

## ASSESSING THE CREATIVE IMPROVISATION OF A CHIEF BUILDER IN OVERCOMING TECHNICAL PROBLEMS OF INTERIOR DESIGN PROJECT USING LINKOGRAPHY

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**Abstract.** The production process in the interior design project implementation was represented by a chief builder who oversees the field. The chief builder is required to help designers solve technical problems in the field by improvising spontaneously, called outsmarting. This research aimed to understand the chief builders' creative improvisations in overcoming technical problems during the interior design projects implementation. This research was conducted by naturally experimenting on four different interior design project implementations. By using a concurrent protocol, the discussion process between the interior designer and the chief builder was recorded, transcribed, and processed using linkography. It was found that in solving problems, the chief builder; (1) relied on the information gained from previous experience in overcoming similar problems, (2) matched the conditions in the field with the expectations that were originally expected, and (3) changed the method or the system formation to be more effective without changing the design. In providing a solution to the problem, the chief builder was very dependent on the directions and expectations conveyed by the interior designer. This research can be used as material in the training process of chief builders to increase their independence in overcoming technical problems in the interior design projects implementation.

**Keywords:** *production process, problem solving, interior design, project implementation, chief builder, linkography, creative improvisation.*

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### 1. Introduction

The production stage in a design is one of the most important activities. Archer (1965) in his journal entitled "Systematic Method for Designers" said that the process of forming a design into an artifact is also important to define a design. As stated by Goldschmidt (2001) in Christopher Alexander's book, it is said that design is a special activity where the translation into an indirect form occurs, or in other words executed by another party. In the production stage, designers are assisted by other parties who have specific expertise on the problems to be solved so that the design object can be realized.

Design is also said to be a problem-solving activity. In the "Linkography" book, Goldschmidt (2001) said that design is a series of problem-solving activities in which analysis is derived from a collection of information that is used to produce alternative

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solutions to problems. From several alternative solutions, a solution that is considered the most optimal will then be selected. The series of processes of solving problems into solutions is said to be a design process. The activity of solving problems in design starts from the conception process, and iterates onwards until the design object with the most optimal solution is generated.

A lot of research on the design process has been done, but in general, the research is carried out in the early stages with the designer as the subject. Research conducted by El-Khouly and Penn (2013) analyzed the creative thinking mechanism that occurs in the architectural design process. The research was conducted using the linkography method and equipped with a quantitative analysis of the data that was obtained from direct observations in the architect's work process. The results of this research indicated that the mechanism of creative thinking can be analyzed using the linkography method. Observations that were made directly can also provide actual data that can represent a common design process. The research provides insight into how linkography can provide detailed analysis in researching the design process. Cai et al. (2009) used linkography to analyze creativity and the effect of fixation on sources of inspiration in design. This research was conducted to investigate design patterns in designers with different skill levels. This research is exploratory research conducted by giving the same task to designers with different skills. By using linkography, a detailed analysis of a design process was obtained.

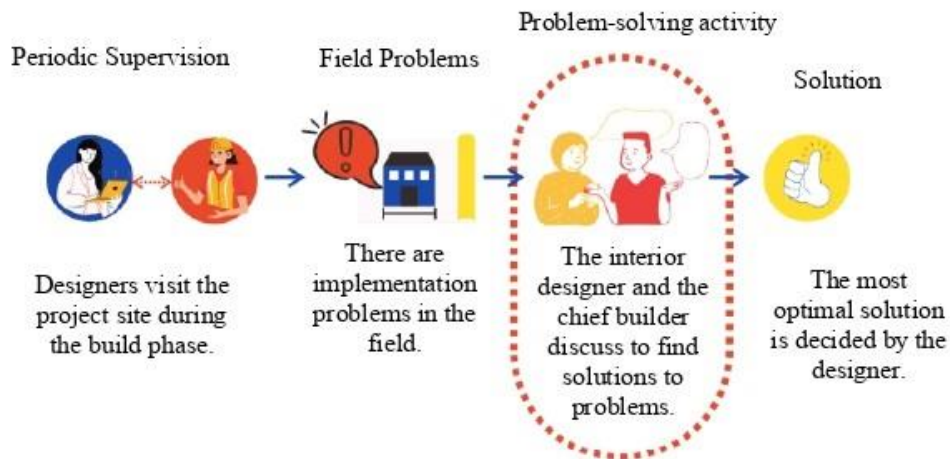
Research on the production process in the design is not done as much as in the design process. Several types of research related to the production process in the design were carried out by Snider et al. (2013) that analyzed the creative processes that occur in the later stages of the engineering design stage. In this research, Snider et al. created a code system that can be used to analyze creative behavior in the later stage of the design process. The analysis provides an overview of the two approaches to creative behavior that is identified in the later stage of the design process. The research explained how the coding process can be done to analyze the factors that influence design behavior. In addition, Hatcher et al. (2018) argued that research that generally measures creative output has not been able to describe the creative thinking process as a whole. In their research, Hatcher et al. conducted 10 experiments on groups of 3-5 participants each, who were asked to build a solution using two methods, namely design improvement and brainstorming. From this research, it was found that in building solutions at a later stage, designers are more progressive when looking for solutions by brainstorming.

Several previous types of research regarding chief builders have been conducted. Kassem et al. (2021) observed the effect of equipment management efficiency on productivity in infrastructure projects. This research aims at understanding and develop the process of measuring the productivity of the use of equipment in the implementation of infrastructure projects against the need to develop performance in construction projects. Lemna et al. (1986) conducted research on the productivity of a chief builder, which was carried out by trying to identify the characteristics of a chief builder who was classified as productive and less productive. In this research, it was concluded that the chief builder who planned a work schedule was more productive than those who could not make a schedule. Positive feedback on the work done affects the productivity of the chief builder. Shohet and Laufer (1991) explained that the function of the chief builder in the implementation of construction projects received less attention. This research examined the behavior of the chief builder in the implementation of a construction project and analyzed the activities carried out by the chief builder. Lahouti and Abdelhamid

(2012) examined that in the implementation of a construction project, the workers are faced with ambiguous problems and they are required to re-evaluate even though they have received the work instructions. This research found that more explicit job instructions would result in more effective and efficient work.

There has not been much research on chief builders and their role in the production process, especially in relation to the production process in design. There is no research that specifically examines the creative improvisation of the chief builder in overcoming technical problems that occur at the implementation stage of interior design projects. Therefore, the results of this research are expected to contribute to the programs carried out to increase the capacity of resources in developing the creative abilities of the chief builder as involved in the process of implementing interior design projects.

This research is exploratory research conducted by directly observing the discussion process between the interior designer and the chief builder that occurs at the stage of periodic supervision in the implementation of interior design projects. The research was conducted when the interior designer coordinated with the chief builder in the periodic supervision stage (Figure 1).



**Figure 1.** The process of solving problems during periodic inspections

In the supervision process, the chief builder conveys the field conditions that occurred to the interior designer, and reports and asks if there are problems in the field that will affect the design. To solve field problems, the interior designer and the chief builder will discuss finding a solution. The chief builder as a representative of the implementing party who knows the conditions that occurred in the field provides solution ideas that can be considered by the interior designer in making decisions. In the discussion process, the chief builder analyzes the problem, synthesizes alternative solutions, and states the alternative solutions to the designer, to be taken into consideration in taking the most optimal solution.

## 2. Methods

The discussion process needed in the analysis using linkography is a specific process so the moment of recording the conversation must be right. Based on the recordings of 10 selected research objects, only four experiments met the needs for the analysis. Due to the research being conducted in conditions that are not conducive to

interior design projects, as well as the limited time in the research, experimental candidates cannot be reproduced. The four teams involved in the research experiment are listed in Table 1.

**Table 1.** Team of experimenters based on the name of the design studio

No.	Consultant Name	Project	Project Progress
1.	Tuju Semesta	Kitchen Set	50%
2.	Artes Studio	Custom Cabinet	50%
3.	Artakara	Wall Treatment	45%
4.	Terabobo	Under Stair Cabinet	50%

The first experiment (A) was carried out on the process of supervising the implementation of the Kitchen Set in residential facilities. The second experiment (B) is the supervision of the implementation of a custom cabinet in private office space facilities. The third experiment (C) is the process of supervising the implementation of the dining room wall treatment in restaurant facilities. The fourth experiment (D) is the process of supervising the implementation of the under-stair cabinet for residential facilities. The four experiments (Figure 2) were carried out during a discussion between the chief builder and the interior designer in a stage of periodic supervision. The experiment was carried out by recording using two cameras so that the discussion process could be recorded optimally.

The recorded data obtained from each experiment was then processed based on the pre-determined data processing stage. The order of processing the data is:

1. Protocol analysis, namely the concurrent protocol, is carried out directly during the interior design implementation process. A concurrent protocol is carried out by directly following and recording the discussion process between the interior designer and the chief builder in the implementation of the interior design project.
2. The data from the protocol analysis was then transcribed and parsed based on the change of speaker or the change of topic in the conversation. To find out the issues in each transcript description, a coding process was carried out using the F-B-S Ontology method (Gero & Kannengiesser, 2014). F-B-S is used to analyze the factors that influence the thinking process of the chief builder.
3. The transcript description data marked with the F-B-S code was then analyzed using the linkography method (Goldschmidt, 1990). Linkography processes the data transcript into graphs that illustrate patterns of linkage between transcript descriptions so that from these patterns, the train of thought of the builder can be analyzed, as well as the productivity of the observed conversations.

### **2.1. Protocol Analysis**

The protocol analysis method used is concurrent protocol analysis, which is an analysis that is carried out while the thinking process is being carried out. The goal is to get the actual events and what they are from a discussion process between the interior designer and the chief builder. The data generated from the concurrent protocol can provide knowledge about the steps in decision making that occurred between the explanatory stimulus provider and the selected result (Kuusela & Paul, 2000).

Protocol transcription is obtained from data in the form of video and audio recordings that have been collected and then decomposed into conversation transcriptions. Not all transcript descriptions can be used in the analysis process, so there are categories of transcript descriptions that can and cannot be used. The description categories that can be used are those that meet the following criteria:

1. Spoken by a different subject.
2. A description that contains a theme related to the design.
3. A brief description such as “yes” if it is the answer to a description containing the design theme.

Categories of transcript descriptions that are not used as data analysis are:

1. Descriptions that discuss issues outside the context of implementation.
2. Descriptions provided by other than the interior designer and chief builder.
3. Words that are mentioned repeatedly in one description.

The recorded data was then processed into a conversation transcript which was parsed based on the change of speakers or changes in the topic of conversation (Table 2).

**Table 2.** Example of the transcription of protocol analysis

No.	Speaker	Utterance
1.	AB	<i>"This size is out of the picture, right, what size is the iron?"</i>
2.	JC	<i>"46, 40, 25"</i>
3.	AB	<i>"But there must be a spare."</i>
4.	JC	<i>"It's usually a box, isn't it?"</i>
5.	JC	<i>"46, 40, 25, this is 58 huh? 50, isn't it? Do you want to combine it in 58?"</i>
6.	JC	<i>"Just use 58 so that it can be it line with the door."</i>
7.	AB	<i>"That's it?"</i>
8.	JC	<i>"How about a picture of the cut from the side, how wide is it?"</i>
9.	AB	<i>"It's 4 centimeters thick.. oh it's 40."</i>
10.	JC	<i>"It's 46, right?"</i>

## 2.2. F-B-S Ontology

From the description of the transcript obtained by protocol analysis, then the coding process for each word was carried out using the F-B-S code compiled by Gero (2014). The coding scheme was used to identify the issues contained in each word description in the transcript. The F-B-S code specified in each description of the transcript is used to analyze the factors that influence the thinking process of the chief builder. With this F-B-S ontology, the process of transformation of issues in conversation can also be identified, which in this research is used as one of the data to analyze the train of thought of the chief builder.

Each description of the transcript can only be assigned one F-B-S code that represents the contents contained in the description. Determination of the code in each description cannot be done only by looking at the words in the transcript description, but also by looking at their relationship to the words before and after them. This is because the issues in a presentation can be different even though they contain the same words. For this reason, in the coding process, the recorded data was also overlooked to find out the flow of the conversation. The F-B-S code scheme used is described in Table 3 below.

**Table 3.** F-B-S code scheme

Code	Issue Description	Example Issue	Sample Transcript
<b>R</b>	Requirements Directions or design provisions of an artifact.	<ul style="list-style-type: none"> <li>• Dimension</li> <li>• Material</li> <li>• Design</li> </ul>	<i>"...it means that 65x147, 147x52x32, and 147x87x32 are the one with the frame."</i>
<b>F</b>	Function The function that the artifact has is based on the needs and expectations.	<ul style="list-style-type: none"> <li>• Practical</li> <li>• Economical</li> <li>• Cozy</li> </ul>	<i>"Let's close it so when people go down the stairs a little, they don't see it."</i>
<b>S</b>	Structure The elements that make up an artifact.	<ul style="list-style-type: none"> <li>• Mounting system</li> <li>• Material</li> <li>• Installation path</li> </ul>	<i>"We will close it with HPL again later. After being ripped off, we'll add more HPL."</i>
<b>Be</b>	Expected Behavior The quality of the expected and planned structure of an artifact.	<ul style="list-style-type: none"> <li>• Estimated price</li> <li>• Expected strength</li> <li>• Expected speed</li> </ul>	<i>"We'll lock it for two centimeters so that we can fulfill the early one."</i>
<b>Bs</b>	Behavior by Structure The quality that is formed from the actual condition of the structure.	<ul style="list-style-type: none"> <li>• Cost</li> <li>• Formed strength</li> <li>• Execution speed</li> </ul>	<i>"But there are so many HPL connections."</i>
<b>D</b>	Description The final state of a structure.	<ul style="list-style-type: none"> <li>• Finalization</li> </ul>	<i>"Right, it's the same."</i>

**Table 4.** Distribution of Issues in the F-B-S ontology

No.	Code	Distribution Type	Distribution Description
1.	R→F ; F→Be	Formulation	The process of translating requirements into a function that is expected to occur.
2.	Be→S	Synthesis	The process of determining a solution in the form of a structure that forms the expected requirements.
3.	S→Bs	Analysis	The process of adjusting the solution to the conditions that occur.
4.	Be↔Bs	Evaluation	The process of comparing expected uses with actual uses.
5.	S→D	Documentation	The process of finding a solution which is then shaped into an agreed decision.
6.	S→S'	Reformulation 1	The process of reformulating the components that make up the requirements into new components.
7.	S→Be	Reformulation 2	The process of formulating the components that make up the requirements to fit the expected needs.
8.	S→F	Reformulation 3	The process when a structure creates a new function.

The code represents the issues contained in each description of the transcript. For the transformation of issues in F-B-S, a code that represents the change in process that occurred in the chief builder's mind when solving problems is also given. The description of transformation of issues based on the F-B-S ontology is described in Table 4.

The description of the exposure that has been coded based on the issues contained in it is processed using the linkography method, with the use of LINKOgrapher software (Pourmohamadi & Gero, 2011). LINKOgrapher makes it easy to get linkography graph analysis that is equipped with general statistical data from the linkography graph. Although the analysis process was assisted using the software, the process of determining the relationship between design moves was done manually.

### **2.3 Linkography**

The linkography method discovered by Goldschmidt (1990) has advantages in processing verbal analysis data into a graphic form that illustrates the relationship between the steps that occur in a design discussion process. In general, linkography is used to analyze the design process. However, in this research, linkography was used to analyze the processes that occur in the process of design formation, namely the implementation of interior design projects. The aim is to analyze the thinking mechanism used by the chief builder in solving design problems, the factors that influence the thought process, and the productivity of the conversation between the chief builder and the interior designer. As stated by Goldschmidt (2004), productivity in design is a structure that can be analyzed using linkography. By using this method, the mechanism of thinking carried out by the chief builder can be seen based on the limitations that are generally considered in making design decisions.

The mechanics of thinking of the chief builder head can be analyzed based on the patterns formed in the linkography graph. The linkography elements and patterns used in this research to analyze the mechanics of the chief builder include:

#### *a. Design move*

The description of the sentences obtained from the protocol analysis that has been coded F-B-S in the linkography was used as a design move. The design move represented a chief builder's train of thought about the problem or condition in the field that will be solved. In solving problems, the design move was information from the chief builder's thoughts which would then be analyzed or synthesized into a problem solution.

#### *b. Links*

The links that were created in a series of linkography would form a pattern that was used to analyze the mechanics of thinking of the chief builder. Design moves that had a large number of links indicate that the chief builder's thinking process tended to be productive.

#### *c. Chunk Pattern*

The chunk pattern formed in the linkography indicated a problem-solving process that occurred during the discussion process between the chief builder and the interior designer. By identifying this chunk pattern, it can be seen what thoughts and issues were considered by the chief builder when making creative improvisations in solving technical problems in the field. A chunk pattern was also used to analyze the type of chief builder's thinking process when solving problems.

#### *d. Critical Move*

It is a design move that has a recurring relationship with the previous or subsequent design move. Critical moves are divided into two types, which are referred to as backlinks and forelinks.

- A forelink ( $>$ ) occurs when a design move has a recurring link with the design move that follows it. Forelink signifies a new thought, which leaves what has been done. The analysis of the thinking mechanism in solving the forelink pattern problem indicates the existence of a divergent thinking process.
- A backlink ( $<$ ) occurs when a design move is related to the previous design move. The backlink shows that the subject is concentrating on what has happened. The backlink pattern indicates a convergent thought process.

#### *e. Pivotal Move*

A pivotal move is a design move that forms a pattern of backlinks and forelinks. By analyzing the issues contained in a pivotal move, the thought process of the chief builder who can bring up new ideas that are the result of analyzing previous information can be seen.

### **3. Results**

#### **3.1. Experiment A**

Experiment A was carried out during periodic supervision of the production of a residential kitchen set. The conversation between the interior designer and the chief builder lasted about 12 minutes. At the time when the experiment was carried out, the installation had been running for one week in the field, with 50% progress. In the process, there are several sections that become the topic of discussion regarding the process of installing the kitchen set. Also, the interior designer and the chief builder were faced with an obstacle where the height of the kitchen set in the field did not match the dimensions contained in the drawing document, so a solution was needed to ensure that the kitchen set produced was still in accordance with the design approved by the assignor (Figure 2). There was also another obstacle to the difference in the width of the cabinet with the design so that it was not parallel to the wall.



**Figure 2.** Kitchen set installation conditions in Experiment A

Experiment A consisted of 103 design moves, with a total of 222 links. From the linkography pattern in experiment A (Figure 3), it was found that in the conversation, there were seven changes in the topic of conversation to the object of the kitchen set.

Experiment A showed that the thinking process of the chief builder in developing the solution occurs in a structured manner. In solving the problem of the size difference in the kitchen set, the chief builder was imagining the addition of material used to cover the side of the cabinet so that it is in line with the wall. In finding solutions, these thoughts go through a process of re-analyzing of the proposed solutions that are expressed and synthesized into a new thought, which underlies further analysis. The analysis-synthesis process occurs repeatedly so that a solution decision approved by the interior designer was obtained.

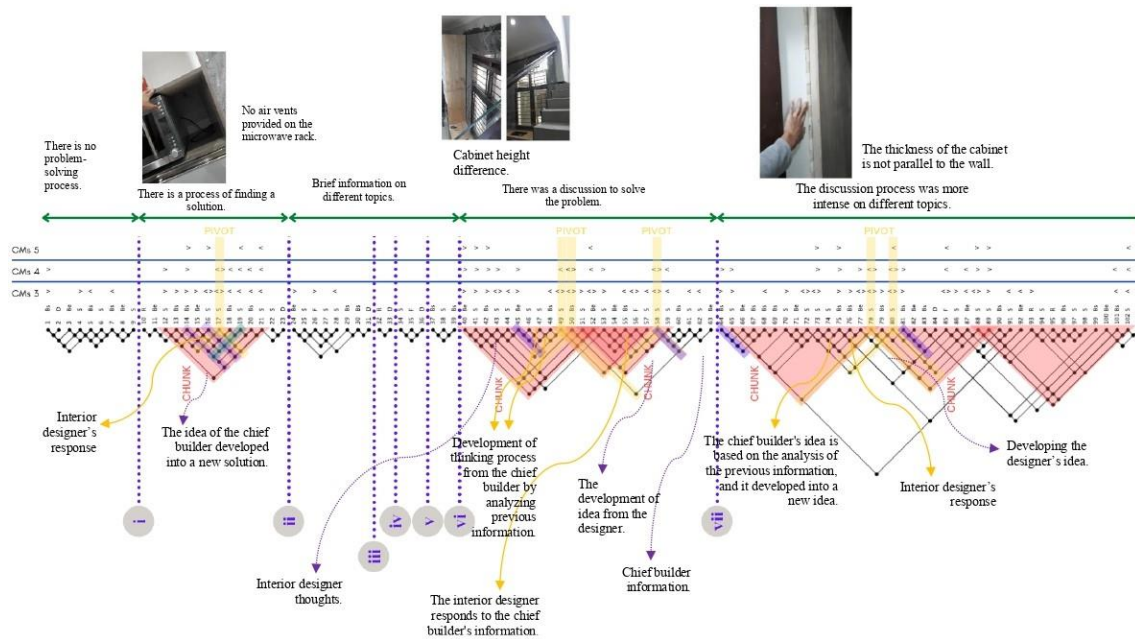


Figure 3. Linkography of the Experiment A

In experiment A, the chief builder's thinking process was quite productive in providing ideas that are considered by the designer in determining the most optimal solution. Generally, the issues contained in the potential thinking are related to the installation system or the formation of a kitchen set that is proposed by the chief builder to the interior designer. The factor that influenced problem solving was the information disclosed by the interior designer, which is related to the design process. The problem-solving process began with a question from the interior designer. Another influential factor was the conditions that occurred in the field, caused by changes in the installation system. Changes to the elements that make up the kitchen set affected the thinking process of the chief builder in finding solutions.

In analyzing the kitchen set problem, chief builder A's thoughts were influenced by the idea of the conditions that should occur based on the design concept given by the interior designer listed in the drawings. The information on the design expectations was then used by the chief builder to analyze the conditions that occurred in the field. By comparing the design expectations with the conditions that occurred in the field, the chief builder tried to synthesize a new installation system that did not change the components of the kitchen set, so although it was different, it did not change the design such as changing the shape of the part that covers the top of the kitchen set by adding an area of the size differences. In addition to changing the components, the chief builder in

experiment A analyzed the components that make up the kitchen set when compared to the conditions that occurred in the field.

Productivity in Experiment A was analyzed based on the comparison of the percentage of critical moves with backlink and forelink patterns on linkography. From these data, it was found that the percentage of backlinks and forelinks in Experiment A was balanced (Figure 3). Although they tend to be balanced, in experiment A, the divergent thinking (forelink) was slightly greater. In solving problems, the chief builder was able to find new solutions to problems that occurred, based on the results of analyzing information on previous problems or conditions. This information arose either from information submitted by the interior designer or from the experience of the chief builder in dealing with similar problems. Experiment A had good productivity with sufficient intensity between links. In the analysis of experiment A, it was found that one design move has an average relationship of 2.16% or 2 links with other design moves.

### **3.2. Experiment B**

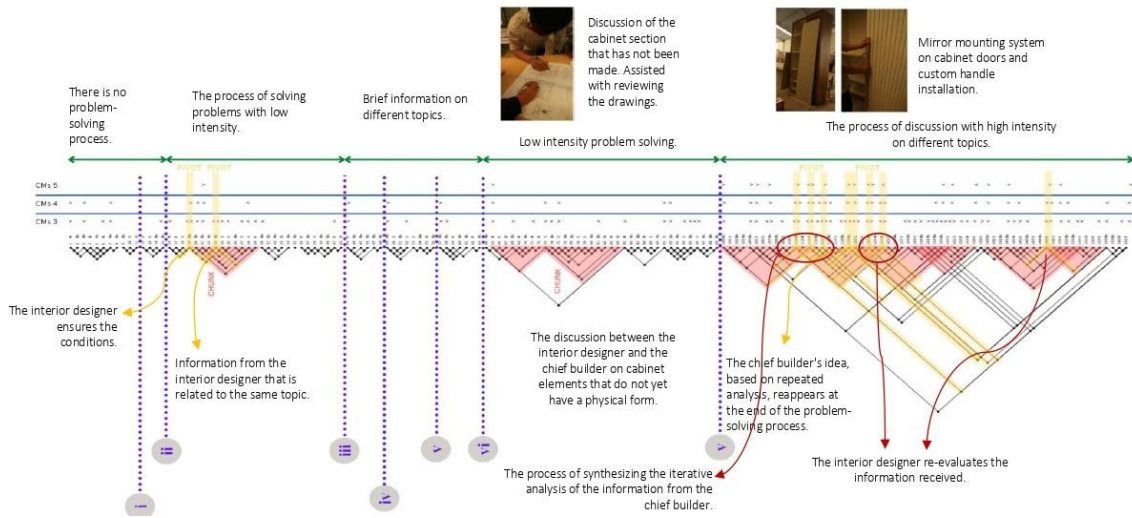
Experiment B is the second experiment conducted in the process of supervising the implementation of a custom cabinet (Figure 4). When the supervision was carried out, the progress of the work was 50%. The cabinet body was almost finished, but the interior designer and implementer ensure that there were no changes to the custom components before entering the finishing stage. Constraints found in this periodic supervision process were related to the technical installation of mirrors on cabinet doors which are less strong. In addition, the designer ensures that the workmanship of special components such as cabinet handles was in accordance with the expected function.



**Figure 4.** Supervision of custom cabinet work in Experiment B

Experiment B has a total of 161 design moves, with 312 links (Figure 5). The problem-solving process in Experiment B lasted for 24 minutes with five changes to the topic of conversation. Similar to experiment A, in experiment B, the process of solving new problems occurred with fairly good intensity. In addition, the new systematic thinking process occurred on the last topic of discussion. The process of systematic thinking happened when the chief builder is faced with a problem related to the strength of the installation system. The head of the analyzer was able to produce thoughts that develop when faced with technical problems. This systematic thought process occurred when the interior designer did not fully agree with the thoughts expressed by the chief builder. In Experiment B, the presence of a far link distance showed that during the

process of solving the problem, the chief builder evaluated the thoughts previously expressed by both the chief builder and the interior designer.



**Figure 5.** Linkography of the Experiment B

The chief builder's thought process in the Experiment B was strongly influenced by the designer's response to the solutions proposed by the chief builder. This was influenced by the interior designer's expectations for the installation of mirrors so that the designer can analyze the thoughts expressed by the chief builder repeatedly. By considering the thoughts of the interior designer, information regarding changes to the installation system is adjusted to the expectations of the interior designers. The thinking mechanism in Experiment B showed that the chief builder pre-determines the formation expected by the interior designer. The solution proposed by the chief builder is generally done by finding a new installation system, which matches the expectations of the interior designer.

Similar to experiment A, in solving problems, the chief builder tends to propose new solutions based on the results of the problem analysis. The difference with Experiment A lies in the problem solving that occurred after the interior designer reanalyzes the thoughts expressed by the chief builder. However, in experiment B, the development of information into a new solution was more common. The chief builder can adapt the proposed solution to the interior designer's expectations.

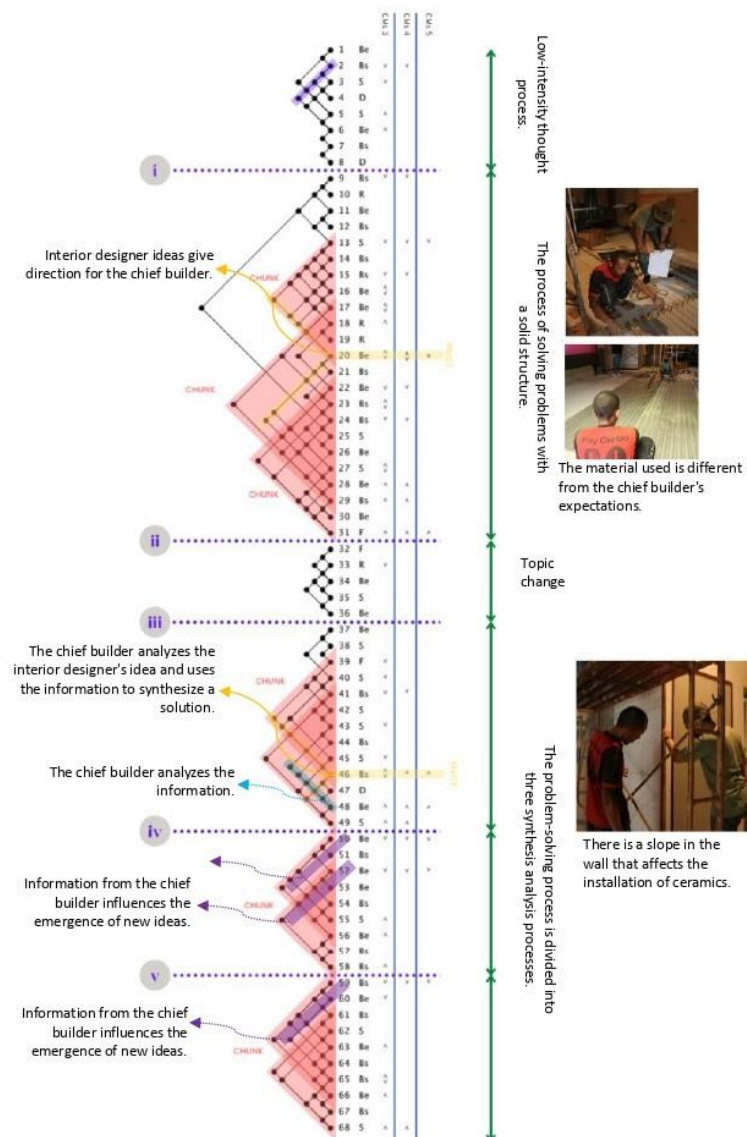
### 3.3. Experiment C

Experiment C is an experiment carried out in the periodic supervision of a process of installing wall treatment (Figure 6). The conversation lasted for 12 minutes. The experiment was carried out when the interior designer carried out periodic supervision when the progress of the wall treatment was 45%. During the periodic supervision carried out by the chief builder, he asked the interior designer about the technical installation of wall treatment materials, where problems were found on the slope of the walls in the field. In addition, there are unplanned differences in material modules, where the previous chief builder used a different type of material.

Experiment C consisted of 68 design moves, with a total of 133 links (Figure 7). The thinking process in Experiment C showed that there was a difference in the way of thinking of the chief builder compared to the two previous experiments.



**Figure 6.** Experiment C on the supervision of wall treatment work



**Figure 7.** Linkography of the Experiment C

In experiments A and B, the chief builder was faced with problems that arose from the expectations of the designer, thus stimulating a systematic way of thinking where the chief builder developed previously known information into a proposed new solution. In contrast to the two experiments, the problems that arose in Experiment C began with differences in the expectations that come from the thoughts of the chief builder. In this experiment, the wall finishing material used is different from what is usually used by the chief builder, so in solving the problem, the chief builder tried to find several alternative solutions so that the installation of the material remains in accordance with the design.

When the chief builder's expectations of the material to be used differed from what was found in the field, the chief builder and designer explored several possible installation systems. In solving the problem, the chief builder in Experiment C did not develop one piece of information into a new thought, but he tried to find several alternative solutions. In this process, the interior designer's input of information becomes important information that influences the way of thinking of the chief builder.

In solving problems, the chief builder solved more problems by analyzing the solutions that were previously carried out, or which are usually done. The difference with the previous experiment is, in Experiment C, the thinking process carried out by the chief builder tends to converge. This relates to the thinking mechanism of the chief builder who was always influenced by previous experience in dealing with the work to be done. Almost similar to the previous experiments A and B, the intensity of conversation in Experiment C was quite effective.

### 3.4. *Experiment D*

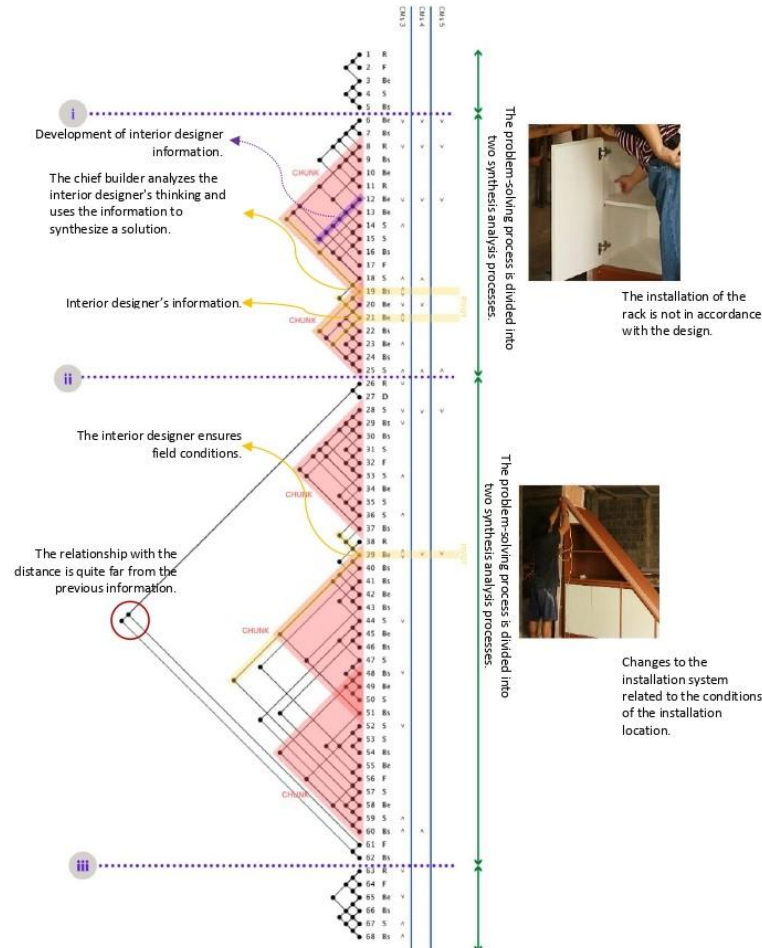
The last experiment (D) was carried out on a process of periodic supervision of the implementation of a custom cabinet to be placed in the area under the stairs (Figure 8). The conversation lasted for 14 minutes. In the monitoring process, the progress of the work has reached 60%. The obstacle in this process is the connection between the upper cabinet body attached to the foot of the stairs which must fit the field conditions. In addition, another obstacle faced was the placement of the cabinet on the second floor of a residence, which had insufficient access to transport the cabinet from the ground floor, causing the cabinet to be divided into several modules.



**Figure 8.** Supervision on the work of the custom cabinet in Experiment D

From the conversation that lasted for 14 minutes, 68 design moves were obtained. The linkography was analyzed based on the resulting pattern (Figure 9). Experiment D had a total of 68 design moves, with 115 links. In Experiment D, the topic of conversation

changed three times. With a 14-minute conversation, compared to other experiments, Experiment D did not have many changes to the topic of conversation. The obstacles faced in the process of implementing Experiment D were quite significant and affected all parts of the cabinet, so the topic of discussion focused on these problems.



**Figure 9.** Linkography of the Experiment D

In finding a solution to this problem, the field condition affected the thinking mechanism of the chief builder in solving the problem. In overcoming these conditions, the components that made up the cabinet became an issue that was considered by the chief builder in order to stay in line with the designer's expectations for the under the stair cabinet. The chief builder evaluated the problem by comparing the conditions that occurred in the field with the conditions that were originally expected. In addition, the chief builder reformulated by changing the components that made up the cabinet into new components, namely by dividing the cabinet into several modules to facilitate the transportation and installation process. In contrast to other experiments, in Experiment D, there is a synthesis and analysis process which occurred based on the direction of the interior designer. In the process of supervising the Experiment D, the chief builder analyzed the problem more by referring to the initial information, in other words, the resulting solution is not something new.

## 4. Analysis

### 4.1. The Chief Builder's Thinking Mechanism

From the analysis carried out on each experiment, the pattern of the thinking mechanism of the chief builder was found, as well as the factors influencing the process of solving problems in the implementation stage of the interior design project. The analysis showed that the thinking mechanism of the chief builder in solving problems and making decisions on the implementation of interior design projects had almost the same pattern. The following is the conclusion of the analysis based on the results of the four experiments.

### 4.2. Chunk Pattern Analysis in Linkography

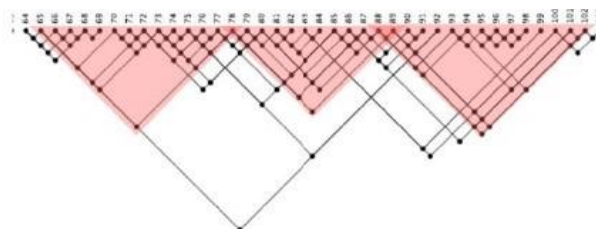
In observing the thinking mechanism, the chunk pattern in linkography was an indication of how the thinking mechanism was carried out in solving problems. This was because in the chunk pattern, there was a design move that had a fairly solid relationship to the next design move (which starts with a forelink pattern), with the end where a design move is related to another design move (ended by a backlink). From the four experiments conducted, two types of patterns from the chunk series were found (Figure 10). The two chunk patterns are:

#### 1. Sequential chunk pattern.

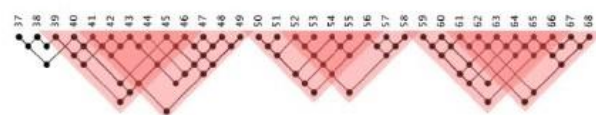
The sequential chunk pattern (1) showed that the chief builder solves the problem by developing information into a new thought, analyzing it, and developing it again into a new thought, which occurred repeatedly until a decision in the form of a potential solution is made and proposed to the interior designer.

#### 2. Stacked chunk pattern.

The stacked chunk pattern (2) showed that the problem-solving process is carried out by analyzing and synthesizing different information, so that there are several alternative ideas.



(1.) The sequence of chunk patterns that showed the process of developing ideas



(2.) The sequence of chunk patterns that indicated the search for alternative ideas

**Figure 10.** Two types of chunk patterns

The chunk pattern of the four experiments showed that the chief builder's thinking process in solving problems was quite structured. The sequential chunk pattern showed that there were several synthesis analysis processes carried out in finding solutions to the problems. The stacked chunk pattern showed that in finding a solution, the synthesis of the problem was carried out repeatedly from different information. The chief builder tried to solve the problem from some of the information submitted by both the designer and the chief builder himself.

#### ***4.3. Issue Distribution Process Analysis***

By analyzing the distribution of processes that occurred in conversation, the processes that occurred the most in the thinking mechanism of the chief builder were known. Based on the comparison of the types of transformation issues of the four experiments carried out (Table 5), the thinking process used by the chief builder in solving problems is identified. Based on the F-B-S code system (Gero & Kannengiesser, 2014), three types of transformations of the eight types of transformation issues that are carried out by the chief builder in solving problems are found.

**Table 5.** Distribution of the processes of the four experiments

<b>Distribution Type</b>	<b>A (%)</b>	<b>B (%)</b>	<b>C (%)</b>	<b>D (%)</b>
Formulation	1	4	1	1
Synthesis	20	18	9	13
Analysis	29	26	7	11
Evaluation	23	48	37	23
Documentation	3	4	1	0
Reformulation 1	49	22	5	13
Reformulation 2	19	20	12	7
Reformulation 3	4	12	2	1

The three types of the thinking process are explained as follows:

##### **1. Recalling**

In developing ideas, the chief builder tended to recall information from previous experiences in dealing with similar problems. In addition to remembering his experience, the chief builder also analyzed the information conveyed by the interior designer when the problem-solving process was happening. Although the chief builder solved a new problem, the rationale for the proposed solution was not new.

##### **2. Completing**

The type of thinking process that was done in solving the second problem was by completing. In solving problems, the chief builder matched the conditions that occurred in the field with the expectations of the interior designers, both in the form of design of the drawings, as well as the expectations of interior designers when carrying out periodic supervision. The chief builder thought effectively by filling in the deficiencies found in the execution to match the designer's expectations.

##### **3. Reformulating**

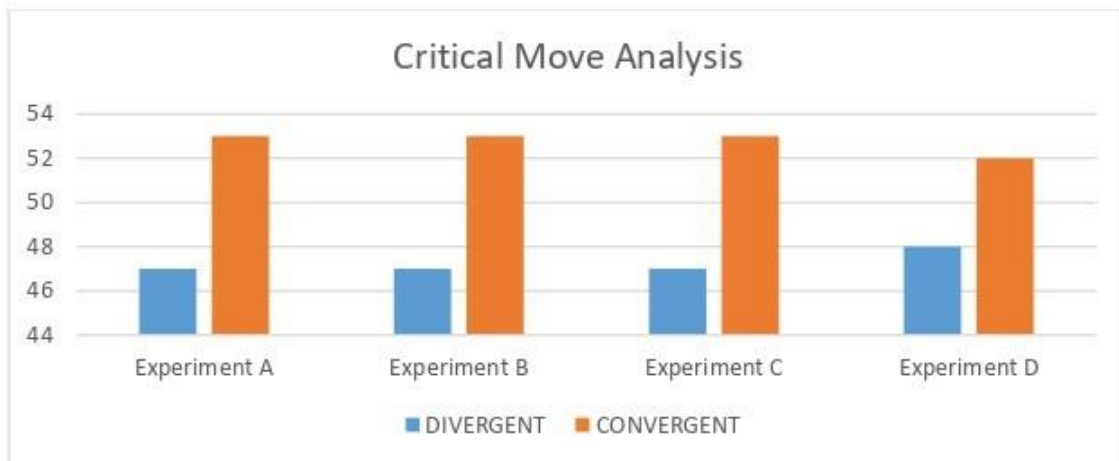
The third type of thinking process in solving problems was done by changing the way of working in the implementation, both related to the installation system or the workflow so that it did not change the design. The chief builder analyzed the information related to the work system and turned it into a new work system.

#### 4.4. Mode of Thinking

One of the methods used to analyze design behaviour is by identifying the thinking modes applied in the process of problem solving or solution finding. By analyzing the thinking behaviour used, we can also summarize the thinking mechanisms involved in a person's decision making process. Observing the thinking mechanism used by a designer in the process of finding a solution is a common method in our effort to understand the behavior of designers in solving problems.

There are two modes of thinking in the process of decision-making, which are the fast mode, and the slow mode (Kahneman, 2011). The character of the fast mode of thinking is intuitive, however, the slow mode is more rational. Gabriela Goldschmidt (2014) sees this fast thinking mode as similar to divergent thinking, and the slow thinking mode to convergent thinking. This divergent thinking is used for finding new solutions in problem-solving, and convergent thinking is used for analyzing the problems in order to find the solution (Goldschmidt, 2014). The divergent thinking mode is more likely breaking one thought into sub-thoughts, yet the convergent thinking summarizes sub-thoughts into one conclusion. In design problem solving, the convergent thinking mode is used to analyze and evaluate the problem.

From the four experiments conducted in this research, it has been shown that in finding solutions to problems that occurred in the process of implementing interior design projects, although they tend to be balanced, the mode of thinking that was generally used by the chief builder in solving problems is the convergent mode of thinking (Figure 11). This shows that in finding solutions to the problems, the chief builder used his ability to analyze information more, either from his experience or expressed by the interior designer.



**Figure 11.** Comparison of the critical moves from the four experiments

The chief builder was much influenced by the information conveyed by the interior designer. In solving problems, the chief builder often analyzed the interior designer's information, then synthesized it into new solutions. Although the chief builder had ideas in solving problems, these thoughts were only synthesized after the interior designer asked a question about a problem.

#### ***4.5. Influential Factors***

Based on the analysis of the four experiments that have been carried out, three factors influencing the thinking process of the chief builder in solving problems and making decisions was found. Although the percentages between the influencing factors were different in the four experiments, there were similarities in the factors that most often appeared. These differences were related to the different problem conditions in each experiment. The three factors are:

##### **1. Structure**

Structure is an issue related to the components that make up the design such as materials, installation techniques, etc. These constituent components affect the chief builder's thinking process in solving problems. In looking for alternative solutions, the chief builder tended to consider the processing of the installation system, the use of materials, et cetera.

Examples of the components include the one in the Experiment B where the chief builder provided a solution to the mirror installation system on the wardrobe door, so that the door could still support the load of the mirror, and remained invisible using the frame. Another example is in experiment D where the chief builder proposed a solution to a cabinet installation system that was made into a modular form.

##### **2. Expected Behavior**

The second influential factor appearing in the four experiments is a factor related to the conditions that were expected to occur in the implementation process. The expectations in question were not only based on the expectations of the interior designer in the form of a design concept, but also the expectations of the chief builder on the conditions that occurred in the field.

An example of expected behavior in Experiment C occurs when the material used was a different material than the one normally used. In the installation, the head of the builder had different expectations from the conditions that occur. Another example is in Experiment A where the expectation came from the design made by the interior designer. These expectations affected the mechanics of thinking in solving problems.

##### **3. Behavior by Structure**

The third factor influencing the thinking mechanism of the chief builder was the condition that was formed based on the condition of the components that made up an artifact. This condition occurred based on the condition of the forming components when carried out in the field.

An example of behavior by structure was shown in Experiment A where the field conditions are not the same as the design so that the components that make up the kitchen set in Experiment A did not seem to match the field conditions. In addition, it was also shown in Experiment C where the ceramic wall mounting system changed the condition of the walls in the field which were basically tilted.

#### ***4.6. Productivity***

Productivity that occurs in an interior design project implementation process can be measured by comparing the percentages of two types of critical moves in linkography, namely backlinks and forelinks in a linkography data. In addition, it can also be identified by looking at the number of links owned by a design move (link index). Based on the four research experiments, a comparison of critical move and link index was obtained, which is presented in Table 6.

**Table 6.** Comparison of Link Index, and Critical Move

Experiment	Move	Link Index	%CM3	%Backlink CM3	%Forelink CM3
A	103	2.16	72	53	47
B	161	1.94	55	53	47
C	68	1.96	66	53	47
D	68	1.69	40	52	48

From the four experiments conducted, the intensity of the conversations tended to be the same. However, when viewed based on the duration of the conversation, Experiment A was a conversation with a better conversational intensity. Meanwhile, the intensity of the conversation in Experiment B tended to be less, due to the longer duration of the conversation, but the intensity of the conversation was relatively low.

Based on the comparison of backlink and forelink patterns from the four research experiments, similarities were found. The four experiments tended to be productive, with the percentage of backlinks and forelinks that tended to be balanced. However, the four experiments also showed that in solving problems and making decisions on the implementation of interior design projects, the chief builder used convergent thinking mode more than divergent ones. Thus, in solving problems, the chief builder often relied on his analytical thinking skills.

## 5. Conclusion

From this research, we are able to discover the thinking mechanism of chief builders when solving problems in interior design projects. By using the linkography, the research can conclude several modes of thinking done by the chief builders in interior design projects. However, the research has some limitations in explaining a more complex and detailed explanation of the chief builders' thinking mechanism due to the number of cases analyzed. By analyzing more samples with more specific design problems, the linkography can discover more factors affecting the chief builder's mode of thinking.

Several conclusions regarding the thinking mechanism of the chief builder in solving problems and making decisions at the implementation stage of interior design projects were obtained, namely:

1. In solving problems in the implementation of an interior design project, the chief builder used his experience as information to analyze the situation, and process it into a proposed new solution.
2. The chief builder evaluated the expectations and what should happen first, so that the proposed solution was complementary to the conditions that had already occurred in order to be more effective, without changing the needs that must be met.
3. The factors influencing the thinking process of the chief builder in solving problems and finding solutions are:
  - a. Information and expectations expressed by the interior designer.
  - b. Knowledge of the chief builder to the conditions commonly encountered and with similarities.
  - c. Information held by the chief builder in engineering and workmanship system.

4. The chief builder's thinking mechanism in solving problems was classified as productive. In searching for a solution, the chief builder was motivated to develop his prior information from both the interior designer and his experience.

## 6. Recommendation

The research that has been done can conclude how the thinking mechanism and the factors influence it. However, there are limitations in the number of subjects observed. To get more accurate research results, the research can be developed by increasing the number of observation subjects. Due to limited time and conditions that were not conducive to conducting direct observations, the number of objects and experimental subjects in this research could not be increased. Based on the project criteria that became the object of observation, although the object has special specifications, this research could only represent a part of the classification and category of interior design projects. Experiments in research with more complex problems related to other interior-forming elements will optimize the resulting data.

This research focused on the thinking mechanism of the chief builder in solving problems in the process of implementing interior design. Another factor that has not been found in this research is the link between the thinking mechanism when compared to the analysis of the drawings or sketches made in the field. This is because the four experiments carried out did not obtain the sketch data made in the implementation process. By this, a larger number of cases with a more in-depth conversation that includes sketching is recommended for future research. Also, the research can be conducted by doing an experiment that includes different types of chief builders, given the same interior design task to explore ways of thinking in solving the same case.

Our study gives an original perspective of how the design is processed and seen by the builders which actually has a big contribution in the making process of the design. From this research, it is hoped that designers can provide additional information that can help the process of making design concepts more effectively implemented. In addition, knowing the factors that influence the thinking mechanism of the chief builder is expected to help interior designers in the process of coordinating with the chief builder. In terms of the chief builder, the results of this research can be used as a learning material in training aimed at increasing the ability and productivity of the chief builder.

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