To innovate or not to innovate: A Russian case of the construction industry

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Abstract. *There are several primary factors that influence or force decision-makers at construction companies to acknowledge innovation implementation as a priority process to improve the efficiency and effectiveness of the industry. First of all, there is a need to create an environment where innovative organisations have a successful access to innovative technologies and are able to maintain high-tech business. In other words, innovations have to be attractive. To improve construction innovation performance and overcome the excessive conservatism, the study attempts to define what policy recommendations and various innovation planning strategies the Russian government, industry and universities should implement to achieve robust development of the construction industry over time. The problem of poor innovation performance in construction should be seen in light of the industry complexity and the inherent dynamics of the construction innovation diffusion. A holistic modelling procedure was applied to investigate the problem of the low level of innovative activity in the construction industry from a system of innovation perspective. The chosen research approach aims to support the understanding of the multi-dimensional construction innovation process by actively involving stakeholders.*

Keywords: *construction innovation diffusion, innovation system, stakeholder engagement, participatory modelling, attractiveness of being innovative.*

1. Introduction

The construction sector plays a key role in any country's economy. By 2017, the construction industry was estimated to contribute about 5.6% of the Russian GDP. The government is planning to increase the share to 6.8% by 2030 (RSCI, 2017). However, the innovation implementation process in the construction industry is extremely slow. Technological weakness and outdated processes are forcing national companies to stay behind foreign competitors.

Russian market is not well-presented in the world markets of science-intensive construction products. One of the reasons is a significant gap between the creation of theoretical foundations of technology within R&D and their absorption and application in mass production. Consequently, the stronger interaction of the scientific and industrial organisations is needed in order to fill the gap, keep pace with innovation, and support continuous functioning of the innovation system under high uncertainty. Given the nature of the country under study, it is the government's mission to make the industry and research institutions collaborate in the innovation process by supporting funding aspects and incentive mechanisms that influence innovation output in a dynamic way.

The motivation for this research is to investigate potential innovation planning strategies under uncertain situational context scenarios. Moreover, the analysis should be done holistically, considering a nonlinear nature of the innovation process and importance of interrelationships among diverse components of the innovation system. In other words, it is very important to promote common interests of all system's actors in order to improve innovation performance (Gann and Salter, 2000; Malerba, 2002; Bergek et al, 2008; Ozorhon and Kutluhan, 2017).

A brief background of the case study is provided by focusing on the current state of innovation processes in the Russian construction industry. This research approach is explained. This is followed by results and discussion regarding the innovation diffusion in the construction industry. This research has shown that a company's willingness to be involved in the innovation process, i.e. develop and diffuse construction innovation is determined by sufficiency of government policies and supportive strategies as well the state of the administrative and regulatory burden. Eventually, the last section highligh the work completed herein and future research directions.

2. Background of the case study

In the Russian construction industry 70% of the total implemented innovations are technological, involving the utilisation of technical approaches to either process or product innovation such as machinery and engineering equipment, cutting edge technology, software for architectural and construction design as well as information modelling. Such products aim to improve the efficiency of construction works and to accomplish high economic, technological and functional values to building operations. Domestic manufacturers produce a wide range of traditional building products, but innovations are mainly imported to Russia.

The proportion of construction companies implementing technological innovations is less than 5% of the total market size compared to other sectors of Russia's economy such as energy (22%) and biomedical (29%) industries (Gorodnikova et al., 2017). This low rate occurs mainly because micro and small companies make up around 90% of the construction industry. According to the Bureau of statistics, about half of construction works in the country are completed by companies with an average number of employees up to 15 people and annual revenues of less than 100 million roubles (1.8 million USD at February 2018) (FSSS, 2018). It goes without saying that such firms are forcedly conservative and cannot afford to invest in innovation and take advantage of technological know-how.

According to the government forecast, the number of innovative construction companies is going to increase significantly over time (Figure 1).

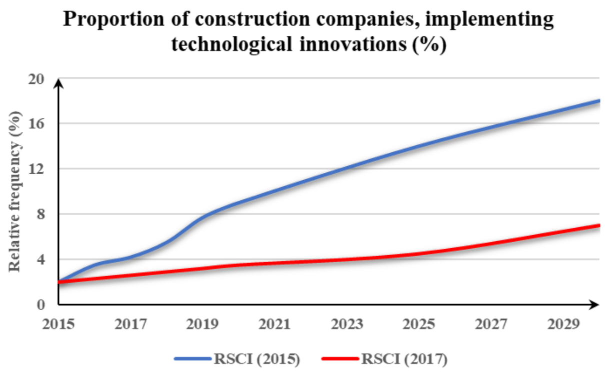


Figure 1. Reference mode diagram showing the government forecast (RSCI, 2015, 2017)

As can be seen, there are two versions of an “Innovative development strategy for the construction industry in Russia for the period up to 2030” (RSCI, 2015, 2017). Initially, the Russian government was expecting ten time increase in the frequency of innovative construction companies by 2030. Nevertheless, it seemed to be a very ambitious plan given the relatively short period of time and current political and business issues that might affect innovation diffusion in the country and the industry, in particular, in a negative way. Undoubtedly, a number of systematically targeted strategies and rational policies is needed to achieve such results. However, the strategy was readjusted in 2017 showing a new trend (RSCI, 2017). According to the new forecast, the level of technological innovation is planned to be tripled by 2030. This change proves the observed complication of manufacturing processes in the construction sector, including introduction of an innovative component.

Given the ever-changing political context, the government prefers to take measures aimed at supporting the demand for domestically produced innovative goods and services (TASS, 2014). Hence, domestic companies need to continue their innovative activities and seek additional sources of funding during the difficult financial climate.

Industry, government, and academia contribute to and benefits from the introduced innovations as they constitute part of the innovation system’s environment in their role as innovation generators, policy makers and knowledge brokers. In goes without saying, that construction development is highly influenced by the variety of complex interactions between these three actors. For instance, government plays a major influential role within the construction industry contributing to the system’s balance as a policy-maker and legislator. Innovation generators represented by construction firms, design companies and knowledge developers need to be encouraged to innovate through public policies, laws and incentives mechanisms (Slaughter, 1993; Miozzo and Dewick, 2002). In addition, government as a client significantly influences and motivates other actors by driving demand for research and innovation through regulatory frameworks and procurement schemes.

Public funds comprise institutional funding granted specifically to universities and research centres. Meanwhile, industrial and scientific organisations contribute to the country’s GDP. Research organisations and universities are responsible for training the next generation of innovators and knowledge diffusion within the innovation system. Furthermore, academia improves overall national innovation capabilities by assisting construction companies in testing and evaluating research results and innovative solutions (Hampson et al., 2014). Hence, the industry may be considered as a mediator between R&D institutions by investing in research.

3. Research approach

For the purposes of analysing the innovation diffusion process within a highly complex innovation system, a robust system understanding is needed. The chosen research procedure aims to improve innovation performance and innovative capabilities in the construction industry by employing a holistic, qualitative and quantitative analysis under an integrated decision support tool. The integrated approach brings together various stakeholders and, hence, allows them to be a part of the entire modelling process from setting the goals and objectives of the study, to the discussion of innovation planning strategies, policy interventions and uncertain situational context scenarios.

The core of the chosen modelling procedure is the development of an SD model that can aid interpretation of the complex cause-and-effect relationships between government, academia and industry within the construction innovation system. The modelling process is carried through the following stages: primarily, the problem definition stage, which clarifies the problem and identifies variables having an influence on it (Forrester, 1961; Sterman, 2000; Maani and Cavana, 2007; Grösser, 2017). Then, the conceptual model is built. It reveals relationships among the variables. The central element in model development is a structural analysis using MICMAC technique followed by stakeholder workshops. The structural analysis enables a modeler to underline the variables that are essential to the system's evolution (Godet, 2006). The conceptual model, in the formulating stage, further develops into an appropriate dynamic model followed by an analysis of model behaviour. Eventually, policy analysis and identification of possible pathways for improving the results for the system functioning is done.

Given the multi-actor nature of the system under study, high uncertainty and lack of data involved, an active stakeholder engagement is carried out at all stages of the modelling cycle. The participatory elements include questionnaire-based opinion surveys, face-to-face interviews, consultations, and a series of stakeholder workshops. The modelling process is highly iterative and a modeller, together with stakeholders may revise their decisions until the model is completed. The study participants were researchers and academics specialising in construction management, civil and structural engineering; designers, project managers and directors of construction companies; and public servants.

4. Results and discussion

4.1. Conceptualisation

Model conceptualisation phase assists a modeler in structuring the systems problem and assigning of a model’s boundaries. This stage is particularly important for our research given the multi-actors nature of the system under study and lack of data involved. In order to achieve a higher level of innovation activity within the construction sector it is fundamental to identify how the cause-and-effect relationships among the variables of the innovation system can be combined into a complex model. The use of conceptual models allows to assess policies impact and investigate system’s behaviour under various scenarios.

The central element in model development is a structural analysis using the MICMAC technique (Godet, 2006) followed by stakeholder workshops. For extended details of this modelling step, the reader is referred to the article published by the authors (Suprun *et al*., 2016). Once the role of each variable is identified, it is necessary to look at the system as a whole in order to understand how the variables are interrelated. Influence graphs are created with the MICMAC software to highlight the networks of elements that influence one another (Figure 2). Interconnections among variables are indicated by arrows representing different levels of impact of the variables on each other from weak to strong. Within the context of systems modelling, these arrows illustrate the dynamic behaviour of the system under investigation while the influence diagrams are associated with a cause-and-effect diagram. It goes without saying that MICMAC influence graphs are not user-friendly, particularly for stakeholder engagement purposes. However, the graphs work as an initial reference for the logical building of a Causal Loop Diagram (CLD). The process of a qualitative model construction is always subjective. Nevertheless, the transformation of the generated influence diagrams into the systems conceptual model in a form of a CLD is based on a comprehensive analysis of interconnections among dynamic variables. Furthermore, a solid theoretical foundation, and previously conducted exploratory study followed by expert participation sessions corroborate the modelling process. The visualization of conversion of the influence graph into a CLD is illustrated in Figure 2.

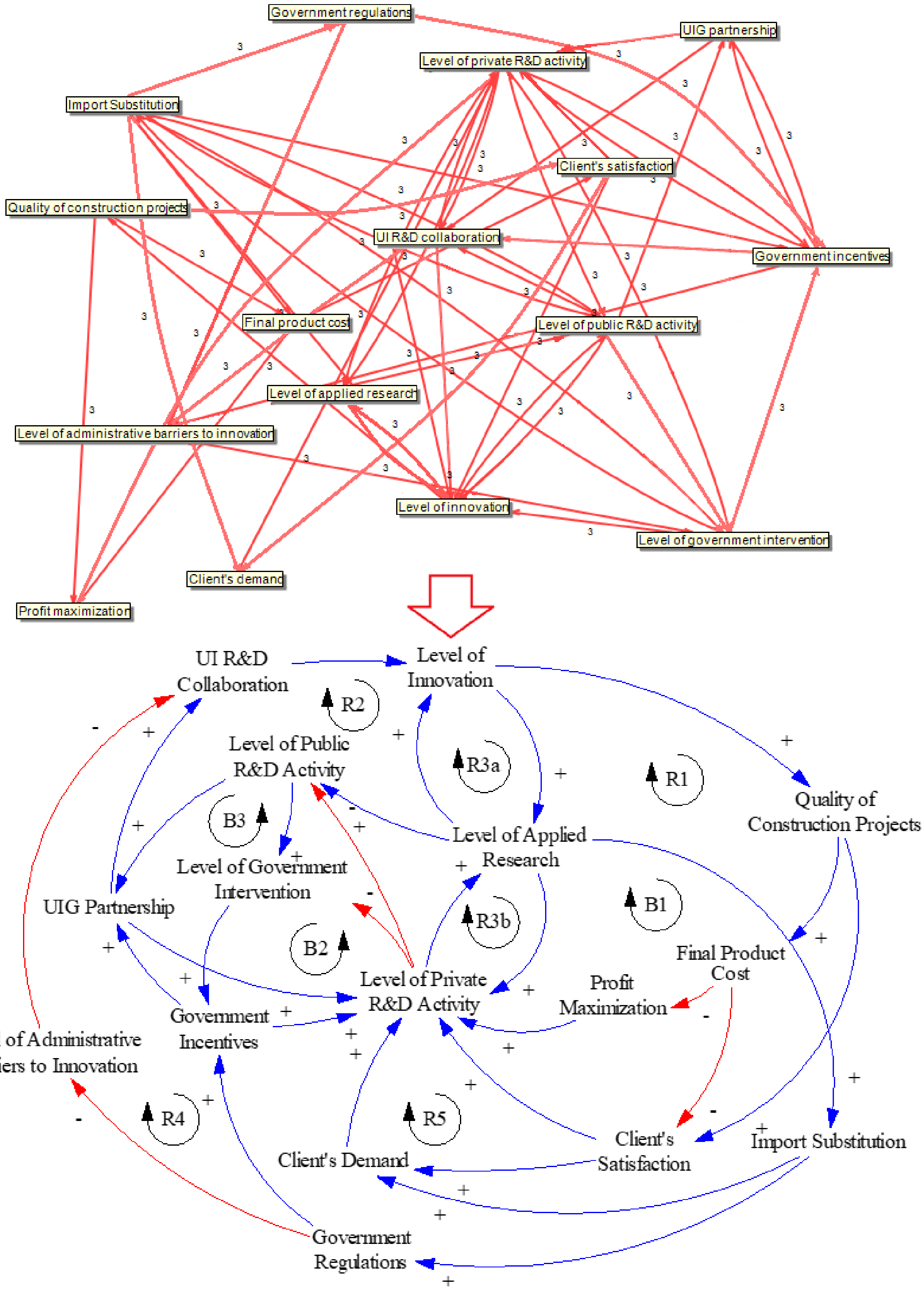


Figure 2. Conversion of the direct influence graph representing strongest interrelations between system's variables into a causal loop diagram

As can be seen, only the strongest connections among the key variables are observed. The analysis investigates how the elements affect each other and how their actions can be transmitted throughout the system. It also should be taken into account that relations between some of the variables can occur through other variables. Additionally, a modeler applies the accurate knowledge when identifying positive and negative causal relationships by asking the question: “What are the impacts of variable i on variable j at the present?” The polarity is ‘+’ when two elements change in the same direction (i.e. increase or decrease together). The polarity is ‘-’ when one variable increases while the other decreases, and vice versa.

Seven main feedback loops were emerged from the constructed causal loop diagram representing involvement of the industry, government and academia in the innovation process within the construction innovation system (Table 1). The relationships among the variables are dominated by reinforcing loops. The same reinforcing loop can have positive or negative impacts on the system, depending on how the loop is triggered. In other words, reinforcing processes can be helpful for improving innovation performance in the construction industry, or can serve to hinder the industry’s development. The positive description of the identified feedback loops is provided below.

Table 1. Summary of feedback loops

Feedback loops	**Loop name**	**Structure**	**Key message**
R1	Industry’s motivation	Level of innovation → Quality of construction projects → Client's satisfaction → Level of private R&D activity → Level of applied research→ Level of innovation	Increase in construction companies R&D activity due to improvement in business performance
R2	Government’s role	Level of government intervention → Government incentives → UIG partnership → UI R&D collaboration → Level of innovation → Level of applied research → Level of public R&D activity → Level of government intervention	Government involvement in construction innovation process
R3a, R3b	Practical application	Level of applied research → Level of innovation → Level of applied research Level of applied research → Level of private R&D activity → Level of applied research	Necessity of research results application
R4	Reduction of regulatory burden	Import substitution → Government regulations → Level of administrative barriers to innovation → UI R&D collaboration → Level of innovation → Level of applied research → Import substitution	Building environment for development of domestic innovations
R5	Need for innovation	Client's demand → Level of private R&D activity → Level of applied research → Import substitution → Client's demand	Import substitution policy requirements
B1	Expectation of short-term profit	Level of innovation → Quality of construction projects → Final product cost → Profit maximization → Level of private R&D activity → Level of applied research → Level of innovation	Industry’s conservatism due to high expenses and insufficient short-term profits
B2	Support for innovation	Level of private R&D activity → Level of government intervention → Government incentives → Level of private R&D activity	Necessity of additional support in order to boost innovative activity
B3	Overcoming isolation	Level of private R&D activity → Level of public R&D activity → UIG partnership → Level of private R&D activity	Implementation of policies promoting R&D collaboration

As the next step, stakeholder workshops were conducted to refine and extend the initial conceptual model created on the base of the structural analysis with MICMAC.

4.2. Dynamic model formulation

After the model refinement, stakeholder workshops were held in order to translate the created CLD into a system dynamics model. The equations of the model have been regulated by using data from the development strategies (RSCI, 2015, 2017), statistical sources (Gorodnikova et al., 2017; FSSS, 2018), previously conducted structural analysis with MICMAC and stakeholder workshops. One of the main outcomes of the model is behaviour of the 'Level of innovation' variable that measures the frequency to which construction enterprises perform technological innovative activities. Due to the complexity of the dynamic SD, only an extract of the stock and flow diagram, representing the core of innovation diffusion process in the construction industry is provided (Figure 3).

As can be seen, the proposed model of the construction innovation system integrates the core structure of the Bass diffusion model (Bass, 1969; Kunc, 2004) from an industry-wide perspective. Innovation and imitation rates represent the number of construction companies that implement technological innovation through R&D and adoption from others annually, respectively. Additionally, based on the discussions with experts, we introduce an 'Innovativeness attraction rate' variable. In other words, a construction firm may be potentially capable of becoming innovative, however, a number of significant conditions influence its decision to consider higher investments in cutting-edge ideas. Hence, potential innovative companies should be willing to innovate before becoming actual innovative companies. A comprehensive explanation of the model, including definitions, units, equations and assumptions is given in Table 2.

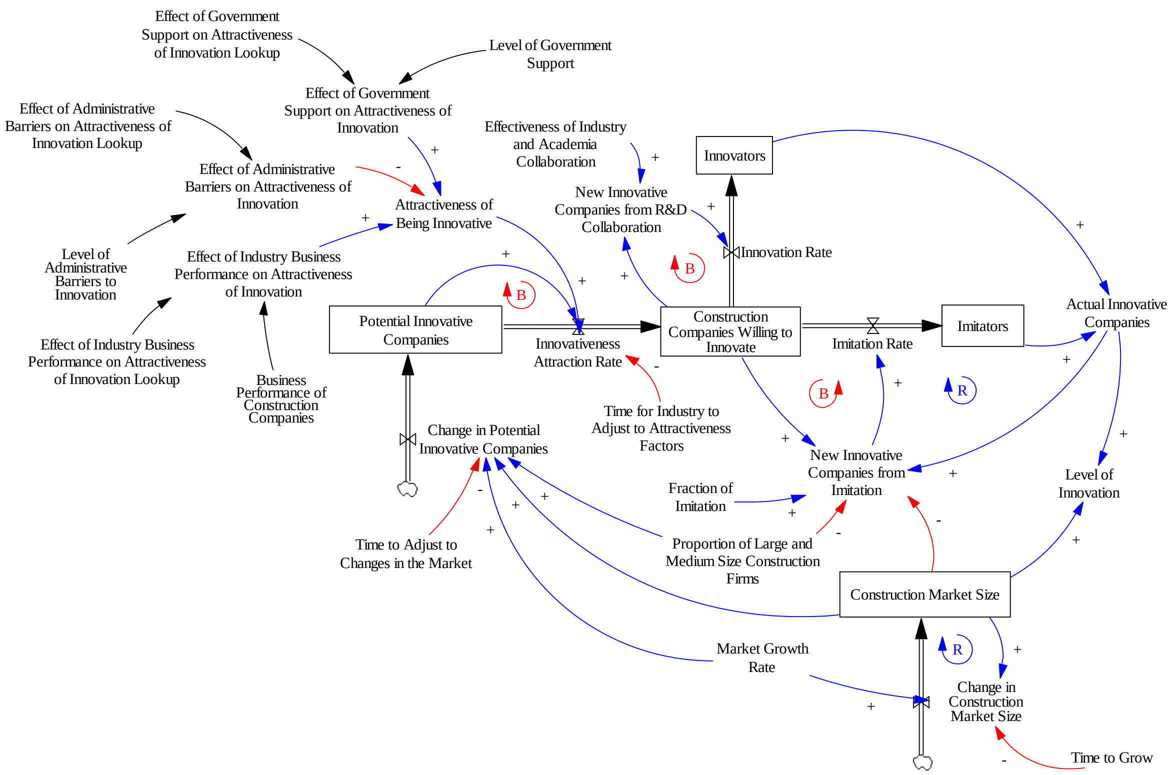


Figure 3. Stock and flow diagram of innovation diffusion in the construction industry

Table 2. Summary of variables within the stock and flow diagram of innovation diffusion in the construction industry

Variable	Unit	Description	Equation and/or assumption
Potential innovative companies	Firm	Number of medium and large-sized construction firms that have not introduced / implemented technological innovation yet	INTEG (Change in potential innovative companies – Innovativeness attraction rate, initial potential innovative companies stock) Initial potential innovative companies = Proportion of large and medium-sized construction firms * Construction market size – Actual innovative companies
Construction companies willing to innovate	Firm	Construction firms making decision in favour of introducing / implementing technological innovation depending on change in attractiveness of being innovative based on business performance of construction firms, level of government support and level of administrative barriers	INTEG (Innovativeness attraction rate – Imitation rate – Innovation rate, initial construction companies willing to innovate stock) Initial construction companies willing to innovate = Potential innovative companies * 0.18 0.18 is the initial attractiveness of innovation
Innovators	Firm	Number of construction firms introducing / implementing technological innovation as a result of collaborative R&D	INTEG (Innovation rate, initial innovators stock) Initial innovators = 1177
Imitators	Firm	Number of construction firms introducing / implementing technological innovation by adopting from others	INTEG (Imitation rate, initial imitators stock) Initial imitators = 3530
Actual innovative companies	Firm	Number of innovative construction firms	Imitators + Innovators
Construction market size	Firm	Total amount of construction companies	INTEG (Change in construction market size, initial construction market size stock) Construction market size = 235351
Innovativeness attraction rate	Firms/Year	Construction firms making decision in favour of introducing / implementing technological innovation annually	Potential innovative companies * Attractiveness of being innovative / Time for industry to adjust to attractiveness factors
Innovation rate	Firms/Year	Construction firms introducing / implementing technological innovation through R&D annually	New innovative companies from R&D collaboration
Imitation rate	Firms/Year	Construction firms introducing / implementing technological innovation through adoption from others annually	New innovative companies from imitation
Change in construction market size	Firms/Year	Construction companies entering or exiting the market annually	Construction market size * Market growth rate / Time to grow
Change in potential innovative companies	Firms/Year	Construction companies becoming medium and large-sized annually	Construction market size * Market growth rate * Proportion of large and medium-sized construction firms / Time to adjust to changes in the market

Variable	Unit	Description	Equation and/or assumption
New innovative companies from R&D collaboration	Firms/Year	Construction firms introducing / implementing technological innovation through R&D annually according to the effectiveness of the industry and academia collaborative effort with the pool of potential innovative companies	Construction companies willing to innovate * Effectiveness of industry and academia collaboration
New innovative companies from imitation	Firms/Year	Construction firms introducing / implementing technological innovation annually by adopting innovations from others. The number of firms is driven by the rate of contacts among potential adopters and active innovative companies. The adoption from competitors is small if the number of active innovative companies relative to the total number of construction companies is small.	Fraction of imitation * Actual innovative companies * Construction companies willing to innovate / (Construction market size * Proportion of large and medium-sized construction firms)
Effectiveness of industry and academia collaboration	1/Year	Research results leading to innovation implementation according to the effectiveness of industry collaboration with academia	0.011
Fraction of imitation	1/Year	Rate at what potential innovative construction companies adopt innovative solutions from innovative competitors due to companies access to innovation-related information	0.22
Market growth rate	Dimensionless	Proportion of construction companies entering or exiting the market	0.02
Level of innovation	Dimensionless	Proportion of innovative construction companies in the total market size	Actual innovative companies / Construction market size * 100
Proportion of large and medium-sized construction firms	Dimensionless	Proportion of construction companies potentially capable of introducing / implementing technological innovation	0.152
Attractiveness of being innovative	Dimensionless	Index based on three factors that influence industry's decision to consider higher investments in innovation: business performance of construction companies, level of government support and level of administrative barriers	Effect of Government Support on Attractiveness of Innovation * 0.33 + Effect of Industry Business Performance on Attractiveness of Innovation * 0.26 + Effect of Administrative Barriers on Attractiveness of Innovation * 0.41
Effect of industry business performance on attractiveness of innovation	Dimensionless	Level of attractiveness of innovation as a function of the industry's business performance	Effect of industry business performance on attractiveness of innovation lookup (Business performance of construction companies)
Effect of government support on attractiveness of innovation	Dimensionless	Level of attractiveness of innovation as a function of the level of government support	Effect of government support on attractiveness of innovation lookup (Level of government support)

Variable	Unit	Description	Equation and/or assumption
Effect of administrative barriers on attractiveness of innovation	Dimensionless	Level of attractiveness of innovation as a function of the level of administrative barriers to innovation	Effect of administrative barriers on attractiveness of innovation lookup (Level of administrative barriers to innovation)
Business performance of construction companies	Dimensionless	A function of a company's profitability and client satisfaction as ones of the most essential industry motivation points.	0.4
Level of government support	Dimensionless	State of public support and public policies (e.g., federal targeted programmes, direct financial investments)	0.4
Level of administrative barriers to innovation	Dimensionless	Barriers related to the conservative building codes and standards; government contracts with inflexible fixed budgets, and so forth.	0.7
Effect of administrative barriers on attractiveness of innovation lookup	Dimensionless	Lookup function showing relationship between level of administrative barriers to innovation and attractiveness of innovation (exponential decay behaviour)	Lookup function (Figure 4a)
Effect of government support on attractiveness of innovation lookup	Dimensionless	Lookup function showing relationship between level of government support and attractiveness of innovation (goal seeking behaviour)	Lookup function (Figure 4b)
Effect of industry business performance on attractiveness of innovation lookup	Dimensionless	Lookup function showing relationship between industry's business performance and attractiveness of innovation (s-shaped growth behaviour)	Lookup function (Figure 4c)
Time to grow	Year	Time for construction companies to set up business and start functioning	1
Time to adjust to changes in the market	Year	Time needed for companies new to the market to become medium and large-sized	4
Time for industry to adjust to attractiveness factors	Year	Time needed for the industry to make a decision in favour of innovation pathway due to improving business performance, reducing administrative and regulatory burden as well as a result of active government involvement in the innovation process	2

Innovativeness attraction rate is influenced by a number of factors aggregated into an 'Attractiveness of being innovative' abstract term defined in collaboration with the stakeholders. It is an index which takes normalized values between 0 and 1 and refers to how strong is a company's desire to implement innovations based on the following important factors:

- business performance of construction companies is a function of a company's profitability and client satisfaction as ones of the most essential industry motivation points;
- level of government support refers to a state of public support and public policies (e.g., federal targeted programmes and direct financial investments);
- level of administrative barriers to innovation represents barriers related to the conservative building codes and standards, technical regulation, and so forth.

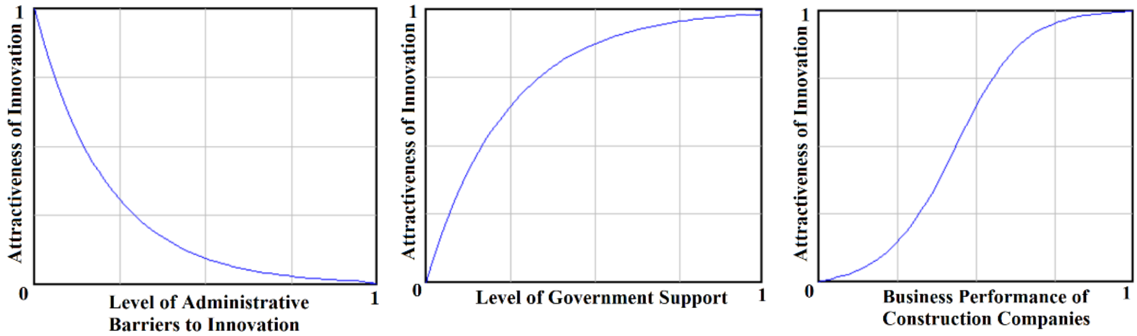
All the influential variables have values of 0 to 1 (from 0 to 100%, alternatively). The normalization procedure is based on the literature (HSE, 2013; Suprun and Stewart, 2015; Suprun et al., 2016; Eriksson and Szentes, 2017; Ozorhon and Kutluhan, 2017), government reports (RSCI, 2015, 2017) and stakeholder workshops. Table 3 shows categories of the three variables-indicators.

Table 3. Qualitative scale for variables impacting attractiveness of innovation

Variable	Scale (%)	Characterisation
Administrative barriers	< 20	Acceptable
	20 – 40	Medium
	40 – 60	High
	60 – 80	Excessive
	80 – 100	Insurmountable
Government support	< 20	Insufficient
	20 – 40	Poor
	40 – 60	Adequate
	60 – 80	Sufficient
	80 – 100	Perfect
Industry business performance	< 20	Poor
	20 – 40	Unsatisfactory
	40 – 60	Satisfactory
	60 – 80	Good
	80 – 100	Perfect

Given the highly qualitative nature of the key variables, the relationships between them need to be quantified. In the modelling process the specified nonlinear relationships are used as lookup functions. In order to identify the influence of each of the mentioned factors on the attractiveness level, experts were asked to create a graphic description of the relationship between the variables (Ford and Sterman, 1997; Hovmand, 2014). Figures 4a-4c illustrate distinguished nonlinear relationships between change in the 'Level of administrative barriers to innovation', 'Level of government support' and 'Business performance of construction companies' and change in 'Attractiveness of innovation', respectively.

Figure 4a implies that the higher the 'Level of administrative barriers to innovation', the less desirable innovations are seemed to be for companies. It is simply because the time and investments needed to overcome these impediments sometimes are not worth it. Subsequently, lower levels of barriers contribute positively to the innovation process. This relation is consistent with literature (HSE, 2013; Dansoh et al., 2017). The graph represents an exponential decay behaviour created by a reinforcing loop. The relationship between attractiveness and government support is defined by a goal seeking behaviour arising from a balancing loop. The more government provides incentives for construction organisations the more they tend to be involved in the innovation process. However, as discussed with the experts, government abilities are not boundless, and promotions cannot go forever. Moreover, at some point companies have to be able to invest in know-how themselves. Finally, relationship between attractiveness and business performance of companies implemented innovation is graphically presented as an S-shaped growth. In other words, the growth of attractiveness level is exponential at first, but then gradually slows until the state of the system reaches 1.



(a) **(b)** **(c)**

Figure 4. Relationship between level of attractiveness of innovation and factors that influence industry's decision to innovate

Attractiveness of innovation is an index that aggregates three functions mentioned above. However, the role of the impacting elements is not equal. Weight of each variable affecting attractiveness of innovation was calculated based on the previously conducted structural analysis with MICMAC. Hence, the equation for the 'Attractiveness of innovation' is the following:

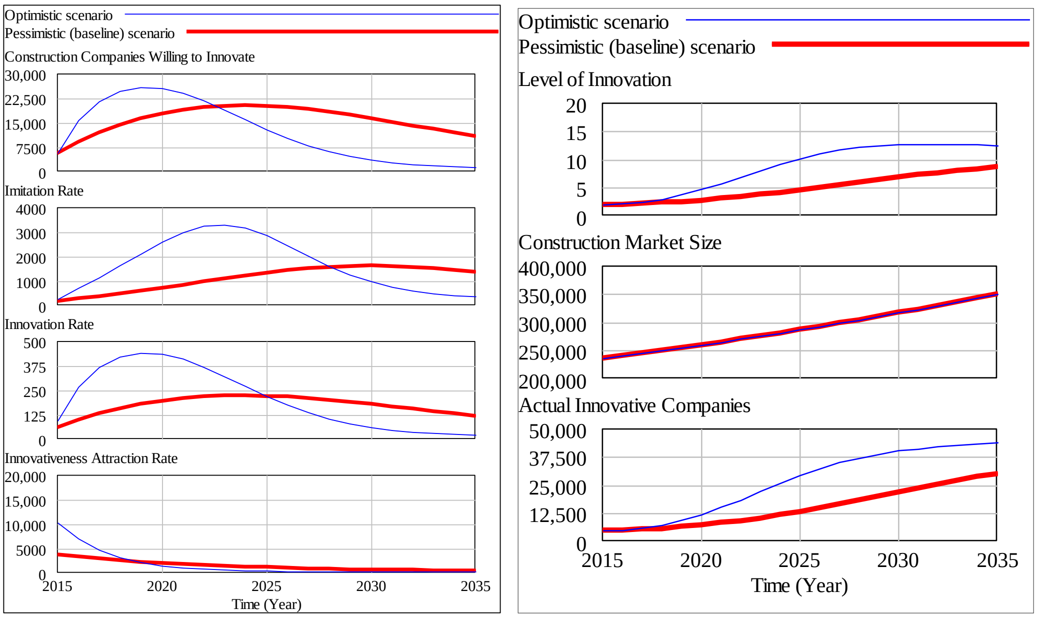
$$\begin{aligned} &Attractiveness\ of\ innovation \\ &= 0.41 \times Attractiveness(Administrative\ barriers\ to\ innovation) \\ &+ 0.33 \times Attractiveness(Government\ support) \\ &+ 0.26 \times Attractiveness(Industry\ business\ performance) \end{aligned}$$

It is important to understand that any action taken by the government, industrialists or research institutes do not have immediate consequences. Thus, according to the government reports (RSCI, 2015, 2017) and expert judgment, it takes approximately 2 years for construction companies to consider implementing innovative solutions as a result of active government involvement in the innovation process, high business performance and reduced administrative and regulatory burden.

4.3. Model analysis and simulation

Once the SD model is developed, it needs to be tested. There is a variety of tests to improve simulation models (Sterman, 2000; Maani and Cavana, 2007). We first verified dimensional consistency of the model in order to test its structural validity. Then a number of validation tests were conducted to check whether the model behaves realistically under extreme conditions. For instance, we checked that if level of administrative barriers to innovation is insurmountable, level of government support is insufficient and business performance of construction companies that implemented innovation is poor then attractiveness of innovation stays stable and equals to 0. As a result, the number of construction companies willing to innovative practically decreases gradually does as there is no motivation for them to be involved in the innovation process. Conducted sensitivity analysis confirmed that the model functions are sensitive to the parameters of the model as it is expected in real life.

The simulation horizon is set equal to twenty years to be able to explore the behaviour in the level of innovation change up to 2035 and compare the results with the government forecast (RSCI, 2015, 2017). The ability of the SD model to reproduce the behaviour that is observed in the real-world, constitutes another validation test known as a behaviour reproduction test. The test showed that the model can produce behaviour patterns similar to the government forecast once the initial values are met correctly. The government forecast has been discussed in section 2 and the simulation results are shown in Figure 5.



(a) **(b)**

Figure 5. Simulation results

Table 4 shows a comparison of the model output and the forecast in the period between 2015 and 2035. In the set of simulations, a pessimistic (baseline) scenario and an optimistic scenario are equivalents of the government predictions in the development strategies of 2017 and 2015, respectively (Table 4).

Table 4. Government forecast and simulation results for the level of technological innovation (%)

Year	**Government forecast**		**Simulation results**	
	RSCI, 2017	RSCI, 2015	Pessimistic (baseline)	Optimistic
2015	2	2	2	2
2016	2.3	3.5	2.1	2.1
2017	2.6	4.2	2.2	2.5
2020	3.5	9	2.8	4.7
2025	4.5	14	4.6	10.2
2030	7	18	6.8	12.7

On one hand, the baseline scenario replicates the readjusted in 2017 government predictions quite precisely, i.e. the proportion of construction companies implementing technological innovation, as a result of simulation equals to 6.8% while the forecasted value is 7%. On the other hand, the initial ambitious plan of the government is practically not achievable, i.e. predicted 18% versus simulated 12.7%. It does not mean that such results cannot happen in the foreseen future, however, a cardinal reconstruction of the innovation system needs to be done within a very short period of time. Table 5 shows different settings for the model variables. It is worth noting that within the optimistic scenario values for the level of business performance and government support are high accompanied by an acceptable level of administrative barriers. Rate of companies involved in R&D and adopting innovative solutions from competitors also increase the number of innovative companies a lot. Nevertheless, as mentioned previously, only large and medium-sized construction firms have a potential capability to implement innovative solutions. Proportion of such companies is around 15% at the moment. Hence, another thing to consider while investigating potential pathways to rational decision-making along with innovation planning strategies is to support the increase of the market size.

Table 5. Settings for the model variables

Set of parameters	Simulation results	Pessimistic (baseline) scenario	Optimistic scenario
Business performance of construction companies		0.4	0.7
Level of government support		0.4	0.8
Level of administrative barriers to innovation		0.7	0.2
Rate of industry and academia collaboration		0.011	0.017
Rate of imitation		0.22	0.33
	Attractiveness of innovation	0.238	0.665
	Innovators (firms)	3912	5281
	Imitators (firms)	17710	34860
	Actual innovative companies (firms)	21620	40140
	Level of innovation (%)	6.8	12.7

The model's purpose is to serve as a virtual environment where various assumptions can be tested and explored to check future scenarios. Even though the model output does not fully fit the forecast, it, however, reproduces the main pattern of the predictions, hence can be considered to produce plausible dynamics. Moreover, the model development process is based on working with and has been confirmed by the stakeholders.

5. Conclusions and further research

The goal of this research was to formulate a system dynamics model that structures the problem of innovation diffusion in the construction industry. In the majority of cases insufficient technical and technological capabilities of construction companies hinder the industry's ability not only to implement innovative solutions but also quickly adapt to new opportunities. In order to cope with the unwillingness of the industry to innovate, the government needs to implement policies promoting science, to invest in higher education and techno-parks to enchase public R&D activity first. This, in turn, establishes integrated R&D collaborations required for effective implementation of technology-using strategies and research commercialisation and boosts industry participation in the process. The Russian government tends to take measures aimed at promoting the production of domestic innovative materials and technologies as a response to the inflicted Western sanctions. The process affects changes in construction-related legislation, rules, and building codes, that leads to simplifying administrative procedures.

The further research stage will be focused on discussing the potential pathways to rational decision-making along with recommendation framework that aims to improve construction innovation performance in the Russian Federation. It is important to set essential arguments around the changes to be made in the government innovation strategy overall. For the purposes of scenario and policy analysis followed by a further model implementation, a set of simulations is required to get insights about the effects of selected strategies on future performance of the construction industry. In our research, we will use outputs from the conducted structural analysis with MICMAC and consultations with the stakeholders to define and evaluate the potential strategic pathways, and to apply the policies that overcome innovation diffusion challenges in the Russian construction industry. Scenario planning and analysis is chosen to be based on the Great Transition Initiative (GTI).

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