Adoption of Innovation in Segregated Construction Project

Rakhmat Fitranto Aditra[1] and Agus S. Ekomadyo[1]

[1] School of Architecture, Planning, and Policy Development, Institut Teknologi Bandung
rakhmat.aditra@gmail.com

ABSTRAK

Perkembangan di industri konstruksi saat ini semakin menunjukkan segregasi dalam proses industrialisasi yang berlangsung.. Penelitian ini merupakan hasil telaah terhadap sebuah fenomena segregasi dalam suatu kegiatan adopsi inovasi pada sebuah proyek kecil, seperti segregrasi pada industri konstruksi pada umumnya. Studi kasus yang digunakan adalah proyek konstruksi Musholatorium, singkatan dari Musola dan Planetarium, yang terletak di Lembang, Bandung. Inovasi yang dimaksud dalam penelitian ini adalah perancangan dan penerapan struktur kubah geodesik pada bangunan ini. Metode yang digunakan terdiri dari (a) deskripsi proyek serta (b) analisis. Proses proyek terdiri dari (a) Inisiasi, (b) desain Arsitektur, (c) desain komponen, dan (d) fabrikasi komponen dan konstruksi. Berdasarkan analisis, dapat dinyatakan bahwa terdapat ketidakefisiensian dalam distribusi pengetahuan mengenai inovasi akibat kurangnya kolaborasi. Hanya pemilik proyek yang ikut serta dalam keseluruhan proyek dan dapat menyimpulkan dan mengembangkan inovasi Musholatorium tersebut. Karakteristik proyek konstruksi, yaitu tersegmentasi, menyebabkan aspek inter-disiplin sulit untuk dikomunikasikan antar aktor. Untuk memperkenalkan sebuah inovasi dalam proyek kontruksi bangunan, menjadi sangat penting untuk semua aktor ikut terlibat di dalam proyek sebagai suatu kerja secara kolektif.

Kata kunci: kubah geodesik, adopsi inovasi, musolatorium, konstruksi

ABSTRACT

The development in construction industry in recent times show the tendency of segregation in industrialization process. This research observes the segregation phenomenon of innovation adoption on small scale construction project as like as segregation phenomenon of construction industry at common. Case study in this research is Musholatorium, which is an abbreviation of Mushola (prayer room) with planetarium, in Lembang Bandung. The innovation on this research was the geodesic dome structure as a Musholatorium. The method used in this research consisted of: (a) describing the project and (b) analysis. The project process consisted of (a) initiation, (b) architectural design, (c) component design, and (d) component fabrication and construction. From the analysis, it could be suggested that there are inefficiencies of knowledge distribution during the project process since the knowledge was transferred without sufficient collaboration. Only the owner involved during the whole process and could actually conclude the whole to develop the innovation. The nature of construction project, which usually be segmented, caused the inter-discipline aspect hard to be communicated between actors. In order to introduce innovation into building construction project, it is important for the actors to involve and collaborate inside the projects as a collective works.

Keywords: geodesic dome, innovation adoption, musholatorium, construction

1. Introduction

Construction industry has been recognized as industry with slowest innovation adoption (World Economy Forum, 2017). Even though there were innovation in material or digital technologies, the gap between the innovators and the users is still wide. It also apparents that the development in construction industry during the previous decade was moving towards segregation and industrialization (Oxman, 2010; GIrmscheid. 2005). As the problems and knowledge in each process of industry getting deeper, segregation grew wider. While it was suggested that this segregation creates limitation on design, this research would explore the effect of segregation towards the adoption of innovation.

This research analyses the adoption of innovation on project that mimicking the segregated phenomenon of construction industry on small scale. Case study in this research is Musholatorium in Lembang. It was owned by an Astronomy entrepreneur, Hendro Setyanto, as the main actor of the Musholatorium. Musholatorium is one of the facilities in Imah Noong Community, a community focused on education of religion and astronomy. Imah Noong was founded and led by the main actor, with several young volunteer. This community also collaborate with the neighbourhood, which mostly does not familiar with astronomy community, to support its program. Children from the neighbourhood were joined the program. The neighbourhood also support the program by providing food, beverage and other commerce.

Figure 1. Musholatorium Imah Noong

Innovation as the focus on research was the geodesic dome structure of the Musholatorium, which was designed in previous research project. Musholatorium was a new term first used for the first built structure which became this research object. Musholatorium was an abbreviation of Mushola (prayer room) with Planetarium. Musholatorium built in Lembang was based on geodesic 2 variaton structure with wide span of 6 meter. This structure could be considered as innovation since it was the first combination of such two programs and also the geodesic dome was not familiar among dome makers. This project could be considered as the miniature of whole construction industry since it includes the whole cycle of building project: design, manufacture, and construction.

2. Research Question

This research will try to analyze the adoption of innovation phenomenon in incrementally executed project. Research questions in this research are:

a) What are the effects of the innovation characteristic to the adoption of the innovation?

b) What are the effects of the segregation in the project to the adoption of the innovation for each stake holder?

3. Methodology

The methodology used in this research was descriptive methodology. The method consisted of (1) describing the project process, and (2) Analysis of adoption of innovation process.

3.1 Describing the project process

The project process will be explained from idea generation to the completion of the building. Project process was divided into 5 stages: (1) initiation, (2) Architectural Design, (3) Component design, (4) Component fabrication and construction, and (5) Operation. This division was selected due to the innovation involved in this project, and the involvement of the actors. The information was collected from (1) interview with the owner of Musholatorium, and (2) observation of the design to build process.

3.2 Analysis of adoption of innovation process

Logical argumentation research method was used in this analysis (Groat and Wang, 2013). Logical relationship between project process and adoption of innovation process was built to show the correlation between those two aspects.

The adoption process experienced by the actors was then analyzed. The analysis will be based on adoption of innovation process by Rogers (2003). Since it was found that there was segmentation in the project process, more detailed processes of each actor were cross-categorized based on the project process and the adoption of innovation process. The involvement of actors in each project process also described. Subjects considered to be actors were the individuals/groups that involved directly in the project. Involvement of each actor in every stage of the project process and adoption of innovation stage was also cross-categorized.

The aim of this analysis method was to see the pattern of adoption between each actor and analyzed the correlation between this pattern to the inefficiency of adoption and miscommunication between actors that occurs.

4. Result

4.1 Project Process

To understand the phenomenon deeper, it is important to describe the history and process of the project as it is. It is started by the owner idea and then incrementally executed until the construction of the building.

4.1.1 Initiation

The main actor first saw the geodesic as planetarium in Nanjing institute of Astronomical optics & Technology. As most of dome in mosque or mushola in Indonesia use a radial structure, he interested to market the geodesic configuration as Musholatorium since it has unique style.

The main actor was a member of Boscha Observatorium Community. Here, he met Prof. Widjaja Martokusumo, an architect who then led the architect team to design the preliminary design for the Musholatorium. The financial support of the preliminary design process was from the University grant.

4.1.2 Architectural Design

The architecture team was consisted of the team who were involved in the design and construction of geodesic bamboo dome in World Bamboo Festival 2015 in South Korea (Aditra & Widyowijatnoko, 2016). The team used this experience as the starting point of the design of geodesic dome. The same script for the modeling was used to create the geodesic dome configuration. At this stage, the team came up with the 2V geodesic dome configuration, overall structure of geodesic dome, landscape design and toilet facility. The architectural design process actually intertwined with the component design since the architect team used the algorithm approach that enabled a direct communication between both processes. Most of iteration of architecture design is based on the change in the component design.

Figure 2. Built geodesic dome in World Bamboo Festival 2015
(Source: Project documentation, 2015)

Architect team only design the preliminary design of the interior. On the concept of inner dome, it was designed to be able to channel the hot air inside of the room from the opening between the wall and the inner dome to the top opening.

4.1.3 Component Design

In this project, most of the attention directed toward the component design, since its unique geometry and function. The first drawing for the inner structure was inspired by the bamboo geodesic dome. In case of bamboo geodesic dome, the connection was designed to be adjustable to comprehend the imprecision caused on site (Figure 3). Architect team collaborate with a steel fabricator to get input about the fabrication difficulties and to fabricate the connection and struts prototype. The steel fabricator was not involved in the construction process.

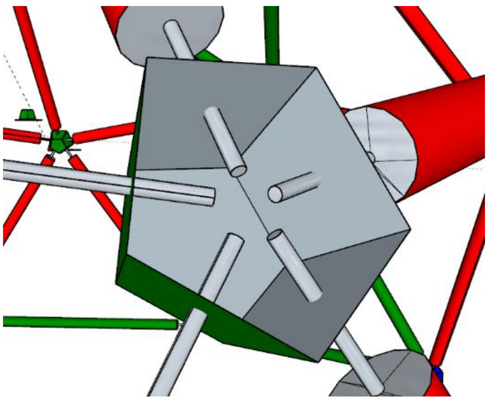

Figure 3. 3D model of the 1st connection component

(Source: Architect team documentation, 2019)

After prototyping one segment of the first alternative of geodesic structure component with the collaboration with a steel fabricator, the cost of the whole structure was estimated. It was due to its three connections type which required CNC to be manufactured. The expensive cost encouraged the owner and architect team to come up with simpler structure component design. Thus, the architect team designed the second alternative. It was inspired by the common steel geodesic strut construction. It has the simpler manufacture process but did not have any adjustment system.

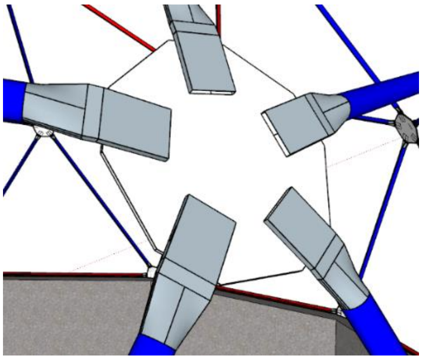

Figure 4. 3D model of the 2st connection component
(Source: Architect team documentation, 2019)

4.1.4 Component fabrication and construction

Both of structure system alternative prototypes were fabricated during the architecture design process, but only the second alternative that selected. The component design was also changed during the fabrication and construction process. Fabrication and construction process were created simultaneously and incrementally. For this fabrication and construction process, several donations to the foundation were used, mostly from corporation CSR, Imah Noong visitor, and Institut Teknologi Bandung alumni.

At the fabrication stage, several component details were changed. After the design was created and the foundation of dome was done, the owner continued to finish the structure. The owner met a dome constructor. The dome constructor was a firm that was experienced in constructing mosque dome. In this stage the constructor only took the main concept and dome size as an input which then processed again to create new drawings. As the constructor used to build mosque dome, they used their experience to build Musholatorium. Here they used different rod size and configuration. The 25 mm diameter rod designed by architect team was changed into 50 mm diameter rod. The change was done based on the constructor experience, especially to support the weight of builder during the construction process.

The connection plate design also changed. The architect team design was a set of slightly uneven polygon. This uneven design was due to the different angle which the struts connect with each other. This difference was considered not to significant by the constructor, thus the connection was simplified into round plate.

Figure 5. New design of connection plate, and struts
(Source: Owner documentation, 2018)

The entrance and the mimbar structure were also based on the same steel frame, instead of the concrete frame designed by architect. Roofing was change from the calcium board which designed by architect to enamel, which used mostly for mosque dome. The top opening of dome, which is designed to flush out the heat also not applied due to the difficulty of construction. Additional struts were added to divide the triangle segment to support the use of enamel and to support buckling

Figure 6. Steel frame for the entrance, detail of enamel roof, and additional struts
(Source: Owner documentation, 2018)

Separated from the outer structure, the inner structure was constructed with different stakeholder. It was made of fiberglass, was casted offsite, and assembled on the site. While the design was provided by architect team, the segmentation and connection were designed together by the main actor and the fabricator. After the connection of the inner dome, the inner surface was then smoothed by gypsum and painted. Ventilation concept on the inner dome was not presented due to the absence of top opening, change in the inner dome dimension and also the sealed connection between the inner dome and the wall.

Fig 7. Fiberglass inner dome and sealed connection between the inner dome and the wall
(Source: Owner documentation, 2018)

4.1.5 Operation

The musholatorium facility was finally opened at 5 November 2017. Up until now, this facility has been used for praying and 360^{o} video screening. Several problems that need to be upgraded have been observed by the owner, such as:

- Enamel joint at the intersection of dome and the prism were leaking. There was no flashing design on that area.
- Hot air was collected in the dome. While the opening in the wall is able to exchange the air at the elevation of 60cm from floor, hot air above the wall is still trapped.
- To achieve the optimum cost, the main actor and the dome constructor considered that the geodesic dome structure needs to be enlarged up to 8 meters diameter. They also considered that it needs up to 75 cm void between the inner dome and the geodesic structure for construction easiness and sound system
- The finishing of the fiberglass inner dome was found to be meticulous and created imperfection.
- Fiberglass considered to trap the heat and to hinder the sound system. At this stage, the owner found that using a perforated metal would be more appropriate to absorb sound, ventilate the interior, and achieve smoother surface.
- Most visitor and consumer gave feedback about finishing, which is the least considered part of whole project.

4.2 Adoption Process Analysis Result

4.2.1 Adoption Process Experienced by Each Actor

The adoption process experienced by each actor will be explained in the Table 1 to 3. Each steps of adoption of innovation will be compared with each step of the project process.

Table 1. Owner Innovation Adoption Process

Owner	Initiation	Architectural design	Component Design	Component fabrication and construction	Operation
Knowledge	About geodesic dome	About geodesic dome configuration	About existing geodesic component design	About enamel construction, simpler geodesic dome design	About the operational problem and further improvement

Persuasion		Approaching the architect team		Approaching the constructor team	Re-negotiation with the constructor team
Decision		Component design version 2	Component design version 2	Component design version 2#	
Implementation					
Confirmation					Continuation of mass-produced Musholatorium dome

From the Table 1, it could be suggested that the owner underwent iteration of innovation adoption process throughout the project. Owner acquired new knowledge about the innovation in every stage of the project. From the experience during the operation, owner then could decide whether to continue the usage of the same technology to be commercialized. Thus, it could be also suggested that the owner was acting as innovator by "researching by trial and error" about the Musholatorium geodesic dome.

Table 2. Architect Team Innovation Adoption Process

Architect Team	Initiation	Architectural design	Component Design	Component fabrication and construction	Operation
Knowledge		Musholatorium idea	Component design 1 and 2		
Persuasion			Elaboration of version 1 and 2		
Decision			Selection of component design 2		
Implementation					
Confirmation					

Architect team only involved during the architectural design and component design, but experienced knowledge to decision adoption process. Architect team already had experience and knowledge about geodesic dome but still acquire new knowledge of Musholatorium from the owner. The previous knowledge and experience made the knowledge process during the Architectural design faster while also created redundancy during the component design. By collaborating with steel fabricator, architect team acquire new knowledge about their initial component design and also new inspiration to create the second component design.

Table 3. Constructor Team Innovation Adoption Process

Constructor Team	Initiation	Architectural design	Component Design	Component fabrication and construction	Operation
Knowledge				Musholatorium idea Component design no 2	
Persuasion				Evaluating the component design no 2 from architect	
Decision				Adjustment of component design	
Implementation					
Confirmation					Re-evaluation of construction fee

Constructor only involved during the component fabrication and construction to operation, but experienced whole process of innovation adoption. They experienced the first knowledge inquiring about the geodesic dome and the Musholatorium, and able to evaluate the execution. They experienced the persuasion to implementation process without collaboration with the architect team as they only worked based on the architect team's drawing. Thus, the component design was according to their experience on building mosque dome.

4.2.2 Involvement of Actors in the Project Process

Involvement of Actors in the Project Process will be summarized in Table 4. This table was created by overlaying the Table 1 to 3.

Table 4. Actor Innovation Adoption and Project Process

Actor involvement	Initiation	Architectural design	Component Design	Component fabrication and construction	Operation
Knowledge	Owner	Owner Architect	Owner Architect Fabricator	Owner Constructor	Owner
Persuasion		Owner			
Decision		Owner			
Implementation					
Confirmation					Owner Constructor

From the Table 4, it could be suggested that the owner, architect team, and constructor team, never completely engage together throughout the project. Yet, all of the actors also experienced the first process of adoption which is knowledge.

4.3. Discussion

From the result above, it could be suggested that there was an attempt to increase the efficiency of knowledge distribution during the project process through collaboration. Architect and steel fabricator collaboration in the component design resulted improvement from first component design to the second component design. If the steel fabricator was not involved, the cost of iteration might be higher.

Yet there were still some inefficiencies of knowledge distribution during the project process since the knowledge was transferred without sufficient collaboration. Opposite to the collaboration between architect and fabricator, collaboration between architect and constructor was not happening. Some of the problems arose in the building implementation could be prevented if these two actors collaborated (Table 5). Other than that, each actor undergone the almost whole adoption of innovation process in each stage of project. It showed the inefficiencies whether in the adoption of the innovation or in the project delivery. Only the owner involved during the whole process and could actually conclude the whole project and operation of building to further use and develop the innovation.

Table 5. Constructor and Architect Miscommunication

Building aspect	Design	Implementation	Possible better design
Steel struts	Dome structure is separated from the entrance and window structure to prevent leaking	Using similar struts system as the window and entrance structure. No separation with the dome structure. Leaking happens in the connection between them	Using enamel as the roof covering, but separate the entrance and window structure with the dome structure.
Roof covering	Calcium board panel	Enamel	
Outer and internal dome	The top opening of dome to flush out	Top opening was not applied, due to lack of detail design using enamel as the roof covering	Additional detail drawing to support the top opening of the dome

This phenomenon is similar with one of innovation problem mentioned by Yuliar (2011). One of the problems faced by the researcher in Indonesia is how to connect the research problem with the problem of the society or industry. Some researchers tend to solve the problem by expand their network to the industry which also shifts the researcher paradigm into industrial one (Figure 8). But, as mentioned by Ekomadyo (2018) and Yuliar (2011), it is important for the network to expand among all of the actors (Figure 9). This network expansion turned out to be important during an innovative building construction project.

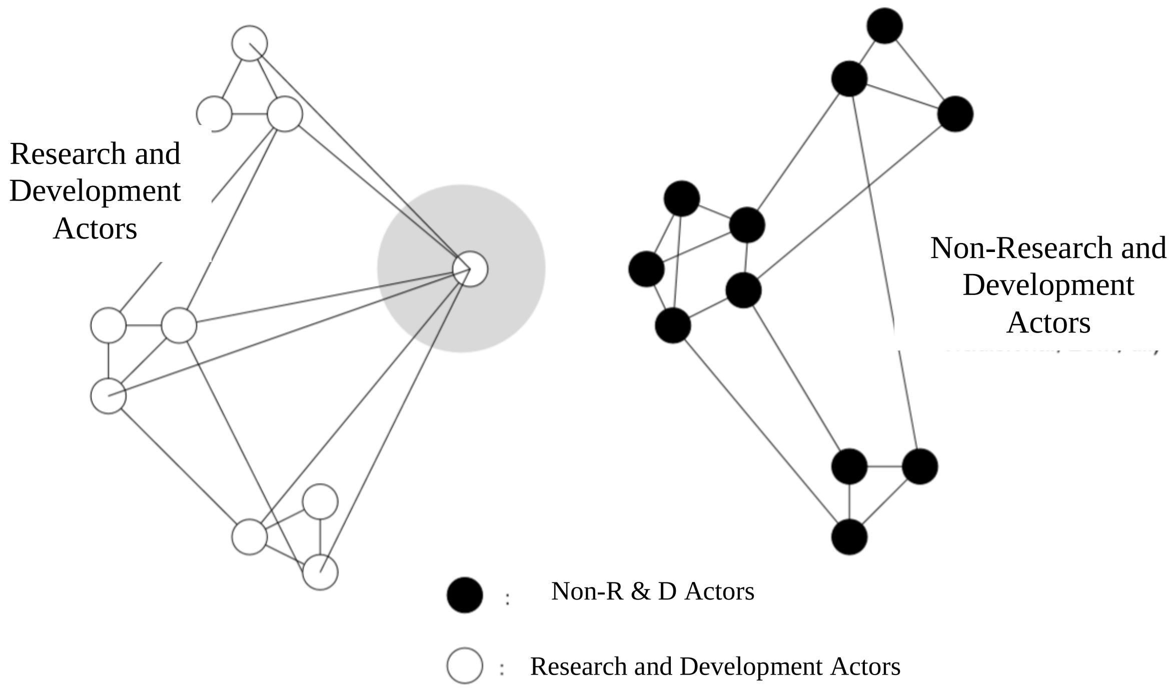

Fig 8. Researcher Dispersion among Non-research Network – Contra Research and Development Situation
(Source: Yuliar, 2011, with editting)

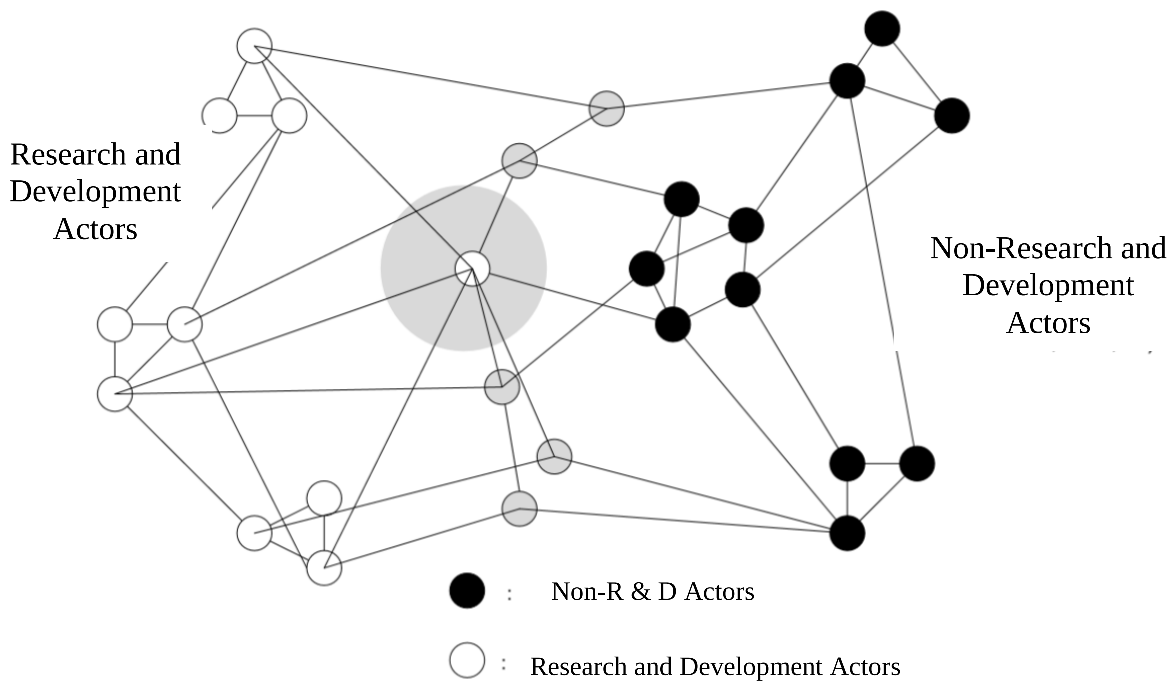

Fig 9. Mutual Extension between Research and Non-research Network through Mediators – Pro-Innovation Situation
(Source: Yuliar, 2011, with editting)

5. Conclusion

From the analysis, it could be concluded that the segregated project process was affecting the adoption of innovation. Each actor will experience separated innovation adoption process without collaborating with each other. It will create backtracking in the design process and also ineffectiveness of innovation application. In this case, the backtracking process and ineffectiveness could be seen where the constructor altering the component design without the architect insight which create problem that should be found if both actors collaborated.

From this research, it could be seen why it is difficult to innovate in construction industry, especially if the innovation involved inter-discipline concern. The nature of construction project, which usually be segmented as the project getting bigger, caused the inter-discipline aspect hard to be communicated between actors. The result from this research also suggested that, in order to introduce innovation into building construction project, it is important for the actors to involve and collaborate to discuss the whole process of the project.

Acknowledgement

We would like to say thanks to Hendro Setyanto who have involved as in the design and research of Musholatorium. We also say thanks to Widjaja Martokusumo who have involved as the design team.

Reference

Aditra, R. F. and Widyowijatnoko, A. (2016). *Combination of Mass Customization and Conventional Construction: A Case Study of Geodesic Bamboo Dome.* CAADRIA 2016 [Proceedings of the 21st International Conference on Computer Aided Architectural Design Research in Asia]. Melbourne (Australia), 30 March–2 April 2016, 777–786

Ekomadyo, Agus S., Santri, Tyas., and Riyadi, Andhika. (2018). *Habitat for Innovative Milieu: A Place-Making Study of University and Start-up Enterprises Relationship.* OP Conf. Ser.: Earth Environ. Sci.152. Doi: 10.1088/1755-1315/152/1/012020

Girmscheid, Gerhard. (2005). *Industrialization in Building Construction – Production Technology or Management Concept?* Understanding the Construction Business and Companies in the New Millenium, Helsinki: Technical Research Centre of Finland (VTT) / Association of Finnish Civil Engineers (RIL)

Groat, L. and Wang, D. (2013), *Architectural Research Methods, 2nd Edition*, John Wiley & Sons.

Oxman, Neri. (2010). *Material-based Design Computation*. Massachusetts Institute of Technology. Url: hdl.handle.net/1721.1/59192

Rogers, E. M. (1983). *Diffusion of Innovatoon*. New York. The Free Press

Yuliar, S. (2011). *Research Transformation to Innovation*. National Research Council, Jakarta

World Economic Forum. (2017). *Shaping the Future of Construction: Inspiring innovators redefine the industry*. Geneve. World Economic Forum