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# Identifying drivers and barriers to green remodeling projects from the perspective of project participants

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A B S T R A C T

Green remodeling is becoming popular as it reduces greenhouse gas emissions in the existing building stock and improves the quality of the indoor environment. South Korean government is encouraging this trend by introducing green remodeling policies and incentives. To achieve successful implementations of green remodeling approaches, smooth cooperation among the various participants (i.e., design companies, construction companies, and consulting companies), with everyone understanding each requirement and what is expected of them, as well as support policies that take into account the characteristics of each participant are needed. Thus, this study aimed to examine the major drivers and barriers of green remodeling projects in South Korea for the main project participants. To achieve the research objectives, this study employed a questionnaire survey aimed at experienced practitioners. The survey results were analyzed by exploratory factor analysis and multivariate analysis of variance (MANOVA). As a result, four main drivers for the activation of green remodeling projects were identified: (1) environmental impacts, (2) social factors, (3) economic effects, and (4) occupants' satisfaction. There were five barriers: (1) lack of technology, (2) uncertainty, (3) lack of social acceptability, (4) economic feasibility, and (5) government policies. Design and construction companies regarded occupants' satisfaction as the most important driver factor while consulting companies thought social factors were the most important. For the barrier factors, all the participant groups considered economic feasibility to be the most important. These results can theoretically support the idea that adequate regulations, standards, and supporting policies are needed to promote green remodeling projects. Identifying the targets and main concerns of project participants will help boost technical development, promote collaboration, and establish effective processes. Municipalities interested in promoting green remodeling projects will find this study useful.

**Keywords:** green remodeling; green retrofit; exploratory factor analysis; MANOVA; South Korean construction industry

## Introduction

Environmental issues caused by greenhouse gas emissions are becoming a critical issue in communities around the world. International agencies have made significant efforts to overcome these problems and issues via initiatives such as the 2015 United Nations Climate Change Conference, COP 21, and the Kyoto Protocol. Since buildings are one of the main contributors to greenhouse gas emissions, with construction alone accounting for 6% of the global greenhouse gas emissions in 2010 [1], all construction industry participants need to make a more significant effort to integrate green principles into their daily practices and policies. In the built environment, green building approaches can be implemented to reduce energy and water consumption, green building materials can be used, and efforts can be made to improve the indoor environment and to minimize site disturbances and environmental issues over the entire building life cycle [2]. As part of this endeavor, the building sector has introduced a number of green building rating systems, including LEED, G-SEED, Green Globe, and BREEAM for the design, construction, operation, and maintenance of buildings that will enable stakeholders to be environmentally responsible and make the best use of scarce resources. To meet global targets for the reduction of greenhouse gas emission laid down in the COP 21 agreement and implement green building practices, we will need to upgrade existing buildings since their energy efficiency is often very poor and they, therefore, offer many opportunities to reduce energy consumption and, ultimately, greenhouse gas emissions [3]. In response, South Korea, which is the ninth biggest emitter of $CO_2$, releasing 595.39 million tonnes in 2016 [4], has developed the so-called 2030 basic roadmap for reducing greenhouse gas emissions. This roadmap suggests greenhouse gas reduction targets for each industrial sector, with 32.7% of the total greenhouse gas reduction target assigned to the building/construction sector [5].

As part of the effort to cut greenhouse gas emissions in the building sector, the concept of green remodeling has been developed and implemented. Green remodeling, also known as green retrofitting, aims to improve energy efficiency and reduce carbon emissions during a building's life cycle while maintaining satisfactory service levels and acceptable indoor environmental comfort [6]. A green remodeling project improves a building's energy efficiency and environmental performance, reduces its water usage, and maximizes the comfort level of the indoor environment [7, 8, 9]. The proportion of old buildings (defined as those over 30 years old) is rapidly increasing in South Korea, representing over 36% of the nation's building stock by 2015 [10]. Thus, there are extensive opportunities to implement green remodeling to reduce energy consumption and improve the quality of the indoor environment in the existing building stock.

Increased demand for green remodeling projects is expected, and various policies, regulations, and standards designed to support green remodeling projects need to be provided to encourage this trend. At present, green remodeling projects in South Korea are in their infancy, and green remodeling is an emerging technology that requires cooperation between the construction, energy, and mechanical systems [11]. To achieve successful implementations and firmly establish green remodeling approaches in South Korea, smooth cooperation among the various participants, with everyone understanding each requirement and what is expected of them, as well as support policies that take into account the characteristics of each participant are needed.

The main purpose of this study is to identify the drivers and barriers to the implementation of green remodeling projects. The priorities for each of the main drivers and barriers were established for each of the different project participants, and the relevance of each driver and barrier analyzed in order to develop appropriate policy portfolios that will activate the drivers and mitigate the barriers to support the effective and efficient implementation of green remodeling projects. A combination of methodologies was used to identify the drivers and barriers. First, an in-depth literature review was carried out to reveal our current understanding of the drivers and barriers to green remodeling projects. In the second phase, exploratory factor analysis was applied to identify underlying clusters of green remodeling project motivations. Finally, a multivariate analysis of variance (MANOVA) was performed in order to rank the various driver and barrier groups to gain further insights. The results of this study provide useful basic data to support efforts to develop effective supporting policies, regulations, and standards for green remodeling projects. In addition, the targets and priorities among the driver and barrier groups will contribute to sustainable technical development, better collaborations, and the establishment of effective green remodeling processes in South Korea. The results can be adjusted to suit the conditions in other countries that are also just beginning to implement green remodeling projects to help them develop appropriate policies and establish a strong collaborative foundation for this internationally important endeavor.

## Drivers and Barriers for Green Remodeling Projects

### Green remodeling projects in South Korea

The building sector has the most significant potential of any industry to contribute to the reduction of greenhouse gas emissions [2]. In the building sector as a whole, the construction process accounts for more than 30% of the total final energy consumption and 25% of the total greenhouse gas emissions [12, 13]. To reduce these environmental and energy impacts, many developed countries have established multiple strategies such as urban planning policies and technologies to support energy efficiency, improve the performance of existing buildings, achieve net-zero operating emissions, and improve all their energy management buildings [12]. In South Korea, the government introduced a green remodeling implementation policy designed to increase the energy efficiency of the existing building stock in 2013. Green remodeling refers to a combination of strategies and technologies designed to achieve better energy performance while maintaining a good indoor environment and supporting the occupants' health and safety [14].

In South Korea, the Korea Land and Housing Corporation (LH), a government-owned corporation responsible for the development of land and the maintenance of land and housing, established the "Green Remodeling Center" to implement green remodeling policies and strategies. The Green Remodeling Center is tasked with providing green remodeling finance programs, technical support for green remodeling design and construction, and promoting green remodeling participants' green remodeling projects. The center has classified the green remodeling process into three phases: consultation, design (planning), and construction. As of December 2018, 415 green remodeling participants were registered with the Green Remodeling Center to promote their businesses, of whom 81 (19.5%) were design companies, 217 (52.3%) were construction companies, and 63 (15.2%) were consultancies (Table 1).

Table 1. Green remodeling project participants as of December 2018

| Type of business | Task | Number |
|---|---|---|
| Design | building condition investigation, planning and design, energy saving estimation, optimal costs examination | 81 (19.5%) |
| Construction | thermal insulation, window, air-tight and solar radiation control equipment construction | 217 (52.3%) |
| Consultancies | green building certification system consulting, energy performance consulting, energy performance analysis and evaluation | 63 (15.2%) |
| Other | research, education, real estate, green material development | 54 (13.0%) |
| Total | - | 415 (100%) |

Green remodeling projects in South Korea are still under development. Though the effort devoted to green remodeling continues, few substantive policies reflect participants' actual needs due to a general lack of experience. Identifying the drivers and barriers from the participants' real-world experiences is expected to increase demand for green remodeling and lead to the successful completion of more such projects in South Korea. As the first step in investigating the drivers and barriers for green remodeling projects, we began by examining existing studies seeking to develop successful green remodeling projects.

## Literature Review

To identify potential drivers and barriers, an in-depth literature review on green remodeling projects was carried out. Hwang et al. [11] identified potential risks in green retrofit projects in Singapore, often referred to as a leader in advocating sustainability in the construction industry. They compared the risk criticalities between conventional and green retrofit projects to develop a set of mitigation measures based on a total of 20 risks relevant to green retrofit projects identified in a literature review. This study provides an in-depth understanding of the risk criticalities in green retrofit projects in Singapore and basic data related to risk management in green retrofit projects. Jin et al. [15] suggested the concept of a green retrofit industry chain. An industry chain is constructed based on the life cycle concept and involves the project survey, feasibility analysis, project design, and scheme optimization. This is a comprehensive linked program of action that not only subdivides the industry chain into individual fields but can also be used to highlight any integrated and contracted features. They suggested applying the industry chain concept to existing building green retrofits as an effective way to maximize integration and optimize a company's human, material, finance, and technology resources. Kumar et al. [14] sought to perform a case study of a green retrofit project. However, as there were no major green retrofit projects in India at the time of their study, this was impractical, so instead, they conducted real-time experimental studies. The building constructed for this case study produced around 50% energy savings and improved thermal comfort during the summer. A cost-benefit analysis revealed that although the initial cost of the proposed energy retrofits was relatively high, they would pay for themselves in from 5 to 10 years based on the cost of energy in India. Tramontin et al. [16] provided a list of strategies for sustainable building design and retrofit in developing countries. They compared South Africa's sustainable building regulations and requirements with those in developed countries, pointing out that the climatic and economic conditions in South Africa represented a key design strategy and the most important passive strategies suitable for the local context supported climate-sensitive buildings. Deslatte et al. [17] investigated inequalities in the adoption of green building policies in US cities based on a survey of local government municipalities. The results showed that green building tools were likely to be valued differently across local governments, sectors of the economy, and citizen subgroups from socially inclusive policy goals, even when the latter promoted sustainability.

Given that green remodeling is an essential part of green building strategies [11], drivers and barriers were extracted from studies about green building as well as green remodeling. Bond [18] studied barriers and drivers to green building in Australia and New Zealand, discovering that the most cost-effective way of reducing greenhouse gas emissions was to improve the energy efficiency of buildings and appliances and that householders' lifestyle choices within their homes impacted their energy use and motivation to conserve energy. This survey was designed to test a hypothesis. The researcher concluded that barriers to energy efficiency in households include larger homes and smaller households, the initial cost of installing sustainable features, and a lack of consumer information about the benefits and savings to be gained incorporating energy-efficient devices. Windapo [19] examined green building drivers in the South African construction industry to identify any key drivers' changes. The green building's key drivers included rising energy costs, the industry's green star rating system, competitive advantages, and legislation, and these key drivers had not changed significantly over time. This study also suggested that the increase in green building has little to do with ecological factors and more to do with economic factors. Hwang and Tan [20] identified obstacles and solutions for green building projects by comparing the delivery systems needed for conventional and green building construction. They found that the design-bid-build delivery system was the most appropriate for green construction projects because better communication was required among project team members. In contrast, the most crucial obstacle in green building project management was the high-cost premium, which made it difficult to keep within the project budget due to the need to utilize green technologies on-site, adopt green alternatives and arrange for the certification of buildings in green building projects [20].

Our examination of the above studies enabled us to extract 19 drivers (listed in Table 2) and 19 barriers (listed in Table 3) related to green remodeling. Multiple studies agreed on the need to include the effect of green remodeling projects on reducing energy consumption, green construction material development and supply, and the building's state of deterioration as important drivers. Insufficient regulations and standards, low technical skills, high initial costs, and long payback periods represent important additional barriers.

**Table 2.** Drivers of green remodeling projects identified in the literature review

| No. | Drivers | References | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | [11] | [15] | [14] | [16] | [17] | [18] | [19] | [20] | [21] | [22] | [23] | [24] | [25] | [26] | [27] |
| 1 | Energy consumption reduction | ● | ● | ● | | | ● | | | ● | ● | ● | ● | ● | ● | ● |
| 2 | Reinforcement of regulations and enforcing existing regulations | | | | | | | ● | | | | | | | | ● |
| 3 | Change in owners' cognition | | | | | | | | | | | | | ● | | ● |
| 4 | Introduction of subsidies and support policies | ● | | | ● | | | ● | | ● | | | | | | ● |
| 5 | Owner's demand for green remodeling | | | | | | | ● | | ● | | | | ● | | ● |
| 6 | Building's state of deterioration | | ● | | | | | | | | ● | ● | ● | ● | ● | ● |
| 7 | Rise in building's value | ● | ● | | | ● | | | | ● | | | | | ● | |
| 8 | Reduced maintenance and rehabilitation costs | ● | | ● | | | | ● | | | | | | | | |
| 9 | Improved indoor air quality | ● | ● | ● | | | ● | | | | ● | | | | | |
| 10 | Increasing social understanding | | ● | | | | ● | | | | | | | | ● | ● |
| 11 | Carbon emission reduction | | | | | | | | | | | | | | | |
| 12 | Green construction material development and supply | ● | ● | | | | | | | | ● | ● | ● | ● | ● | ● |
| 13 | Expansion of green building education | | ● | | | | | | | | | | | | | |
| 14 | Supply expansion of renewable energy | | | | ● | | | | | | ● | | | | | |
| 15 | Waste reduction | | | | | | | | | | | | | | ● | |
| 16 | Expansion green certification system | | ● | | | | | | | | ● | | | | | |
| 17 | Economic benefits for local community | | ● | | | | | | | | | | | | | |
| 18 | Water resource conservation and preservation | | | | ● | | | | | | | | | | | |
| 19 | Environmental cost reduction | | ● | | | | | | | ● | | | | | | |

**Table 3.** Barriers to green remodeling projects identified in the literature review

| No. | Barriers | References | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | [11] | [15] | [14] | [16] | [17] | [18] | [19] | [20] | [21] | [22] | [23] | [24] | [25] | [26] | [27] |
| 1 | High initial cost | ● | | | | | | | | ● | | | ● | ● | | ● |
| 2 | long payback period | ● | | | | | | | | ● | | | ● | | ● | ● |
| 3 | Lack of support policies and incentives | ● | | | ● | | | | | | | | | | ● | ● |
| 4 | Owner's lack of understanding | ● | | | | | ● | | | | ● | | | ● | | |
| 5 | Inadequate regulations and standards | ● | | | ● | | | ● | | | ● | | | | | ● |
| 6 | Society member's lack of understanding | ● | | | | | ● | | | | | | | | | |
| 7 | Uncertainty about future price rises | ● | | | | ● | | | | | | | | | ● | ● |
| 8 | Absence of green remodeling financing | ● | | | | | | | | | | | | | ● | |
| 9 | Lack of green remodeling business model | ● | ● | | | | | | | | | | | | | ● |
| 10 | Consideration of maintenance cost | | | | | | | | | | | ● | | | ● | ● |
| 11 | Increasing cost of green remodeling tests | | | ● | | | | | | | ● | | | | | |
| 12 | Architect's lack of understanding | ● | | | | | ● | | | | | | | | | |
| 13 | Lack of technical understanding of green construction | ● | ● | | | | | | | ● | | | | ● | | |
| 14 | Project schedule delays | ● | | | | | | | | | | | | | | |
| 15 | Lack of diagnosis technology for green remodeling | | | | | | | | | ● | ● | ● | | | | |
| 16 | Low technical skills | ● | ● | ● | | | | | | ● | ● | | | ● | | |
| 17 | Lack of green remodeling process | | ● | | | | | | | ● | ● | | | ● | | |
| 18 | Limited supply of green construction material | ● | | | | | | | ● | | | | | | | |
| 19 | Lack of knowledge regarding green construction material | ● | | | | | | | ● | | | | | ● | | |

# Research Methodology

A questionnaire survey was employed to investigate the participants' characteristics and priorities regarding the drivers and barriers for green remodeling projects. Survey methods are used to understand the respondent's opinions better and differentiate between subjective and objective opinions by collecting many responses and performing a thorough analysis [28]. This section describes the questionnaire's design, the distribution and collection procedure utilized, and the data analysis methodology.

After the authors developed the first draft of the survey, five construction experts working on green building or green remodeling projects reviewed the survey items. All of the experts have more than 20 years of experience in construction. Three of them have more than ten years of experience in green building and green remodeling, and the others have experiences engaged in green remodeling projects. According to the experts, all 19 drivers and 19 barriers that had been identified were independent of each other. The item-specific content validity index (CVI) was calculated based on the experts' opinion, and five drivers and three barriers were revised as suggested. After this procedure, the CVIs of individual drivers and barriers ranged from 0.80 to 0.91, indicating that all included valid content.

A questionnaire survey method aimed at experienced practitioners was employed in this study since the purpose of this study is to identify the underlying driver and barrier groups and then analyze these groups from actual participants' perspectives. Currently, the Korea Land & Housing Corporation (LH)'s Green Remodeling Center supports green remodeling construction and promotes green remodeling operations, so green remodeling participants who were registered with the Green Remodeling Center were eligible to answer the questionnaire if they had practical experience and had already participated in green building or green remodeling projects. Participants were recruited between April 2018 and August 2018. For ease of access and convenient analysis, the survey was conducted online. The analysis utilized the Statistical Package for the Social Sciences (SPSS) 21.0; exploratory factor analysis and multivariate analysis of variance (MANOVA) were performed.

# Analysis

## Demographic information

The survey used in this research collected data from green remodeling project participants, including architecture companies, construction companies, and green building consultants. 351 questionnaires were distributed, and a total of 182 respondents completed the survey, yielding a 51.9% response rate. Table 4 shows the demographic information for the participants returning usable questionnaires.

Table 4. Demographic information for participants

| | | Number | Percentage (%) |
|---|---|---|---|
| Type of business | Architecture design company | 54 | 29.7 |
| | Construction company | 78 | 42.9 |
| | Green building consultancies | 30 | 16.5 |
| | others | 20 | 11.0 |
| Number of employees | Less than 10 employees | 47 | 25.8 |
| | 11-50 employees | 49 | 26.9 |
| | 51-100 employees | 19 | 10.4 |
| | 101-250 employees | 10 | 5.5 |
| | 251-500 employees | 22 | 12.1 |
| | More than 501 employees | 35 | 19.2 |
| Years of working experience | Less than 10 years | 33 | 18.1 |
| | 10-20 years | 64 | 35.2 |
| | 20-30 years | 80 | 44.0 |
| | More than 30 years | 5 | 2.7 |

## Groups of drivers for green remodeling projects

In this study, exploratory factor analysis was used to identify underlying groups of drivers and barriers. Exploratory factor analysis is a statistical technique used to identify a relatively small number of individual factors that can be used to represent relationships among sets of many interrelated variables [29]. It was conducted to reduce the 19 drivers and 19 barriers extracted from the literature review into a small number of underlying driver groups and barrier groups.

As a result of the exploratory factor analysis, four underlying driver groups were extracted, accounting for 66.3% of the total variance in responses. To evaluate the appropriateness of the factor model, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett’s test of sphericity was used. The KMO value of the drivers was 0.865, indicating a “good” degree of common variance [30]. Bartlett’s test for sphericity was used to test the hypothesis that the correlation matrix was an identity matrix, which would indicate that no relationship exists among the items [31]. The chi-square value for the drivers was 1388.174, and the p-value is 0.000, which implies that the population correlation matrix is not an identity matrix. As the requirements of KMO value and Bartlett's test of sphericity were both achieved, the factor analysis results showed that this methodology was appropriate for this research, and the analysis could proceed with confidence and reliability.

Exploratory factor analysis provided a simple four-factor construct, factor loading, Eigenvalue, and percentage of explained common variance, all of which are shown in Table 5. Factor loadings less than or equal to 0.7 were deleted [32]; as a result, 15 drivers were analyzed.

**Table 5.** Results of exploratory factor analysis (drivers)

| | Drivers | Factor loading | Eigenvalue | Percentage of variance explained | Cumulative percentage of variance explained | Cronbach's alpha |
|---|---|---|---|---|---|---|
| Driver Group 1 | Water resource conservation and preservation | 0.891 | 5.114 | 26.915 | 26.915 | 0.918 |
| | Environmental cost reduction | 0.829 | | | | |
| | Green construction material development and supply | 0.821 | | | | |
| | Waste reduction | 0.821 | | | | |
| | Carbon emission reduction | 0.769 | | | | |
| | Expansion of green building education | 0.768 | | | | |
| Driver Group 2 | Reinforcement of regulations and enforcing existing regulations | 0.800 | 3.122 | 16.429 | 43.345 | 0.816 |
| | Change in owners' cognition | 0.730 | | | | |
| | Expansion green certification system | 0.717 | | | | |
| Driver Group 3 | Economic benefits for local community | 0.759 | 2.330 | 12.264 | 55.609 | 0.747 |
| | Reduced maintenance and rehabilitation costs | 0.726 | | | | |
| | Introduction of subsidies and support policies | 0.714 | | | | |
| Driver Group 4 | Reduction in energy consumption | 0.753 | 2.029 | 10.680 | 66.289 | 0.675 |
| | Building's state of deterioration | 0.729 | | | | |
| | Improved indoor air quality | 0.704 | | | | |

*Driver Group 1 − Environmental impact*. All six of the drivers in this group, namely water resource conservation and preservation, environmental cost reduction, green construction material development and supply, waste reduction, carbon emission reduction, and expansion of green building education, are concerned with using renewable energy and reducing energy consumption, both of which are fundamental objectives of green building projects. As global population growth suggests that the potential demand for buildings will double by 2050 [13], energy consumption, and greenhouse gas emissions will increase accordingly, demonstrating the enormous potential of green building methods. The importance of environmental-friendly building technologies and improvements in existing buildings' energy performance will only grow over the next few years. Eventually, because green remodeling projects' objectives coincide with the increasing global interest in "sustainability," the environmental impact of green remodeling may well become the most important driver group.

*Driver Group 2 − Social factors.* There were three drivers in this group, namely the reinforcement of regulations and enforcing existing regulations, changes in owners' cognition, and an expansion of green certification systems. These are related to systems such as the regulations and certifications associated with managing green remodeling projects, and society's understanding of green remodeling. For successful green remodeling project implementations, more investment in construction technology, as well as better social understanding and more support policies, must be in place. Positive perceptions of green remodeling and effective and support policies both stimulate green remodeling and building projects. Thus, government support systems for green remodeling and improved social cognition of green remodeling's positive aspects will be crucial to ensuring green remodeling project success.

*Driver Group 3 − Economic effect*. There were three drivers in this group, namely economic benefits for the local community, reduced maintenance and rehabilitation costs, and the introduction of subsidies and support policies. All these drivers relate to the economic impact of green remodeling projects. Green remodeling's primary purpose is to reduce greenhouse gas emissions and energy consumption and contribute to a more sustainable environment. The economic effect focuses on the additional advantages of green remodelings, such as the energy cost reduction achieved by installing energy self-production equipment and receiving green building certification incentives. Green remodeling's economic advantages are likely to be the biggest motivation for a building's owner accepting green remodeling. Thus, when a government establishes new policies for green remodeling projects, they need to consider additional effects such as these economic effects and the environmental advantages.

*Driver Group 4 − Occupants' satisfaction*. Once again, three drivers in this group, namely reduced energy consumption, the building's state of deterioration, and improved indoor air quality—these drivers concern occupants' satisfaction with the green remodeling implementation outcomes. Occupants' satisfaction refers to improvements in the occupants' quality of life, such as better indoor air quality and an extension of the building's life span. Green remodeling achieves better energy efficiency while maintaining satisfactory service levels and acceptable indoor thermal comfort [14]. By engaging in green remodeling, occupants can be guaranteed better indoor air quality and lower energy consumption by replacing energy-intensive facilities, making these advantages another of the key driver groups.

## Groups of barriers to green remodeling projects

As with the drivers, exploratory factor analysis was conducted, and five underlying barrier groups were extracted, accounting for 67.4% of the total variance in responses. The KMO value of the barriers was 0.788, indicating a "good" degree of common variance [30]. The chi-square value for barriers was 1136.346, and the p-value was 0.000, which implies the population correlation matrix was once again, not an identity matrix. As the KMO value requirements and Bartlett's test of sphericity were both achieved, factor analysis was deemed appropriate for this research and could proceed with confidence and reliability. Table 6 shows the results of the exploratory factor analysis for barriers. The drivers' factor loadings of 0.7 or below were deleted [32], leaving 15 barriers for the subsequent analysis.

*Barrier Group 1 − Lack of technology*. There were four barriers in this group: the lack of a green remodeling process, low technical skills, a limited supply of green construction materials, and the lack of diagnosis technology for green remodeling, all of which are related to insufficient technical skills. Green remodeling requires a highly skilled workforce with good cooperation between different work sections [11]. Because green remodeling projects in South Korea are still relatively new, no business model and business process specifically tailored to the South Korean construction environment have been established, and the technical level is also relatively low. Thus,

**Table 6.** Results of exploratory factor analysis (barriers)

| | Barriers | Factor loading | Eigenvalue | Percentage of variance explained | Cumulative percentage of variance explained | Cronbach's alpha |
|---|---|---|---|---|---|---|
| Barrier Group 1 | Lack of green remodeling process | 0.834 | 3.414 | 17.969 | 17.969 | 0.855 |
| | Low technical skills | 0.826 | | | | |
| | Limited supply of green construction materials | 0.773 | | | | |
| | Lack of diagnosis technology for green remodeling | 0.717 | | | | |
| Barrier Group 2 | Project schedule delays | 0.851 | 2.799 | 14.730 | 32.699 | 0.796 |
| | Uncertainty about future price rises | 0.823 | | | | |
| | Increasing cost of green remodeling tests | 0.732 | | | | |
| Barrier Group 3 | Lack of technical understanding of green construction | 0.758 | 2.532 | 13.325 | 46.023 | 0.786 |
| | Society member's lack of understanding | 0.749 | | | | |
| | Architect's lack of understanding | 0.724 | | | | |
| | Owner's lack of understanding | 0.711 | | | | |
| Barrier Group 4 | Long payback period | 0.879 | 2.146 | 11.293 | 57.317 | 0.692 |
| | High initial cost | 0.728 | | | | |
| Barrier Group 5 | Lack of support policies and incentives | 0.834 | 1.919 | 10.098 | 67.414 | 0.676 |
| | Absence of green remodeling financing | 0.745 | | | | |

inexperienced companies or companies that are unwilling to collaborate with others are a serious barrier. Developing the necessary technical skills and establishing a sound support system for technical development will be vital to overcome this barrier group.

*Barrier Group 2 − Uncertainty*. There were three barriers in this group: project schedule delays, uncertainty about possible price rises, and the increasing cost of conducting green remodeling tests. Uncertainty refers to the risk of not achieving the required performance, project schedule delays, and unexpected costs. Though green remodeling shows relatively higher initial costs, it can be compensated by incorporating self-energy production or other additional performance improvements. However, these characteristics of green remodeling projects, namely the relatively high up-front investment and delayed reward, effectively embed this uncertainty. Thus, a contracting system that adequately reflects these characteristics of green remodeling in South Korea is needed.

*Barrier Group 3 − Lack of social acceptability*. There were four barriers in this group: a lack of technical understanding of green construction techniques and practices and a general lack of understanding among the public, architects, and owners. This lack of understanding leads to misunderstandings between owners, architects, and members of society regarding every aspect of green remodeling, which is considered a costly technology because it involves replacing facilities and remodeling with relatively high-cost materials. These misunderstandings discourage people from embarking on a green remodeling project, even though it has a beneficial impact on our environment. Thus, by educating owners and members of the public about such matters, the demand for green remodeling will increase, and green remodeling projects will become more popular.

*Barrier Group 4 − Economic feasibility*. There were two barriers in this group, namely the long payback period and the high initial cost. The initial cost of a green remodeling project will be high due to the expensive technologies involved, which will be a major factor in calculating a project's economic feasibility. In general, green remodeling costs more due to its use of green materials and replacing existing facilities with newer and more efficient ones [33]. Though the initial cost of a green remodeling project is expensive, the investment cost is rewarded through reduced energy consumption as time passes. Green remodeling's economic feasibility may cause building owners to hesitate as they contemplate the economic feasibility of a project.

*Barrier Group 5 − Government policies*. There were two barriers in this group: the lack of support policies and incentives and green remodeling financing options. As green remodeling gradually becomes more popular, the government's policies should pay more attention to this growing sector by introducing appropriate regulatory support and encouraging financial institutions to develop financing options. Although green remodeling supporting programs are now in place in South Korea, the maximum support available amounts to only 4% of the construction interest cost. The maximum period for which it is available is only five years [34]. Another issue is that the South Korean government provides the same support policies regardless of individual green remodeling participants' characteristics, which means that the support programs are limited, the substantive policies they are based on do not reflect participants' needs, which can vary widely. To successfully grow the market for green remodeling projects, the government's policies need to be reviewed and updated to match the ground's reality.

## Discussion

### Driver groups of green remodeling projects from the perspective of each participant

A multivariate analysis of variance (MANOVA) was used to identify the importance of each driver and barrier through different participants' eyes and compare the differences between them. MANOVA assesses the statistical significance of the effect of one or more independent variables on a set of two or more dependent variables [35]. In this study, MANOVA was performed to determine whether there were any significant differences among the influences perceived by design, construction, and consulting companies due to the various driver and barrier groups for green remodeling projects described above. The results for the driver groups are shown in Table 7; all the driver groups had $p<0.05$, which means the type of participants and driver groups have a correlation and the MANOVA result achieves reliability.

From the perspective of an architectural design company, occupants' satisfaction was the most important driver group (scoring an average of 3.69), followed by social factors (average 3.57), economic effects (average 3.35), and environmental impact (average 3.14). In most construction projects, architectural design companies are in charge of planning and design work. One of their main objectives is to fulfill the future occupants' expectations for a higher quality of life by satisfying the project owner's project requirements. In green remodeling projects, architectural design companies are also responsible for checking the current state of buildings and suggesting energy saving

**Table 7.** Driver groups of green remodeling projects revealed by MANOVA

| | Design (n=54) | | | Construction (n=78) | | | Consulting (n=30) | | | ETC. (n=20) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Standard deviation | Ranking | Mean | Standard deviation | Ranking | Mean | Standard deviation | Ranking | Mean | Standard deviation | Ranking |
| Environmental impact | 3.14 | 0.786 | 4 | 2.98 | 0.873 | 4 | 3.10 | 0.717 | 4 | 2.8 | 0.840 | 4 |
| Social factor | 3.57 | 0.784 | 2 | 3.30 | 0.857 | 3 | 3.95 | 0.654 | 1 | 3.59 | 0.947 | 1 |
| Economic effect | 3.35 | 0.876 | 3 | 3.43 | 0.722 | 2 | 3.48 | 0.841 | 3 | 3.21 | 0.853 | 3 |
| Occupants' satisfaction | 3.69 | 0.686 | 1 | 3.70 | 0.622 | 1 | 3.69 | 0.666 | 2 | 3.56 | 0.917 | 2 |

Note: $p<.05$ for all factors.

methods to renovate deteriorating facilities based on the building's energy diagnosis [34]. Consequently, design companies regard occupants' satisfaction as the most significant driver group. This includes reducing the building's energy consumption, addressing its state of deterioration, and improving its indoor air quality, all of which are related to the ultimate objectives of green building projects.

From the perspective of the construction company, the occupants' satisfaction was once again the most important driver group (scoring an average of 3.70), followed by economic effect (average 3.43), social factors (average 3.30), and environmental impact (average 2.98). In green remodeling projects in South Korea, construction companies typically replace windows and install insulation [34]. They are less concerned with their green remodeling projects' environmental and social impact, which are only indirect results of green remodeling, making them less important driver groups. Thus, direct economic support from the government and a building owner's strong desire to implement a green remodeling project will encourage construction companies to participate.

In consulting companies, unlike architecture design and construction companies, social factors are the most crucial driver group (average 3.59), with the reinforcement of existing regulations and their enforcement being the most important driver. These companies provide experts in green certification systems and the analysis and evaluation of energy performance and environmental performance in green remodeling projects. Green remodeling project owners recruit consultants to help them meet the requirements for governments' support policies, with the consulting company assuming responsibility for satisfying the often complex requirements. Therefore, from the consulting company's perspective, increasing the demand for green remodeling projects through societal change and the enforcement of government support policies are the most important driver group.

Interestingly, environmental impact was found to be the least important driver group for all three participant groups. Although the reductions in energy consumption and greenhouse gas emission achieved through having more sustainable buildings are the ultimate purpose of green remodeling projects, actual green remodeling project participants tend to consider additional impacts such as the economic effect and occupants' satisfaction as being more important than what is ostensibly the main purpose of green remodeling projects. Thus, reconciling government policy and support systems and drivers that the participants regard as important can lead to the successful completion of more green remodeling projects.

## Barrier groups of green remodeling projects from the perspective of each participant

MANOVA was also utilized to analyze the five barrier groups identified for green remodeling projects: (1) Lack of technology, (2) uncertainty, (3) lack of social acceptability, (4) economic feasibility, and (5) government policies. All the barrier groups showed $p<0.05$, confirming that the type of participants and the various barrier groups do have a correlation, and the result obtained with MANOVA has reliability.

**Table 8.** Barrier groups of green remodeling projects by MANOVA

| | Design (n=54) | | | Construction (n=78) | | | Consulting (n=30) | | | ETC. (n=20) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Standard deviation | Ranking | Mean | Standard deviation | Ranking | Mean | Standard deviation | Ranking | Mean | Standard deviation | Ranking |
| Lack of technology | 3.29 | 1.013 | 5 | 3.05 | 1.103 | 5 | 3.38 | 0.662 | 5 | 3.66 | 0.709 | 3 |
| Uncertainty | 3.51 | 1.070 | 4 | 3.35 | 1.279 | 4 | 3.51 | 0.727 | 4 | 3.49 | 1.119 | 5 |
| Lack of social acceptability | 3.54 | 1.096 | 3 | 3.47 | 1.083 | 3 | 3.94 | 0.765 | 3 | 3.92 | 0.680 | 2 |
| Economic feasibility | 3.91 | 1.017 | 1 | 3.73 | 1.164 | 1 | 4.14 | 0.578 | 1 | 3.50 | 0.930 | 4 |
| Government policies | 3.83 | 1.050 | 2 | 3.67 | 1.188 | 2 | 4.03 | 0.781 | 2 | 4.13 | 0.536 | 1 |

Note: $p<.05$ for all factors.

The priorities of the different barrier groups appeared to be identical for all three types of participants. Economic feasibility was revealed as the most important barrier group (average 3.91), followed by government policies (average 3.83), a lack of social acceptability (average 3.54), uncertainty (average 3.51), and a lack of technology (average 3.29). Any consideration of the economic feasibility of green remodeling projects must include its long payback period and high initial cost. As mentioned earlier, a number of risks pertain to South Korean green remodeling projects because the industry is in its infancy, so many of the participants have little or no experience. Therefore, it would be helpful if the government were to provide adequate business models and financial support to boost the economic feasibility of these otherwise risky projects, thus lessening the participants' economic burdens and encouraging more and more successful, green remodeling projects. Perhaps not surprisingly, government policy was found to be the second important driver group. The South Korean government has implemented an interest support policy for green remodeling private operators since 2013 [34]. However, the support provided is quite small, up to a maximum of 4% of the total loan, and companies must meet higher criteria to obtain this financial support. Thus, the government should provide specific financing programs for the green remodeling project and relax the criteria if it is to minimize the barriers to green remodeling projects and build an active green remodeling market.

## Limitations and Future Work

The results of this research are based on the collected survey data. This study limited the eligible respondents to green remodeling participants who were registered with the Green Remodeling Center. This did not secure many respondents due to the complicated process of registering for the center. Green remodeling is a relatively new concept in South Korea. Another insight will be gained after techniques and strategies related to green remodeling are well adopted, and their effectiveness is validated. The results of this research apply only in the context of the South Korean construction environment. If we can compare various countries with the same approach, the results will likely provide further insights. Finally, the proposed results are specific to the South Korean context, and there is a need for future studies on other countries that have tried to adjust green remodeling.

## Conclusion

The purpose of this study was to identify the underlying drivers and barriers for green remodeling projects and prioritize these groups from the perspective of actual participants' in such projects in South Korea. The participants, all of whom were active in the field, were asked to complete a survey asking about the most important driver and barrier groups which they must face during their actual green remodeling project experiences. To achieve this, drivers and barriers were extracted from an analysis of previous studies in this area. The results were subjected to an exploratory factor analysis to cluster the drivers and barriers, and then MANOVA was used to determine the perspectives of each of the participant groups and rank the individual driver and barrier groups by means of quantitative analysis. This research contributes to the improvement of green remodeling projects in South Korea by identifying important driver and barrier groups from each participant's perspective to help government agencies develop and implement better and more supportive policies and regulations. Having identified the drivers and barriers to green remodeling projects, government decision-makers will now have sufficient evidence and useful pointers to help them determine which drivers and barriers are important for green remodeling projects and what types of policies are actually needed to support this growing sector of the economy. Our findings will also help green remodeling operators to establish appropriate targets and priorities based on the budgets for their projects and which technologies require further development. A better understanding of each other's targets and priorities will also support better collaborations between the various project participants. This study will be useful for countries that are also embarking on green remodeling initiatives in the near future. Nevertheless, it is important to note that the empirical studies in this paper focus on the current conditions in the built environment in South Korea.

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