Mapping the Construction Innovation System in the Russian Federation: Conceptual Model Development

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Abstract - This is an ongoing research project combines System Dynamics (SD) and participatory modelling to identify variables forming the Russian Federation construction innovation system and to create an initial comprehensive conceptual model supported by stakeholder-based techniques. Quantification of this complex and dynamic construction innovation system is complicated as it includes a range of components such as information, resources, strategies, time and uncertainty. To map and conceptualize the system, system thinking and participatory techniques have been used. Methods employed academic and industry consultation and stakeholder engagement through participatory interviews. In this current paper we present the development of a conceptual model as a causal loop diagram to understand the causes, impacts and pathways leading to greater innovation performance in the Russian Federation construction industry. Moreover, the created model underpins the future development of an operationalized system dynamic model.

Keywords – Model conceptualisation, participatory modelling, system dynamics, and construction innovation

I. INTRODUCTION

Globally, the construction industry is often described as being a ‘laggard’ industry, with few exceptions. According to the previously conducted exploratory study of the authors [1], in the case of the Russian Federation this problem is even more significant, since it is a country spread across a massive territory with unique impediments to innovation diffusion. It is clear that the level of innovative activity within the construction sector needs to be improved.

Turville [2] (p. 4) points out that a country’s innovation activity depends on inter-linked activities which include: industrial research; publicly funded basic research; user-driven research; knowledge transfer; institutions governing intellectual property and standards; supply of venture capital; education and training of scientists and engineers; innovation policies of government departments; science and innovation policies of RDAs; and international scientific and technological collaboration.

Innovation and innovation diffusion in the construction industry as a project-based sector should be seen in the light of the specific characteristics of a dynamic systematic context. The construction industry is closely connected to the national social structure and therefore, is highly influenced by governmental and other institutional

actors. In order to improve the level of innovative activity within the construction sector, it is fundamental to identify how the interrelations among these key actors and variables of the innovation system can be combined into a complex dynamic model to create scenarios and understand policies impact. The continuously developing innovation system of the construction industry is a complex system of innovation activities highly influencing the development of construction [3]. It involves innovative milieu, different policies, interactions and a range of participating system actors such as a government, organizations, universities and research institutes.

Obviously, the linear approach to conceptualizing innovation does not offer a clear insight into the complexities of the innovation process over time. Hence, the innovation system at any context is perceived to involve mechanisms that govern the alignment of committed resources and interrelated innovation activities [4].

The herein reported, current stage of the study sought to achieve the following objectives:

- To identify the main variables of the construction innovation system and relationships between them.
- To develop a comprehensive conceptual model that utilises a causal loop diagram to link relevant innovation factors in order to better understand the behaviour of different elements that make up the Russian Federation construction innovation system.

II. METHODOLOGY

According to Sterman [5] (p. 85), “there is no cookbook recipe for successful system dynamics modelling, no procedure you can follow to guarantee a useful model”. The modelling process, in general, is a very iterative step-by-step process. A predominant framework for system dynamics modelling in particular was developed by Sterman [5] and divided into five steps: the first two stages (i.e. Problem articulation; Formulating dynamic hypotheses) concern qualitative modelling, while the other three stages (i.e. Formulating a simulation model; Testing; Policy design and evaluation) concern computer-based modelling for quantitative simulation.

This present study completes activities to Step 2 of the modelling process [4]. Construction of the model is supported by a complete understanding of the system. A causal loop diagram (CLD) is a tool for mapping a set of relationships forming the complex system. It provides a

more visual understanding of the existing systematic relationships between the system's components. The CLD consists of both quantitative (measurable) and qualitative (non-measurable) variables.

The innovation system in the construction industry is a complex topic requiring the use of a systemic approach. This modelling approach will assist understanding of important feedback mechanisms that characterise the dynamic behaviour of complex systems.

It is not enough for researchers to build and run computer models of complex systems using only desktop studies in order to support issues concerning innovation problems [4]. Incorporating stakeholder input in such models is essential to ensure that they facilitate effective decision making over the short-, medium- and long-term. Participatory modelling often includes involving public representatives and decision makers into an analytic modelling process [6].

As mentioned previously, many factors are involved in complex innovation systems. The list of the system's components identified through literature review and the previously conducted study must be approved by experts and stakeholders; this opinion ensures that all relevant elements are included and redundant variables removed. This process was completed through consultation with industry and academic professionals.

The selected interviewees had diverse roles, including managers, designers and researchers. As a result of consultation with the interviewees, a total of 30 of the 80 factors were retained based on their importance (Table 1). The interactions between these 30 factors were considered as described later.

Further stakeholder engagement was conducted through facilitated interviews where interactions between variables were established. Steps were then undertaken to:

- i. Identify relevant stakeholders (e.g. representatives from construction and related industries, the public sector, universities and the research community);
- ii. Contact nominated stakeholders and invite them to interviews; and
- iii. Conduct opinion survey on the construction innovation system and discuss the key problems related to innovation in the industry.

Unstructured and highly interactive interviews were conducted with experts who have played a role in managing the innovation implementation and diffusion process in construction and the innovation policy field in Russia.

These interviewees included researchers and academic staff, private and public construction companies' employees and contractors, design consultants (i.e. design engineers), building product manufacturers, and public authorities' representatives.

TABLE I
LIST OF VARIABLES

Variable	Brief description	References
Level of innovation	One of the main characteristics of every industry development	[3,7]
Quality of construction projects	Productivity and quality of construction projects (final product or service)	[7,8]
Final product cost	Final cost of a construction product or service	[8,9]
Client's satisfaction	Satisfaction with final product quality	[9]
Profit maximization	Maximize profitability and maximize cost effectiveness	[1,9]
Level of public R&D activity	Public policies promoting science and R&D	[8-10]
Level of private R&D activity	Private sector innovative activities	[8-10]
R&D expenditure (public)	Funds a government spends at universities and research	[9-11]
R&D expenditure (industry)	Firms investments on R&D	[9-11]
Client's demand	Government and private clients may affect the use of innovations	[1,8,9]
Level of applied research	Development of methods, products, systems, techniques etc.	[8-10]
Level of basic research	Research developing industry's theoretical foundations	[9,10]
Government regulations	Legislation, rules, building codes, certification procedure	[1,8]
Government incentives	Public stimulating mechanisms for industry development	[1,9]
Level of government intervention	Public support and public policies	[1,9]
PPP	Cost sharing: Public-Private Partnership	[1,11]
Level of tax incentives	Fiscal arrangements and tax privileges	[1,11]
UIG partnership	Partnerships between universities, research institutes, government and industry	[3,9,11]
UI R&D collaboration	Collaborative R&D with greater industry participation	[1,8,11]
Level of technological cooperation	Technological cooperation with related and supporting industries.	[1,8,9]
New procurement approaches	PPPs and other concession projects	[1,12]
Life cycle cost practice	Assessment of construction project over its life-cycle	[11]
Awareness and training	Access to the best available information on innovation	[1,9]
Level of IPR protection	It supports efficient flows of knowledge	[1,9]
Level of innovation commercialization	Knowledge produced through R&D transforming into products with commercial value	[11]
Quality of higher education	Support the development of educational programs	[1]
Venture funding	Investment funds in start-ups and SMEs	From interviews
Import substitution	Import substitution is Russia's response to imposed sanctions	From interviews
"Brain drain"	Increasing due to lack of support and incentives for innovation	From interviews
Level of administrative barriers to innovation	The variety of building codes and standards; low levels of government support for industry development	From interviews

III. CONCEPTUAL MODEL DEVELOPMENT

After the key variables were identified, the respondents were also asked to rank the intensity of influence and dependency between variables. Fig. 1 details the variables positions given their dependence and influence level rank. Every factor was classified into Influential, Relay, Dependent and Autonomous variables, as described below:

- *Influential variables* represent input variables that exert some influence on other elements, but are not dependent from the others. They must have a priority when considering strategic scenarios.
- *Relay variables* are also important as they are both influence the system and are dependent from influential variables.
- *Dependent variables* represent system's output variables that are the most impacted by other variables and the system.
- *Autonomous variables* are neither influential nor dependent and do not significantly affect the system.

A modeler along with stakeholders develop a CLD After asking the question: “Which impact of variable A on variable B can be observed at present?” the next step is to identify the most important relationships that allow logical construction of the associated causal loop diagram.

It also should be taken into account that some variables do not have direct connection with each other but influence can occur through other variables. Additionally, a modeler can enhance other meaningful interrelations between dynamic variables through taking into account the experts opinions during data collection, previous desktop study as well as applying the tacit knowledge of researchers analyzing the system.

The process of model construction is always subjective. However, interactions of variables are supported by experts that provide a high degree of reliability. As a result, the generated qualitative model (Fig. 2) was built using a rigorous and comprehensive analysis of the different factors involved. The finalized causal loop diagram reveals the systemic relationships and provides a broad vision of interactive factors that are part of the complex construction innovation system.

The factors used in a CLD are both quantitative (measurable) or qualitative (non-measurable). Obviously, non-measurable elements, such as *Client's satisfaction*, *Government regulations* and *Quality of construction projects* are not generally measured directly; however, their inclusion adds considerable realism and power to the model. In a CLD, the elements are linked together by arrows that indicate a causal relationship as a direct influence. A causal link between two variables implies direction of change between the cause and effect pairs. The polarity is “+” when two elements increase or decrease together and the polarity is “-” when one variable increases whereas the other decreases, and vice versa.

Fig. 1. Four groups of variables

IV. DISCUSSION AND CONCLUSION

The first stage of the research consisted of the identification of essential system's factors undertaken through an expert consultation with industry and academic representatives in order to validate the list of variables. The following stage employed stakeholder engagement using the Systems Thinking technique to determine the cause-and-effect relationships between different variables within the system. This stage systematically assists the modelling of complex innovation system through creating an initial CLD integrating both qualitative and quantitative variables. The contribution of experts representing three groups of innovation system's actors was undoubtedly useful due to the knowledge they have of the situation and problem addressed.

Based on the information derived from the variables dependence and influence level ranking, eight influential variables were revealed having a priority when considering strategic actions or scenarios for the industry development. They included level of administrative barriers to innovation, government regulations, and PPP. It has been found that the key influential and dependent variables are the level of public and private R&D activity, import substitution, and government incentives. Identification and classification of key variables was essential for developing a framework suited for the Russia's construction innovation system, whereas the CLD revealed potential strategic pathways to overcome innovation diffusion challenges in the construction sector.

The conducted research is part of an ongoing project with three further research stages to be completed. The CLD explains interactions and interrelations. However, it may be considered as a didactic tool in order to understand the complexity of the system because the changes over time cannot be seen. Hence, this constructed CLD provides a roadmap for reference and is the basis for refinement and further building of a simulation model using the System Dynamics technique.

Fig. 2. Comprehensive conceptual model of construction innovation in the Russian Federation

Once the stock and flow model is developed it can be simulated by populating it with data. Available quantitative data will be collected. Nevertheless, the innovation system is very complex and consists of many relationships that are too qualitative to be expressed trustworthily by a mathematical formula. Hence, the next round of data collection will employ a participatory modelling approach in the form of workshops. Stakeholders from all three groups of the innovation system actors will discuss the

outcomes of the present research analysis and focus on portraying system structure. It is especially relevant in the case of the Russian construction industry where high uncertainty and lack of data is involved. Finally, different scenarios related to construction industry development innovation diffusion, as well as the impact of a range of strategic practices and policies will be examined in rigorous manner.

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