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ANALYSIS OF CRITICAL SUCCESS FACTORS OF THE GERMAN PASSIVE HOUSE IN TECHNICAL MANAGEMENT PERSPECTIVE

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ABSTRACT

The Passive House (PH) concept first presented in Germany is an excellent eco-friendly construction technology that enhances not only energy efficiency, but also occupants' comfort. PH construction presupposes high-standard, green technologies to ensure optimal insulation, airtightness, window system, thermal bridge, and ventilation. This study was conducted to determine critical factors for successful implementation of PH from the perspectives of technology and construction management using German success cases. To this end, we performed a literature review and conducted a focus-group interview (FGI) with German PH experts. The interview results were assessed via hierarchical classification by grouping similar items in an expert workshop. A relative importance analysis was performed by conducting a questionnaire survey with Certified Passive House Designers (CPHDs) based on the resulting hierarchically structured items. As a result, construction management factors, such as interdisciplinary collaboration and inter-field cooperation, were found to have high importance in addition to technological factors. Therefore, it is considered essential to consider both technological and managerial aspects of development for successful implementation of the PH concept.

Key words: Passive house, Energy cost, Focus group interview (FGI), Management factor, Relative importance analysis.

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1. INTRODUCTION

The concept of sustainable development was defined by the 1987 World Commission on Environment and Development (WECD) report entitled "Our Common Future" as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs.[1]Accordingly, every country has been developing and supporting various efforts to achieve sustainable development. In the sector of sustainable energy policies in Europe, Germany has been responding to climate-related challenges in a well-organized and efficient manner. However, Belgium, the Netherlands, Britain, and Denmark are facing serious challenges related to sea level rise caused by climate change. [2]The Passive House (PH) concept is a flagship case of German low-energy policies. PH is a green technology that helps reduce energy use while simultaneously enhancing occupant comfort. Currently, there are 1,085 buildings with 7,200 units certified by the German Passive House Institute (PHI) and a much larger number of uncertified buildings constructed using PH technologies.[3] The energy consumption required for heating a typical PH is 75% lower than a low-energy house and over 90% lower than a normal house. Technological factors for PHs, including thermal insulation, airtightness, window system, thermal bridge, and ventilation, meet precisely specified criteria. However, in addition to technological factors, managerial factors play an important role in PH construction. This study analyzes the management factors related to PH construction, focusing on critical success factors. The results of the analysis are expected to contribute to developing a systematic management approach to PH construction.

2. METHODS

In this study, critical success factors for PH construction from the management perspective were identified by applying the following research methods:

1) Technological critical success factors were derived from a literature review.

2) Managerial critical success factors were derived from a focus group interview (FGI) with German PH experts.

3) Extracted critical success factors were classified according to scope and purpose in a workshop with Korean PH experts.

4) The importance of each classified factor was measured from a questionnaire survey to Certified Passive House Designers (CPHDs) in Europe

2.1. Identify Critical Success Factors: Literature Review

PHs have been studied extensively in Europe, with Germany playing the lead role. Most studies concern technological aspects related to the principles of the PH concept. We identified technological success factors by conducting a meta-analysis of related papers. An overview of the results of the analysis is presented in Table 1.

Table 1 Overview of Literature Review

Division	Contents
Outline	Extracting technical critical success factors by literature analysis for passive houses in Europe
Method	Extracting technical critical success factors through the research keywords grouping after selecting research literature
Scope	Conduct for the research literature target related to the technical aspects of a passive house
Objective	Extraction for item categories (Level 1) of technical critical success factors

2.2. Identify Critical Success Factors: Focus Group Interview

Interviews with German PH experts were conducted to compile their views on technological critical success factors for PH construction. Experts were informed of the purpose of the study at the beginning of the interview. Experts provided their responses in writing.

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2.3. Critical Success Factor Classification: Expert Workshop

A workshop with Korean PH experts was conducted to identify and categorize the scope and purpose of critical success factors derived from expert interviews. The results of this workshop are outlined in Table 2.

Table 2 Overview of Expert Workshop

Division	Contents
Period	6th October 2014
Participants	- Registered Architect 1, Ph.D. 1 - Mechanical Professional Engineer 1, - Researcher 2
Method	Systematic classification according to the scope and purpose for each critical success factors

2.4. Critical Success Factor Analysis: Expert Survey

European CPHDs were asked to respond to a questionnaire designed to measure the importance of the extracted PH-related technological critical success factors using a 5-point Likert scale. The survey results are outlined in Table 3.

Table 3 Overview of Expert Survey

Division	Contents
Period	20th December 2014 – 20th January 2015
Participants	- Europe Certified Passive House Designer (CPHD) 25 - PH engineer 5
Survey purpose	Importance analysis of the German passive house technical critical success factors

3. RESULTS

3.1. Literature Review Results

We performed a meta-analysis of 36 papers dealing with the technological aspects of PH. Table 4 outlines the results of the meta-analysis. Items most frequently dealt with (excluding social and policy-related factors, such as user satisfaction, social design, consumer finances, and economic feasibility) were technological factors including energy efficiency, high insulation performance, comfort, airtightness, heating and cooling system, and local applications. The extracted keywords were grouped based on similarities. The resulting 19 technological success factors are presented in Figure 1.

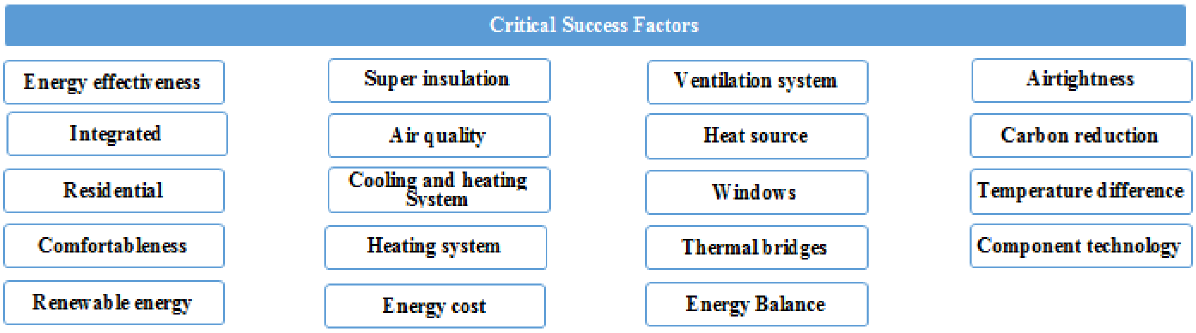

Figure 1 Extraction results of technical critical success factors

Table 4 Extraction results of critical success factors and technology areas through the literature analysis

Division	Critical Success Factors	Section
1	Insulation	Skins
2	Air tightness	Joints
3	Ventilation system	Ventilation
4	Temperature difference	Whole
5	Energy effectiveness(Energy Balance)	Whole
6	Integrated management	Whole
7	Cooling and heating System	Equipment
8	Heat source	Equipment
9	Windows	Windows System
10	Air quality	Inside
11	Thermal bridges	Joints
12	Energy cost	Whole
13	Renewable energy	Application by technology type
14	Component technology	Wall, Floor, Joints
15	Heating system	Equipment
16	Carbon reduction	Whole
17	Residential environment	Location
18	Comfortableness	Inside

3.2. Expert Interview Results

Fifteen experts participated in the expert interviews to define technical critical success factors. All of them are from Germany where original PH technologies were first developed. Figure 2 shows the composition of the interviewed German PH experts.

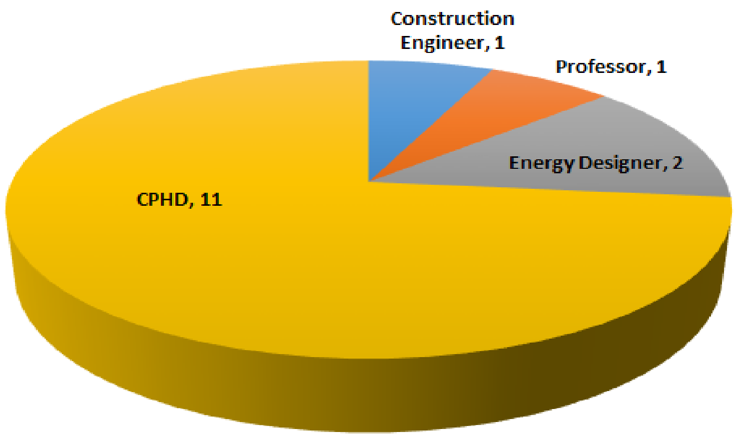

Figure 2 Overview of the experts interview participants

The results of expert interviews yielded 20 technical critical success factors, as presented in Table 5, which are categorized into technical sectors. The results were largely consistent with those of the literature review in that many of them concerned the original PH technologies. However, a considerable number of management-related factors were also identified.

Table 5 Extraction results of critical success factors through expert interview

Division	Critical Success Factors	Section
1	Economics of equipment system	Equipment
2	Simplicity of equipment system	Equipment
3	Receptivity of equipment system	Equipment
4	Ventilation system	Ventilation
5	Energy cost	Whole
6	Cooling and heating loads	Equipment
7	Energy balance	Whole
8	Linkage of design and construction	Whole
9	Insulation	Skins
10	Insulation materials	Skins
11	Design quality	Whole
12	Construction quality	Whole
13	Cooperation between Each Field	Whole
14	Interdisciplinary Collaboration	Whole
15	Engineer Expertise	Whole
16	Ecology	Location
17	Facilities Value	Whole
18	Sunshine	Location
19	Sustainability	Whole
20	Temperature Balance between Season	Internal space

3.3. Factors Classification Results

Technical critical factors for successful implementation of PH construction were identified from the results of a literature review and individual interviews via email with German PH experts. This section describes the workshop conducted with Korean PH experts to determine the scope and purpose of those factors. The results of the workshop are outlined in Table 6.

Table 6 Classification result according to the scope and purpose of critical success factors

Division	Critical Success Factors	Application scope	Purpose
1	Insulation performance	External(Skins)	Ensure the insulation performance
2	Airtightness	External(Skins), Internal	Ensure the airtightness performance
3	Ventilation System	Equipment(Internal) space	Ensure the comfort
4	Air Circulation (Indoor door, etc.)	Equipment(Internal) space	Ensure the comfortableness
5	Energy effectiveness (Energy Balance)	Internal	Ensure the economic
6	Integrated management	Management	Ensuring economic efficiency of design and construction
7	Cooling and heating	Equipment(Internal) space	Comfortableness
8	Heat source (Radiant heat, body heat, etc.)	Management	Economic efficiency
9	Windows System	External	Economic efficiency
10	Air quality	Internal	Comfortableness
11	Thermal bridges	External boundary section	Economic efficiency, Comfortableness
12	Energy cost	Internal	Economic efficiency
13	Renewable energy	External	Maintainability
14	Segmental Technology (Walls, floors, etc.)	Internal and External	Constructability
15	Heating system	Internal	Maintainability
16	Carbon reduction technologies	Management	Maintainability, Economic efficiency
17	Residential environment	External(Location)	Comfortableness
18	Economics of equipment system	Equipment(Internal)	Energy effectiveness, Economic efficiency
19	Simplicity of equipment system	Equipment(Internal)	Economic efficiency, Maintainability
20	Receptivity of equipment system	Equipment(Internal)	Maintainability, Receptivity
21	Cooling and heating loads	Equipment(Internal)	Comfortableness
22	Energy balance	Internal	Energy effectiveness,
23	Linkage of design and construction	Management	Constructability, Maintainability, Durability
24	Insulation performance	External(Skins)	Ensure the insulation performance
25	Insulation materials	External(Skins)	Ensure the insulation performance
26	Design quality	Management	Comfortableness, Maintainability
27	Construction quality	Management	Comfortableness, Maintainability
28	Cooperation between Each Field	Management	Constructability, Economic efficiency
29	Interdisciplinary Collaboration	Management	Technical ability
30	Engineer Expertise	Management	Technical ability
31	Ecology	External(Location))	Comfortableness
32	Facilities Value	Management	Economic efficiency
33	Sunshine	External	Economic efficiency, Maintainability
34	Sustainability	Internal and External	Maintainability
35	Temperature Balance between Season	External	Maintainability

The technological critical success factors were then classified using a hierarchical system, as shown in Figure 3. The three main categories (Level 1) – internal technological factor, external technological factor, and construction management factor – were coded as IF, EF, and CMF, respectively. In the next section, the importance of each technological success factor established above as a contributing factor towards the success of the PH was analyzed.

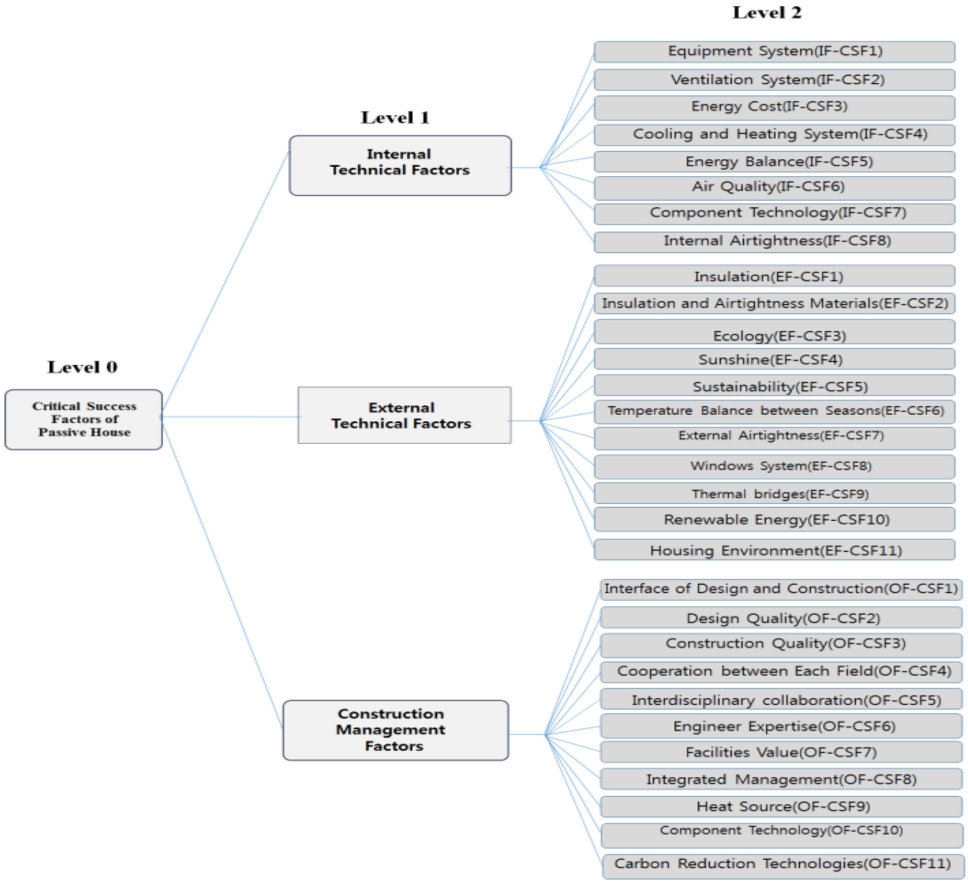

Figure 3 Establishing hierarchy structure of passive house technical critical success factors

3.4. Important Analysis Results

The following section summarizes the results of the importance analysis based on the expert survey on the three Level 1 categories and Level 2 factors.

3.4.1. Results of Level 1 Importance Analysis

Table 7 presents the results of the Level 1 importance analysis. The factors of all categories were found to have high importance, with the factors related to PH construction management marking the highest score (4.45).

Table 7 Expert survey results for Level 1

Division	Level 1	Geometric Mean	Rank
1	Internal Technical Factors	4.16	3
2	External Technical Factors	4.24	2
3	Construction Management Factors	4.45	1

3.4.2. Results of Level 2 Importance Analysis: Internal Technological PH Factors

Table 8 presents the importance analysis results for internal factors. These factors have high overall importance scores, with internal airtightness marking the highest importance score (4.54), followed by ventilation system (4.43).

Table 8 Expert survey results for Level 2 (Internal Technical Factors)

Level 1	Level 2	Geometric Mean	Rank
Internal Technical Factors	Equipment System (IF-CSF1)	3.27	7
	Ventilation System (IF-CSF2)	4.43	2
	Energy Cost (IF-CSF3)	3.08	8
	Cooling and Heating System (IF-CSF4)	3.61	5
	Energy Balance (IF-CSF5)	4.09	3
	Air Quality (IF-CSF6)	4.06	4
	Component Technology (IF-CSF7)	3.46	6
	Internal Airtightness (IF-CSF8)	4.54	1

3.4.3. Results of Level 2 Importance Analysis: External Technological PH factors

Table 9 presents the importance analysis results for external factors. These results reveal considerable inter-item deviations. The highest importance score was achieved by window system (4.68), followed by thermal bridge (4.64), insulation (4.46), and airtightness (4.42).

Table 9 Expert survey results for Level 2 (External Technical Factors)

Level 1	Level 2	Geometric Mean	Rank
External Technical Factors	Insulation (EF-CSF1)	4.46	3
	Insulation and Airtightness Materials (EF-CSF2)	3.87	5
	Ecology (EF-CSF3)	2.76	11
	Sunshine (EF-CSF4)	3.45	6
	Sustainability (EF-CSF5)	2.82	10
	Temperature Balance between Season (EF-CSF6)	3.36	8
	Airtightness (EF-CSF7)	4.42	4
	Windows System (EF-CSF8)	4.68	1
	Thermal bridges (EF-CSF9)	4.64	2
	Renewable Energy (EF-CSF10)	2.91	9
	Housing Environment (EF-CSF11)	3.44	7

3.4.4. Results of Level 2 Importance Analysis: Construction Management PH Factors

Table 10 presents the importance analysis results for management factors. Except for the two subscales, no significant inter-item deviations were observed. Construction quality demonstrated the highest importance score (4.57), followed by cooperation between each field (4.45), and interdisciplinary collaboration (4.34). These results led us to believe that the high importance of construction-related management factors should be reflected in PH construction plans beside PH-related technological factors.

Table 10 Expert survey results for Level 2 (Construction Management Factors)

Level 1	Level 2	Geometric Mean	Rank
Construction Management Factors	Interface of Design and Construction(CMF-CSF1)	3.86	6
	Design Quality (CMF -CSF2)	4.16	4
	Construction Quality (CMF -CSF3)	4.57	1
	Cooperation between Each Field (CMF -CSF4)	4.45	2
	Interdisciplinary Collaboration (CMF -CSF5)	4.34	3
	Engineer Expertise (CMF -CSF6)	3.87	5
	Facilities Value (CMF -CSF7)	3.05	10
	Integrated Management (CMF -CSF8)	3.62	7
	Heat Source (CMF -CSF9)	3.22	9
	Component Technology (CMF -CSF10)	3.24	8
	Carbon Reduction Technologies (CMF -CSF11)	2.66	11

4. CONCLUSIONS

The main direction of Germany’s energy policies is toward improving energy efficiency and enhancing the competitive edge of renewable energy. As one of the measures for improving energy efficiency, the German government supports low-energy building construction and retrofitting new and old buildings. PH enables over 70% reduction of energy consumption compared to conventional construction methods.

In this study, we identified technological critical success factors for implementing the PH concept through a literature review and interviews with PH experts in Germany. These 35 critical success factors underwent hierarchical structure classification. As a result, the factors were classified as internal technological factors, external technological factors, or management factors. To analyze the importance of individual factors, we conducted a survey with certified German PH designers. As a result, construction management factors, such as interdisciplinary collaboration and inter-field cooperation, were identified as factors with high importance along with PH-related original technologies such as window system, airtightness, insulation, and thermal bridge. Therefore, for successful implementation of the PH concept, it is essential to address both the engineering aspects related to technological factors and construction-related systematic management factors.

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Notes

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