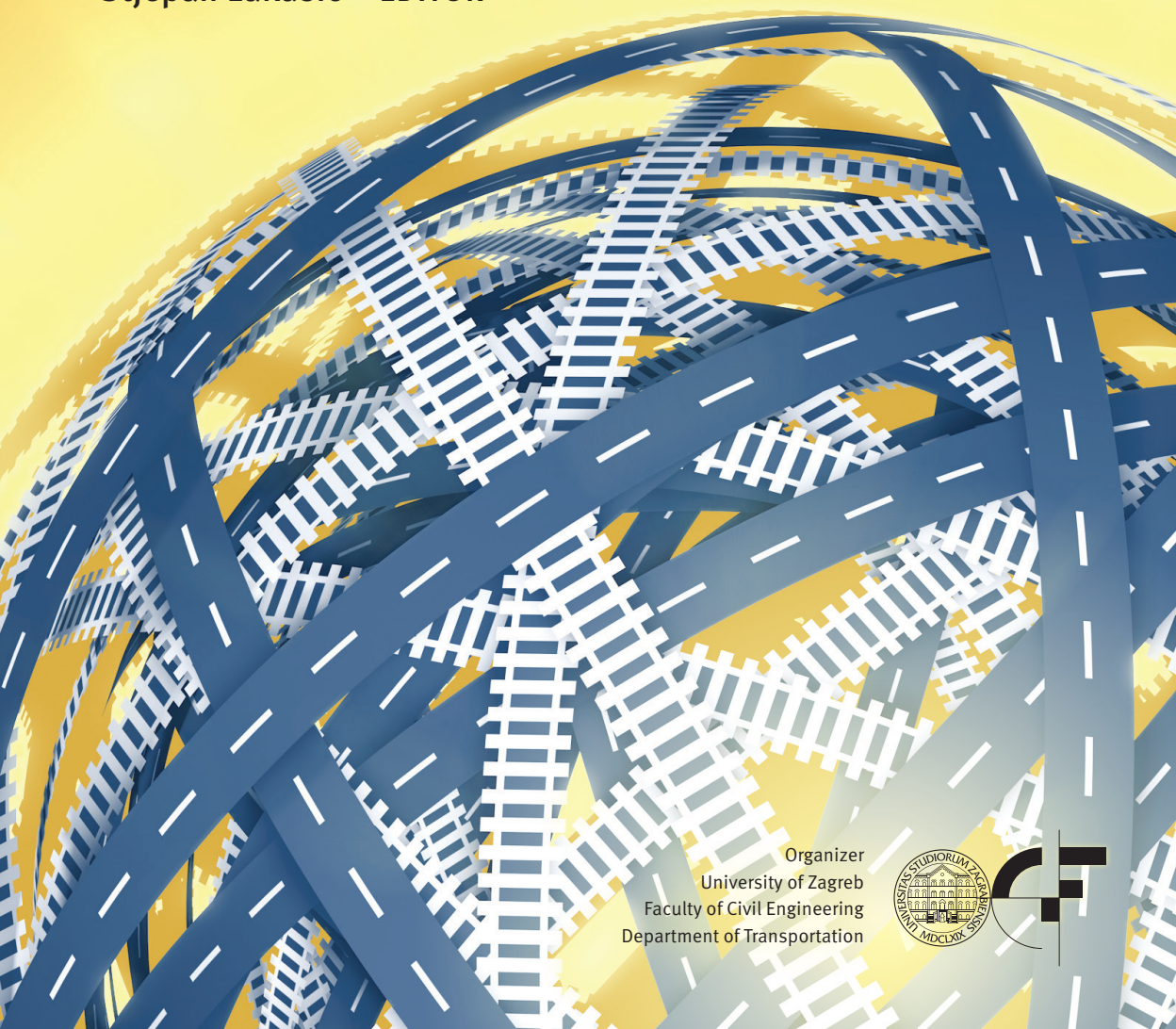
CETRA 2016

4th International Conference on Road and Rail Infrastructure
23-25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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IMPACT OF THE ENVIRONMENT OF AN ORGANISATION ON ITS CAPACITY FOR THE DIFFUSION OF INNOVATIONS: ITT APPLICATION AND BIM ADOPTION

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Abstract

Architecture, Engineering and Construction (AEC) industry is an industrial branch in which innovations are introduced relatively slowly, whether they are new products and/or new or significantly improved production processes. Two principal phases of the process of diffusion of innovations within an AEC organisation were defined in the earlier conceptual model of diffusion of the Building Information Modelling (BIM) as an innovation: the initial phase which precedes the decision making on adoption of the innovation and the next phase – implementation. In this Paper it is attempted to recognise the influential factors of an organisation's environment on the initial phase of the diffusion of innovations within the organisation. A quality research was carried out on two expert groups: on the expert team for BIM, and on the expert team for asphalt technology. The latter team investigated innovative application of the Indirect Tensile Test (ITT) method for asphalt, according to the harmonised standard HRN EN, with the purpose of improving designing, i.e. dimensioning of asphalt courses in pavement structure. Each expert team recognised environmental influential factors and grouped them in three principal groups: factors of the general or social environment of the organization, factors of the business environment, and internal factors within the organisation. The Paper presents the analysis of the obtained research results for each group, as well as their comparative analysis. Influential environmental factors were defined, which impact the adoption of innovations in AEC organisations in the Republic of Croatia. This measurement instrument may be used to continue a research in order to rank and recognize those influential factors that should be acted upon primarily, with the goal of increasing the capacity of an AEC organisation for adoption of innovations.

Keywords: diffusion of innovations, Building Information Modelling (BIM), Indirect Tensile Test (ITT), environmental factors

1 Introduction

Common opinion is that innovations are introduced relatively slowly in Architecture, Engineering and Construction (AEC) industry. Many innovations in our country do not get appropriate feedback, among other things, because of our lack of information [1]. Two examples are discussed: innovative application of the Indirect Tensile Test (ITT) method for asphalt and Building Information Modelling (BIM) as an innovation. Identification of the actual parameter values of the stiffness module of asphalt is applied to verify critical stresses and strains that occur in layers of the pavement structure due to the given traffic load. In Croatia, outdated and inaccurate data on the properties of materials are used, which were obtained by testing the dynamic elastic modulus as a function of temperature, conducted 49 years ago [2].

As innovative application, ITT relates to the identification of stiffness module at exploitation temperatures of mixtures, types of hot asphalt mixtures currently used for road construction in Croatia, in order to obtain input parameters to check strains and stresses that occur in pavement structure [3]. Although BIM is perceived as an innovation that brings a number of benefits for all stakeholders in the realization of a construction project, BIM is not yet accepted worldwide in the expected volume and the expected rate of adoption [4]. According to Murphy [5], the problem of BIM implementation can be successfully solved if approached as implementation of innovation. BIM diffusion process at the level of organization has been identified within the theoretical framework of diffusion of innovations (DOI) [6]. The proposed model identified the following main groups of influential factors on the DOI in an AEC Organization: social and business environmental factors, internal organizational factors, previous related knowledge, perceived properties of an innovation, and communication channels.
This paper presents a qualitative research of the impact of environmental influential factors of an AEC organization on its ability to acquire and assimilate an innovation. The research was carried out on the example of BIM and ITT as an innovation, with participation of experts from both fields, in order to investigate whether it is possible to recognize the environmental factors that influence the diffusion of innovation, regardless the type of innovation.

2 Innovation in construction

According to Guidelines for collecting and interpreting innovation data ("Oslo Manual") from 2005, "An innovation is the application of a new or significantly improved product (good or service) or process, a new marketing method or a new organizational method in business practices, workplace organization or external relation"[7]. Slaughter [8] defines innovation as the actual use of non-trivial change and improvement in the procedure, product or system, which is new for the institution developing this change. The innovation is "any idea, practice or object that is perceived as new by an individual or other unit of adoption. It matters little, so far as human behavior is concerned, whether or not an idea is objectively new as measured by the lapse of time since its first use or discovery." [9]. It is important that the idea is perceived as new by the individual.

2.1 BIM

Building Information Modelling (BIM) is defined in different ways in literature [10], [11], [12] but all the definitions have several key elements in common: the process of creating a digital model, combination of "smart" elements containing both qualitative and quantitative data, interoperability of data, integration of processes based on a high level of mutual cooperation of all stakeholders with a joint goal – to manage the structure efficiently throughout its entire lifetime. The result of this process is a "building information model" – "a digital representation of physical and functional characteristics of a facility, a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle" [13].
According to the Oslo Manual, it follows that BIM is both a product innovation and a process innovation [7]. According to the classification model [8], BIM is a systemic innovation, since BIM requires changes in information and communication terms in different organizations, which leads to complex problems of interoperability, which depends on the interconnectedness and cooperation of stakeholders, and on cultural changes, all aimed at creating a unique system in order to raise the quality of execution.

2.2 ITT

Resilient or reversible module is the ratio of repeated stress and reverse (resilient) relative strain due to repeated short-period stress corresponding to the load of wheels of a moving

vehicle. Resilient module describes the effectiveness of different layers of road structure on the stress distribution within the pavement structure, resulting from traffic loads. The theory of elasticity is used to predict the relative resilient strain or shift during mechanistic design of flexible pavement structures. In laboratory, resilient modulus of asphalt mixtures is usually determined by indirect tensile testing ITT, [14]. Testing is not destructive because stresses are very low.
According to the results of a previous research [3] the determined moduli of stiffness at four temperature values, confirm that the ITT method – indirect tensile tests can optimize the composition and properties of asphalt mixture. Based on the obtained results, the parameters of actual performance of asphalt pavement structures will be used during exploitation. This innovation contributes to reducing deviations from the actual values in calculations of stresses and strains of individual layers due to traffic load, and thus optimizing the process of structural design, and also of quality control of built asphalt pavement structures.

3 Absorptive capacity for the diffusion of innovations

The diffusion is "the process by which an innovation is communicated through certain channels over time among the members of a social system" [9]. The definition itself contains the four basic elements of diffusion of innovation: (1) innovation, (2) communication channels, (3) time, (4) social system.
The process of BIM diffusion at the level of organization, according to the conceptual model [6], takes place in two main phases: the initial and the implementation phase. The initial phase consists of two sub-phases: "Awareness of the need for BIM adoption" and "Feasibility study and proposal to adopt", after which the decision on BIM adoption is reached. If the decision is positive, the implementation phase follows, which consists of the following: "Adapting the organization to BIM", "Training and user support for wider use", "Sustainability of the continuous application" and "Evaluation and improvements". The model also identifies main groups of influential factors on the diffusion of innovation (BIM) in an AEC Organization (Fig. 1).

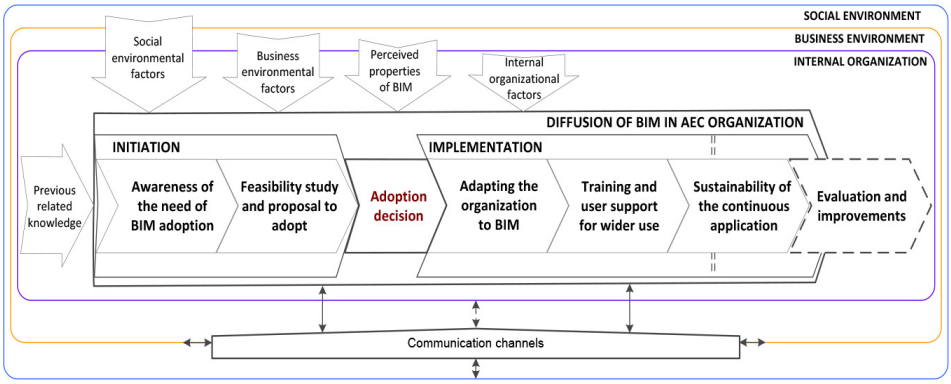

Figure 1 Conceptual model of BIM diffusion in AEC organizations [6]

The conceptual model of the diffusion of innovations in construction industry on the example of BIM diffusion as innovation is based on the theoretical model of the diffusion of innovation, but it is also supplemented with the basic tenets of the absorption capacity concept.
The most cited contribution to the development of the theory of absorptive capacity is the work of Zahra and George in 2002 which defined the absorptive capacity (ACAP) as "set of organizational routines and processes by which firms acquire, assimilate, transform and exploit knowledge to produce a dynamic organizational capability" [15]. The following four dimen-

sions of ACAP arise from the very definition: acquisition, assimilation, transformation and exploitation. The authors define "acquisition" as "a firm's capability to identify and acquire externally generated knowledge that is critical to its operations." "Assimilation" refers to the firm's routines and processes that allow it to analyze process, interpret and understand the information obtained from external sources. "Transformation" refers to "a firm's capability to develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge." The fourth component "Exploitation" refers to "the ability of the organization based on processes that allow the organization improvement, expansion and use of existing competences or create new ones by applying the adopted and transformed knowledge in its operations."

3.1 Organization environment

Each organization acts under the influence of the environment in which it conducts business (Fig. 2). According to Buble [16], "the environment denotes the totality of participants that influence the business operation of a company, and which need to be respected by the management during decision making". In doing so, he distinguishes external environment which is divided into general or social environment and business environment or the environment of the task and the internal environment. While the main characteristic of the general or social environment is the fact that is not under direct control of the company, business environment or task environment is constituted by active participants in the immediate environment of the organization that have an influence on its capacity to service this environment. The internal environment represents "the part of the total company environment that is contained within itself" [16]. It can be fully influenced and controlled (Fig. 2).

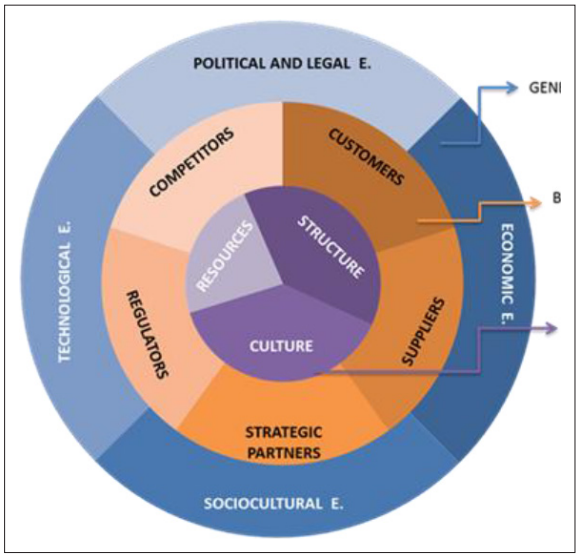

Figure 2 Organization environment according to Buble [6]

The research, the results of which are presented in this paper, is carried out in order to identify the environmental influential factors that affect the capacity of the AEC organization for the acquisition and assimilation of innovation, i.e. the ability of the AEC organization to recognize and accept the external innovative knowledge, and to understand and process it, in order to enable the management making decision whether to start the implementation phase of such innovation.

4 The process of defining the key environmental factors

The process of defining the key environmental influential factors was carried out in three phases. The first phase was creation of the initial set of items. It was followed by the phase of testing content validity of this set of items through a qualitative research by a panel of experts, for each of innovations separately. The content validity and construct validity was rated for each expert group. The third phase consisted of a comparative analysis of the research results for both innovations which resulted in certain conclusions.

4.1 Creating the initial pool of items

Creating the initial pool of environmental influential factors of the organization consisted of three groups of factors: external social, external business factors and business environment within the organization. Although it is not possible to determine the exact number of items that the initial set should contain, the general rule is: "the larger initial set, the better." [17]. The initial set of items for this research resulted from the literature review and published research results, and consisted of 22 items in total social environmental factors, 12 items in the group of business environment factors and 39 items in the group of internal environment factors, i.e. total of 73 items. The qualitative analysis of gathered information about environment factors, the initial set of items is narrowed down to total of 46 factors: 12 factors of the social environment, 13 businesses and 21 factors of internal environment.

4.2 Testing the content and construct validity of environmental factors

To ensure the content validity of an instrument, in the next step of the performed research, the experts' replies were collected through a questionnaire that was submitted them by e-mail. A letter explaining the objectives and method of completing the questionnaire was attached to the questionnaire. The questionnaire was prepared in the form of MS Excel sheets, and it consists of 46 factors of the organization environment. The comments contain explanations of certain terms used in the questionnaire. The respondents were supposed to determine the importance of each factor for the acquisition and assimilation of innovation (BIM / ITT) at the level of organization in construction industry, and by selecting one of the propose answers (1 not a relevant factor, 2 important, but not decisive; 3 essential; 0 I cannot answer). In addition, they could make comments for each of the factors as further detailed observation with regard to its relevance, clarity of description, etc.. A panel of experts involved in the research consisted of 10 individual experts for each example of innovation. Lawsche equation (content validity ratio, CVR) [18] was used for rating of the content validity:

$$CVR = \frac{\left(n - N/2\right)}{N/2} \tag{1}$$

where N is total number of responses, n is frequency number of panelists who evaluated the item with 2 or 3 (a positive response to the assessment of the individual environmental influential factors). The minimum value of CVR coefficient of 10 respondents is 0.62 [18].

The questionnaire also asked the panelists to classify each of the listed environmental factors in one of groups: SO – General or social organization environment, PO – Business organization environment, IT – Internal organization environment and O – Other (factor not appropriate for any of the listed groups of environmental factors). Although the respondents categorized all offered factors, only those factors that have passed the previous CVR test are included in the analysis of construct validity of the instrument. If an item is consistently classified into a

specific category, it is considered that it has the validity of convergence with that construct and discriminant validity with others.

4.2.1 Expert panel for BIM

Expert panel for BIM consisted of four university professors, four experts employed in the AEC organizations and two experts from organizations that sell appropriate software. After analyzing their responses, a total of 29 items passed CVR test. After sorting environmental factors per groups, total of 25 items remained (Table 1). The calculated Cohen's kappa coefficient is 0.72, which shows good agreement of experts participating in this research with the classification factor according to theoretical divisions and results of previous researches in accordance with the literature. Further review of comments of respondents and qualitative analysis of other factors provided a list of 27 environmental factors of the AEC organization that affect its acquisition and assimilation of BIM (Table 1).

Table 1 Results of research of environmental factors for BIM

Target category	Initial	After CVR test	After sorting	Qualitative analysis
Internal environment	21	12	11	12
Business environment	13	10	9	10
Social environment	12	7	5	5
TOTAL	**46**	**29**	**25**	**27**

4.2.2 Expert panel for ITT

Expert group of respondents for ITT consisted of four laboratory experts, three university professors and three designers of pavement structures. Total of 27 items passed CVR test. After sorting into individual groups, 9 internal environmental factors, 7 factors of business and 4 factors of the social environment were recognized for which the expert team agreed to have an impact on the acquisition and assimilation of ITT in organizations in the construction industry. The calculated Cohen's kappa coefficient is 0.6 and shows good agreement of experts participating in this research with the classification of factors according to the analysis of literature. Qualitative analysis of other factors provided a list of 23 environmental factors of the AEC organization that affect its acquisition and assimilation of ITT (Table 2).

Table 2 Results of research of environmental factors for ITT

Target category	Initial	After CVR test	After sorting	Qualitative analysis
Internal environment	21	14	9	10
Business environment	13	7	7	7
Social environment	12	6	4	6
TOTAL	**46**	**27**	**20**	**23**

4.3 Comparative analysis of environmental factors

The comparative analysis of research results of the environmental influential factors of the organization on the acquisition and assimilation of innovation in the example of BIM and ITT has shown that 9 internal environmental factors were recognized as important influential factors for the acceptance of innovation in AEC organization. The Cohen's kappa for these two groups of experts related to the issue of internal factors amounts to 0.62 and shows good agreement of experts in their assessment.

However, Cohen's kappa coefficient for the group of business environmental factors is 0.20, which represents a poor agreement of the two expert groups (in only six factors). For the group of social environmental factors, the calculated Cohen's kappa coefficient is negative, which means that there is no agreement of expert groups in assessing the significance of these factors (they agree only for two factors). The list of common environmental factors (recognized by both expert groups) is shown in Table 3.

Table 3 Environmental factors of AEC organization that influence the acquisition and assimilation of innovation

INTERNAL ENVIRONMENTAL FACTORS
· Support of senior management at the organization level
· Level of IT/ technological expertise of employees
· Level of IT infrastructure of the organization
· Standpoint of the organization management on competition and entrepreneurship
· Available funds that the organization intended for the procurement and maintenance of IT infrastructure and training of employees to adopt new knowledge and technologies
· Formalization of rules, procedures and communication channels at the organization level
· Availability of human resources with the required knowledge, skills within the organization
· Systematic training of the organization employees
· Available time within the organization for adoption of new knowledge and technologies
EXTERNAL BUSINESS ENVIRONMENTAL FACTORS
· Pressure of competition at national and EU level to accept innovation
· Pressure of the construction sector at national and EU level to accept innovation
· Implementation of innovation to meet the client's needs
· Level of the market demand for a given innovation
· Willingness of partners who collaborate with the organization for the adoption of new knowledge and technologies
· Willingness of partners who collaborate with the organization for the adoption of new knowledge and technologies
· Cooperation with foreign partners in research, educational and development projects
EXTERNAL SOCIAL ENVIRONMENTAL FACTORS
· Legislation through general and specific laws and technical requirements
· Economic recession affecting the construction sector

5 Conclusion

The problem of adoption of innovations at the AEC organizations can be seen as the diffusion of innovation throughout the organization, which firstly needs to develop its potential and realization absorptive capacities for external adoption of innovative knowledge. In such a process, the organization is influenced by the external social environment, business environment and internal environment of the organization itself. The results of the qualitative research carried out on examples of BIM and ITT as innovations in the construction industry show that it is possible to define the key factors of the internal environment of the organization regardless the type of innovation, and the impact of external environmental factors on the analysed cases is not unambiguously defined.

This research is limited by the fact that only two examples of innovation were investigated, a future research of some other examples of acceptance of innovation in the AEC organizations could supplement the conclusions reached.

Further research should be focused to the verification of the results of this research on the wider population of respondents in AEC organizations which would determine the intensity of influence of certain environmental factors that can help the organization management to undertake the necessary actions to improve its potential absorptive capacity to accept innovations.

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