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CONSTRUCTION INNOVATION DIFFUSION IN THE RUSSIAN FEDERATION: BARRIERS, DRIVERS AND COPING STRATEGIES

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Abstract

Purpose - The Russian construction industry is highly conservative and is often criticised for its lack of innovation. Construction firms invest relatively little in innovation adoption, development of new ideas, and formal research and development. The aim of this study is to explore the current situation in the Russian construction industry and the obstacles, drivers, and strategies that affect innovation implementation most significantly.

Design/methodology/approach - This study utilised an extensive literature review followed by a questionnaire survey with 52 experts from the Russian architecture, engineering and construction industry incorporating post-hoc interviews with a selected group of 12 professionals in order to identify the most significant drivers, enablers, barriers and strategies related to innovation diffusion in construction.

Findings - Findings indicated that economic and financial difficulties as well as inappropriate legislation are the most significant barriers to innovation. Financial incentives, legislative improvements and the promotion of alternative construction procurement methods were viewed as the most critical strategies to improve the current lacklustre rate of innovation diffusion.

Originality/value – While there is anecdotal evidence that the Russian construction industry is lagging in terms of technological advancement, its closed nature means that there is still little reported evidence on what are the main barriers to innovation diffusion in this country. Hence, there is a lack of focus on innovation diffusion rates in different construction sectors, such as building and civil infrastructure, and limited consideration on how effectively the research and development sector contributes to innovation.

Keywords Construction, Russian Federation, Innovation diffusion, Barriers, Strategies, Drivers

Article type Research paper

Introduction

The construction sector has always been one of Russia's economic driving forces. However, it has also been criticised for its unwillingness to innovate (Denisov and Kamenetskiy, 2003; HSE, 2013). The performance of the Russian construction industry was analysed in a desktop assessment report titled *Innovation in the construction cluster: barriers and perspectives* (Expert, 2007). Seven years has passed since that report was published and this perception that the industry lacks innovation remains.

Similarly to most countries, the Russian Federation building and construction industry is a major contributor to economic growth and employment. Today, there are more than 200,000 building and construction firms, and 14,000 building-material companies, in the Russian Federation; together, they employ approximately 11 per cent of the working population and contribute approximately 10 per cent to the country's gross domestic product (GDP) (FSSS, 2014; INFOLine, 2013). However, excessive conservatism in relation to innovation implementation has been identified as one of the most common characteristics of not only the Russian but also the global construction sector. In the literature, the sector has long been defined as a "laggard industry" (Dibner and Lemer, 1992; Slaughter, 1993). The Russian construction industry is ranked extremely low in terms of innovation compared to other sectors. Only high-tech sectors such as information and communication technologies, biotechnology and nanotechnology have showed progress (FSSS, 2014).

According to research conducted by the Higher School of Economics (HSE, 2013), innovations usually led to reduced construction costs, operating costs and construction schedules, but do not significantly change the technological mode. Consequently, it is clear that the level of innovative activity within construction firms needs to be improved. Higher levels of innovation in the industry will improve productivity (Gann, 2000) and profitability (Tatum, 1991) in this notoriously low return and high risk industry, ultimately improving economic growth and living standards.

The Russian Federation is a unique country, spread across a massive territory. For the last 20 years, it has been and continues to be a country that faces significant structural reforms and associated economic turmoil as it struggles to transform into an efficient market economy based on knowledge and innovation. In terms of the construction sector, Russia is also different; it is the only country with ample natural resources and an extraordinary variety of natural conditions that have no analogues in developed countries: there are temperature regimes, seismic, permafrost and so forth (HSE, 2013). The science development and active construction work in the Soviet Union clearly influenced the introduction of some new technology and innovation diffusion. However, Russia has significantly lagged behind the construction leaders (e.g. USA, Japan, Germany, etc.) even before the collapse of the USSR, and this sudden regime change resulted in an even worse period of technological backwardness and failure to support innovation (Expert, 2007). Nowadays, despite serious efforts to support innovative activity, the Russian government has not yet been

able to create a positive innovation diffusion cycle dynamic in the construction industry. The public funds are spent inefficiently and the construction sector continues to face factors which hinder the current rate of innovation diffusion (Russian Newspaper (RG), 2014).

This study has one overarching objective to discover the barriers to innovation diffusion in the Russian construction industry and to identify possible strategies to overcome them. It also provides a fresh view on contemporary innovation development in the industry. The findings of study will be used to guide the next stage of the research, which seeks to operationalise a set of fit-for-purpose strategies that the Russian government could implement in order to more rapidly stimulate innovation activity. The problems covered in this paper are relevant not only to Russia but are reflected in academic discourse globally (Blayse and Manley, 2004; Bossink, 2004; Marceau *et al*., 1999).

Many studies have been undertaken to examine innovation in the construction context (Anderson and Manseau, 1999; Bossink, 2004; Davidson, 2013; Ebgu, 2004; Panuwatwanich *et al.*, 2008, 2009a, 2009b; Sayfullina, 2010; Slaughter, 1993; Tatum, 1987). In this current research study, innovation is defined as a new idea that is adopted in a construction project; it comes with potential additional benefits but might also be associated with potential risks (Ling, 2003). It may refer to a new design, material, technology, component or construction method deployed in a project.

This research focuses on barriers to innovation diffusion experienced by firms within the Russian construction industry. There is a large body of construction management literature (Blayse and Manley, 2004; Miozzo and Dewick, 2004; Stewart *et al.*, 2004; Panuwatwanich *et al.*, 2009a, 2009b) addressing the need for investigation of impediments to and strategies to overcome the development of innovation activity. Nevertheless, there is a knowledge gap in studies specifically advocating barriers to innovation implementation experienced by firms in the Russian construction industry. Moreover, there is a lack of focus on innovation diffusion rates in different construction sectors, such as building and civil infrastructure, and limited consideration on how effectively the research and development sector contributes to innovation. This research work has a number of implications for the government and construction businesses, seeking to explore the process of innovation diffusion and to develop the potential benefits of implementing the enhanced strategic plans.

The literature review is provided in the next section, which was conducted to identify the drivers, barriers, outcomes and effective strategies for innovation diffusion in the construction industry. Moreover, historical and cultural backgrounds that have influenced the industry's development were analysed. Following the literature review is a description of the research method and an explanation of the survey results, followed by an analysis of the results and a discussion. Finally, recommendations and conclusions are presented based on the research findings.

Literature review

This work draws from literature on construction management and innovation diffusion with particular emphasis on Russia's failure to innovate. A literature review was completed using international as well as domestic Russian academic journals, government and industry reports, and news resources.

Construction innovation diffusion

It is widely accepted that for any country, innovation is paramount for economic growth and development, higher living standards and competitiveness (OECD and Eurostat, 2005; Seaden *et al*., 2003). Many studies have been conducted on how innovation could be defined and the importance of innovation in the construction industry (Anderson and Manseau, 1999; Bossink, 2004; Davidson, 2013; Ebgu, 2004; Sayfullina, 2010; Slaughter, 1993; Tatum, 1987). Sexton and Barrett (2003) indicate that new ideas must be followed by successful implementation and must improve overall organisational performance for innovation to be effective. Ebgu (2004) divides innovative efforts into two categories, namely, organisational (introduction of advanced management techniques, marketing, methods of production) and technical (new design, material, technology, component or construction method). Slaughter (1998) argues that it is necessary to take into account the unique nature of innovations; manufacturing innovations are significantly different to the organisational context of construction. Some studies focus on why innovation takes place and who innovates (Anderson and Manseau, 1999; Denisov and Kamenetskiy, 2003; Bossink, 2004; Ozorhon *et al.*, 2010), and others discuss the typologies of innovation and reasons for innovating (Davidson, 2013; Davidson and Ivanova, 2011). Many authors have focused on how innovative solutions can be implemented in the construction process (Slaughter, 1993, 1998; Ling, 2003, Manley, 2008; RuGBC, 2013) and how construction firms manage the innovation process (Gann, 2000; Drejer, 2002; Zavlin *et al*., 2006).

Construction as a process industry faces many challenges related to introducing new ideas and technologies as well as understanding the innovation diffusion process which plays an important role in a process of innovation implementation. According to Rogers (2003, p.5), diffusion is "the process by which an innovation is communicated through certain channels over time among the members of a social system". Wolfe (1994), points out that innovation diffusion studies involve the following models: (1) diffusion of innovation including exploration of potential adoptions and analysis of the innovation itself; (2) organizational innovativeness, where innovativeness with organizations are explored; and (3) process theory focusing on refinement and adaptation of innovation during their life cycles by organizations (and individuals). Innovation diffusion includes two major processes (Rogers, 2003): (1) the innovation-decision process of making a decision to adopt or reject the innovation; implementing the innovation; and confirming the decision by individuals (members of an organization); and (2) the innovation process in an organization involves initiation of innovation adoption and implementation of the adopted innovation.

Relatively few studies have addressed the diffusion of innovation in the construction industry (NAHB, 2004; Manley, 2008; Panuwatwanich *et al.*, 2009a, 2009b). In order to successfully implement innovation and develop the construction sector, policy makers and construction organisations should have a deep understanding of both the process of construction innovation adoption by companies and the overall diffusion within the industrial sector. In doing so, some authors (Nam and Tatum, 1992; Blayse and Manley, 2004; Miozzo and Dewick, 2004; Stewart *et al.*, 2004*;* Expert, 2007; HSE, 2013) suggest to firstly identify the factors influencing effective diffusion. Understanding these barriers very clearly characterises the industry. However, their role and importance in affecting the adoption and diffusion of construction innovation are not sufficient without exploring the motives for construction firms to adopt an innovation and the ways how the development of innovation can be encouraged.

Influence of Russian Federation context

The Russian Federation has gone through significant economic changes since the collapse of the Soviet Union. It has been slowly attempting to transition from a globally isolated and centrally planned economy to a market and globally integrated economic system for the last two decades. This transition has been less linear than other formerly planned economies such as China.

In post-war USSR, under centralized state governance free of market relations, construction was an active but well controlled instrument for building the socialist society. The main task of the Office of Building Technology and the Academy of Science was “to assist in introducing the advanced achievements of construction technology into architectural design, building and infrastructure construction and to find new, highly rational and economical structural elements” (Ten years of the Academy 1944, p. 45). The period was characterized by transition from representative “Stalinist” architecture to mass industrial construction methods, mostly prefabricated housing moving building technology to the forefront of questions relating to construction. Using industrial methods for large quantity housing construction the Soviet Union came in first place in the world for production of cement, precast concrete structures and components, slate, window glass, wall and other materials. According to Lyudvig (1961) the construction materials industry, as a major branch of heavy industry, “got its second start” at that time. However, these achievements have been accompanied with a number of shortcomings. At the beginning of the 1960s the industry faced the problem of insufficient supply of capital and construction resources to meet the requirements of a large number of construction sites. The volume of unfinished construction dramatically increased in the following decade, which was also associated with a significant level of bureaucracy and corruption (Ivanova, 2011).

In the Soviet Union, innovation was only associated with domestic science and developments because of the country being closed behind the Iron Curtain (HSE, 2013). The period of 1970-80s is characterized by an

increasing number of research institutes and universities, interaction between science and production sectors in the priority sectors of the economy, implementation of research results into industrial activity of heavy, light, food and construction industries and the military sector. The Scientific and Production Associations (NPO) and the Inter-branch Scientific and Technical Complexes (MNTK) were established during this period. Experimental design and industrial enterprises significantly reduced the duration of research and production cycle. In term of construction, the NPOs involved more than 60% of the research institutes (Belanovsky, 1994). The main objectives of these organisations were innovation diffusion through the in-depth training of professional engineer-constructors, the expansion of the conditions for joint work of engineers and architects, as well as an analysis of the possible effects of innovative technologies and solutions on the economic and social progress (Belanovsky, 1994).

However, the end of the centralised funding of science following the collapse of the USSR led to the disappearance of the all-Union network of state scientific institutions responsible for conducting research in individual sectors of the national economy including construction industry. Around 25,000-100,000 highly qualified professionals have left the country since the collapse (Klochikhin, 2012).

The period of 1990-2000s is characterized by a crisis of innovation, and as a result, replacing domestic production and developments with foreign imports, new materials and technologies. Since 2000, the construction industry and its supporting research sectors have gradually begun to improve due to an improvement in the Russian economy. There was openness of borders and activity of trading networks. However, necessary changes to the construction industry's regulatory framework have not kept up with foreign innovation developments filtering into the country. In March 2014, at the government session devoted to problems associated with introducing innovation in construction, it was concluded that the main problems in the industry are still related to inadequate public policy and regulation as well as lack of incentive mechanisms to promote innovation diffusion (RG, 2014).

In particular, the Russian construction procurement and tendering process hinder innovation development. In contrast to Russian system, in developed countries (e.g. USA, UK, France, Australia) the minimum cost of design and/or construction is no longer the only selection criteria. A range of criteria are considered for winning a tender, including the tenderer considering factors such as the projects' life cycle cost, safety, quality, environment, design innovation, to name a few. Moreover, contracts are structured such that the government does not compensate properly for any variations that may occur during design. Consequently, designers stick to conservative designs that fit within the tight confines of the original budget. Innovation is rarely encouraged on government projects unless the project has national significance. Often, another consequence of the Russian system is that while the design process may occur quickly due to design replication, the construction process may go for an extended period due to many unexpected variations not considered by the designer in their limited brief of works (HSE, 2013).

Generally the majority of implemented innovations in the Russian construction industry have the single objective to save money, rather than to increase quality, safety or environmental conditions. Although cost savings is an important objective, like many other countries the Russian construction industry faces many environmental problems. For example, presently there is also more focus in Europe, USA, Australia and Japan to recycle demolition materials for reuse as innovative eco-friendly construction materials. In addition, developed countries have the ultimate goal to concurrently enhance the architectural aesthetics of buildings and infrastructures, standards of living through increased asset functionality, and resource savings, when introducing construction innovation (Expert, 2007). The Russian construction industry is still narrowly focused on short-term fixes that produce low-cost but also low quality infrastructure and building assets.

Considering the role of modern infrastructure in achieving long-term growth, the Russian government invests in road construction. However, the budgeted funds are spent ineffectively. According to the President of the Russian Federation, “the same roads are repaired every year instead of progressively increasing the volume of high-quality road construction. The introduction of innovative solutions still rests on the bureaucratic wall that absolutely does not encourage designers and contractors to use the new, cost-effective, durable materials and construction technology” (RIA News, 2014). In this instance, innovative pavement management systems could be introduced to reduce the life cycle cost of road infrastructure in Russia.

Presently, various political and business problems have also occurred that might affect innovation diffusion in the country and particularly construction industry in a negative way. Hence, the government prefers to take measures aimed at stimulating the production and demand for domestically innovated goods and services (TASS, 2014). The ever-changing political context means that there is rarely the necessary extended period of market stability where innovation can be properly transferred from outside or developed internally using domestic or foreign capital.

Barriers

Many obstacles influence the implementation and diffusion of innovation in the building and construction industry. This study highlights several categories of barriers to construction innovation (Table 1). The group of barriers relating to regulations, standards and public policy is crucial for Russia and are considered the most significant problems for the Russian construction industry because of the arduous procedures for obtaining building permits and project documentation processes (HSE, 2013). Access to the world construction market is extremely difficult for Russia because of a lack of proper public policy and support, historical background, culture and language.

Problems related to the level of regulation and standardization in Russia have not been solved for the last twenty years. An overhaul of the construction industry regulatory framework is long overdue. Currently, the expenditure on innovation in the Russian construction complex consists of: applied R&D (31.9%), construction process (47.6%), production and testing of a prototype of new equipment (16.1%) and design (4.4%) (FSSS, 2014). Limiting the cost of services for design is not conducive to innovation implementation in design and engineering companies. In addition, designers will not risk considering alternative materials in construction projects without sufficient legal and technical support. It is primarily related to issues of expertise (HSE, 2013). The current state expert examination causes irreparable damage to the state and society. Its main task is to assess the compliance of project documentation to requirements of technical regulations which actually do not exist. Coordination of project documentation and obtaining building permits is considered one of the most acute problems of the Russian industry. According to the *Doing Business* 2015 report, Russia takes the 156th place out of 189 for the time and ease of obtaining construction permits. In comparison, Germany occupies the 8th place, UK – 17th, Australia – 19th and the USA – 41st. Despite a number of measures taken by the government to simplify administrative procedures, 239 days are still spent to receive the construction permits while for Europe and Central Asia it is 177 days on average (Doing Business, 2014).

One of the main features of the Russian construction sector is that the criterion of price is often not overlayed with a review of quality or value for money (i.e. you get what you pay for) (Denisov and Kamenetskiy, 2003; Sayfullina, 2010; HSE, 2013).This happens due to a number of reasons. In the majority of cases, government tenders favour proponents using the cheapest materials and technology. Tenders offering higher quality project outcomes are discouraged since they will never win in a race to the bottom. The cheapest design solution doesn’t consider the long-term life cycle cost of buildings and civil infrastructures meaning that in Russia it is not uncommon for the life maintenance costs to exceed the initial cost of construction by many multiples (Expert, 2007).

The other significant problem is that the high social status of engineers and scientists has been reduced dramatically during the crisis in the country’s post USSR transition period (Ivanova, 2011; Klochikhin, 2012). Industrial research and universities lost 31-35% of their staff after 1991 (FSSS, 2014). The government has recently made an attempt to rebuild the Russian science and engineering research profile but has yet to stem the tide of young scholars still wishing to leave the country for better work environments.

[Insert Table 1]

Enablers and drivers

This sub-section identifies the factors that positively influence or force construction firms to be innovative. Innovation drivers and motivating factors are summarised in Table 2. During the research, it became evident that some factors can be regarded as both drivers and barriers depending on the context. The desire of construction companies to capture a competitive advantage is significant driver of innovation diffusion. Sayfullina (2010) analysed the innovation characteristics of the Russian construction sector and indicated that many firm-level strategies have been changed because of market pressure to innovate, even though the firms' strategies have traditionally been technology-oriented. It is important to note that innovative pilot projects related to sustainable use of materials and resources could be financially supported for testing and evaluation of innovations. For example, opportunities to increase energy efficiency in the Russian construction industry were reviewed at the government session in March 2014. It was concluded that the policy making should focus on the stimulation scheme through the development of regulations (RG, 2014). Diverse technical capability is also a function of successful knowledge exchange and innovation quality guarantee, which are influenced by information technology (IT) programs and tools, and access to modern technologies before market launch.

[Insert Table 2]

Public policy strategies for enhancing innovation diffusion

The principal mission of organisations' innovation activity is to improve the efficiency and effectiveness of the construction industry. National governments can play a significant role in innovation diffusion, by creating a market environment that is conducive for companies to take up innovative construction processes through a range of measures including, economic incentives and fiscal methods, create demand for new alternatives and increase awareness of different actors in the construction process (Dewick and Miozzo, 2002; Seaden and Manseau, 2001). Seaden and Manseau (2001) present an overview of national public policy instruments within 15 countries that drive construction innovation. According to their research, and that of some others (Mitropoulos and Tatum, 2000; Bowen and Thomas, 2004; Blayse and Manley, 2004), government incentives and policy for innovation are the most critical. Table 3 provides a summary of the key supportive public policy strategies to improve rates of innovation diffusion in the construction industry of the Russian Federation. As previously mentioned, the link between research institutions and industry in the Russian Federation are particularly weak when compared to other countries (Osipov, 2014). There are some exceptions, with the construction and building materials manufacturing industry ranking sixth among the 64 industries, in the intensity of international coordination between researchers in various fields of the applied sciences.

[Insert Table 3]

Research methodology

Methodological approach

According to Easterby-Smith *et al.* (2002), it is necessary to understand philosophical assumptions of conducting researches to clarify the research design and formulate the adopted research strategy in order to provide appropriate answers to research questions and assess the potential research outcomes. Taking into account the nature of this study (social science, management research in the field of construction), the prevailing philosophical assertion in the construction-specific literature is rooted in positivist and interpretivist approaches, which characterise the epistemological stance (Blause and Manley 2004, Panuwatwanich *et al.*, 2008). The first stage is related to quantitative research using organised methods of empirical observations, whereas the second stage is associated with a qualitative research approach that is conducted for a deeper understanding of people's opinion and experiences (Love *et al.*, 2002). The current study used a sequential multi-method approach adopting positivism as the primary approach following by the interpretivist approach to provide a better understanding of the research problems.

Research design

Firstly, a literature review was conducted in order to establish a repository of knowledge on the obstacles, drivers and strategies for innovation diffusion, particularly in the Russian Federation construction industry context.

Exploration of the research objectives requires a sequential hybrid-method research design integrating both quantitative and qualitative research approaches (Holt and Goulding, 2014). Some authors have recommended such mixed-method approaches for studying construction innovation diffusion (Love *et al.*, 2002; Panuwatwanich *et al.*, 2008). A quantitative-based questionnaire survey was conducted and statistical analysis was performed to identify barriers to, drivers of and strategies for innovation diffusion. Following this stage, a qualitative approach of data collection consisting of one-on-one in-depth interviews was employed to gain a deeper understanding of the relevant issues and to help to fully contextualise respondents' perceptions on barriers, drivers and strategies. Research findings from both the quantitative and qualitative components of the study were discussed and culminated in a number of important recommendations for enhancing construction innovation in the Russian Federation construction industry. Readers should note that the mixed-method research design was formulated in order to partially compensate for the extreme difficulty in obtaining large samples of respondents in the Russian construction sector.

Quantitative analysis

The primary purpose of the quantitative research consisting of questionnaire survey targeting Russian AEC organisations was to define the significance of the suggested drivers, obstacles and incentive strategies for construction innovation found in the literature. This research phase determined the extent to which different factors influenced the innovation process and what strategies are the most effective to cope with such barriers. This is a common approach to studying problems in the construction management field of study (Stewart *et al.*, 2004; Ozorhon *et al.*, 2010).

The survey was conducted using the data obtained from 52 professionals, representing 19 Russian AEC firms and research institutions. The respondents represented experts from various institutes and companies, from researchers to private and public construction company employees and contractors, including firm directors, project managers and senior managers as well as consultants (architects and design engineers) and manufacturers who were willing to share their experience and opinions.

All items in the questionnaire devoted to the barriers to and drivers of innovation diffusion was measured using a five-point Likert scale ranging from 1 ('not significant') to 5 ('most significant'). The Spearman rank correlation test was also conducted in order to examine the degree of agreement in ranking of the barriers and drivers between two groups of respondent's scores representing the building and civil infrastructure sectors (Mendenhall *et. al.*, 1993; Naoum, 2007).

Qualitative analysis

In addition to the questionnaire, a qualitative survey research was conducted with a selected group of 12 AEC professionals using one-on-one, semi-structured post-hoc interviews. The purpose of these interviews was to reveal in-depth understanding on the reported barriers and strategies and to answer a range of follow-up questions that helped unpack the findings from the questionnaire survey such as: (1) to examine the applicants' views and opinions about the current situation in the Russian construction industry; (2) to describe the significant barriers to innovation diffusion and the government's role; and (3) to identify suitable mechanisms that could be implemented to foster construction innovation in the Russian Federation. Participants were chosen on the basis of their experience and knowledge of the adoption and implementation of innovation and their role in the construction process. The selected interviewees had diverse roles, including directors, managers, designers and researchers.

An interview guide was created to ensure that useful data was collected. All interview transcripts were analysed with the goal to establish consensus on some workable and fit-for-purpose strategies that could be implemented in the country in order to overcome the predominant barriers to innovation diffusion.

Throughout the interviews, a number of themes have emerged. The study used descriptive coding (Blaxter *et al.*, 2010; Miles and Huberman's, 1989) to categorise narrative data. Each interview was transcribed and then the transcripts were coded to classify a large number of individual answers and group them into the relevant common categories. The following codes were developed, based on the key research issues (i.e. barriers (B), drivers (D), strategies (S) and general (G) questions):

- Code B-DEFICIT – Reasons of a funding deficit
- Code B-TENDER_A – Aims of public tenders
- Code B-TENDER_O – Outcomes of public tenders
- Code B-REGULATORY – Current Russian regulatory framework
- Code B-REGIONAL – A lack of local level governance
- Code B-RESEARCH_O – Obstacles to construction innovation R&D
- Code B-RESEARCH_I – Incentives for research institutions
- Code B-FRAGMENT – Fragmentation of the industry
- Code B-INFO – Consequences of a lack of information
- Code D-PILOT – Importance of pilot projects
- Code D-COMPETITION – Competitive advantages
- Code D-RESEARCH – Objectives of research institutions
- Code D-STAFF – Experienced employees or new graduates
- Code S-CAS – "Carrot and stick" approach
- Code S-LEGISLATION – Ways to the legislation development
- Code G-CURRENT – The current situation regarding innovation diffusion in Russia

Results and discussion

Study sample and respondent profiles

The questionnaires were sent by e-mail and 52 completed questionnaires were received in total. This represents an average response rate of 68 per cent, which can be considered high for a voluntary e-mail survey (Saunders *et al.*, 2009, p. 395). Given the scope, the questionnaire was distributed to a random sample of construction experts representing firms which were split into three groups based on their industry sector: (1) building (24 participants); (2) civil infrastructure (28 participants); and (3) research and development sector (4 participants). The respondents represented engineers and builders (28 per cent), architects and designers (14 per cent), directors and managers (39 per cent), manufacturers (11 per cent) and researchers (8 per cent). In addition to completing a questionnaire survey that requested respondents to rate items, 12 selected applicants were asked to take part in a personal semi-structured interview for a deeper study of the relevant issues. The interviewees represented engineers and builders (17 per cent), architects and designers (17 per cent), directors and managers (25 per cent), manufacturers (8 per cent) and researchers (33 per cent).

The Spearman rank correlation coefficient method was employed to measure the differences in ranking and to test the level of agreement between the two groups of respondents representing building and civil infrastructure sectors in order to determine whether there is statistical validity to the findings. The following formula was employed (Mendenhall *et. al.*, 1993):

$$r_s = 1 - \frac{6\sum d^2}{N(N^2-1)} \quad (1)$$

where:

r_s – Spearman rank correlation coefficient;

d_i – the difference in ranking between two groups of respondents;

N – the number of variables, equals to 16 for barriers and 9 for enablers and drivers.

According to Mendenhall *et. al.* (1993), for a given level of significance, the rejection region of null hypothesis (Ho) occurred if *r*s ≥ *r*o or if *r*s ≤-*r*o, where *r*o is the critical value of Spearman's rank correlation coefficient. Using the data from Tables 5 and 6 along with the formula shown in equation (1), the rank correlation coefficient (*r*s) for the barrier and driver variables categories is 0.89 and 0.90, respectively. The critical values of Spearman's rank correlation coefficient at the level of confidence of 95% are 0.429 and 0.600, respectively (Mendenhall et al., 1993). Based on this test, there is agreement between the respondent categories on the ranking of the barriers to and drivers of construction innovation diffusion.

Types of innovative activity

In the first question, participants were asked to indicate the most preferred type of innovative activity in their role. The responses were divided into three groups—processes, technological innovations and organisational innovations, as shown in Table 4.

[Insert Table 4]

Approximately half of the survey participants nominated the *introduction of new materials, technologies, machinery and equipment* as the most preferred type of innovative activity in their role. Representatives of the civil infrastructure sector preferred to use new materials and equipment while those in the building sector favoured the application of new technologies (e.g. advanced software). Tatum (1988) argues that technological innovations are required to increase competitive advantage. This was confirmed by several interviewees, who believed that the implementation and integration of complex computer simulation at all stages of the construction process is a first-priority task. According to them, preference should be given to advancing the current lacklustre implementation of advanced computer modelling approaches such as building information modelling (BIM), which is rapidly replacing simpler CAD design software in most

advanced nations, but has only been used on a few nationally significant projects in the Russian Federation construction industry. BIM was developed in the mid-1990s but architects, engineers, designers and contractors have only commenced using it in recent years. The total number of United States design and construction companies using BIM increased from 28 per cent in 2007 to 49 per cent in 2009 and 71 per cent in 2012 (McGraw-Hill Construction, 2012). In the Russian Federation, BIM is still largely a new concept but is beginning to gain some popularity in a few larger firms (HSE, 2013).

In the building and civil infrastructure sectors, 32 per cent and 23 per cent of respondents, respectively, reported that their companies had launched completely *new processes and design*. This confirms that the building sector is more focused on design processes and their enhancement than the civil sector (Koskela *et al.*, 2002). Slaughter and Shimizu (2000) also stress that large volumes of innovative solutions relate to design. The lowest proportion of applicants (20–23 per cent) pointed to the importance of improvements to *business practices* in the innovation process. Human resource practices, staff training and development, and strategic management were named as the most critical business practices to innovate. This is consistent with findings that organisational processes play a supporting role to technological development and innovation adoption (Hamdani, 2001).

Barriers

Understanding the key barriers to innovation diffusion in the Russian Federation construction industry, as well as the motives for launching new innovations, is essential for identifying the right regulatory and other levers to improve rates of diffusion. The barriers have been grouped into six categories as a result of the literature review: economic conditions (EC); regulations, public policy and supporting mechanisms (RS); research component (RC); availability of information, methods and tools (IM); cooperation (CP); and client and developer understanding (CU). Respondents were asked to rate the significance of a set of listed barriers to adopting new technologies or practices using a five-point Likert scale (Table 5).

[Insert Table 5]

Economic conditions related to *additional investments to innovation* (4.91), *substantial economic risk* (3.98) and, as a result, a funding deficit are perceived to be the most significant obstacles to innovation diffusion. These hindrances influence the building and construction sectors equally. According to the interview respondents, innovative materials are more expensive than traditional materials and also require trained professionals to use them. The main reason of a funding deficit is the high cost of bank loans, insufficient tax privileges and other general economic limitations. The other economic factor "*expectation of short-term profit*" does not seem to be a sufficient barrier to construction innovation diffusion.

In terms of significance, these barriers are followed by a large group of regulative factors, such as *low level of government support for industry development (*4.90), *restrictions imposed by regulations* (4.75), *tendering and procurement* (4.51), hostile *attitude of designers and builders to contracts with fixed prices* (4.59) and *the variety of building codes and standards* (4.07). There is a marked difference in the tender process awarded by the building and civil infrastructure sectors (4.39 and 4.62, respectively). The selection criteria for contracts are also different for the civil infrastructure and the building sectors (4.75 and 4.42, respectively). Government projects for the construction of civil infrastructure such as roads, bridges, railways and so forth, often have unrealistically low budgets and very constrained tender options (i.e. no opportunity to suggest innovative design or construction alternatives) meaning innovation is stifled in this sector (Expert, 2007). The building sector is a little more open with a number of privately tendered projects with sophisticated clients, meaning there is more opportunity to compete using alternative design approaches, materials, etc. instead of competing only on lowest price. According to the respondents' points of view, the main goal of public tenders in the Russian Federation is to accept contractors with prices that are lower than their assigned budget rather than considering the total project cost with variations included as well as the life cycle cost of the infrastructure. This approach to construction procurement often leads to poor quality design (i.e. poor function), materials and equipment being used that deteriorates rapidly and leads to a much higher life cycle cost for the infrastructure or building asset.

The current regulatory framework in Russia is outdated and hinders the development of the construction industry, particularly in terms of innovation development. For instance, there are no essential building standards covering energy efficiency in buildings, although the government is starting to become concerned with this aspect. One interviewee summarized their views on this issue: "*there is practically no system of economic incentives for construction innovation. Justifying the high initial cost of innovation investments and the risk that they will not improve our competitiveness in the market has meant that we do not take the first step. It would seem that the industry needs to be assisted and encouraged to offer more innovative solutions. Presently, there are far too many barriers and an incredible amount of complicated approvals [involved in] when justifying the use of innovative alternatives to our mainly conservative government clients*".

The barrier *regional features in both the technical and legal aspects* also received a relatively high score (3.41). One respondent commented that there is a lack of proper legislation to encourage innovation and an overcentralisation of all issues, even for pilot projects to trial new construction innovation. The interviewee suggested that a significant proportion of building and construction regulations currently governed by the Federal government should be transferred to the municipal level in order to accelerate approval processes.

Equally important is the need to stimulate not only those who introduce the new technologies but also those who discover and develop them. Hence, a score between 3 and 5 points was frequently given to barriers

related to research and development (R&D). The rates are approximately the same for the entire AEC industry: *limited funding for innovation research* (4.45); *lack of established processes to take innovations from research laboratories to testing in an operational environment* (3.51); and *fragile contracts between scientific research institutes and the construction industry* (2.73). According to the National Russian Statistics (FSSS, 2014), the country's domestic expenditure on R&D was 699.87 billion rubles (20.36 billion USD at July 2014) in 2012. Almost three-quarters of the total amount was concentrated in three sectors: engineering and metalworking (43.6 per cent), chemical and petrochemical (16.1 per cent) and fuel (14.8 per cent). Construction R&D amounted to only 1.2 per cent of the total budget. This problem is not specific for Russia. Percentages of Gross domestic expenditure on R&D (GERD) are not high in other countries as well: Australia (2.4%), Germany (2.8%), and the USA (2.9%) (Hampson *et al.*, 2014). However, as previously mentioned, in the uncertain years following the collapse of the USSR, research was poorly funded. Although, in more recent years the government has attempted to invest more money into the construction research sector, outcomes from research activity have not yet shown any significant signs of recovery.

To study this aspect in greater detail, interviews were conducted with eight representatives of the construction and manufacturing sectors and four experts from university research centres. Three key messages about construction innovation R&D were evident from the interviews:

1) Ten out of 12 respondents mentioned that as a client, the government allocates some material resources for research at the local level. However, these resources do not allow for the funding of advanced R&D or the subsequent implementation of findings into the manufacturing and construction process.
2) Seven out of 12 interviews pointed out that today, R&D and innovation diffusion relies on the personal contribution of an author (scientist) in order to turn good ideas into a viable product, who expects to receive some sort of incentive to participate in the commercialisation process. The current university and research system in the Russian Federation is not sufficiently flexible to provide incentives for star researchers to commercialise and profit from their research. Good research ideas are often funded and commercialised outside of Russia.
3) Seven out of 12 respondents mentioned that Russian scientists and engineers in government-owned research institutes and universities receive a much lower level of income compared to those people employed in multi-national innovation companies or advanced country research institutions meaning that many of the best people have left the sector and only the lower skilled and less motivated researchers remain.

These three reasons for a lack of innovation diffusion are reflected in the literature (Hall *et al.*, 2001; Bruneela *et al.*, 2010; Australian Government Productivity Commission, 2007). Another significant barrier is *non-effective cooperation between all members of the construction process* (3.79). Between 2000 and 2011,

the number of construction companies in Russia grew by 60%, from 129,340 to 209,185 (FSSS, 2014). The Russian construction market is extremely fragmented. This fragmentation significantly hinders the promotion and diffusion of new technologies and solutions. The interviewees identified that confined project briefs, regulatory hurdles and lean design budgets meant there was little potential for architects and engineers to spend a lot of time exploring innovative solutions such as incorporating advanced materials and/or applying innovative technologies into their projects. According to the interviewees, designers tend not to apply new solutions to typical projects without adequate regulatory and technical support, as deriving these new solutions often involves high technical expertise and project delivery risk. This barrier is closely connected with the problems of industry governance, which reconfirms the need to improve existing legislation, particularly in the civil infrastructure sector of the industry.

Another obstacle that cannot be ignored is the *lack of necessary information and modern technologies* (3.40). According to the experts, there are many uncertified products on the market, which makes participants in the construction process cautious about adopting innovations. *Fear of innovation implementation* also received a high rating: 3.39 and 3.95 points for the civil infrastructure sector and the building sector, respectively. As mentioned in the literature review, disadvantages of new solutions and technologies may only become evident after the infrastructure asset has been operated for some time. Therefore, builders are extremely cautious about selecting new materials and/or construction methods. This factor reflects the *lack of demand and willingness of clients and developers* (3.39). It was also suggested that municipal authorities should reinforce their role in providing comprehensive information about industrial innovations. The fear of innovation implementation is more significant for building construction because of the high level of responsibility borne by all members of the construction process. Design errors caused by the use of inappropriate technology can jeopardise multiple lives if a building fails.

Enablers and drivers

The enablers were grouped into three categories on the basis of the literature review: (1) external pressure and support (EP); (2) knowledge exchange (KE); and (3) technological and technical capability (TC). Respondents were required to rate the significance level of various factors that motivate Russian construction firms to innovate using a five-point scale (Table 6). As was mentioned above, most of these factors can act as a driver of motivation and a barrier to innovation diffusion at the same time.

[Insert Table 6]

Motives for innovation implementation are similar among the firms operating in the building and civil infrastructure sectors of the industry. The results show that the dominant factor is government support, such as grants, funds and subsidies. Nevertheless, market demand, competitive pressure, R&D cooperation and

information gathering are close behind. This confirms that an external force is always required to assist in the process of innovation diffusion. However, *prescriptive regulations* that oblige companies to build according to standards are not perceived as a substantial driver of innovation (2.46). Many companies in the industry simply follow the strict conservative building and construction standards of the Russian Federation and do not attempt to improve the construction process using innovation approaches. These findings align with those above exploring barriers to innovation diffusion. Current legislation requires further development and remains one of the most serious obstacles to innovation diffusion.

As shown in Tables 5 and 6, the standard deviation values for the entire sample ranges from 0.30 to 0.80. This range suggests that there is reasonably close agreement in the ratings given by the representatives of the construction sector.

Almost 90 per cent of respondents rated *financial public support* as the most significant enabler (4.88). If innovations were demanded by government, it is expected that they would be financially supported for further development. As mentioned previously, the Russian government has recently begun to fund pilot projects and has created some regulations to stimulate innovative firms to use modern technologies and solutions in order to more rapidly advance the national construction industry. According to the interviewed respondents, sustainable public funding of pilot projects promotes the economic interest of organisations without forcing them to wait for short-term economic benefits. Hence, municipal authorities and other participants in the construction process—such as clients, research and scientific institutes, designers and contractors—are interested in large-scale rapid innovation implementation.

In terms of ranking, *financial public support* is followed by the desire of construction firms to work in a *competitive environment* (4.86). It has been theoretically justified and empirically confirmed that competition is a key incentive to innovativeness (Mitropoulos and Tatum, 2000; Sayfullina, 2010). It encourages businesses to preserve their existing strengths and to engage in a variety of improvements to gain additional income. According to Drucker (2007), innovative activity is a special tool that allows the entrepreneur to use the innovations and turn them into new opportunities. Developers are forced to look for ways to reduce production costs and expand into new markets. Companies that pioneer cost-effective innovations receive a significant advantage over their competitors. However, for small businesses, competition can be a serious problem. According to the respondents' opinions, not all firms are able to cope with competitors offering new products and services, and this reduces the internal incentives to innovate.

An organisation's ability to adopt external innovations and apply them successfully depends on its related prior *information gathering* (4.67). In many firms, managers monitor and share information about new market demands, innovation technologies, materials and products. It is common practice among commercial companies in the industry to adapt new knowledge to practical fields with the assistance of consultants.

Several respondents (16 per cent) mentioned that small and medium-sized enterprises (SMEs) experienced difficulties in being innovative by themselves. Consequently, the only opportunity for these enterprises to innovate involved cooperating with innovative partners through joint ventures with international construction firms.

As discussed above, contracts between scientific research institutes and construction firms are strong overall but remain insufficient considering the problem of limited research funding. Hence, *coordination with universities and scientific research institutes* was rated at 4.58. These interactions are realised through participation in various conferences on construction innovation as well as via the assistance of scientists and researchers, and, as a result, the transfer of innovative laboratory ideas to the practical environment. According to the opinions of the interviewed experts, the main objectives of research centres and universities dealing with innovation are: the development of new materials; the modernisation of materials by improving their quality and reducing costs; technological design; the development of new processes, technologies and software; and the adaptation of foreign technologies. These findings were indicated by a number of authors (Bruneela *et al.*, 2010; D'Este and Patel, 2007; Hall *et al.*, 2001).

There is a noticeable difference in the ratings of the next external factor, a *demanding market* (i.e. 4.27 among the respondents from the civil infrastructure compared to 4.67 for building-sector respondents). This finding reflects the role of end-users in influencing innovation implementation. Gann (2000) states that all the participants in the construction process should work together to fulfil users' needs. It is obvious that end-users have a much greater influence on the construction of residential housing, especially private luxury housing, than on the construction of public infrastructure such as roads and bridges.

The *participation of personnel* factor was accorded a high score (4.36). Despite the industry having been criticised for its lack of professionals and imperfect educational system, this strategy remains effective for innovation diffusion. Interviewed respondents indicated that it is more effective to hire experienced employees but new graduates are usually more flexible and willing to as adopt new innovations and tended to be more advanced in their use of modern IT programs and methods. Training procedures are vital for innovation improvements and enhancing technical capabilities.

The factor *access to modern technologies, practices and solutions* (4.20) complements and helps to coordinate the other enablers, such as information gathering and R&D cooperation. Advances might be adopted from external sources or introduced as the outcome of scientific work. This fact supports the literature-review findings that technical and technological development is a result of internal facilities as well as openness towards information and knowledge exchange (Caloghirou *et al.*, 2004).

According to the findings that *cooperation between all members of the construction process* is a significant barrier, there is evidence to suggest that this factor is non-effective as a driver of innovation implementation (3.09). However, it was accorded a relatively high score by respondents. All participants in the innovation process have different but complementary roles: clients demand particular materials and products as well as stimulating other participants to introduce new solutions; manufacturers and suppliers produce these products; and architects and designers consult contractors and coordinate the project using innovative ideas.

Supportive strategies

Respondents were asked the question, "Do you believe that the government is obliged to promote innovation development in the construction industry?" The majority of respondents agreed that government should participate in processes of innovation implementation through regulatory and financial arrangements as well as incentive mechanisms. Some experts indicated that government intervention would help to destroy not only the organisational and administrative barriers to innovation diffusion, but also the existing prejudices and stereotypes that hinder innovative ideas in construction. The government should generate greater innovation development and stimulate companies' interest and eventual economic growth. However, according to one respondent, the process of innovation development should be an evolutionary trend without government participation. This viewpoint is reflected in recent research by the Higher School of Economics (HSE, 2013).

Respondents were asked to choose the most effective strategy that could be implemented by the government to support innovation diffusion. A list of possible methods was created according to the literature review and the fact that the Russian construction industry requires real changes in public policy and legislation. The preferred strategies in ranked order according to the respondents are as follows:

1. Improved legislation (20%)
2. Improvement in the quality of higher education (15%)
3. Promotion of non-traditional forms of construction procurement (15%)
4. Support of R&D by scientific research institutes (14%)
5. Support for the transfer of R&D results into practice (11%)
6. Direct budget subsidies (11%)
7. Tax incentives (7%)
8. Funding of pilot projects (7%).

One-quarter of respondents nominated financial incentives and fiscal arrangements as the most significant aspects of public policy. It should be noted that public policy and support for construction innovation may be diverse. They include direct budget subsidies (11 per cent), which are the most costly incentive mechanisms to enable the relevant criteria in the tender documentation. They also include taxation support and grants for

successful pilot projects (both 7 per cent). The creation of appropriate fiscal measures would increase the attractiveness of investments and allow firms to compete despite the additional construction costs.

Survey respondents cited the improvement of regulations, standards and legislation (20 per cent) as the most effective strategy. Regulations, standards and legislation represent the most serious obstacles to innovation in the Russian construction industry. Moreover, according to the interviewees, it is necessary to develop legislation related to copyright and intellectual property protections. This would be especially important for authors of cutting-edge ideas as satisfactory payment rates would stimulate industrial and business implementation of innovations. This finding is consistent with other studies (Ozorhon *et al.*, 2010; CPWR, 2012).

One of the experts stressed that the main government strategy should be a “carrot and stick” approach, with the “stick” being the systematic advancement of building codes and standards, and the “carrot” being the subsidisation of construction innovation (Hansen, 2013; Thomas and Forney, 2011). European building regulations have been enhanced dramatically over the last few decades, resulting in the mass introduction of innovative technologies in construction (HSE, 2013). The Russian government plans to gradually strengthen its regulations for energy efficiency. Every five years, beginning in 2011, the rules will be tightened by 15 per cent (HSE, 2013). Some respondents were asked to share their opinions about this strategy in the context of the Russian Federation. Most experts believe that this method is extremely effective. The “stick” is required for innovation implementation and improvement of the quality and operational characteristics of construction processes while the “carrot” may assist the development of R&D.

It is important to revise legislatively the government’s role in the system of relations described as innovation–government–business–users. The government should stop being a general client of innovation products, passing the relevant authority and ability to market players. Fifteen per cent of experts emphasised the need to change the traditional forms of procurement. Effective models of partnership between state and private businesses have existed in developed countries for some time, particularly in the construction of facilities such as roads with free-of-charge operation. According to Deloitte (2006), there are three distinct stages of PPP maturity across the world. The Russian Federation occupies the third initial stage along with Brazil, Finland and other countries. In comparison, other countries have higher PPP maturity such as the USA, Canada and France (second stage) and Australia and the UK (first stage).These partnerships are based on various forms of PPP. The concession is one of the most common practices adopted under conditions of the free operation of roads in accordance with the legislation. In addition, this form of procurement may solve the problem of economic incentives within construction firms involved in projects aimed at improving the quality of work and innovation. Solving this problem is achieved through offering long-term contracts that motivate contractors to consider the life-cycle stages of a project in order to reduce its overall

maintenance budget through the construction of a more resilient infrastructure asset in the first place (Leiringer, 2006; Li and Akintoye, 2003).

Another quarter of applicants considered that one of the government's main goals is the improvement of the research sector and its integration with the industry via the support of R&D and scientific research institutes as well as support for the transfer of R&D results into practice (14 per cent and 11 per cent, respectively). As mentioned previously, it is necessary to stimulate not only those who implement new technologies and products, but also those who introduce and develop them. This need is now being recognised actively. Russia's federal budget for 2010–2015 includes 37 billion rubles (1.08 billion USD at July 2014) to support scientific research in the field of innovation (RG, 2014).

The final measure is education and knowledge management. Fifteen percent of respondents selected the "improvement of the quality of higher education" as the key strategy. There is a correlation between specialists who have been taught from a base of cutting-edge sources and technologies, and successful implementation of innovative solutions, technologies and processes (INFOLine, 2013). Users' general knowledge about these sources and technologies should also be increased (RG, 2014).

The opinions of interviewees varied with regard to the final question, addressing the current situation regarding innovation diffusion in the Russian Federation. The majority of respondents indicated that new materials and technologies are being introduced only very slowly because of the many barriers and obstacles mentioned above. The initial investment required to introduce innovations is extremely high, considering the uncertain results. Although these investments should be made, the innovations are largely experimental at present. In addition, there is no proper system of incentives and encouragement for all participants in the construction process. Nevertheless, positive support was received from several experts. Overall, there is a strong need to advance the Russian construction industry, but there are pockets of highly progressive construction practice such as those applied on the Winter Olympic Games facilities in Sochi and the Summer Universiade facilities in Kazan. There are many Russian clients, design institutes and construction companies who have had the courage to implement new technological advances. The majority of developers are becoming more responsible for the selection of materials used in their projects. There is a variety of training courses and seminars available to inform distributors and architects. Consequently, the process of innovation diffusion in the Russian construction industry has begun to change for the better in recent years.

Recommendations

Based on the questionnaire-survey and interviews results, it can be concluded that there are no real technical barriers to innovation diffusion in the Russian construction industry. Rather, the hindrances are political,

economic and social. The recommended measures to overcome the identified obstacles are detailed in Table 7.

[Insert Table 7]

Financial and economic problems are significant barriers to the uptake of innovative solutions and technologies in the Russian Federation construction industry. Consequently, there is a need for government intervention to create effective measures to allow construction firms to deal with extra construction costs, lack of R&D funding and economic risk. The primary goal of a public policy is to stimulate the diffusion of innovative solutions among all actors in the construction industry (Blayse and Manley, 2004; Expert, 2007). This not only removes the obstacle of the additional cost of innovation but ultimately stimulates interest in increasing investment in R&D and saving resources (energy, material, labour and time). The first step is to work out the best way to focus incentives to ensure outcomes are achieved. Support should initially be focused on certain industry sub-sectors that show the most potential or concentrated on certain limited regions of the country. Models and mechanisms of government support for innovation should be customisable to the various industry sub-sectors (see Table 7). Ideally locally developed innovative construction components and materials should be promoted, rather than blind technology transfer from advanced economies (HSE, 2013; TASS, 2014).

The Russian Federation government, at both the national and provisional levels, plays a crucial role in overcoming the barriers to innovation diffusion. A number of changes are required to facilitate the promotion of construction advances. Russian building codes need to be harmonised with Eurocodes, which represent an alternative system of building codes that has already been translated into Russian. National annexes to every Eurocode have been developed. International constructors have the opportunity to design and build construction facilities in accordance with the Eurocodes on Russian territory today (HSE, 2013). However, such codes are only implemented on very significant Russian projects usually involving joint ventures with international contracting firms, with the majority of buildings and civil infrastructure still being constructed using very prescriptive and conservative Russian building codes.

A worldwide certification process exists but it takes a long time in Russia. It is necessary to change the process, and introduce additional criteria in order to stimulate the market launch of innovative products. The current criteria do not stimulate the diffusion of innovation in the market. For instance, according to the current system, an innovative product with outstanding features receives exactly the same certificate as an outdated product with inferior characteristics.

Government influence is significant not only in the legislative and regulatory areas. In particular, state programmes for international sporting and political events, such as the Asia–Pacific Economic Cooperation

(APEC) forum in Vladivostok, the Summer Universiade in Kazan and the Sochi Olympic Games actively promote the introduction and diffusion of advanced technologies and materials. In preparation for events such as these, Russian AEC professionals are coerced into adopting international standards to avoid losing face in front of international colleagues.

Currently, the emphasis on reducing construction costs occurs with the state order. Obviously, this phenomenon distorts the market. Developers on *fixed-price contracts* use the cheapest construction solutions without considering their operational properties in order to meet the rigid state construction budgets. At the same time, the operating costs for the life cycle of buildings, roads and so forth are several times higher than the construction costs. When making construction decisions, the government should give priority to contractors and operators demonstrating innovation development. Some Russian laws, such as the “Law on the federal contracting system” and the “Law on the public–private partnership”, introduce the concept of the life cycle of buildings, roads and so forth. This concept should result in a change of pricing principles for construction by taking into account the subsequent operation of construction facilities (HSE, 2013).

Eventually, improvements to the innovation process could be developed not only by building standards and regulations, but also by means of effective relationships between all participants in the construction process. A greater level of cooperation between the government, designers, developers, contractors, researchers, local authorities and training providers is essential to overcome barriers such as the risks and uncertainties of using innovative ideas. It is extremely important to develop the competence of designers as the link between developers and the building materials industry. This could be achieved by improving professional education in the field of construction innovation.

Clients’ and developers’ inflexibility and resistance to the adoption of innovative ideas, techniques and products seems to be a significant hindrance to innovation development. The government needs to gain knowledge and experience as well as to develop the availability of appropriate information and tools to adopt advanced practices in construction innovation. This could be achieved by increasing investment in training to enable access to high-quality learning resources. All members of the construction community should be aware of national energy-efficiency programmes as well as the environmental and economic benefits of innovation implementation during the design, construction and operation stages. The government should also stimulate demand for innovation implementation by engaging contractors with public pilot projects.

Altogether, the formulated recommendations could stimulate and encourage all members of the construction process to implement new ideas and solutions to improve the industry’s innovativeness.

Conclusion

The paper represents the findings from the initial stage of an ongoing research study concerned with designing an innovation diffusion framework for the Russian Federation construction industry. Given that there has been limited research focus on construction innovation in the Russian Federation, this study provides some useful insights into such innovation barriers and Russian construction professionals' perceptions on measures that the government can implement to improve innovation take-up in the industry. Despite the relatively low sample size of respondents, the overarching research findings complemented those presented in similar studies conducted in other countries (Blayse and Manley, 2004; NAHB, 2004; Expert, 2007; Panuwatwanich *et al*., 2008, 2009a,2009b; HSE, 2013).

Based on the literature review and research findings, it is can be concluded that problems related to innovation that the Russian construction industry faces today are partly rooted in its history in spite of the past achievements of Russian scientists and engineers. Generally, the main problem related to innovation diffusion in the Russian construction industry today is the inability of the government to build up an institutional, regulatory and legislative framework that would encourage construction firms to innovate. Deficit of funds, high economic risk and the lack of research support were also identified as significant obstacles to construction innovation diffusion. According to the respondents, a lack of awareness, availability of tools, and client and contractor understanding, as well as the fragmented nature of the construction industry, has an average rate of influence. Nevertheless, they remain relevant to the question of how to improve innovation diffusion.

Although there are many barriers hindering the diffusion of innovation within the Russian construction industry, a number of factors can positively influence the innovation process and drive firms' successful adoption of innovative technological advancements. The most significant factors are external such as government support including grants, funds and subsidies and also maintaining a healthy level of industry competitiveness. These enablers are followed by R&D collaboration, information and knowledge gathering, and market demand. The survey results suggest that construction firms and the industry in general require assistance and support from government to overcome existing barriers and obstacles. There is practically no system of economic innovation incentives in the Russian construction industry; hence, it is necessary to improve the situation through fiscal and economic arrangements. Consequently, legislative and regulatory government pressure on the construction industry in general is extremely important to promote new materials and implement innovative technologies through major public projects, such as the Summer Universiade and the Olympic Games.

The reported findings should be interpreted in light of several research limitations such as the difficulty in soliciting responses from industry professionals and government officers in the Russian construction

industry. First, the number of respondents was relatively low for detailed statistical analysis. The survey included only large firms operating in the central regions of the Russian Federation. To enhance the generalizability of findings, further research is required to extend the geographical coverage of the findings to involve participants from across the entire construction supply chain. There is also a need to investigate the interaction between the identified barriers to innovation diffusion in the construction industry and the effect of supportive strategies in order to improve the explanatory power of the results. Further research is important because there is an obvious need for Russian enterprises, companies and scientific institutes to have a much more supportive environment for embracing technological and managerial innovations that are becoming normal practice in advanced economies.

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List of tables

Table 1 Barriers to innovation diffusion in the Russian Federation construction industry

Barrier category	Barrier	Reference	Definition/comments
Economic conditions	High construction cost	Hydes and Creech, 2000; HSE, 2013; Miozzo and Dewick, 2004; Stewart and Mohamed, 2000, 2002	The nature of additional investments may come from price increases on new materials, use of technologies, consultants' fees and high expenses for the professional development of the contractors, managers and design team.
	Substantial economic risk	Denisov and Kamenetskiy, 2003; Loosemore, 2014; Miozzo and Dewick, 2004; Slaughter, 1998; Taipale, 2010	The reasons for the risk are lack of existing information, adoption of unfamiliar techniques and ideas, lack of government and manufacturer support, lack of experience and uncertainty of the success of the construction process.
	Expectation of short-term profit	Budworth, 1996; Grigoryev, 2011	A large number of investors and owners of construction companies focus only on how much profit they will obtain; as a result, expenditure on innovation is reducing in favour of the use of traditional, well-recognised methods.
	Restrictions imposed by regulations	Blayse and Manley, 2004; Bowley, 1966; Ling, 2003	These regulations include building codes and certificate schemes.
Regulations, public policy and supporting mechanisms	Tendering and procurement	de Valence, 2011	The building and construction industry is different from many other industries, where firms compete via marketing campaigns and new products. The use of tenders and project procurement might be a serious obstacle to innovation implementation in the construction industry because the traditional tendering process for building works usually does not encourage widespread design innovation.
	Administrative barriers	National Association of Home Builders (NAHB), 2004	Administrative barriers include the variety of building codes and standards as well as the regional features of both technical and legal aspects; low levels of government support for industry development; the often hostile attitude of designers and builders to the tender process; and government contracts with inflexible fixed budgets.
Research and development collaboration		NAHB, 2004	The research component includes fragile contracts between university research centres and the construction industry, limited funding for innovation research and the lack of established schemes for commercialising research.
Availability of information, methods and tools		Grigoryev, 2011; Veshosky, 1998; Stewart *et al.*, 2004	The design team and project managers need to have access to the best available information on technologies and tools in order to introduce the innovation in the stages of design and construction. A lack of information and modern technologies, such as automatic calculation procedures, is a serious obstacle to effective cooperation between all the actors involved in the construction process. Further, access to up-to-date tools is required for optimal operational process during a building's life cycle.
Cooperation between all construction process stakeholders	Fragmentation of the industry	Davidson, 2013; HSE, 2013; Nam and Tatum, 1992; Pries and Janzen, 1995; Stewart and Mohamed, 2000, 2002	The innovation process requires close interaction between professionals, suppliers and users. However, in reality, designers, contractors and consultants are isolated from each other. By setting developing goals, public building processes may initiate private design and construction companies into modern methodologies.
	Disinterest of designers and architects		Architects and designers should be the link between developers and the building materials industry by including advanced materials and innovative technologies in their projects. However, designers tend not to take risks without sufficient legal and technical support.
Client and developer understanding	Demand and willingness of clients and	Gumba, 2009; Ivory, 2005	As clients, government and local authorities significantly affect the use of new materials, technologies and methods, in contrast to the private sector. However, a private client may also suppress

	developers		innovation, in the case of public and residential construction, because the client has to bear all the risk of the innovation while the users reap the benefits.
	Fear of innovation implementation	Ivory, 2005; Nam and Tatum, 1992	The most common fear is a risk of defects in the future; obviously, clients want to avoid any risk associated with innovations. Technologies that appear infallible initially may show defects during the long-term operation of buildings, roads, bridges and other structures.

Table 2 Innovation diffusion drivers in the Russian Federation construction industry

Driver category	Driver	Reference	Definition/comments
External pressure and support	Market environment	Mitropoulos and Tatum, 2000; Nam and Tatum, 1992; Sayfullina, 2010; Stewart, 2007	It was found that innovations were implemented because of market demand. The capturing of competitive advantage is one of the factors forcing innovation adoption.
	Regulations	Gann *et al*., 1998; HSE, 2013; Mitropoulos and Tatum, 2000	Regulations can affect innovation implementation in two ways: by forcing companies to innovate through detailed specifications and strict standards as well as by urging progressive innovators in a certain direction through public support, awards, subsidies and grants.
Knowledge exchange	Information gathering	Kangari and Miyatake, 1997; Veshosky, 1998	Many studies recognise information and knowledge sharing as an effective motivating factor for innovation implementation. Consequently, there is a need for innovation both within and between companies.
	Cooperation between participants of the construction process	Barlow, 2000; Gumba, 2009; Mitropoulos and Tatum, 2000; Nam and Tatum, 1992; Tatum, 1989	Cooperation is an effective enabler of the innovation process because it allows all involved participants to share the project risks and benefits. For innovation stimulation, construction firms depend on suppliers of innovative materials and tools as well as clients who involve themselves in the construction project.
	Personnel participation	Barlow, 2000; Bowen and Thomas, 2004; Dulaimi *et al*., 2002; Love *et al*., 2002	Many authors highlight the importance of personnel participation in all firm-level innovation processes, as well as the need to hire new specialists and graduates. The innovation process requires experts who are capable of and willing to implement effective innovations. Firms should create conditions that encourage personnel to experiment with new ideas.
	Coordination with universities and scientific research institutes	D'Este and Patel, 2007; Nam and Tatum, 1992	Research and development (R&D) is an important factor, because many new materials and technologies are introduced as the result of long-term research and new product development.
Technological and technical capability		Caloghirou *et al*., 2004; Gumba, 2009; Miozzo and Dewick, 2004; Nam and Tatum, 1992; Stewart *et al.*, 2004; Tatum, 1989	This category represents the technical and technological capabilities of a firm that enable the industry to implement innovative products, solutions, technologies and processes as well as quickly adapt to new opportunities. The introduction of new materials, technologies and processes is an important instrument and the main technical driver of innovation. Continuous integrated R&D efforts are required for effective implementation of technology-using strategies.

Table 3 Supportive public policy strategies for construction innovation

Strategy	Reference	Definition/comments
Financial incentives, fiscal arrangements and economic methods	Blayse and Manley, 2004; Gokhberg *et al.*, 2001; Mitropoulos and Tatum, 2000; NAHB, 2004; Stewart *et al.*, 2004	These strategies are perceived as the most effective in overcoming the fear of extra construction costs, which is a significant obstacle to innovation implementation. Additional costs could be borne with the assistance of economic arrangements such as grants, awards, funds and taxation. In particular, public financial stimulating mechanisms need to be further reinforced in the Russian Federation. Many Russian pilot projects, such as "Innovation road" and "Green building", aim to improve innovation implementation and the development of new technologies, processes and solutions related to energy efficiency and ecological compatibility. These programmes are based on the fact that it is (four times) more profitable to save than to invest in new energy capacity. However, the procedure for grants access needs to be facilitated because many participants are small in comparison with champions in the construction industry; their access to information resources regarding subsidies and awards is limited.
Non-traditional forms of procurement	de Valence, 2011; Leiringer, 2006; Li and Akintoye, 2003	By avoiding traditional forms of procurement, a client has the opportunity to encourage innovative solutions. These might include public–private-sector partnerships (PPPs) and other concession projects, and build and maintain (B&M) contracts where the maintenance costs of the facility are important factors in design decisions. These forms transfer back to the government at the end of the contract and eventually create the industry alliances that significantly influence the marketplace.
Knowledge and education management	Barlow, 2000; Bowen and Thomas, 2004; Gokhberg *et al.*, 2001; Stewart, 2007; Stewart and Mohamed, 2000	Imperfect education and knowledge management is one of the reasons why the construction industry has long been criticised for its conservatism. There are several serious problems in Russia related to the training of specialists engaged in the design process, construction and manufacturing. Hence, government should support the development of educational programmes aimed at contractors, designers, manufacturers, consultants and end users for further diffusion of innovative ideas and solutions.
Integration between the industry and research sector	Hall *et al.* 2001; Nam and Tatum 1992; Ramstad 2009; Rynes *et al.* 2001	Public support is required for integration and collaboration between scientific research institutes and the architecture, engineering and construction sector as well as the manufacturers of building materials. Further, strong cooperation with research centres is necessary for testing and evaluating research results and new solutions to problems impeding further progress.

Table 4 Categories of innovation activity

Category of innovation activity	Percentage (%)		
	Building sector	Civil infrastructure sector	Overall
Introduction of new design and construction processes	32	23	25
Introduction of new materials, technologies, machinery and equipment	45	57	52
Introduction of new business practices	23	20	23
Total	100	100	100

Table 5 Ranking of barriers to innovation diffusion

Rank	Barrier	Category	Mean significance			Standard deviation		
			Overall sample	Civil infrastructure sector	Building sector	Overall sample	Civil infrastructure sector	Building sector
1	High construction cost (funding deficit)	EC	4.91	4.92	4.90	0.32	0.33	0.30
2	Low level of government support for industry development	RS	4.90	4.89	4.90	0.32	0.31	0.33
3	Restrictions imposed by regulations	RS	4.75	4.72	4.78	0.50	0.47	0.52
4	Hostile attitude of designers and builders to contracts with fixed prices	RS	4.59	4.75	4.42	0.60	0.52	0.68
5	Tendering and procurement	RS	4.51	4.62	4.39	0.58	0.56	0.60
6	Limited funding for innovation research	RC	4.45	4.48	4.42	0.71	0.68	0.73
7	The variety of building codes and standards	RS	4.07	4.05	4.09	0.74	0.75	0.72
8	Substantial economic risk	EC	3.98	3.98	3.99	0.65	0.62	0.68
9	Non-effective cooperation between all members of the construction process	CP	3.79	4.15	3.42	0.75	0.76	0.75
10	Fear of innovation implementation	CU	3.67	3.39	3.95	0.57	0.50	0.63
11	Lack of established promotion schemes for new technologies from research laboratories to testing in an operational environment	RC	3.51	3.59	3.43	0.70	0.71	0.69
12	Regional features in both the technical and legal aspects	RS	3.41	3.42	3.39	0.62	0.60	0.64
13	Lack of necessary information and modern technologies	IM	3.40	3.36	3.46	0.70	0.73	0.66
14	Lack of demand and willingness of clients and developers	CU	3.39	3.47	3.31	0.65	0.66	0.63
15	Expectation of short-term profit	EC	2.91	2.89	2.93	0.66	0.65	0.67
16	Fragile contracts between university research centres and the construction industry	RC	2.73	2.76	2.69	0.65	0.63	0.66

Table 6 Ranking of enablers and motivating factors

Rank	Enabler / motivating factor	Category	Mean significance			Standard deviation		
			Overall sample	Civil infrastructure sector	Building sector	Overall sample	Civil infrastructure sector	Building sector
1	Public support through subsidies and grants	EP	4.88	4.89	4.87	0.40	0.41	0.38
2	Competitive pressure	EP	4.86	4.88	4.85	0.34	0.32	0.35
3	Information gathering	KE	4.67	4.71	4.63	0.50	0.47	0.52
4	Coordination with universities and scientific research institutes	KE	4.58	4.55	4.61	0.56	0.57	0.54
5	Demanding market	EP	4.47	4.27	4.67	0.58	0.56	0.59
6	Personnel participation	KE	4.36	4.28	4.44	0.58	0.60	0.56
7	Access to modern technologies, practices and solutions	TC	4.20	4.16	4.25	0.62	0.63	0.62
8	Cooperation between participants of the construction process	KE	3.09	3.09	3.10	0.56	0.55	0.57
9	Strict standards and regulations	EP	2.46	2.48	2.45	0.54	0.55	0.54

Table 7 Recommended measures for overcoming barriers to innovation diffusion

Barrier	Category	Strategy
High construction costs (funding deficit)	EC	• Economic incentives support: – federal targeted programmes – funding through the scientific and technological departments – direct financial investments – foundation of clusters, including special economic zones – investment preferences associated with the purchase of technological equipment – fiscal incentives • Stimulation of demand for innovative local manufacturing components and products
Substantial economic risk	EC	
Expectation of short-term profit	EC	
Limited funding for innovation research	RC	
Low level of government support for industry development	RS	
Restrictions imposed by regulations	RS	• Improvement of legislation: – harmonisation of Russian building codes with Eurocodes – development of new building standards and improvement of technical regulations regarding the use of advanced technologies and materials – legislative support for scientific research institutes – introduction of responsibility for construction quality – improvement of the certification process • State programme for world-class sporting and political events
The variety of building codes and standards	RS	
Regional features in both the technical and legal aspects	RS	
Fragile contracts between university research centres and the construction industry	RC	
Lack of established promotion schemes for innovations from research laboratories to testing in an operational environment	RC	
Hostile attitude of designers and builders to contracts with fixed prices	RS	• Non-traditional forms of procurement
Tendering and procurement	RS	
Non-effective cooperation between all members of the construction process	CP	• Development of teamwork and competence of designers • Professional education
Fear of innovation implementation	CU	
Lack of demand and willingness of clients and developers	CU	• Development of availability to work with appropriate information and tools • Engagement with public pilot projects
Lack of all necessary information and modern technologies	IM	