



The Improvement Priority of Inhibitory Factor for Invigorating the Modular Building - Focused on Professional of Work Related to Modular Building

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ABSTRACT

Purpose: Recently, there has been a gradual rise in interest for modular building due to its advantages of shortened construction periods, quick removal, and practical use of land. However, widespread interest has yet to present itself in the markets and actual cases of construction based on modular building has been limited to military barracks, dormitory facilities, and single housing units. In light of this, this research aims to uncover factors that will encourage greater utilization of modular building and rank such factors according to their improvement priorities. **Method:** The method of research of this study first involved the uncovering of factors that discourage modular building through analysis of previous research and consultation with experts. Second, expert surveys were conducted for the purpose of improving the uncovered factors that discourage modular building. Third, based on the findings of the surveys, IPA analysis was carried out to establish the improvement priority rankings of the inhibitory factors. **Results:** The results of the analysis indicated that the encouraging factors were concentrated in the planning and ordering phase as well as the production and manufacturing phase. Rather than focusing on the dismantling and reuse of modular building, it was found that market entry and development of housing technologies were more immediately needed. Also in order to encourage the utilization of modular building, greater efforts by relevant personnel as well as continued studies by researchers are needed.

KEYWORD

 모듈러 건축
 공업화 주택
 저해요인
 개선 우선순위

 Modular Building
 Industrialization House
 Inhibitory Factor
 Improvement Priority

ACCEPTANCE INFO

 Received Aug, 17, 2017
 Final revision received Nov, 5, 2017
 Accepted Nov, 10, 2017

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1. Introduction

1.1. Background and purpose

Modular building has a big advantage as a construction method to maintain Korea's land in environmentally friendly way with its strengths such as shortened construction periods, quick removal, and practical use of land. However, its market has yet to developed, and actual cases of construction based on modular building have been limited to military barracks, dormitory facilities, and single housing units. In an effort to invigorate modular building, the *Housing Act* was revised in 2016 to incorporate the entire or partial residential space into the range of industrialized housing, which was previously defined as major structures. The revision also improved its effectiveness by deleting a clause stating that construction shall start within 1 year after approval, but still there is no business obtained this approval showing its limitations in boosting modular building.

Therefore, surveys were conducted targeting modular building professionals, improvement priority was established, and then expert surveys were performed with an aim of uncovering practical factors to invigorate modular building. The results of this research are intended to

be utilized as basis data in raising awareness of the public regarding industrialized housing and responding to government policies.

1.2. Research method and scope

This research is about establishing priorities to improve factors undermining the invigoration of modular building. Specific research methods and details are as follows:

First, factors discouraging modular building were identified through analysis of previous research and consultation with experts. Second, expert surveys were conducted for the purpose of resolving the uncovered factors that discourage modular building. Though understanding the current public awareness on modular building is important, survey targets were limited to professionals working in the modular building sector considering the unique nature of the Korean construction industry in which modular building has yet been invigorated. Third, based on the findings of the surveys, IPA analysis was carried out to establish the improvement priorities of the inhibitory factors. IPA (Importance Performance Analysis) method enables simultaneous analysis of how survey respondents recognize importance and satisfaction of survey items and prioritization of survey items. This method provides meaningful information to efficiently develop improvement items when a problem needs to be resolved with defined manpower and budget.

Fourth, the results from IPA were verified through in-depth expert surveys.

IPA analysis results are displayed on a plane as in <Figure 1>. The first quadrant is the most important but least satisfactory area, meaning that it needs urgent improvement because survey respondents think the surveyed items important, but actually their satisfaction level is low.

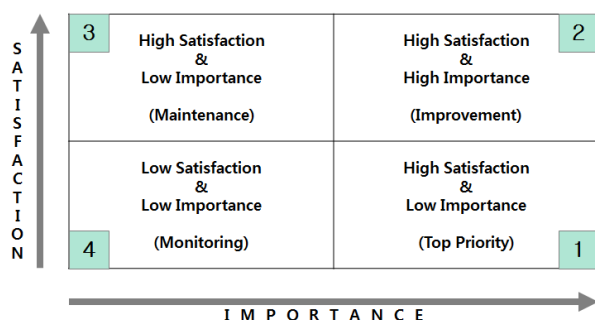


Fig. 1. IPA Matrix

The second quadrant in which respondents think the survey items important and feel satisfied is the area requiring improvements with close attention. In the third quadrant, respondents consider the importance of survey items as low, but their satisfaction level is high, meaning extra effort is not necessary. The fourth quadrant implies that respondents give low priority and satisfaction level is also low, requiring close attention and mid and long-term solutions.

2. Literature review

2.1. Concept of modular building

Modular construction method refers to production and construction method of a building which is constructed by assembling individual modules produced from a factory, and modular building means buildings created using modular construction method and building activities. Modular building has advantages such as shortened construction period, lightweight, flexibility, and mobility.¹⁾

In Korean laws, the terminology, ‘industrialized housing,’ which is used in Japan, is also used, and the range of industrialized housing was expanded after the revision of the *Housing Act* in 2016. However, it only applies to detached or apartment housing, and there is no legal terminology for buildings for other purposes.

On the other hand, terminologies like modular, panelized, manufactured, off-site, prefabrication, format housing, and factory-produced housing are used.²⁾

1) Haisier Abudukeha, A study about Deducing the Influential Factors for Revitalization of high-rise modular construction in domestic, Yeungnam University, The Department of Architectural Engineering, Msc these, pp5-7, 2012

2) See materials from CSA A277 Evaluation system (Canada), Off-site Construction association (UK), Prefabrication association (Japan)

2.2. industrialized housing approval system

The industrialized housing approval system was first introduced in 1992 to improve the quality and boost Korea’s industrialized housing, and has been revised as shown in <Table 1>. However, its low effectiveness such as lack of incentives (Article 53 of the *Housing Act*: If a person who has more than one architect and structural engineers, or has more than one architectural execution engineers construct, construction and inspection regulations are eased) resulted in only four recent (since 2010) approval cases of industrialized housing.

Table 1. Status of Major Enactments and Amendments of the Industrialized Housing Approval System

Landmark Events	Enactments and Amendments of Standards
’92.12.08	<ul style="list-style-type: none"> • Introduction of an approval system for industrialized housing • Revocation of approval • Construction of housing regarding industrialized housing
’93.08.11	<ul style="list-style-type: none"> • Designation of a performance and structural assessment institution for industrialized housing
’03.05.29	<ul style="list-style-type: none"> • Approval, revocation of approval, and promotion of construction of industrialized housing
’11.12.28	<ul style="list-style-type: none"> • Simplification of the approval applications for industrialized housing
’15.12.10	<ul style="list-style-type: none"> • Amendment of co-housing approval standards upon approval of industrialized housing • Amended 3 times (’99, ’13, etc.) since its establishment in ’93
’16.01.19	<ul style="list-style-type: none"> • Expansion of the scope of approval of industrialized housing • Relaxed standards of approval revocation for industrialized housing
’17.01.17	<ul style="list-style-type: none"> • Relaxed floor structure building standards for industrialized housing

Table 2. Study of Existing Research Encouraging Modular Building

Researcher	Content and methods
Kim Hu-yong et. al. (2017)	<ul style="list-style-type: none"> • Proposal of methods to reduce construction costs through mass production and automated production
Hwang Eun-Kyoung et. al. (2016)	<ul style="list-style-type: none"> • Methods of encouragement based on the approval system, support, and incentives
Kim Hyeong-do et. al. (2016)	<ul style="list-style-type: none"> • Deletion of excessive industrialized housing performance standards and proposal of methods of related systematic improvements
Lee Mun-seok (2016)	<ul style="list-style-type: none"> • Proposal of procurement contracts regarding methods of purchasing goods, new establishment of name of goods in the Public Procurement Service inventory system, and improvement of modular building procurement contracts such as procurement contracts due to multiple supplier contracts
Lee Jun-sik (2016)	<ul style="list-style-type: none"> • Perceptual improvements through the proposal of a prototype applied with improved standardizations of exterior materials and facade designs

Haisier, Abudukeha (2013)	<ul style="list-style-type: none"> Classification of direct factors that encourage modular building regarding production, structure, construction, and materials and of indirect factors that encourage modular building regarding related systems, society, and environment through case studies of high-rise modular buildings in the UK
Moon Yeong-a et al. (2013)	<ul style="list-style-type: none"> Proposal of a method of encouraging modular building by classifying factors of encouragement by the speed, financing, sustainability, and economy of modular building
Park Junyeong et al. (2013)	<ul style="list-style-type: none"> Proposal of systems for industrialized housing such as the development of appropriate performance assessment methods

2.3. Previous research on modular building

Research on how to encourage modular building has been continued since 2010. In the study of Kim Hu-yong (2017), automation for mass production was proposed, and Lee Jun-sik (2016) tried to improve the awareness by standardizing exterior materials. Haisier, Abudukeha (2013) and Moon Yeong-a et al. (2013) examined Korean and overseas cases to study direct and indirect factors or classified factors into speed, flexibility, sustainability, economical efficiency. The encouragement method by regulations on industrial housing was suggested in research by Hwang Eun-Kyoung et al. (2016), Kim Hyeong-do et al. (2016), and Park Junyeong et al. (2013), while Lee Mun-seok (2016) presented a proposal of procurement contracts. The previous research was centered on the encouragement through technical or systematical improvements. However, improving all factors comes with many restrictions such as time and money. Therefore, to boost modular building, prioritization of these factors is necessary.

3. Identifying factors that inhibit the expansion of modular building

3.1. Research tool

Research tool used in this study is as follows: Based on the previous research and literature, factors hampering the expansion of industrialized housing were identified and the first preliminary survey of experts was conducted to validate the reliability of the tool. It was conducted three times from September 27 to December 10, 2016, targeting professionals working for industrialized housing production companies. By combining factors drawn from the previous research and the preliminary survey, the total of 37 factors inhibitory the encouragement of modular building in actual modular construction sites. This research applied Cronbach's Alpha to measure the respondent reliability of the survey questions by life cycle in relation to inhibitory factors.

The life cycle of industrialized housing is separated by seven phases, and Cronbach's Alpha reliability by life cycles was analyzed as follows: planning and ordering phase (.649/8), design and authorization phase

(.549/3), production and manufacturing phase (.747/6), packaging and shipping phase (.573/4), construction and inspection phase (.739/7), maintenance phase (.710/3), and dismantling phase (.754/3).³⁾

3.2. Identifying factors that inhibit the expansion of modular building

To identify inhibition factors, factors were drawn from previous research papers such as 'Off-site Ultra High-speed Housing Construction Technology R&D,' 'Study of methods to encourage factory produced construction,' 'Study of methods to encourage industrialized building for the development of the professional construction industry,' and 'R&D of end-user oriented customized housing.' In addition, basic survey of modular building experts was performed to add more factors.

Unlike general building, modular building includes packaging, shipping, preservation, dismantling and reusing in its life cycle, a unique characteristic of modular building.

Inhibitory factors are categorized into eight phases by life cycle including strategic phase for the expansion, maintenance phase, and dismantling and reusing phase.

Table 3. Analysis of factors that inhibit the expansion of modular building by life-cycle phase

Life-cycle phase	No	Inhibitory Factors
Public Awareness and the Industrialized Housing Market	(a)-1	Negative perceptions among the public and promotions regarding industrialized housing
	(a)-2	Current approved scope of industrialized housing
	(a)-3	Expansion of various markets other than the current market limited to military barracks and dormitory buildings
Planning and Ordering Phase	(b)-1	Module technology assessment standards for bidding
	(b)-2	Possibility of cooperation among industry segments due to the separate placement of orders
	(b)-3	Calculation of costs of construction according to the applied lowest bidding system
	(b)-4	Limitations in participating in bidding due to small scale construction
	(b)-5	Possession of an unreasonable industrialized housing production factory
	(b)-6	Unit cost standards not applied with industrialized housing properties
	(b)-7	Registration as unit module with the Public Procurement Service
	(b)-8	Absence of standards requiring the publicizing of primary costs
Design Phase and Authorization Phase	(c)-1	Modular standard designs and MC design standards
	(c)-2	Level of professional designing offices
	(c)-3	Review of structural safety upon authorization
Production and Manufacturing Phase	(d)-1	Standards of construction materials, parts, and production facilities
	(d)-2	Increase of material costs
	(d)-3	Specified manufacturing technologies for each unit module
	(d)-4	Efficiency of production and error mitigation

3) Notation: (Cronbach's Alpha/ variable used in the analysis)

		when producing units
	(d)-5	Basis of automated and industrialized manufacturing
	(d)-6	Level of professional production and manufacturing offices
Packaging, Shipping, and Preservation Phase	(e)-1	Storage of unit modules due to construction delays
	(e)-2	Absence of packing methods and packaging standards
	(e)-3	Standards of road widths in consideration of module transportation
	(e)-4	Entry of equipment for urban construction projects
Construction and Supervision Phase	(f)-1	Standards of construction and manuals (absence of specifications)
	(f)-2	Level of professional contractors that specialize in industrialized housing
	(f)-3	Secure fireproofing of joints during construction
	(f)-4	Absence of methods of conserving indirect costs when construction periods are shortened
	(f)-5	Absence of supervision standards for industrialized housing
	(f)-6	Division of roles and responsibilities between construction companies and producers
	(f)-7	Impossible to make task requests to subcontractors
Maintenance Phase	(g)-1	Maintenance manual
	(g)-2	Occurrence of burden of responsibility regarding defects between the manufacturer and builder
	(g)-3	A/S that reflects the characteristics of the manufacturing industry or consistent maintenance of quality
Dismantling and Reusing Phase	(h)-1	Standards regarding dismantling methods
	(h)-2	Standards regarding reuse/recycling
	(h)-3	Levying of acquisition and registration taxes (double) regarding industrialized housing that has been removed and constructed

These inhibitory factors from research papers and the expert survey were categorized into seven life cycle phases and the public awareness and modular building market. As shown in <Table 4>, there are items that are duplicated or with similar meaning by each life cycle, so wording was reorganized to study importance and satisfaction.

As a result, 37 factors were developed for the actual analysis required for this research, and the details are displayed in <Table 3>.

4. Survey results

4.1. Data collection and survey analysis

Surveys were performed targeting professionals working in various fields related to industrialized housing. 74 copies of the survey were distributed from May 16 to June 15, 2017 and 56 copies of them were collected. Among the collected survey sheets, 50 valid ones were used for the final analysis. Frequency analysis, technical statistics, IPA, and T-test analysis were conducted using IBM SPSS 23.0. Survey questions were shown in <Table 5>, consisting of items on general information of respondents such as field of work and experience, scope awareness level in relation to industrialized housing terms like image of industrialized housing terminology, necessity of improvements in terminology, and preferred terminology, and satisfaction and importance regarding 37 inhibitory factors <Table 3>. Concerning the priority ranking identified by IPA, additional opinions were collected through in-depth survey of experts for two days from August 3 and 4 in 2017.

Table 4. Extraction of Factors that Discourage the Expansion of Modular Building

Source	Inhibitory Factors	No	Inhibitory Factors	No
Off-site Ultra High-speed Housing Construction Technology R&D	Absence of means of designing construction materials and parts	(d)-1	Demand for performance standards not applied with properties regarding modular or industrialized housing	(b)-1 (f)-3
	Absence of standard construction standards or manuals	(f)-1	Absence of common standards regarding industrialized housing design	(c)-1
	Lack of a basis for industrializing key materials and parts as well as automated manufacturing	(d)-5	Absence of unit cost standards and appropriate construction standards for industrialized housing	(b)-6 (f)-1
	Problem of negative perceptions towards industrialized housing	(a)-1		
Study of methods to encourage factory produced construction	Limited cooperation among industry segments due to the separate placement of orders for industrialized housing	(b)-2	Lack of common design and construction technologies leading to a dependence on the production location for manufacturing	(c)-1 (f)-1
	Limitations of approving the performance of general industrialized buildings other than housing units	(b)-1 (f)-3	Concerns of lowered quality due to the absence of professional contractors regarding factory production	(d)-6
Study of methods to encourage industrialized building for the development of the professional construction industry	Lack of promotion and perception of industrialized housing	(a)-1	Conflict between current systems of law oriented towards local production methods	(f)-1
	Concerns related to difficulties in securing consistent quality due to the absence of standardized design methods	(c)-1	Lack of appropriate reflection of construction costs due to the application of a lowest price bidding system	(b)-3
	Obscurities associated with the responsibility to deal with defects between the material producer and builder	(g)-2	Minimization of the industrial role of builders due to the manufacturing oriented shifts of the construction industry	(f)-6 (f)-7
	Lack of professional and functional personnel regarding industrialized and modular building	(d)-6 (f)-2	Burdens associated with price hikes of materials and ingredients	(d)-2
R&D of end-user oriented customized housing	Difficulties in standardizing materials and parts due to the lack of MC design applications	(c)-1	Increases in primary costs of construction due to the expansion of residentially open facilities and use of high quality finishing materials	(d)-2
	Industrialization cannot be expected without the standardization of materials	(d)-1	Difficulties in standardized manufacturing due to differences in MC standards by manufacturing companies	(c)-1
	Absence of a system that can be commonly applied to the building design and materials segment	(c)-1 (d)-1	Requirement of initial investment costs when using developed technologies in existence due to the need for production facilities	(b)-5

	Increases in primary costs of construction due to special structural formats such as steel frame structures and Rhaman structures	(d)-2	Lack of precedent regarding the application of tools used during delivery and assembly processes	(e)-2 (f)-1
	Insignificance of the effects of production due to small numbers of households	(b)-4	Application of environmental performance standards(heat, acoustics) being greater or equal to that applied to general co-housing	(f)-3
	Insignificance of competition among businesses due to the modular building market being in its initial stages of development	(a)-3		
Basic surveys by professionals regarding inhibitory factors of modular building	Lack of professional designers and design technologies regarding modular building	(c)-2	Current approved scope of industrialized housing	(a)-2
	Due to high factory unit production costs, there is little economy in saving primary costs associated with shortened periods of construction	(a)-3	Needs supervisors or professional management due to differences in the production and installation sites	(f)-5
	Lack of technician training and lack of modular building education programs	(a)-1	Limitations of entry of material lifting equipment for use in urban construction projects	(e)-3 (e)-4
	Absence of standard design guidelines or basic guidelines for design	(c)-1	Occurrence of process delays due to absence of linkage between site planning and production	(e)-1 (f)-7
	Lack of production technologies compared to advanced countries	(d)-5	Limitations of securing fireproofing of joints during construction	(f)-3
	Current conditions only allow for large scale projects due to issues associated with economies of scaled production	(b)-4	Limitation of ability to respond to construction errors	(d)-4
	Difficulties of securing production quality	(d)-4 (g)-3	Absence of a construction manual	(f)-1
	Lack of production technologies specified for each unit module	(d)-3	Difficulties of distinguishing between the concept of contracts and subcontracts due to differences in production rates of affiliated production processes	(f)-6 (f)-7
	Lack of a basis for industrialized and automated production	(d)-5	Difficulties in selecting companies having experience with modular building	(b)-1
	Demand for high performance levels on par with general buildings	(f)-3	Lack of awareness by the government and the public	(a)-1
	Limitations of maintaining consistent quality due to the absence of specifications	(f)-1 (g)-3	Levying of acquisition and registration taxes (double) regarding industrialized housing that has been removed and constructed	(h)-3
	Absence of standards regarding floor layering and production facilities	(d)-1	No cases currently in existence in South Korea regarding the reinstallation of a modular unit	(h)-2
	Lack of expense data and maintenance manuals	(g)-1	Lack of technical know-how regarding dismantling methods	(h)-1
	Registration as unit module with the Public Procurement Service	(b)-7	Review of structural safety upon authorization	(c)-3
	Absence of standards requiring the publicizing of primary costs	(b)-8	Absence of supervision standards for industrialized housing	(f)-5

Table 5. Survey Questions

Studied Items	Studied Content
General Items	<ul style="list-style-type: none"> Field of Work, Experience
Reestablishment of industrialized housing terms	<ul style="list-style-type: none"> Scope of industrialized housing Image of Industrialized Housing Vocabulary Need to amend industrialized housing vocabulary Priority Ranking of Industrialized Housing Vocabulary Amendments
Factors that inhibit the expansion of industrialized housing	<ul style="list-style-type: none"> Overall degrees of inhibition by industrialized housing life-cycles Degrees of Inhibition Regarding Each Factor of Inhibition by industrialized housing life-cycles

4.2. Survey results and discussion

1) General items on survey respondents

Fields of work consist of module production company, construction company, building design, research institution, and civil servant, and over 70% of respondents are working in construction company (40.8%) and module production company (34.7%). Also, the proportion of respondents with less than five years or five to ten years of experience was high. Details are shown in <Table 6>.

2) Necessity of redefining industrialized housing terms

Through awareness on industrialized housing terminology, this study aimed to come up with the necessity of redefining the terminology and its priority.

The survey on terms considered as industrialized housing showed that Factory Production On-site Assembled Housing was the highest with 31.2% followed by Unit Modular Housing (30.1%), Wood-based Assembled Housing (16.1%), PC Assembled Housing and Container Housing (9.7%).

This survey used multiple response analysis, and the result implies that terms showing distinction to RC structure are recognized as industrialized housing.

Some experts claimed that negative perception of the general public, which comes from industrialized housing terms, inhibits the expansion of industrialized housing. Compared to Canada which has revised terminology twice since the introduction of CSA factory certification system in 2001,⁴⁾ Korea has never made revision to terms since the

4) In Canada's CSA A277 building factory certification system, terms subject to approval has changed from Factory Built/ Mobile/ Modular/ Panelized in 2001 to

introduction of industrialized housing approval system in 1992.

In this context, the survey examined legal terminology's negative impacts on the expansion of modular housing. 3-point Likert scale was used for analysis in which 1 means negative, 2 normal, and 3 positive. 48% of the respondents said negative and 12% positive.

Table 6. Perception of Industrialized Housing

Perception	Frequency (N)	Percent (%)
Positive	24	48
Normal	20	40
Negative	6	12
Total	50	100

Then, the priority of proper terms for terminology revision was surveyed. Respondents were asked to pick top 3 terms out of 10 candidate terms. As a result, modular housing (53.1%) ranked the top followed by prefabricated housing (30.6%) and assembly housing (18.4%).

Table 7. Scope (Approved) of Industrialized Housing

Item	Frequency(N)	Percent (%)
PC Assembled Housing	9	9.7
Unit Modular Housing	28	30.1
Wood-based Assembled Housing	15	16.1
Container Housing	9	9.7
Factory Production On-site Assembled Housing	29	31.2
Other	3	3.2
Total	93	100

Industrialized housing terms are legally defined, but among the public and in reality, various terms like modular housing and prefabricated housing are used together with industrialized housing. In other words, now it is time to redefine the terminology because other terms are mixed despite the existence of legal terminology.

3) Identifying inhibitory factors

To identify inhibitory factors, modular building was categorized into the 7-phase life cycle and the public awareness and modular building market, and inhibitory factors extracted from literature, previous research, and preliminary surveys were categorized into the life cycle and the public awareness and market.

In this research, IPA method was used to identify factors primarily improved based on the gap between current satisfaction and importance regarding inhibitory factors. The satisfaction and importance level of each factor using 3-point scale is shown in <Table 9>.

Table 8. Need to Amend Legal Terms and Negative Effects of Industrialized Housing Vocabulary by Each Industry Segment

Dependent Variable	Field of Work	Average	Significance F/Probability
Industrialized Housing Negative Influence of Terms	Module Production Company	1.65	.914(.481)
	Construction Company	1.70	
	Building Design	2.00	
	Research Institution	1.20	
	Civil Servant	1.00	
	Other	2.00	
Industrialized Housing Need to Amend Legal Terms	Module Production Company	2.65	.409(.840)
	Construction Company	2.60	
	Building Design	3.00	
	Research Institution	2.80	
	Civil Servant	3.00	
	Other	2.69	

After IPA analysis, 11 factors were identified as top priority improvement item (1st area), and 6 factors for improvement (2nd area).

In the national awareness/market and life cycle phase categories, planning and ordering phase and construction and inspection phase have the most factors which were identified as top priority improvement and improvement items.

Below is the detailed analysis on the top priority improvement and improvement areas for the public awareness/market and life cycle phase categories.

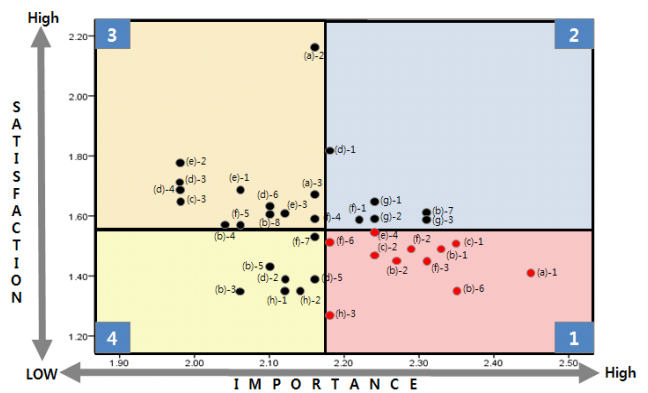


Fig. 2. Modular Building Invigorating MATRIX

In the national awareness/market category (a), out of 3 items, promotion of industrialized housing and negative public perception ((a)-1) was identified as the top priority (1st area), and other factors ((a)-2, 3) were located in the gradual improvement area (3rd area).

This result is similar to the analysis on legal terminology's negative impact to the expansion of industrialized housing.

In the planning and ordering phase, out of 8 items, 3 factors ((b)-1, 2, 6) were identified as the top priority, and one factor ((b)-7) in the improvement area.

Manufactured/ Mobile/ Modular/ Panelized in 2008, and to Prefabricated/ Partially or fully enclosed modules/ Partially or fully enclosed panels in 2016.

Table 9. Priority Rankings to Encourage Industrialized Housing

National Awareness/Market And Life-cycle	Code	Importance (M)	Satisfaction (M)	Importance-Satisfaction	IPA
National Awareness/Market (a)	(a)-1	2.45	1.41	1.04	A
	(a)-2	2.27	1.53	0.74	C
	(a)-3	2.16	1.67	0.49	C
total 1/3 item need improvement(A:1)					
Planning and Ordering (b)	(b)-1	2.33	1.49	0.84	A
	(b)-2	2.27	1.45	0.82	A
	(b)-3	2.51	1.35	1.16	D
	(b)-4	2.06	1.57	0.49	C
	(b)-5	2.10	1.43	0.67	D
	(b)-6	2.35	1.35	1	A
	(b)-7	2.31	1.39	0.92	B
	(b)-8	2.10	1.61	0.49	C
total 4/8 item need improvement(A:3, B:1)					
Design and Authorization (c)	(c)-1	2.35	1.51	0.84	A
	(c)-2	2.24	1.47	0.77	A
	(c)-3	1.98	1.69	0.29	C
total 2/3 item need improvement(A:2)					
Production and Manufacturing (d)	(d)-1	2.18	1.82	0.36	B
	(d)-2	2.12	1.71	0.41	D
	(d)-3	2.06	1.71	0.35	C
	(d)-4	1.98	1.65	0.33	C
	(d)-5	2.16	1.39	0.77	D
	(d)-6	2.10	1.63	0.47	C
total 1/6 item need improvement(B:1)					
Packaging, Transportation, and Lifting (e)	(e)-1	2.06	1.69	0.37	C
	(e)-2	1.98	1.78	0.2	C
	(e)-3	2.12	1.61	0.51	C
	(e)-4	2.24	1.55	0.69	A
total 1/4 item need improvement(A:1)					
Construction and Supervision (f)	(f)-1	2.22	1.59	0.63	B
	(f)-2	2.29	1.49	0.8	A
	(f)-3	2.31	1.45	0.86	A
	(f)-4	2.16	1.59	0.57	C
	(f)-5	2.04	1.57	0.47	C
	(f)-6	2.18	1.51	0.67	A
	(f)-7	2.16	1.53	0.63	D
total 4/7 item need improvement(A:3, B:1)					
Maintenance (g)	(g)-1	2.24	1.65	0.59	B
	(g)-2	2.24	1.61	0.63	B
	(g)-3	2.31	1.59	0.72	B
total 3/3 item need improvement(B:3)					
Dismantling and Reusing (h)	(h)-1	2.12	1.35	0.77	D
	(h)-2	2.14	1.35	0.79	D
	(h)-3	2.18	1.27	0.91	A
total 1/3 item need improvement(A:1)					

In the design and approval phase, out of 3 items, 2 factors ((c)-1: standard modular design and MC design standard, (c)-2: professional designer level) were identified as the top priority.

In the production and manufacturing phase, out of 6 items, there was no top priority factor, but one improvement factor ((d)-1: standardization of construction materials, parts, and production facilities).

In the packaging, shipping, and preservation phase, out of 4 items, one factor ((e)-4: entry of equipment for urban construction projects)

was identified as the top priority.

In the construction and inspection phase, out of 7 items, 3 factors ((f)-2: level of professional contractors that specialize in industrialized housing, (f)-3: secure fireproofing of joints during construction, (f)-6: division of roles and responsibilities between construction companies and producers) were identified as the top priority, and there was one improvement factor ((f)-1).

In the maintenance phase, all three items ((g)-1: maintenance manual, (g)-2: occurrence of burden of responsibility regarding defects between the manufacturer and builder, (g)-3: A/S that reflects the characteristics of the manufacturing industry or consistent maintenance of quality) were identified as improvement factors.

In the dismantling and reusing phase, out of 3 items, one top priority was identified, and the rest were located in the 4th area meaning keeping the status quo. It can be inferred that dismantling and reusing cases are very rare, which is understandable considering the current status and marketability of industrialized housing, and thus the focus is on the technology development and market expansion, rather than the improvement in the dismantling and reusing phase.

The in-depth survey of experts was performed using the identified factors to collect additional opinions. For ((b)-8: absence of standards requiring the publicizing of primary costs), experts said standards of the unit cost for standard design needs to be sophisticated in practice since primary cost is volatile. For ((g)-3: A/S that reflects the characteristics of the manufacturing industry or consistent maintenance of quality), the suggestion for quality maintenance was to strengthen standards on performance or design rather than to improve repair methods. In addition, it was estimated that if the industrialized housing market is expanded first, improvements for ((b)-5: possession of an unreasonable industrialized housing production factory, (d)-3: specified manufacturing technologies for each unit module, (d)-4: efficiency of production and error mitigation when producing units, (d)-6: level of professional production and manufacturing offices) will be made naturally in accordance with supply and demand.

5. Conclusion and future research direction

The purpose of this research is to prioritize inhibitory factors for improvements, and the conclusion is as follows.

First, after the survey on the priority of proper terms for terminology revision, in which top 3 terms were selected out of 10 candidate terms, modular housing ranked the top followed by prefabricated housing and assembly housing.

Second, to identify inhibitory factors, factors extracted from literature, previous research, and preliminary surveys were categorized into the life cycle and the public awareness and market. IPA analysis was used to identify factors requiring urgent improvement based on the gap

between current satisfaction and importance regarding inhibitory factors. After IPA analysis, the planning and ordering phase and the construction and inspection phase have the most factors identified as top priority improvement and improvement items. Characteristics shown in the urgent improvement area are low competitiveness compared to concrete building in terms of cost, which is caused by inactive market, and lack of standards in design, construction and inspection leading to the unclear division of role and responsibility. For some highly inhibitory factors by life cycles, it is estimated that design guideline and controversy over responsibility between constructor and manufacturer will be improved if the division of role is clarified through the improvement in ordering system (joint contract or separate ordering by processes). In addition, the approval scope needs to be expanded from residential building to general building, and module production needs to be designated as professional construction industry to incorporate unapproved module producers which have not acquired the approval for industrialized housing into the system.

This research surveyed modular building professionals, but more comprehensive evaluation can be made by expanding the survey targets when the modular building market is expanded and the public awareness is improved. Also, it is required to conduct continuous research on strategic selection and specific improvements regarding key life cycle and inhibitory items drawn from this study to encourage modular building further.

Acknowledgements

This research was supported by a grant (17RERP - B082887 - 04) from Residential Environment Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

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