Exploring the Development Trends and Characteristics of the U.S. Green Building Market

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ABSTRACT

The AEC industry has witnessed an increasing growth in the green building market in the past decade and continues to expect its promising future. While most of the prior research on the green building market was conducted based on the survey data at the project level, how the corporate dimension develops is still lacking. To fill the gap, this research attempted to explore the characteristics of the U.S. green building market from a corporate perspective both quantitatively and qualitatively. We first collected data of 223 top/representative green building contractors in the U.S. identified by the *Engineering News-Record* over the past decade, and explored the development trend. The 223 organizations were further categorized into three different groups with distinct characteristics and corporate strategy using k-means clustering. This research provided practitioners and academics with a holistic understanding of the U.S. green building market, as well as contributed to the development of green building corporation management strategy.

INTRODUCTION

The Architecture, Engineering, and Construction (AEC) industry is often criticized for its negative impact on the environment, including environmental pollution, waste of energy, and loss of biodiversity. (Chan et al., 2009, Ahn et al., 2013). In this context, the industry-wide "green" transition has emerged over the past two decades. With the rapid development of the global green building market, relevant related research also draws more attentions. However, prior studies were limited to qualitative studies based on the survey results or the market data in the project level, which lacked quantitative analysis on the market from the corporate perspective (Ahn et al., 2013). Given that, the aim of this research is to explore the development trend of the U.S. green building market from a corporate dimension and to identify the characteristics of different types of construction enterprises. A number of 223 representative green contractors in the U.S. were collected, and based on that, statistics analysis and *k*-means cluster analysis were employed to investigate the market-level trend and the corresponding corporate-level characteristics. The findings help to understand the development trend of the U.S. green building market for stakeholders and academics, as well as provide valuable references for practitioners in the industry to develop sustainable transformation strategies in the emerging market.

BACKGROUND

The green building market has grown rapidly among many countries around the world, contributing to a transformation of building products and services. Advanced technologies and

novel products were developed to meet the increasing demands (Kibert, 2004). Research on the development of the green building market has been the focus of many researchers over the past decade. For instance, Chan et al. (2009) explored the factors that enhance the popularity of green building and the obstacles that hinder the markets in Hong Kong and Singapore from the building designers' perspective. The driving forces and obstacles of sustainable construction development in different regional markets were also analyzed in different studies (Ahn et al., 2013, Olubunmi et al., 2016). A recent report by Dodge Data & Analytics (2018) also estimated future green building market, stating that the market demands for green buildings will double by the year 2021.

As green building market develops, sustainability has been identified as a key factor in the corporate strategies for long-term prosperity. Ahn and Pearce (2007) collected data from 87 different companies through survey questionnaires to study contractors' experiences, expectations, and perceptions associated with green building. Boadu et al. (2012) analyzed the LEED project management practices implemented by six U.S. contractors with structured case study interviews. Chang et al. (2017) proposed transition pathways toward sustainability for different groups of construction enterprises by conducting an importance-performance analysis of the critical sustainability aspects. Zuo et al. (2012) investigated the sustainability policy practices adopted by top 50 international contractors listed by the ENR through a critical qualitative approach and disclosed the similarities of sustainability policies focus in these construction contractors, like the energy efficiency and greenhouse gas emission reduction.

Despite the many analyses on the green building market over the past few decades, prior research on the green building market has been based primarily on the survey results or the market data at the project level. Corporate-level research on green building market development is still relatively limited. Further, studies on the sustainability of construction enterprises were mostly qualitative analyses. A quantitative study on the sustainability of construction enterprises is needed to identify generalizable characteristics of green construction enterprises. To this end, the main purpose of this study is to explore the development trend of the U.S. green building market from the corporate dimension and to identify the characteristics of different types of construction enterprises both quantitatively and qualitatively.

METHODOLOGY

To analyze the green building market from a corporate perspective, data of the construction enterprises from the Top 100 Green Contractors ranking lists by the Engineering News-Record (ENR) in the past decade (2008-2017) was first collected. Initiated in 1970s, ENR ranks the companies in different specific market categories annually based on the prior year revenue of these companies. In recent years, ENR ranking data has been employed and validated for research by a number of researchers (Zhao et al., 2016, Zilke and Taylor, 2014, Lu, 2013). Similarly, the Top 100 Green Contractors list is based on the companies' self-report data, which in this case is the volume of sustainable and "Green" projects they have worked on. The information of the contractors from the ENR Top Green Contractors (2008-2017) was collected and analyzed, including average rank, frequency, average percentage of green revenue to total revenue, average market count, average green revenue and average accredited staff.

Descriptive statistics were employed to understand the development trend of the U.S. green building market in the past decade. It is noted that the original data of a certain year indicates the market stage of the previous year, therefore, the 2008-2017 Top 100 green contractors' total annual revenue indicates the 2007-2016 development trend of green building market. Further,

this study utilized cluster analysis technique to classify these contractors into different categories. An unsupervised machine learning technique: *K*-means clustering and four features of the contractors, including average rank, frequency, average percentage of green revenue to total revenue, average market count, were chosen for the cluster analysis. After the identification of different contractor clusters, the characteristics and differences of each group were analyzed, respectively, followed by the case studies of the typical enterprises of each cluster. Both the internal and external critical sustainability aspects in the development of different types of contractors were considered.

RESULTS AND DISCUSSIONS

Green building market development trend

Based on the sum of the Top 100 green contractors' annual revenue and the percentage of five markets that account for the highest annual share of green contracting, the green building market development trend graph illustrated in Figure 1 indicates the growth and transformation of the green building market from the contractors' perspective. In general, the green building market showed a growing trend in the past decade, whereas the market share of individual markets fluctuated during this period. The industry life-cycle theory could "explain the changes in technological development and industry structure over the industry ages" (Peltoniemi, 2011). According to that, industries experience a similar cycle of life as organisms, including emergence, growth, maturity and decline (Klepper, 1997). Leadership in Energy Environmental Design (LEED) is one of the most adopted rating systems in the United States, and it has evolved from the older versions like v2.0, v2.2 to nowadays latest version LEED v4.0. Combined with the ILC theory and the variation of different LEED versions, the development of the green building market in the past decade could be divided into three stages: Emergence and rapid growth stage (2000-2008), Steady growth stage (2009-2013), Maturity and transformation stage (2014-2016).

Emergence and rapid growth stage (2000-2008)

Since the LEED v2.0 officially launched by the US Green Building Council (USGBC) in 2000, the green construction industry was shaping gradually from 2000 to 2008. The introduction of LEED v2.0 enabled the market to have official green building rating standards that can be relied upon, pushing to the emergence of the green building market (Richards, 2012). In this stage, the need for LEED certifications targeting many specific markets occurred, including private sectors (commercial offices, multi-unit residential) and public sectors (education, healthcare, government offices). At the same time, the cost of building green construction projects decreased as the market developed. On one hand, as the contractors' familiarity with green construction projects increased, contractors gradually developed their own green construction vendor pool and no longer need to spend additional green building consulting and market research expenses; on the other hand, the industrialization of materials and facilities required for green construction was also shaping, reducing the costs of building green construction projects (ENR, 2008).

Steady growth stage (2009-2013)

The green building market continued to grow steadily and gradually matured from 2009 to

2013. In this stage, the green contractors' total annual revenue indicated the fluctuating market growth trend, while the market share of different markets had undergone great changes. The 2008 global financial crisis led by the collapse of the U.S. housing bubble has a direct impact on the green building market. After that in 2009, the U.S. Green Building Council introduced the revised new standard for green construction rating, LEED 2009 (previously named LEED v3.0). LEED 2009 focused more on the efficiency of resources and energy of new green buildings. Also, owners began to pay more attention to the actual operating cost reduction of green buildings and treated green construction projects with a much more cautious attitude (ENR, 2010). Affected by the financial crisis, the market share of commercial offices and multi-unit residential (private sectors) in the green building market has shrunk dramatically and didn't recover until 2012. However, the market share of government offices, education and health care (public sectors) reached a peak during this period (see Figure 1). The market share of public sectors rose from 2009 to 2011 and started to decline from 2012 with the gradual recovery of the private sector market.

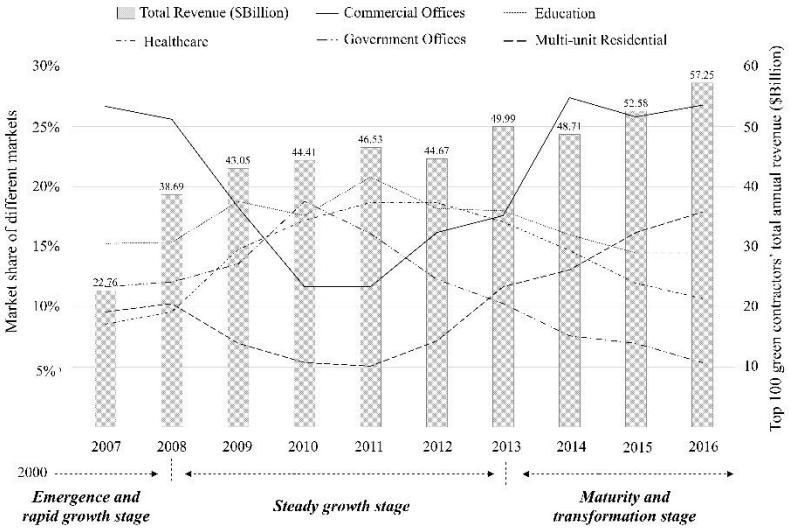

Figure 1. The green building market development trend

Maturity and transformation stage (2014-2016)

The most critical transformation in this stage is the market's shift in attitude towards LEED standards. LEED v4.0 originally launched in 2013 was resisted by many enterprises in the industry. The new version sets a higher standard on the well-being and health of the residents in the building, and thus raises the standard for construction materials. Some chemical raw materials (E.g., vinyl) that are commonly used in the industry are prohibited (ENR, 2014), leading to a huge rise in construction material cost and a blow to construction chemical material manufacturers. Therefore, many stakeholders attempted to prevent the implementation of new standards. Facing the industry's opposition, the USGBC decided to postpone the official implementation of LEED v4.0 to 2016, and to retain the usage of LEED 2009 until then. The impact of the LEED v4.0 on the green building market can be reflected on the fluctuation of the green contractors' total annual revenue from 2014 to 2016. The market share of private sectors continued to grow in this stage. The commercial offices market share returned to the peak before the financial crisis and the multi-unit residential market share grew to 17.9% in 2016. At the

same time, the market share of public sectors continued to decline. All of those indicated the U.S. green building market entered a matured stage of development and transformation towards a new direction.

Green contractors cluster analysis

After data processing and organizing, the 1000 data points (ten years' Top 100 list) were merged into the profile of 223 green contractors. To measure the performance of these contractors, the original data (company rank, green revenue, percentage of green revenue to total revenue, the markets of the green contracting, the number of accredited staff) were integrated into six quantified features representing the companies' sustainable performance, including (1) average rank (1-100), the mean of the company's ranks in the past decade; (2) frequency (1-10), the frequency of the contractor on the top lists; (3) average percentage of green revenue to total revenue (0%-100%), the mean of the company's percentage of green revenue to the total revenue; (4) average market count (1-9), the mean of the market count of the company, which is the number of the firm's green contracting markets, including retail/office, government office, education, healthcare, hotel, multi-residential, entertainment/civic and other markets; (5) average green revenue, the mean of the company's total green revenue in the past decade; and (6) average accredited staff, the mean of the company's accredited staff in ten years.

Since the 223 contractors may have different sustainability performances, *k*-means cluster analysis was conducted to classify them. Due to the wide range of average green revenue and the average accredited staff, these two features are not suitable to be selected as clustering variables. As such, four variables, namely average rank, frequency, average percentage of total revenue, and average market count, were chosen and standardized as the clustering parameters of *k*-means clustering. As a result, 223 contractors were divided into three clusters with different generalizable characteristics. These clusters are characterized as mature large-sized green contractors (cluster 1), market-oriented green contractors (cluster 2), and primary medium-sized green contractors (cluster 3). The cluster center and clustering variables distribution in each cluster are illustrated in Figures 2 and 3.

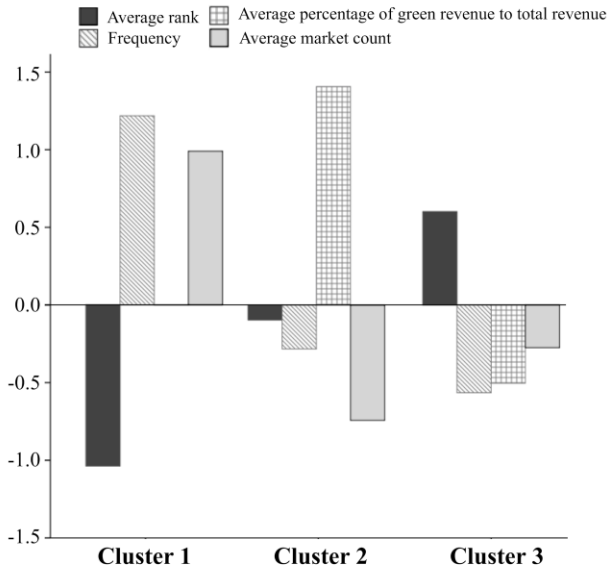

Figure 2. Cluster centers for each cluster

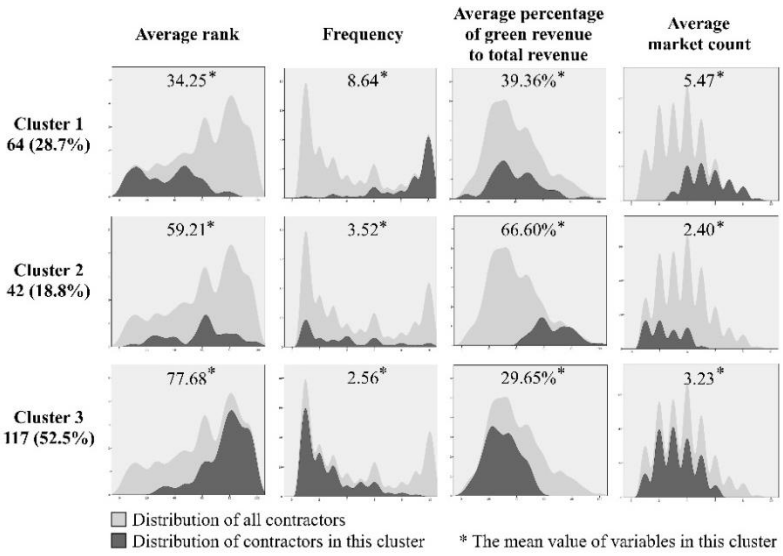

Figure 3. Clustering variables' distributions for each cluster

Mature large-size green contractors (Cluster 1)

There are 64 contractors in Cluster 1, namely mature large-size green contractors, accounting for 28.7% of the total organizations. As the name implies, contractors in this cluster are large-scale enterprises with strong competitiveness and rich experience in the green building market. From the clustering variables perspective, high average rank and high frequency indicate that contractors in this cluster often get high rankings in the ENR Top 100 green contractors ranking lists, which means these contractors could gain higher annual revenue from green construction projects compared with other contractors. From the internal sustainability aspect, mature large-sized green contractors could realize the market potential for green construction and apply sustainability in their projects at the early stage of the market development, accumulating rich experience and expanding markets. Mature large-sized green contractors would also establish their own standards, management processes and database dedicated to green construction projects. Turner Construction Company is a typical example in this category. Turner is constantly ranked No.1 in the ENR Top 100 green contractors ranking lists from 2008 to 2017. During the transformation stage when LEED v4.0 was launched in 2013, Turner's green revenue was fluctuating, the same as the total revenue of all contractors. The percentage of green revenue to total revenue and the number of accredited staffs in Turner increased rapidly in the fast-growing stage of green building market (before 2009), and then fluctuated between a stable value in the steady growth stage and maturity stage (2010-2016). Turner integrates the concept of sustainability into its day-to-day corporate activities, such as training and encouraging employees to earn LEED Accredited Professional credential, advancing corporate projects to LEED certification, and assessing the performance of green projects built by the company. Additionally, Turner continues to focus about the latest developments within the green building market by publishing biennial "Green Market Barometer" to reveal the latest trends.

Market-oriented green contractors (Cluster 2)

Market-oriented green contractors account for 18.8% of all contractors, which is the smallest group among three clusters. The most distinctive characteristics of contractors in this cluster are

the high average percentage of green revenue to total revenue and the low average market count. Market-oriented green contractors' green construction revenue takes quite a large proportion in their total revenue, and these contractors' green construction revenue relies heavily on certain markets. Harper Construction Company is a typical case in this cluster that has a high average percentage of green revenue to total revenue (83%) and low average market count (government offices, education, multi-unit residential). Comparing the development trends of market share in Harper and government offices in Figures 1 and 4, similarities between these two trends can be identified. Harper's green construction revenue grew rapidly in its early stage until it reached its peak in 2010, and then dropped dramatically from 2010 to 2012, which is exactly the same as the development trend of the market share of government offices between 2007 and 2012. This indicates that Harper heavily relied on green construction contracting revenue in the government offices market and was greatly affected by the market. Harper's case indicates that the advantage of market-oriented green contractors would also become their disadvantage. Concentration in one or two certain green building market would not only bring these contractors with market advantage but also lead the company to be easily affected by the market environment.

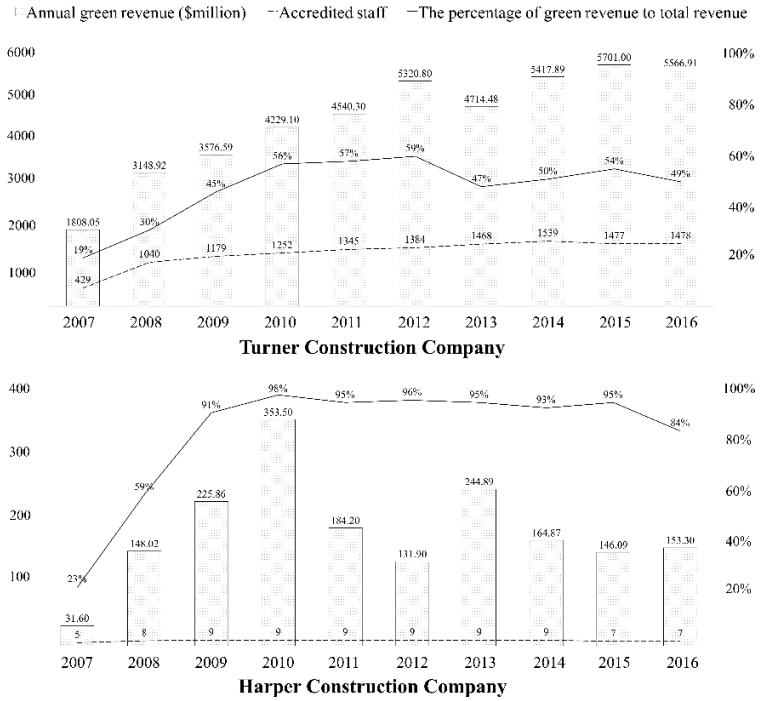

Figure 4. Development trends of two typical green contractors

Primary medium-sized green contractors (Cluster 3)

Cluster 3 contains 117 primary medium-sized green contractors, accounting for the largest proportion of the total, 52.5%. As illustrated Figures 2 and 3, the average of clustering variables in cluster 3 are all comparatively low among the three clusters. There are 49 contractors in this cluster that have been listed on the ENR Top 100 green contractors ranking for only once, and 90 contractors that have been on the ranking for three or less times. The low average rank in this cluster (77.68) and the low average percentage of green revenue to total revenue (29.65%) both indicate that these medium-sized contractors are still in the initial stage of corporate sustainable development transformation. Contractors in this cluster can be further divided into two

categories. The first category of contractors was able to get on the list through the benefits of some large green building projects. However, when the projects were completed, these contractors did not continue to undertake green building projects, resulting in these contractors appearing only once or twice on the list. Another type of contractor has just entered the green building market in recent years and is still accumulating experience in green building projects. This type of contractor clearly recognizes the future trends of the green building market and has developed plans for future development in the green building market. XL Construction Corporation is a typical case of the second type of contractor, averaged 77 in the Top 100 green contractors ranking lists in 2016 and 2017. According to the company's website, XL has been involved in more than 60 LEED projects and will participate in more green construction projects in the future. It indicated that some of the primary medium-sized green contractors are still in still in a period of rapid growth, and it is foreseeable that these contractors will perform better in the coming years.

Discussions

The green building market development trend discussed in this study offers a new perspective of investigation into this topic. Different from the prior research and industry reports disclosing the trend based on the buildings with green certifications (E.g., LEED, Energy star, Green globes), the total annual green revenue generated by the green building contractors and market share of different sectors are integrated and analyzed in this study. The nodes of three different development stage indicates the non-negligible impact of the version update of LEED standards on the green building contractors. The fluctuation of the green building market share in private sectors (commercial offices, multi-unit residential) and public sectors (education, healthcare, government offices) reflects the change of the market structure in different stages. In the Emergence and rapid growth stage (2000-2008), the private sector outperformed the public sector with private owners more willing to apply green building certification in their projects. Such structure flipped in the Steady growth stage (2009-2013) with the private sector in the trough and public sector at the peak due to the financial crisis and the regulations from the government. In the Maturity and transformation stage (2014-2016) the private sector went back to its highland with the public sector went back down in the trend. These findings will be supportive for future research on the factors affecting the green building market from the green building companies' perspective with substantial database.

The clustering of 223 green contractors identifies the sustainable performance of the representative green construction companies in the United States. For the construction companies which have already stepped into the green building market and the companies that have a vision in sustainable development, the characteristics of different types of contractors clustered in this study would provide valuable experiences for these companies. The large size construction companies may refer to the experiences of building green construction information system (E.g., green building subcontractors vender pool), green building professionalism development scheme, and organization structure for green building market from the mature large-size green contractors (Cluster 1). The medium-size and small-size construction companies that are planning to enter the green building market, they may also learn from the practices of market-oriented green contractors (Cluster 2), accumulating green building experiences in a specific sector and trying to expand the market based on that foundation.

CONCLUSION

The AEC industry has witnessed an increasing growth in the green building market and continues to expect its promising future. This study analyzes the development trend of the U.S. green building market from the contractor's perspective and identifies different clusters of green contractors with distinctive characteristics. Based on the 223 green contractors' information collected from the ENR Top 100 green contractors ranking lists in the past decade (2008-2017) and different versions of LEED, the development trend of the U.S. green building market in the past decade is divided into three stages, namely emergence and rapid growth stage (2000-2008), steady growth stage (2009-2013), maturity and transformation stage (2014-2016). Through *k*-means cluster analysis technique, 223 green contractors are divided into three clusters with different sustainability performances, including mature large green contractors, market-oriented green contractors, primary medium-sized green contractors. This research would help practitioners and scholars improve their understanding of the US green building market development process from the corporate perspective as well as increase awareness of key sustainability factors in the development of different green contractors.

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