INCREMENTAL INNOVATION, PERFORMANCE AND FINANCING AS KEY ELEMENTS IN LOGISTIC CONTROL OF CONSTRUCTION COMPANY

Adam Sorokač – Branislav Mišota - Eduard Hyránek

Abstract

Currently, there is constant pressure to increase efficiency of company in construction sector, as in other industry. One of lesser-used methods for increasing efficiency in the construction companies is control of logistics with respect to its performance. These methods can be identifying by incremental innovation with an interdisciplinary approach, which uses correlation of incremental innovation and efficiency of logistics via gradual introduction of information and communication technologies (ICT). This is meant, increasing efficiency of traceability of material flow (logistics information system) at construction. Incremental innovation will be identifying by formulating innovative model with a central model Stage-Gate® Xpress and described the methodology to entry additional methodologies from various disciplines of the construction.

Modular application was designed with initialization innovation and next increment based on outcome of 3I model. The application is in this paper verified by simulation model of one technological operation. This process operation was simulated before and after upgrade. Application suitability has been verified by an expert evaluation.

Application was designed by means of industrial automation and technology with contactless reading of information - Radio Frequency Identification (RFID). We point to connection financial effects in the logistics segment by incremental innovation.

Key words: incremental innovation, construction, logistic information system, automation

JEL Code: L74, O14, O31

Introduction

Now, ICT for increasing traceability efficiency of material flow and logistics performance are clearly defined and used. Applicability of these technologies as well as non-contact transmission of data is verified by realized projects (Wang, Lin, & Lin, 2007) (Lu, Chen, Shen, Lam, & Liu, 2007). Therefore, using of RFID (not only in building logistics) can be considered returnable investment. Limiting factors for implementation of innovation of construction companies are funds and human capital (Forés & Camisón, 2016) (Arbe, 2012). Constrain initiate demand to create a method, which can implement ICT in lower cost in short time frame. The solution can lie through incremental innovation bringing progressive and complex increase of logistics efficiency. Each incremental innovation is a functional contribution to improvement.

Not only, problem solution of constrain, also ensure correct specification of requirements for a technology or other change as the upgrade process (Harty, 2008). Correctness can be achieved by an interdisciplinary approach as a cross-sectional area, which will touch suggested improvements. Interdisciplinary means consideration of possibility of mechanisms for construction site - logistics, requirements for technological procedures of construction - construction technology, flexibility in reflection to customer changes - holistic marketing.

1 Current state of solve issue

Construction industry and production in the construction sector is characterized by individuality of their products (building structures). Virtually, every building is unique and production is on-site product with storage facilities and pre-assembly. Situating warehouses, pre-assembly stage determine a material flow on construction site. Entire supplier chain effect on logistics construction (Saad, Jones, & James, 2002), it includes not only the logistics of construction site as well as all participants on production. The basic document of construction logistics is construction site layout plan. The construction site as a production space is given by building, it is unique in most cases. Therefore, application of logistics information system (LIS) will be designed with a sufficient degree of flexibility and modularity. Flexibility means possibilities to transfer for the new construction site. Modularity as a characteristic of LIS application is given by varying construction site size.

Small and medium enterprises usually do not have sufficient capital to create a separate R & D department (Sexton & Barrett, 2003). Product differentiation is determined by added value of

construction witch is contained in projects. Project respectively realize project is a drawings and text (Keegan & Turner, 2002).

A possible way is using potential of human capital for innovation. Alternatively, cultivate cooperation between academia and enterprises, where some authors (Arbe, 2012) (Oslíková & Tichá, 2016) regarded this cooperation as insufficient. Important is find ways of financing investment projects of construction companies. Incremental innovation creates opportunities to minimize costs, because final version of the solution may consist of several separate functional increments.

2 Research goal

Aim of research in this paper is identify way, which at minimum input costs through innovation can increase the efficiency of the logistics information system of construction logistics as a production process in construction industry. Effectiveness of logistics information system and hence, the efficiency of logistics (Wegelius-Lehtonen, 2001) is given by measure of traceability of material flow. Incremental innovation using an interdisciplinary approach, which was created by an innovation model for open methodologies from other disciplines in the construction industry. We can consider one way to increase logistic efficiency. If one takes objective defined above, then we can talk about following assumptions:

- Creating an innovation model introduced in construction company and its production
- Create solutions based on an innovation model will increase rate of traceability of material flow and efficiency of construction site logistics

Incremental innovations divide concrete solution to several increments, so that it is possible to set up an investment project in a short time frame, as well it is possible to divide financial burden on companies.

To increase efficiency and achieve stated research aim were chosen ICT with means of automation from other industries to minimize investment costs.

3 Methodology of creating interdisciplinary incremental innovation model – 3I model

Starting point is innovation model Stage-Gate® Xpress (Cooper, 2008), which has been indicated in introduction, model allows entry required criteria of disciplines. The new-

generation Stage-Gate® is modified with advantage of shortening time for innovation, and thus suitable for incremental innovation (Ettlie & Elsenbach, 2007).

Innovation model Stage-Gate® Xpress has been modified for individual processes in terms of control access methodologies of disciplines in innovation process. Methodologies are chosen as a cross-section through whole production process or part of this process, which require transfer of material or persons.

From perspective of control access of methodologies in innovation process, it has been determined superior methodology, in our case Stage-Gate® Xpress, which determines performance and innovation time frame of investment project.

3.1 Superior methods as a control function of innovation process

Control function has implemented decision step, which it applies strict criteria for continuation of subsequent events. Decision criteria may be changed only at beginning of innovation process, which is defined in initialization phase, and then it will not change and it must be strictly observe. In some investment action may appear demanding defined criteria as a complication. But, when we talk about the innovation processes, which are repeated at shorter intervals, they can't retain in ongoing process, because they will be block source for next increment. Criteria should be set, so that it can stop the innovation process when the criteria doesn´t satisfy. The criteria are creating by closed questions, or by bounded real value based on empiricism of real projects. It is important to set achievable criteria.

Control function in the form of innovation methodologies should support parallel course of operation. It is an important feature of the methodology, because it minimizes time of one increment. The idea of concept is to set short investment, but with given frequency of increment.

In general control methodology may divided into the following parts (see Fig.1.):

Initialization part – It determine criteria for throughput of innovation, or may be change of frequency of increments, also it will identify sources for investment and whether it is realized with the identification of sources.

Analytical part – this part identifies shortcomings via creating model of existing production process, bottlenecks in logistics

Implementation part – when is create new model of production process with innovation, then it is possible to create a project (technical project for the purposes of documentation, production

materials) on which it will be implement changes, and also recovery new system and its testing operation

Part of evaluation - term real benefits

3.2 Methods with control access to innovation process

The concept of incremental innovation model, in general, in the first phase make current production model and search bottleneck of production through the selected methodology or empiricism bottleneck of production. The second phase will include change in the new model. Methodology for creating model of production process should be:

- *clear*, graphic representation of production or other processes should be transparency, mainly in the case of larger process
- *easy* to apply changes, it should be providing by a manager without in-depth knowledge of the technology
- *modular*, the overall production process consists from various operations that are linked together into a whole, and therefore the selected graphic language should be allow the creation of a database of production operations - modules
- *implemented* (not necessary) respectively expandable through a module included in enterprise software.

3.3 Methods for identification bottleneck

The methods have to allow for specificities of shortcomings and specify of time frame established control methodology. The starting point choice of method is acquisition of added value by manufacturing part, which means method of production:

- *Piece production*, for example construction industry is characterized by individuality of the product. In construction is used project management and production of one product will typically takes a few months or years
- *Series production*, characterized by production of the same or partially different product in a short time

It is not excluded use several methods as follows:

- *Cascade follow-up*, progressive scheme methods, where one method narrow down and follow methods describe the problem in detail

- *Cascade supplementary* scheme methods, where one method can determine the problem alone, but in case of a more detail parameters is used supplementary methods

4 Research result

4.1 Created 3I model creation

According to methodology described above has been formulated 3I model (see Fig.1.) respectively interdisciplinary incremental innovation model. The model is read from top to bottom, when we talking about the time period in 4 parts: initialization, analysis, research and implementation, evaluation of investment. The time frame is guarded by control functions – Stage-Gate® Xpress, where access methods we read from left to right.
3I model has a matrix structure, where y-axis reflects time plane and x-axis reflects process plane.

4.2 Implementation of industry automation means with RFID

Proven technology in logistics of construction is contactless technology - radio frequency identification (RFID). Contactless technology RFID stores information in the, and then readers read data at distances up to several meters. We can read information from tags witch are fixed to logistic means and tracking entities supply chain in the construction. RFID technology is applied with acceptable results to practice (Wang, Lin, & Lin, 2007).

4.3 Autonomous monitoring of concreting

In this part, we didn't set processes within 3I model, but we directly determine technical solutions for implementation. The initial solution is modular concept. Concreting is operation of technological steps - foundations. Concreting is pouring concrete to pre-pit of certain sizes and shapes. Concrete is transporting to construction site by mixer truck and distributed to pit by concrete pump. Quality of concrete evaluate by a paper certificate of truck mixer driver. Concrete pouring must be continuous, so that the layers joined together, either directly from truck mixer, or with a concrete pump with a radius up to 70m.

Table 1 Innovation cost

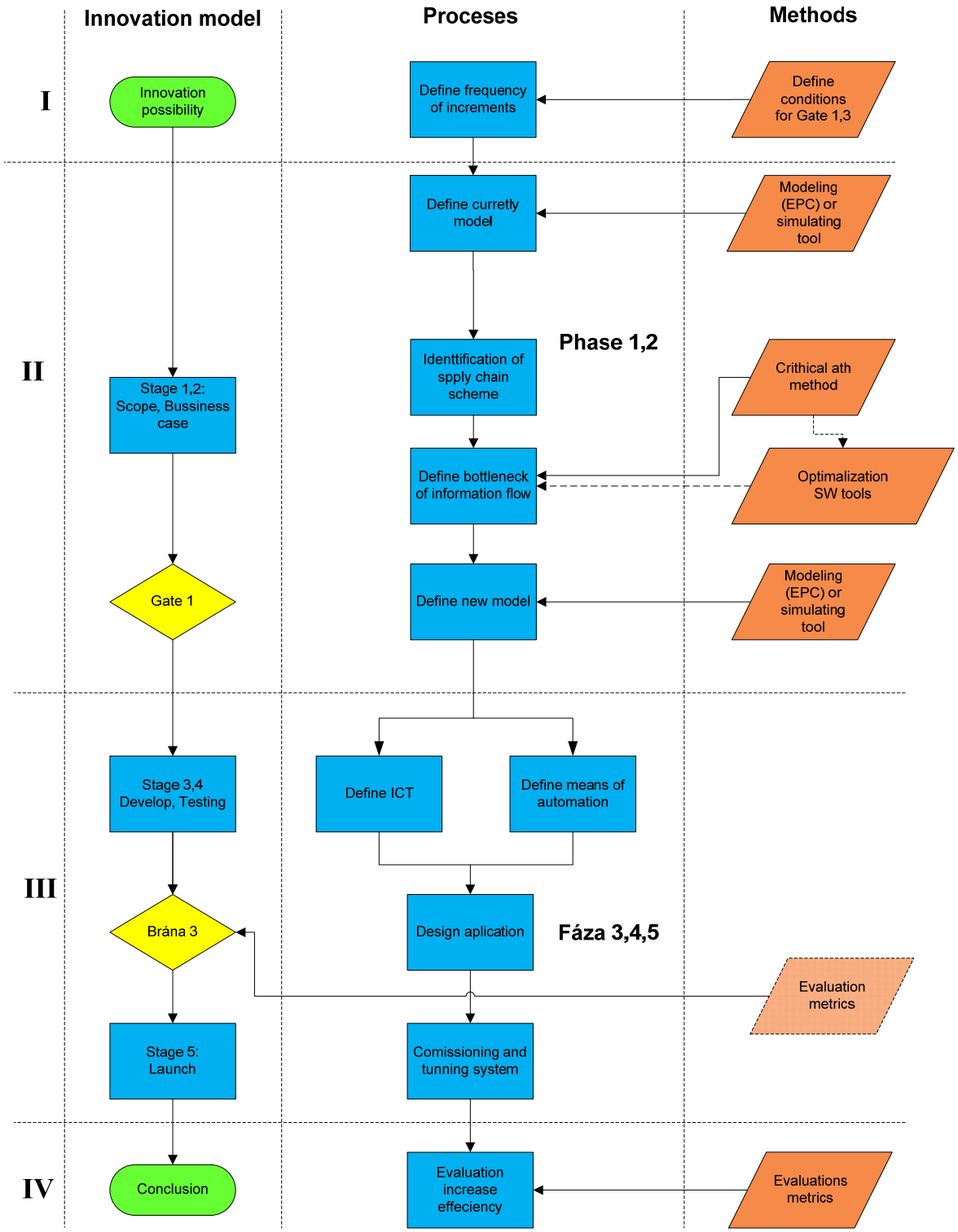
Initialized innovation – Gateway with web server		
Item	Describe item	Sum
1	Tags for mixer trucks, RFID antennas with 4m radius and reader, evaluation device with web server	4 099 €
2	Steel construction for antennas and switchboard	1 280 €
TOTAL	Initialized innovation	5 379 €

Source: Author

5 Discussion

We can talk about a closed area on construction site with imaginary entry in case of concreting foundations. It will be considering one entrance / exit for mixer trucks, on which will be positioned passive tags (without power supply) with information about the quality and quantity of concrete, vehicle identification (driver's name or registration number of the subcontractor) or vehicle license plate with the name of the driver. Information will be read via RFID reader with antennas and central processor unit with web server will be provide this information on website.

Figure 1 3I model



Source: Author

5.1 Simulation

Simulation model was created by simulation software Witness Lanner Group. Where elements were used with the following specifics:

- Mixer trucks with a capacity 7 m3 of concrete.
- Shift has 10 hours
- It was defined one operator, construction manager

Table 2 Results of simulation

Status	Name	% Busy	% Idle	Quantity	No. Of Jobs Started	No. Of Jobs Ended	Avg Job Time
Before	Labor_control	0.84	99.16	1,00	42,00	42,00	0.50
After	Labor_control	5,76	94.24	1,00	42,00	42,00	3,43

Source: Author

Conclusion

Paper does not disclose procedures details of creating and then implementing innovations, but it describe application, currently model of technology operation – concreting and model of concreting with innovation. Experts expect contribution mainly to determine location of mixer trucks on construction site during continuous concreting of large concreting foundation (about 500m^3). The simulation model takes account of control quality and quantity of incoming concrete to construction site by site manager. Simulation model after innovation includes initialized investment and one increment. About Table 1 we save time less than 5% of the time fund site manager, but about expert's greater benefit has been seem other benefits:

- Increase transparency of the material flow at construction site
- Improve the reaction times for response of concrete plants as a guarantor of continuous supply of concrete with a maximum guaranteed downtime between mixer trucks
- Potential reduce of plying mixer trucks
- Remotely overview of construction material inputs via Internet
- Increase efficiency of material flow management on construction site

Information and communication technology constantly progressing to optimize the production process. Trends in industrial automation and mutual communication are continuously deployed into production, but in construction industry, this trend is not applied as in other sectors. Character of construction industry production respectively construction of buildings has

relevant difference, which makes it difficult to implement new ICT innovations and industrial automation means. And therefore the aim of this paper was to identify way of implementation in form 3I model, which we can be implemented new technologies to enhance efficiency of logistics in construction. Design solutions must be fully modifiable, flexible because of the individuality construction production.

Designed applications using ICT with industrial control system wasn't implemented in real production but the benefit has been verified by simulation and proven by experts. Simulation results quantify direct benefits of saving time of construction manager, but more important are the unquantified benefits, that they contribute to higher efficiency of management.

When we correctly adjusted the funding and set up intervals of possible investments for incremental innovation, then is a possible way of implementation of ICT in construction production.

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Contact
Ing. Adam Sorokač
Institute of management, Slovak university of technology Bratislava
Vazovova 5, 812 43 Bratislava
asorokac@gmail.com

Ing. Branislav Mišota, PhD.
Institute of management, Slovak university of technology Bratislava
Vazovova 5, 812 43 Bratislava
branislav.misota@stuba.sk

doc. Ing. Eduard Hyránek, PhD.
Faculty of Business Management
University of economics in Bratislava
Dolnozemská cesta 1, 852 35 Bratislava
eduard.hyranek@euba.sk