducted. In addition, a secondary background study followed, utilising literature from industry facing magazines, and construction and consultancy firms involved in box jacking projects (Glaser and Strauss, 1999).

Interviews

Ten people who worked on the box jacking projects were interviewed, representing a variety of seniority levels and roles within the industry and the approval agencies. A combination of semi-structured and unstructured interview methods was employed to enable maximum input from the interviewees whilst allowing data to be collected uniformly (Glaser and Strauss, 1999). Nevertheless, the interviews gave the researcher the opportunity to develop and analyse the parts of the project that needed to be considered in a more detailed way. In the first, structured part of the interview, the interviewer went through a set of questions (interview pro-forma) through which the necessary data were collected. During this process the interviewee gained a better understanding of the research undertaken and developed a rapport/trust which was essential for the second part of the interview (Bryman, 2008). At the second phase, the interview was unstructured, thus catering for an in-depth discussion over an area which through the first phase was identified as of additional value to the research. At the same time, in order to identify the most appropriate persons to interview a combination of purposive and 'snowball sampling' (Dawson, 2009) took place.

After the interview survey had been completed, two recent case studies were analysed, including contracts, drawings, Gantt/progress charts for project planning, financial statements, journal and conference papers. Both projects had the same contractor, consultant and subcontractor but working with a different governmental approval agency. One schemes involved jacking a box under a motorway and the other under a railway.

Data collection challenges

The predominant research tool employed was research interviews. There were significant challenges related to that process. One of the most common challenges occurring was bias. One of the case studies researched was more successful than the other, therefore some interviewees were distrustful, negative or kept strictly to the meeting agenda. Others purposely derailed the discussion to cover areas that they had performed and completed well, and avoided other areas. More specifically, four main problems were faced in this research. Firstly, the participants' defensive attitude due to the questions with regards to innovation within their organisation. Secondly, answering the questions according to their organisation’s corporate policy rather than providing detailed factual information. Thirdly, a few participants would challenge the question rather than answering e.g. 'you shouldn’t be asking that this way, if I were you I would ask this etc'. Finally, most interviewees did not use terms such as 'offsite' or 'prefabrication' to describe the box-jacking projects, a fact which created the need to discuss the determination of terminology prior to discussing the projects.

Data analysis

The research methods and strategy would be considered as qualitative research since the qualitative continuum is applied as part of the on-going data analysis process. A comparative and thematic analysis were employed to compare the interviewees'

responses amongst themselves and then against the approval authorities in order to allow triangulation of the data (Glaser and Strauss, 1999).

FINDINGS

Offsite as a term in box-jacking

During each interview it was important to determine whether the people involved would consider the project as offsite construction. The majority of the participants were convinced that since the box was constructed on-site, the project could not fall into the offsite category. Furthermore, all the participants thought that offsite projects involve parts or complete structures being constructed offsite, in a protected environment and transported to the location of the building site. The phrase that was used was 'offline construction' where the ‘line’ was the motorway or the rail tracks (Figure 2). Therefore, ‘the box was built offline and pushed into position’. An additional interesting phrase that came up was ‘a movable structure’ or ‘a movable underbridge’ which includes a structure pre-constructed and then moved to its final position.

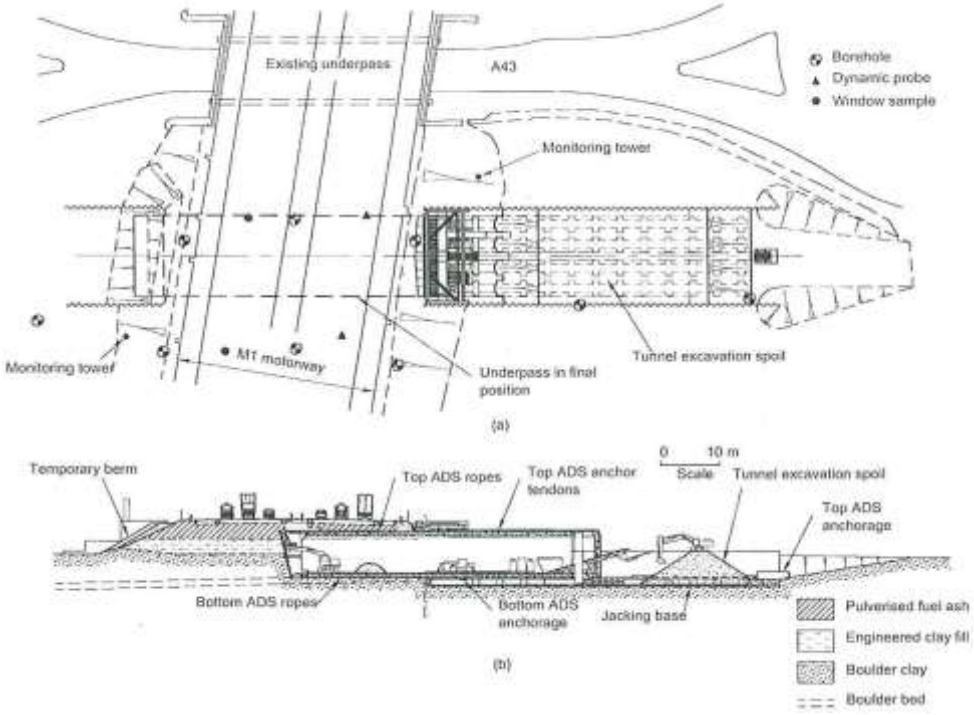

Figure 2 (Allenby and Ropkins, 2004)

Adoption of offsite innovation - theoretically

The strategic approval authorities for railways and motorways involved in both schemes claim that they focus upon and promote innovation, especially as regards offsite because they appreciate its advantages. The benefit identified is the ability to have the asset in public use during construction and, if absolutely necessary, to have either a short term closure or a partial closure.

Through the interview process it was identified that the roads agency has teams of specialists whose main priority is to assess and approve the usage of novel materials and techniques on major road projects. Furthermore, they argue that if a solution’s potential is recognised, they would work with the manufacturer to assist them through the testing and write codes/standards for their solutions. From their point of view, if

the industry is not doing enough, they would aid and push for more innovative solutions (e.g. heat strengthening of steel parts). However, one has to clarify that the approval authorities are highly unlikely to do the testing, instead they would employ other consultants or contractors from the industry to assess the solution. Moreover, there are examples where the entire research on a product would be funded by the agency.

On the other hand, the roads agency acknowledged their conservatism, commenting that they 'can't afford to make mistakes because the public does not accept that, therefore we are conservative by nature'. Nevertheless, they appear keen on employing novel construction solutions first at a 'site trial'. That would include the method or the material being trialled on an A-road, first, and then on M-roads. There are many examples of experimental use of solutions on small projects in a side road or on a small local authority project. Secondly, the authority would review and monitor the performance of a novel solution by visiting the site after a certain period of time or requesting data from the industrial parties involved. The focus would always be upon the cost-benefit risk analysis with main factors being the cost of savings against the potential damages if the system fails. One has to bear in mind that the costs, in case there is a failure, would predominantly occur due to the fact that assets are not kept available for use, therefore the approval authorities for motorways and railways would concentrate on materials and solutions that need minimum maintenance. When there is enough evidence that the product is adequate, then it will be considered for use in more important assets, 'we wouldn't place a new product on a major highway, we would rather try it on a smaller road first'.

In more detail, having considered all the above, the approval authority's team with responsibility of assessing the innovative solution would ask the following questions aimed at raising confidence: 'Has the product been used before?' - If it has been used before the team would review the specific conditions and circumstances aiming to assess if they match the requirements of the proposed scheme. If not then the following question would be raised asking 'what tests have been in place?' If the product has passed the testing criteria, the authority can proceed with greater confidence. Thirdly, if the product is so innovative that there are no common practice testing standards in place the authority would review practices from abroad and the tests employed there (e.g. Sandwich Plate System (SPS) in Canada). Following that, the agency would work with the sub-contractor/manufactures in adopting such standards for the UK market.

From a major consultant's point of view, the industry seems to drive and push for innovation and the approval authorities appear to restrain the move towards offsite implementation and general innovation. One clear point uniformly made during all the interviews was that both national approval bodies, especially the rail agency, seem to employ extremely conservative approaches towards construction modernisation. Such views are completely rejected by the national approval bodies since they argued that if the solution is viable and financially beneficial, they would definitely be keen to approve it rapidly. Moreover, the road agency claim, as mentioned above, that there are cases where the agency would identify a solution employed abroad and introduce it to their projects without external industry pressures, funding the costs of testing to ensure that aligns with the agency's standards.

Adoption of offsite innovation - practically

Through the interviews and the case study analysis of the two box-jacking schemes, the above general statements can be assessed and can review whether when put in practice, the process would align with the theory.

Decision Making
The decision making process was very straight forward because both projects were based on constraint-driven design rather than on a cost-driven design. The box-jacking solution was chosen because there was no other practically alternative solution according to the feasibility study. Box-jacking was not in itself a novel construction process but due to the circumstances and limitations in both schemes, the projects are considered ground-breaking. Arrays of alternative options considered are presented in the literature (Allenby and Ropkins, 2004, Ogborn *et al.*, 2011) but these ideas were developed on 'the back of a fag packet'.

Managing Risk
In order to minimise the project risk for months prior to commencing the design and build works, all parties involved including the approval agency had been engaged in discussions to determine exactly what the approval authority wanted as a final outcome and what their priorities were. The road authority, as a general statement, strongly recommends and identifies beneficial to conduct thorough discussions prior to submitting departures or considering any novel methods of construction. Nevertheless, when the works began, 'it seemed as if the previous efforts never took place'.

Technical risk and execution risk were unofficially divided into subcategories. Structural designs was not considered as a challenge but having unconventional soil conditions, such as contaminated ground, toxic carbons, the 'geotechnical risk' had to be analysed. Although the contractor takes a great part of the technical risk and execution risk, the design teammay well conduct a large partof the risk assessments. In addition, the local authority client of the box-jacking under the railway tracks had identified a methodology for constructing this project and therefore had also undertaken a major risk assessment. To minimise the execution risk, the consultant had appointed a programme manager. A very detailed schedule 'down to the nearest five minutes' was created with contingency times on all activities and warning progress points. With regards to considering the financial risk, the consultants' approach was to 'think ahead and always take the worst case scenario'.

DISCUSSION/ANALYSIS

Challenges in realising offsite innovation

The direct link to the approach of the government approval bodies towards innovative solutions was their financial contribution and necessity level of the scheme. As the box-jacking project took place under railway tracks, the government strategic rail network operator had fractional direct financial involvement in the scheme by providing the 10,26% of the initial secured budget (Ogborn *et al.*, 2011). The scheme took place because it was a necessity for the local authority in order to eliminate a level crossing. The rail agency's single involvement was to ensure that the asset was available to the end user on time and all works were completed according to their regulations. In contrast road agency was the client and the approval authority for the project under a live motorway. The box-jacking was a necessity for the client/government body (Allenby and Ropkins, 2004). Since, there were strict

contractual agreements, the authority approached every step of the approval process with direct interest in the costs, application and execution.

Challenges were faced in the approval of certain sections of the box-jacking of the railway project because the government authority wanted a 'gold-plated solution' since they were not involved in direct contractual agreements. An example includes an approval form, which was reviewed and sent back and forth almost, 20 times before being finalised. The industrial partners argued that this, 'may have been due to personality driven differences or that someone from the contractors or consultants side was not willing to challenge the approval body enough'. In defence to that the approval body claimed that 'a proposal would get rejected if it is badly written, not enough details or poor quality product'. Comparing the two options one can conclude that from the constructor's or consultant's viewpoint they could assume a lack of confidence from the agency. In addition, 'the client's requirements were met but the approval authority would hinder the development of the works that they were not directly involving the asset under their jurisdiction'.

The government approval authorities are clear that 'with regards to structural aspects approval processes, raising confidence is not affected by the interpersonal relationship nor the success of previous projects. It has to do with the capacity of the material or the structure meeting our requirements'. In general, both the contractor and consultant have worked previously with the approval authorities prior to the box-jacking projects. More specifically, the same consortium of companies that worked on the motorway box-jacking project had already worked on the railway project (Allenby and Ropkins, 2004, Ogborn *et al.*, 2011). Acknowledging the above, in the railway box-jacking project, the approval body representative and the people involved in the construction consortium had not previously worked on such projects directly. The regulations from the governmental bodies are to be followed and the representative is there to ensure that that take place. Nevertheless, 'one could do so by collaborating rather than directing'. In one of the case studies reviewed the approval body's representative followed the rules and contributed with 'constructive criticism at times but he would not suggest a method just because he preferred or was familiar with it. We rather had to go back to him again and again with suggestions and keep getting rejected.'

SUMMARY AND CONCLUSION

One of the most important factors influencing the application and realization of innovation in construction is that of government approval bodies (Blayse and Manley, 2004). They can be considered a driver or constraint depending on the approach that has been followed, in order to accomplish an increase of confidence on potential projects. In order to ensure that the approval authority's representative is confident of the method/material proposed a strategy has to be approved and inaugurated. This strategy should be a structured approach in order to increase confidence and is divided into two stages. The first barrier includes: 'would the approval authority let the project commence with this innovative method/material?' This is a challenge partly of a technical nature and partly of design management. It is not sufficient to demonstrate a detailed design and an adequate technical knowledge of the solution. In addition, previous successful projects, good recommendations, highly credible individuals, good reputations, past effective collaborations on similar projects or schemes increase reliability and predictability and therefore should increase confidence in the proposed solution.

From the project comparisons outlined here it appears that if the approval body is also the client, then there is an increased vested interest in the completion of the project. Consequently the approval authority/client has a greater interest in seeing the project through to a successful, timely and cost-effective completion rather than solely maintaining and protecting their assets available to the public. In contrast, if the client is not at the same time the approval body, then there may be additional barriers to overcome since the approval body may take less of an interest in the operation and delivery of the project. Nevertheless, it should be considered an advantage because approval bodies focus on having the asset available to the end users, not on whether the project around it has been completed Therefore, it was quoted in the interviews for example, that 'when box-jacking takes place, if we can assure the approval body that even if the box is not in place the rail/road would be in use then they will be easier to convince.' At this stage of confidence building, regarding the proposed solution, more applied and numerical evidence such as risk assessments, contingency planning and precise contingency methods, strict time planning and backup specialized machinery and equipment 'would increase confidence'.

By understanding the main objectives of the approval bodies and acting accordingly to convince them that the project team's goals align with theirs, the approval bodies could be considered more as a driver rather than as a constraint.

FUTURE RESEARCH

Contractual structure was shown to influence the approval process since the consultant in both cases was 'employed' by the contractor. Therefore, when submitting innovative designs, they would have to go through the contractor to reach the approval body. Could aspects of the contractual structure be considered to drive or hinder adaptation of innovation? Moreover, the local community did not pose any obstruction which may not have been the case with innovative solutions in other projects. How does the local community influence innovation in the decision making of constrain-driven or cost-driven projects?

The key knowledge of an individual authorised by a government approval body to assess and update regulations has direct influence on innovating a specific sector (Gann *et al.,* 1998). The interpersonal relationship between the individuals representing the industry consortium and the approver representing the government authority could be the key factor to accelerate the introduction of innovation.

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